FOREWORD

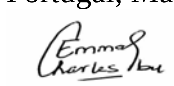
The Built and Natural environments have a profound influence on the quality of life at home and work of everyone. The built environment is ‘the result of human intervention in the natural physical world, where places with different characteristics and identities are created, and the means to keep them functional and interdependent are established’.

The built environment plays an important role in the social fabric of the nation, through the provision of appropriate and affordable housing stocks. Construction processes and their functions, desirability, cost, sustainability and utility of finished products and services therefore affect the quality of life of everyone in the UK. Through the provision of infrastructure projects for other industrial sectors, the built environment also impacts upon major transport infrastructure such as road networks, rail networks and airports. From a sustainability perspective, the built environment addresses the notion of environmental impact of air, water and land on human life and on different ecosystems. From a planning and regulations standpoint, the built environment considers the importance of permissions for proposals likely to have a deleterious impact on existing or planned adjacent uses because of visual intrusion, noise, vibration, atmospheric pollution, unusually high traffic generation, unusual operating times, or any other characteristic which in the opinion of the relevant local Planning Authority would constitute bad neighbourliness.

The natural environment covers a host of areas and our management of the natural resources. This includes such issues as pollution, waste management, land and water management.

This conference is the Second Scottish Conference for Postgraduate Researchers of the Built and Natural Environment (PRoBE). The main aim of the conference is to provide an avenue for postgraduate researchers in academic institutions in Scotland, UK and beyond, to share and exchange research information and knowledge in the areas of the built and natural environment. It is also intended that the conference would help to enhance research and presentation skills for up and coming researchers. In addition, it provides a forum for postgraduate researchers to debate and exchange ideas and experiences on a broad range of issues related to the built and natural environments.

This book contains papers which have undergone a two-stage paper review process. The first involved the review of each paper abstract by two members of the Scientific Committee. The second stage involved the review of each full paper by three members of the Scientific Committee. Of the one hundred and eight (108) papers initially submitted, seventy (70) papers have been selected on the basis of the strict review of the Scientific Committee members to ensure a good quality standard. The papers in this book have come from many parts of the world, including China, Turkey, Nigeria, Portugal, Malaysia, Wales, England and Scotland.



Professor Charles Egbu

(Chair: Scientific Committee and Local Organising Committee)

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CONSTRUCTING A CONCEPTUAL MODEL TO ACHIEVE INCLUSIVE URBAN PUBLIC SPACES FOR MANCHESTER: AN INITIAL OVERVIEW

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Abstract: This paper represents the early stage of an ongoing PhD research, which aims to construct a conceptual model to achieve inclusive urban public spaces. The main focus of the paper is to produce an outline of the research project, exploring the methodological issues of the study. Moreover, it looks at different theories of disability, relating them to the accessibility and inclusive design concepts. This paper also suggests that the attainment of inclusiveness is, in part, a consequence of the application of different models of disability on the development of accessibility policies and standards. It further proposes that accessibility and inclusive design should be approached in a holistic way.

Keywords- accessibility, disability theories, inclusive design, research methodology

1. INTRODUCTION

The aim of this paper is to produce the outline of an ongoing PhD research project that aims to construct a conceptual model to achieve inclusive urban public spaces. This will allow the determination of barriers in public spaces of Manchester City Centre, as well as their causes, in order to contribute to the accessibility optimisation and improvement of inclusion. The paper also looks at different theories of disability, relating them to the accessibility and inclusive design concepts. It further explores the research methodology stating the social constructionism (interpretivism) as the philosophical foundation of this research, and following the nested methodology (Kagioglou, 1998: 7) it justifies the use of the case-study approach with its subsequent research techniques. Finally, it is important to state that due to the early stage of the research, empirical findings will not be presented, but some issues will be drawn from the literature review.

2. BACKGROUND AND HISTORY

2.1 From accessibility to Inclusive Design

Industrialised countries have been studying the matter of accessibility and inclusive design for decades. The evolution towards inclusive design began in the 1950s. In Europe, Japan and the United States, **barrier-free design** that started to remove obstacles in the built environment for people with physical impairments, tended to be segregated and special. Through social policy, disabled people moved from institutional settings into the community. Europe and the United States had enough experience with community integration of disabled people by the 1970s that they moved beyond special solutions towards the idea of normalisation and integration. For the first time, design was a civil rights issue. The legal standards used the term **accessible design**. The laws specified the responsibilities of designers, owners and public agencies. Almost exclusively, those accessible design requirements focused on the needs of people with mobility impairments and were applied to the built environment and not to products. Also in the 1970s, Michel Bednar, an American architect, introduced the new idea that everyone's functional capacity is enhanced when environmental barriers are removed. He suggested that a new concept beyond accessibility was needed that would be broader and more universal (Fletcher, 2002).

By the 1980s disabled people were sufficiently organised in many nations to be appropriately called the 'disability community' and were able to articulate and share perspectives. They challenged the assumption about disability being a rare and static condition related largely to mobility and sensory impairments. They suggested that laws governing accessible design had reduced design to a set of minimum requirements. In the late 1980s Ron Mace, a wheelchair user architect, proposed the term **universal design** defining it in relation to accessible design. Mace and a group of designers created a set of seven principles of universal design in the mid-90s. Since 1998, international conferences on universal design have proliferated (Fletcher, 2002).

Universal or inclusive design is concerned with designing buildings that are suitable for all possible end users and not buildings with inadequate or inappropriate design solutions (Ormerod & Green, 2002). Fletcher (2002) explains this concept as the design of products, environments and communication usable by all people, to the greatest extent possible, without adaptation or specialised design. The message being if it works well for people with impairments, it works better for everyone.

In 1995 the Disability Discrimination Act (DDA) was approved in the UK. This civil rights law aims to end the discrimination faced by disabled people in the areas of employment, access to goods and services, education and transport (DRC, 2005). The employment rights and first rights of access came into force on 2 December, 1996; further rights of access came into force on 1 October, 1999; and the final rights of access came into force on October 2004 (DRC, 2005).

2.2 From the Individual Models to the Social Models of Disability

Priestley (1998: 79) defines two dimensions (nominalist-realist and materialist-idealist) that are applicable to the two key debates in disability theory. Such dimensions produce four basic positions for theorizing disability (See Table 1). The two nominalist positions give rise to individual models of disability, one based on biological determinism, identified as the medical model (Imrie, 1996: 23), the other based on symbolic interactionism that could be associated with the Emener's empowerment model (Imrie, 1996: 40). The two realist positions give rise to the social models of disability (one based on social creationism, defined by Imrie (1996: 43) as materialist perspective, the other on social constructionism (Priestley,1998: 79). The minority group model of disability embodies social constructivist and creationist views of disability (Imrie, 1996: 40). The fundamental distinction between the social model theories (positions 3 and 4) from the individual model theories (positions 1 and 2) is that disability has some real collective existence in the social world beyond the existence or experience of individual disabled people (Priestley, 1998: 83).

Table 1: Four approaches to disability theories (Adapted from Priestley, 1998: 78).

	Materialist	Idealist
Nominalist (Individual)	**Position 1** Individual materialist models. Disability is the physical product of biology acting upon the functioning of material individuals (bodies). The units of analysis are impaired bodies.	**Position 2** Individual idealist models. Disability is the product of voluntaristic individuals (disabled and non-disabled) engaged in the creation of identities and the negotiation of roles. The units of analysis are beliefs and identities.
Realist (Social)	**Position 3** Social creationist models. Disability is the material product of socio-economic relations developing within a specific historical context. The units of analysis are disabling barriers and material relations of power.	**Position 4** Social constructionist models. Disability is the idealist product of societal development within a specific cultural context. The units of analysis are cultural values and representations.

The **medical model** conceives of disability as an individual, physiological, condition biologically produced which can be treated and cured (Imrie, 1996: 28), and where problems faced by disabled people are the result of their physical impairments independent of the wider socio-cultural, physical and political environments (Hellman, 1984, quoted in Imrie, 1996: 28). This model of disability also affects the way disabled people think about themselves. Many people with impairments internalise the negative message that their problems stem from not having 'normal' bodies. They can be led to believe that their impairments automatically prevent them from participating in social activities. This internalised oppression can make disabled people less likely to challenge their exclusion from mainstream society (Manchester City Council, 2005a).

The Emener's (1987) **empowerment model** is concerned with addressing how the professional system of rehabilitation might empower disabled people to gain control over their lives. Its strength is the departure from a model of functional impairment to the notion that a disabled person should have equal opportunity to maximize his or her potential and is deserving of societal help in attempting to do so (Imrie, 1996: 40).

The **minority group model of disability** sets disability in context. This perspective embodies both social constructivist and creationist views of disability. This model situates disability in the wider structural, external environment, denying that it is explicable as a consequence of some personal defect or deficiency. From the **social constructivist position**, this perspective situates disablism within the oppressive and coercive ableist attitudes of the society, attitudes reinforced and perpetuated by the practices and discourses of the dominant institutions (Imrie, 1996: 42). This position regards the worst barriers to access as the attitudinal discrimination rather than the physical barriers. The **social creationist perspective** of the 'minority group' model, situates the source of social oppression of disabled people in the socio-institutional practices of the dominant professional groups. Public policy is a reflection of pervasive attitudes and policies, and disablist attitudes, in themselves, have transformative capacities in influencing in policies and practices of institutions. Thus, the social creationist conception represents an advance on social constructionism because it places values and attitudes in a material context of socio-political practices while recognizing that institutional domination, or the prevention of people from participating in determining their actions or the conditions of their actions, is a key structural facet of administrative and welfare control over the disabled people's lives (Imrie, 1996: 42).

The **materialist perspective** situates disability historically, noting how states of disability are (re)produced and made and not the consequence of an impairment. This social model has been worked out by disabled people who feel that the individual model does not provide an adequate explanation for their exclusion from mainstream society because their experiences have shown them that in reality most of their problems are not caused by their impairments, but by the way society is organised (Manchester City Council, 2005b). This perspective proposes a vital distinction between 'impairment' and 'disability' (Imrie, 1996: 43). Impairment is conceived of as 'the absence in total, or in part, of some physiological function', whereas disability is 'the social imposed state of exclusion or constraint which physically impaired people may be force to endure' (Gleeson, 1995: 12, quoted in Imrie, 1996: 43).

Imrie's theory (1996), seeks to place disablism in the built environment in a broader materialist framework which suggest that a reconstruction of the theorization of disability in the environment requires, as a first step, to place the body in context, to recognize the interplay between the physiological condition and the wider material conditions of existence. There is the need to develop conception that contextualize the body, to consider the structural and contingent conditions of its production and reproduction, to interrelate physiological, and socio-cultural variables as part of a dialectic Imrie (1996: 47).

3. RESEARCH PROBLEM

The United Kingdom possesses a legal framework related to accessibility. Manchester City Council, adopting the social model of disability, has been very active in this matter, however some public spaces and buildings in Manchester City Centre still have physical barriers for disabled people. The MDPAG (Manchester Disabled People's Access Group) carried out an access survey between 2002-2004 within the city centre "key routes" defined by the City Council and found out that only 23.5% of the cafes, 25% of the banks, 38.3% of the shops, 61.5% of the hotels, and 73.7% of the tourist venues, pubs and restaurants, were accessible (MDPAG, 2004).

The research problem is to find out about the process of the achievement of inclusiveness in the built environment, focussing on urban public spaces. This study seeks to understand and interpret the worldviews, needs, aspirations, drives and constraints of all the stakeholders (actors) involved in that process, in order to create a contingency dynamic balanced model of the situation. Moreover, a gap in research in this subject has been identified. The existing theoretical base is poor since the available literature does not provide a holistic conceptual framework. A theory that involves the worldviews, the needs, aspirations drives and constraints of all the stakeholders involved in the process of achievement inclusiveness in the built environment is needed.

4. AIM AND OBJECTIVES OF THE RESEARCH

The aim of this research is to develop a conceptual model to achieve inclusive urban public spaces that allows determining the barriers in public spaces of Manchester City Centre and the causes that origin them to contribute with the accessibility optimisation and improvement of inclusion. To comply with the aim the following objectives are stated:

a. To study the national (UK) and regional legal framework (the policies, laws and standards) related to accessibility analysing the coordination amongst the legal instruments in force that regulate the accessibility in public spaces and buildings.

b. To identify the stakeholders (actors) and variables involved in the achievement of accessibility and inclusiveness in Manchester City Centre urban public spaces, looking for their relationships.

c. To explore and analyse the proposals and responses of the actors to the access needs of disabled people.

d. To look at the public participation mechanisms applied by the UK National Government, Manchester Local Government, access groups, and the private sector (developers) to meet accessibility standards and inclusiveness.

e. To find out about the training in accessibility offered/received by Manchester Local Government, Access Groups and the private sector (developers).

f. To identify the gaps (constraints) between the theory and practice in the achievement of inclusive urban public spaces and what cause them.

5. RESEARCH QUESTIONS

The questions that give validity and direction to the study are:

- How have the access needs of disabled people been included in urban policies, laws and standards in the national (UK) and regional level (Manchester)? How is the co-ordination amongst these legal instruments? At which levels of the urban planning process are the consultations with disabled people organisations included?
- How the built environment has responded to the needs of disabled people in Manchester city centre? How and why do disabled people behave and feel in the public spaces and buildings?
- What are the stakeholders (actors) and variables involved in the achievement of accessibility in Manchester City Centre urban system, and how do they interact?
- Why, in Manchester, are there public spaces with physical barriers, even though British urban planning within its regulation instruments includes accessibility standards and consultation processes with organisations of disabled people to carry out these standards and control the compliance of those standards?

6. RESEARCH METHODOLOGY

This research will be done under the ‘nested’ methodology model, where the research philosophy guides and energises the inner research approaches and research techniques (Kaglioglou, 1998: 7).

6.1 Research philosophy

Easterby-Smith et al (2002: 27) highlights four reasons why an understanding of philosophical issues is crucial when conducting research. First, it can help to clarify research designs. Second, it can help the investigator to recognize which designs will work and which will not. Third, the knowledge of philosophy can help the researcher to identify and create designs that may be outside his or her past experience. Finally, it may also suggest how to adapt research designs according to the constraints of different subjects or knowledge structures. Further, Easterby-Smith et al (2002: 28) defines two philosophical traditions: positivism and social constructionism.

The proposed study has its philosophical base within the social constructionism. In order to validate the Philosophical stand point of the research, several conditions will be depicted. First, in this research the investigator will be part of what is being studied, as this study is centred on current phenomenon in real life settings. Second, the study is driven by human interests, and the explanations seek to increase the general understanding of the stakeholders’ worldviews to develop a conceptual model to achieve inclusive urban public spaces. Through data collection, the conceptual model will be induced. And a small number of case-studies with complex units of analysis have been carefully selected for doing analytic generalization through the replication logic (Yin, 2003: 33, 53).

6.2 Research Approach

Pursuing the line of the nested methodology, the case study approach occupies the interpretivism territory from the epistemological stand and the idealism area from the ontological stand (Keraminiyage, 2005: 471). Yin (2003: 13), defines case study as ‘an empirical enquiry that investigates a contemporary phenomenon within its real life context, especially when the boundaries between phenomenon and context are not clearly evident’. Yin (2003: 3) discusses five research approaches: experiment, survey, archival analysis, history and case study. Further, he suggests three conditions for selecting each research strategy: (a) the type of question posed, (b) the extent of control an investigator has over actual behavioural events and (c) the degree of focus on contemporary events as opposed to historical events (Yin, 2003: 5).

Case studies are the preferred strategy when “how” and “why” questions are being posed, when the investigator has little control over events, and when the focus is on contemporary phenomenon within some real life context. However, some ‘what’ questions are exploratory, and in exploratory studies, any of the five research strategies can be used (Yin 2003: 1). The proposed study is developed around ‘what’, ‘how’ and ‘why’ questions related to the stakeholders (actors) and variables involved in the process of achieving inclusive urban public spaces in Manchester City Centre. Furthermore, in this case, the investigator does not have, or demand, control over events and the study is focussed on contemporary phenomenon within the real life context. These conditions make case study approach the most suitable for this research. This study corresponds to an exploratory case study as its goal is to develop pertinent hypotheses and propositions for further inquiry (Yin 2003: 1).

7. THE CASE STUDY DESIGN

Yin (2003: 19) describes a research design as the logical sequence that connects the empirical data to be collected to the initial questions of study and, ultimately, to the conclusions to be drawn. Following the nested methodology, the proposed study is based mainly in generating theory whilst seeking to contribute to local knowledge rather than universal theory and it uses fieldwork methods. Once again, these choices correspond to the social constructionism (interpretivism) philosophical perspective (Easterby-Smith et al, 2002: 43).

7.1 Multiple-case design

A primary distinction in designing case studies is between multiple- and single-case designs. Multiple-case designs are likely to be stronger than single-case designs due to the fact that their evidence is more compelling, and the overall study is therefore, more robust (Herriot & Firestone, 1983, quoted in: Yin, 2003: 46). The rationale for multiple-case designs derives from the understanding of the literal and theoretical replications (Yin, 2003: 52). The simplest multiple-case design would be the selection of two or more cases that are believed to be literal replications. Any use of multiple-case designs should follow a replication, not a sampling logic (Yin, 2003: 53). In the replication logic, each case must be carefully selected so that it either (a) predicts similar results (a literal replication) or (b) predicts contrasting results but for replicable reasons (a theoretical replication) (Yin, 2003: 46). The proposed study will use a simple multiple-case study design to follow the replication logic. At this stage of the research, three cases have been selected that are believed to be literal replications.

7.2 Criterions for selecting the case studies

Manchester has been chosen as the context of the case studies due to the interesting experience that it possesses in achieving accessibility. Moreover, the City Council aims for Manchester to be recognised as the most accessible city in Europe and it states to be committed to improving access for disabled people to all it services. The City Council wants to ensure that disabled people have an input in the planning and delivery of City Council services and that their needs are taken account of. As part of this initiative, the City Council is removing barriers, improving access and consulting disabled people (Manchester City Council, 2005b).

Yin (2003) suggests that a set of operational criteria for selecting cases studies should be defined prior to data collection. The three cases selected at the moment are: Picadilly Gardens, Albert Square and Millgate Square. The three of them are situated within the 'key accessible routes' defined by the City Council and they are public spaces for massive congregation. Moreover, the three of them are strategically located regarding the huge amount of people who access the city centre by train or metrolink as they have train stations (Picadilly, Victoria and Deansgate) and metrolink stations in their proximities. Likewise, the selected spaces have differences in shape and position in the city. Further, Picadilly Gardens is the centre of a commercial area, Albert Square is the centre of the political-civic hub of the city and Millgate Square is the centre of a cultural area. The last different condition was chosen on purpose as in the city there are areas with different characters (uses). It is expected that the different conditions of the cases do not affect the literal replication. If under these conditions common conclusions can be observed in the three cases, the external generalizability of the findings will be greater (Yin, 2003: 53).

7.3 Embedded-case studies.

The individual cases within a multiple-case study design may be either holistic or embedded. Embedded is when the same case study involves more than one unit of analysis. The selection of the appropriate unit of analysis will occur when the primary research questions are accurately specified (Yin, 2003: 23). This investigation is an embedded-case study. In this research the units of analysis are the accessibility level of the spaces; interactions between the users and the selected spaces; and the understanding of the process of developing inclusive spaces, considering the stakeholders (actors) and variables involved.

8. RESEARCH TECHNIQUES

8.1 Data collection techniques

Main evidence for case studies may come from six sources: documents, archival records, interviews, direct observation, participant observation and physical artefacts (Marshall & Rossman, 1989, quoted in Yin, 2003: 83). In addition, three principles are fundamental to any data collection effort in doing case studies. These include the use of (a) multiple source of evidence covering the same set of facts or findings, (b) a case study database, and (c) a chain of evidence (explicit links between the questions asked, the data collected, and the conclusions drawn). The described principles will be applied to this case study investigation in order to increase its quality (Yin, 2003: 83), helping to construct validity and reliability (Yin, 2003: 85). The research methodology includes a literature review on subjects related to the study matter to construct the framework and to find out the *status quo* of the research related to the theme. It also includes the revision of British urban and policies and laws, the analysis of urban regulation instruments from the accessibility standpoint, and the analysis of documents produced by Manchester City Council and the access groups upon accessibility.

The fieldwork includes mainly the application of qualitative research methods (Taylor & Bogdan, 1987). Through direct observation, the level of accessibility of the spaces in question will be measured, contrasting the physical features to the national accessibility standards and the City Council recommendations. Physical barriers will be illustrated in blueprints as well as the movements of the users, participants in the study. Environmental-behaviour research methods (e.g. focus interviews) will be applied to find out about the interactions between the spaces and users (Zeisel, 1981) and about their perceptions on the physical barriers in the spaces. Open interviews will be carried out with key informants of Manchester City Council, access groups and the private sector. After collecting the data with each actor (stakeholder), a workshop will be proposed with the three actors to reflect the individual findings and to have a better understanding of the situation. Revision of relevant documents and cognitive maps of the case studies will be included as a form of information triangulation. (Taylor & Bogdan, 1987).

8.2 Data analysis techniques

Data analysis consists of examining, categorizing, tabulating, testing or otherwise recombining both quantitative and qualitative evidence to address the initial propositions of a study. Three strategies for analysing case study evidence are: relying on theoretical propositions, thinking about rival explanations, and developing case descriptions. Any of these strategies can be used in practicing five specific techniques for analysing case studies: pattern matching, explanation building, time series analysis, logic models and cross-case synthesis. The first four are applicable whether a study involves a single- or a multiple-case design, and every case study should consider these techniques to produce high-quality analyses (Yin, 2003, p. 109). In a further stage of the research, the technique for analysing the case studies will be stated.

9. CONCLUSIONS

There are two main models for explaining what causes the disadvantage experienced by disabled people, the medical model (individual), that encourages explanations in terms of the features of an individual's body, and the social model, that encourages explanations in terms of characteristics of social organisation. The social model of disability makes the important distinction between 'impairment' and 'disability'.

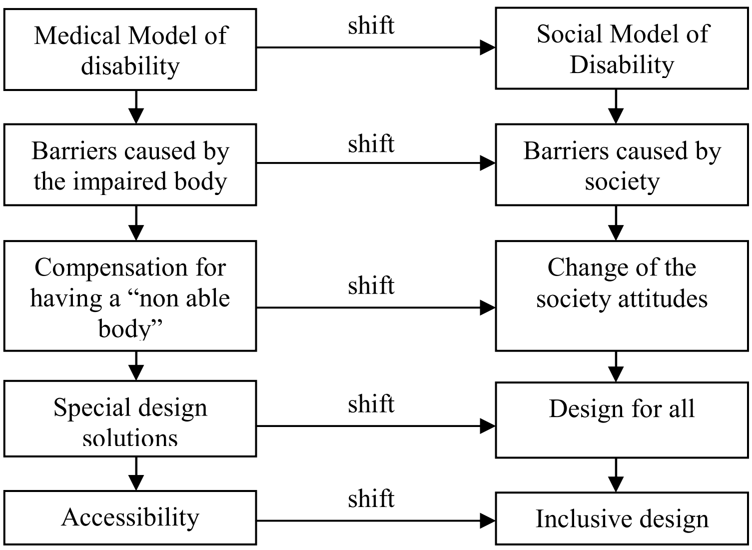

Figure 1: Medical Model of disability - accessibility and social model of disability - inclusive design: interrelated concepts

Any action taken to remove the barriers affecting disabled people depend on what is believed to be the cause then it is necessary to understand the interrelation between the models of disability and the concepts of accessibility and inclusive design (See Figure 1). Using the medical model of disability approach that considers disability as a consequence of the impaired body, special solutions in the built environment are promoted to remove barriers. This leads to segregation of disabled people from non-disabled people through alternative facilities (accessibility). From the social model perspective, the barriers are caused by society where every one should be able to use the built environment without distinctions (inclusive design).

There is a long way to go in the achievement of inclusiveness, however with the advent of the social model and the subsequent design concept, movement in the right direction is happening. The attainment of inclusiveness is, in part, a consequence of the application of different models of disability on the development of accessibility policies and standards. Nevertheless, adaptations of the spaces can do little or nothing to eradicate the underlying, disablist, values of society with its institutional structures within which most disabled people have to lead their lives. Therefore, accessibility and inclusive design should be approached in a holistic way.

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KEY INGREDIENTS FOR GROWTH OF MICRO ENTERPRISES IN THE UK CONSTRUCTION INDUSTRY

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Abstract: This paper explores the issue of growth in micro enterprises in the UK construction industry. The paper highlights the non-growth and high attrition phenomenon which is observed in micro enterprises in the UK construction industry and tries to shed light on three key issues namely the conditions of growth, growth barriers and constraints and the possible growth routes for a micro-enterprise. The paper also contains a growth recipe for micro-enterprises which highlights the key ingredients which are required by a micro-enterprise to achieve growth.

Keywords: Micro-enterprises, Growth Routes, Growth Recipe, Barriers and Constraints.

1. INTRODUCTION

Micro enterprises are very important for the UK construction industry, comprising 93.58% of construction enterprises (NSO, 2005). The FSB manifesto (2001) states that with regard to the construction sector, over 86% of employees work within micro enterprises and is responsible for 75% of the turnover. According to a quarterly survey of 800 micro enterprises operating in the manufacturing, construction and services sector, those in the construction sector continued to buck the UK economy's downward trend in the first quarter of 2005, with buoyant levels of business activity and new orders (PKF Index, 2005). This further indicates their significance to the whole UK economy as a whole.

Micro enterprises in UK construction industry have an attrition rate of about 90 percent (SBS, 2003) and this could be perceived as being detrimental to the industry and may impinge, through a trickle down effect, on the whole construction economy. Growth is widely known to be of fundamental importance to long-term survival of all companies, yet there is little emphasis placed on it by the micro-enterprises. The objectives of this paper are to explore why micro enterprises tend to hold back from achieving growth even though growth is essential for their very survival and also to address various other issues related to growth. The paper also contains a growth recipe for micro-enterprises.

The methods/models employed to tackle these issues were different from each other engendering a mixed approach to research. The investigation of these questions will proceed as follows. The discussion will commence by clarifying what are micro enterprises before moving on to addressing why micro enterprises should look for growth and a brief explanation of different theories of growth.

2. WHAT IS A MICRO ENTERPRISE?

Micro enterprises can be defined using two main approaches namely:

Quantitative: This is based on criterions such as employment, turnover and asset size. These vary by industry and country.
Qualitative: On the basis of ownership or control of the business.

Micro enterprises are quantitatively defined as enterprises which employ fewer than 10 persons and whose annual turnover or annual balance sheet total does not exceed 2 million euro (European Commission, 2005). Glancey and McQuaid (2000) suggest that micro enterprises can be qualitatively defined as firms which are largely independent and not mostly owned or controlled by large firms. The definition which has been adopted by the European Commission (2005) for micro-enterprises is standardized cross-industry but according to Penrose (1959) this should be avoided as micro enterprises in some industries perform better than in other industries owing to better working conditions and opportunities.

3. WHY SHOULD MICRO ENTERPRISES LOOK FOR GROWTH?

As part of research conducted for this paper a series of interviews were carried out with owner managers of micro enterprises; when posed with the question whether they would like to grow their enterprise or not, 77 percent responded that they did not want to growth their form as it involves a great degree of risk.

This reluctance to growth in micro enterprises has to do with the perception of the owner managers whose main reason to start-up a business has to do with independence they enjoy working for themselves; they are often scared that any sort of growth would be akin to giving up their independence (Gray, 1997). But the issue is why a micro enterprise should grow; the following facts and figures would help:

a) In 2002 there were 18,900 registrations in the UK and there were 17,600 de-registrations in the construction industry; this equates to a 93% failure rate of business (SBS, 2003).
b) Over an 11 year period, the rate at which the number of micro enterprises in the construction industry that joined the VAT system has not significantly changed (see Figure 3.1). Considering the number of start ups each year, the statistics for failure are alarming.
c) Micro enterprises in the UK construction industry had a mean survival rate of 55% between Jan 1995 and January 1999 (see Table 3.1).

Considering the position of micro enterprises in the construction industry such a high failure rate and low survival rate would be disastrous for the whole UK construction industry. Thus it would not be wrong to state that growth of micro-enterprises for the survival of the UK construction industry as a whole.

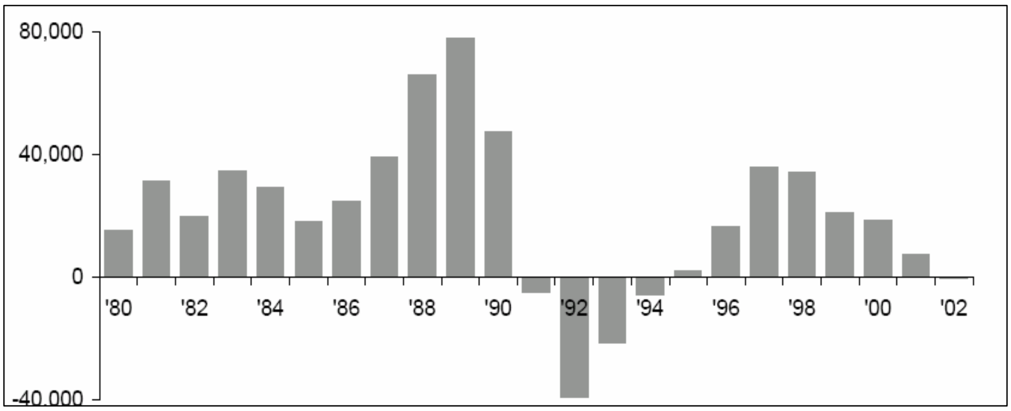

Figure 3.1: Net change in the stock of VAT registered enterprises in the UK construction industry, 1980-2002 (SBS, 2003)

Table 3.1: VAT Survival Rates (SBS, 2003)

Region	Born 1998	Born 1997	Born 1996	Born 1995
Northern Ireland	0.97	0.88	0.80	0.71
South West	0.96	0.81	0.68	0.55
East of England	0.96	0.81	0.67	0.55
South East	0.96	0.81	0.68	0.56
North East	0.95	0.78	0.62	0.49
London	0.95	0.78	0.65	0.54
Yorkshire and Humber	0.95	0.78	0.65	0.52
East Midlands	0.95	0.78	0.65	0.53
Wales	0.95	0.79	0.66	0.55
Scotland	0.94	0.79	0.67	0.55
West Midlands	0.94	0.79	0.63	0.53
North West and Merseyside	0.93	0.77	0.64	0.51

4. WHAT IS MICRO ENTERPRISE GROWTH?

Growth in a micro enterprise is a very complex issue. It is multidimensional in scope and character (Morrison et al, 2003; Scase and Gofee, 1989). Growth is generally on a convergence of owner-manager ambitions, intentions and competencies; internal organizational factors; region specific resources and infrastructure; and external relationships and network configurations (Morrison et al, 2003; Storey, 1994; Glancey, 1998; Mitra and Matlay, 2000; Shaw and Conway, 2000).

O'Farrell & Hitchens (1988) in their review of alternative conceptual frameworks for explaining micro enterprise growth, classify available business growth theories into four main groups:

1) Static Equilibrium Theories: Based on theories derived from the field of industrial economics that tend to be preoccupied with attainment of economies of scale and minimisation of long-run unit costs and is insufficiently concerned with the dynamics of growth.

2) Stochastic models of firm growth: Based on theories developed mainly in the field of economics. There are many stochastic models of firm growth, but Gibrat's law of proportionate effect (1931) stands out, which proposes that business growth rates are independent of enterprise size.
3) Strategic management perspective: This is one of the most widely accepted perspectives to look at micro enterprise growth and hence requires greater attention than the other micro enterprise growth theories. Strategy is often confused with tactic as they have very similar definitions but what sets the two apart is that strategy is long term whereas tactic is short term. Houlden (1993) defines strategy as; "strategy is about choosing - where and how to compete, how to organise, who to appoint and how to allocate resources for the greatest overall success". Strategy is often equated to operational effectiveness but Porter (1996) suggest that operational effectiveness is no longer a strategy instead strategy has to do with 'unique activeness' and doing things 'differently' to others.
4) Theories of economics: According to which micro enterprise growth is viewed as a series of phases or stages of development through which the business may pass in an enterprise life-cycle. These theories have an important role to play in the study of micro enterprise growth and have been reviewed in length in the following section of the literature review.

O'Farrell & Hitchens (1988) suggest that, many factors affect growth and, therefore, there is no dominant theory. McMahon and Stranger (1995) state what seems to be the problem with most of the literature concerning enterprise growth, 'Simplicity and parsimony are qualities which seem to be overlooked in the zeal to provide as comprehensive and nuance-replete an explanation as possible of growth phenomena'.

5. WHAT ARE THE CONDITIONS FOR GROWTH IN A MICRO ENTERPRISE?

The conditions or pre-requisites which need to be in place for an enterprise to grow as suggested by Penrose (1959) are as follows:
Prevailing Environment

1) Skill Base of the Enterprise
2) Perceptions of the Entrepreneur

5.1 Growth depends on the prevailing environment

Penrose (1959) suggests that:

- Environmental control on growth rather than by quality of resources and ingenuity of entrepreneur.
- External environment is not a constant; it cannot be predicted and needs constant monitoring.

Having an awareness of both the general and task environment is a pre-requisite for an enterprise to have a competitive advantage (Wang and Yang, 2000). According to Penrose (1959) the prevailing environment is the most important condition for growth; it is in a constant dynamic state and envelops the enterprise within itself. The external environment which constitutes the macro-economic developments, market conditions, access to resources etc, affects the growth outcomes of the enterprise (Colin and Slevin, 1997). Studies on the importance of external environment for growth in a micro-enterprise are limited in number and were found generally lacking in their effort to prove this point; there has a scope for further research in this field. Micro enterprises have no real control on the external environment; all they can do is to constantly observe the external environment for opportunities and threats and then act accordingly to take measures to counter the threats and make the best of the opportunities so as to gain a competitive advantage.

5.2 Growth is dependant on the core competencies and skill base of the micro enterprise

The ability of the entrepreneur to take advantage of what he sees in the environment is dependant on the types and amounts of productive services existing in the firm and what it is accustomed to operate (Penrose, 1959); from what Penrose (1959) suggests it can be deduced that the core competency of an enterprise has to do with the following:

a) Productive services offered by the firm;
b) And what it is accustomed to do.

Thus it would not be wrong to say that core competencies of an enterprise has to do with what services it specialises in and how adept it is at doing it. There is a general lack of information regarding how the core competency of a micro-enterprise in the construction industry affects its ability to achieve growth and thus opens up a scope of further research in this field. Micro-enterprises need to focus on enhancing their core competency in order to improve their ability to achieve growth. Core competencies are internal factors and hence micro-enterprises have complete control over them.

Skill base of an enterprise has to do with the people who are part of it. Growth of micro-enterprises depends on their skill base; in situations were there is skill shortage their ability to achieve growth is greatly curtailed. Skill base is defined by the external environment and thus it would not be wrong to say that enhancing the skill base is not within the control of micro enterprises and requires external intervention e.g. government led initiatives.

5.3 Perception of the Entrepreneur

Micro enterprise growth as has been proposed does not represent a self-evident phenomenon nor is it a matter of chance, but is a result of clear, positively motivated business intentions and actions on part of the owner manager, driven by the belief that the owner manger can produce the desired outcomes (Morrison et al, 2003; Gray, 2000; Maki and Pukkinen, 2000).

Hyrsky (2000) in a analytical study of small business managers in Europe, North America and Australia identified work commitment and energy, economic values and results, innovativeness and risk taking, ambition and achievement, and egoistic features as dimensions of entrepreneurship. Covin and Slevin (1988) suggested the differences between entrepreneurial style of functioning and non-entrepreneurial style of function on part of the small business managers (see Table 5.1).

Carland et al. (1984) gives a clear distinction between entrepreneurs and owner managers of small businesses; the main concern of an entrepreneur is profitability and growth whereas a small business manager is concerned about securing an income to meet his immediate needs. This suggests that growth intentions and innovativeness are characteristics of entrepreneurial behaviour. Orser et al. (2000) noted that business owners' motives for growth are not homogeneous and reflect experiential and situational differences.

Table 5.1: Difference between entrepreneurial and non entrepreneurial style of functioning on part of the owner managers

Entrepreneurial Style	Non-entrepreneurial Style
• Inclined to taking business risks. • Favour change and innovation. • Compete aggressively with other firms.	• Risk averse. • Non-innovative. • Passive and reactive.

As part of research conducted for this paper it was found that for more than 38% of the micro enterprises, independence was the motivation to start up. This shows that very few owner managers started of with an entrepreneurial seizure; independence was their driving force which does not indicate any sort of entrepreneurial behaviour on their part. This lack of entrepreneurial behaviour may also depend on the background of the entrepreneurs. It is necessary for the owner managers of micro enterprises to have the characteristics and traits of an entrepreneur if they want their enterprise to grow. A list of characteristics and traits required in an owner manager for enterprise growth has been enlisted by International Labour Organization (see Table 5.2).

Table 5.2: Characteristics and Traits Required in an Owner Manager for Enterprise Growth (ILO, 1998)

Characteristics	Traits
Self confidence	Belief in ability, independence, optimism
Strong will power	Persistence and perseverance, determination
Task/result oriented	Achievement-oriented, hard work, initiative
Risk taker	Risk assessment and judicious risk taking ability
Leadership	Good communicator, responsive to suggestions, develops other people
Originality	Innovative, creative, flexible, resourceful, versatile, knowledgeable
Future-orientated	Foresight, vision, perceptiveness

6. WHAT ARE THE GROWTH BARRIERS AND CONSTRAINTS FOR A MICRO ENTERPRISE?

Barriers and constraints are often confused to be one and the same but they are distinct and hence have different effects on a micro-enterprise; barriers are obstacles which a micro enterprise has to cross before they try to look for growth whereas constraints are limitations which are inherent to micro-enterprises and the environment around them which restrict their growth.

As part of a research conducted for this paper respondents were asked to identify what they considered were barriers which prevented them from achieving growth in their firm; they identified the following:

a) Economic cycle (down-turn);
b) Unattractive regulatory environment;
c) Downward industrial life-cycle;
d) Lack of corporate strategy;
e) E-Business lethargy;
f) Organization and leadership;
g) Lack of customer intelligence;
h) Operational and competence gasps.

As part of research conducted for this paper respondents were asked to identify and rank the constraints (see Table 6.1).

Table 6.1: Constraints which prevents micro enterprises from achieving growth

Constraint	**Rank**
Availability and cost of finance for expansion	1
Availability and cost of overdraft facilities	2
Overall growth of market demand	3
Increasing competition	4
Marketing and sales skills	5
Management skills	6
Availability of skilled labour	7
Acquisition of new technology	8
Difficulties in implementing new technologies	9
Availability of appropriate premises or site	10
Access to overseas market	11

Removing the bottlenecks and barriers is of utmost importance if a micro enterprise is to achieve growth.

7. WHAT ARE THE POSSIBLE GROWTH ROUTES WHICH A MICRO ENTERPRISE CAN ADOPT?

This has been achieved by conducting a historical development study and archival analysis of the growth routes adopted by 45 leading construction companies from around the world; all these companies were micro enterprises to begin with. This exercise gives a pattern of what growth routes these companies adopted; this is not necessarily the way forward for micro enterprises as with changing times growth routes might differ. The result of this study would enable micro enterprises to look at what their peers in the industry had done, which would benefit them as most of the companies have to go through the first few stages of growth irrespective of time. There are many growth routes which a micro enterprise in the construction industry can take to achieve growth. These growth routes range from short term decisions (tactic) to long drawn out strategic decisions (strategy) which are implemented over the course of time. As part of this study it was found that most companies chose a mixture of growth routes but a few of these methods were prominently used and hence have been explained in greater depth. The growth routes adopted by the companies are as follows namely:

1) Specialization
2) Innovation
3) Geographic Relocation
4) Geographic Expansion
5) Organic Expansion
6) Partnership
7) Diversification
8) Become a PLC
9) Becoming Incorporated
10) Acquisition
11) Employee Participation
12) Defining Corporate Strategy
13) Advertising and Marketing
14) Disinvestment and Downsizing etc.

Specialization: Specialization is about an enterprise focusing on a single product offering, service or niche in the industry. It would not be wrong to say that all enterprises do specialise in their start-up stage but they tend to go wrong on specialising based on the technical background of the owner manager rather than on the basis of opportunities which exist in the external environment (Southon and West, 2002).

Innovation: Innovation is the effective generation and implementation of a new idea, which enhances overall organizational performance (Barrett and Sexton, 1998). The outcomes of innovation are hard to quantify in monetary terms (profit, asset, value added etc) and hence its adoptions as a growth by a micro enterprise in the construction industry is restricted. There is a dearth of research investigating innovation from the perspective of the construction firm (Egbu et al, 1998, p.605; Gann and Salter, 2000, p. 955). Research conducted as part of this study found that innovation is one of the primary routes adopted by construction firms at the initial stage of their life to achieve competitive advantages over other firms.

Geographic Relocation: Geographic relocation involves an enterprise shifting location from its initial business base. This is a common step which enterprises take when they see that the opportunities in their initial base have dried up and they shut shop and move on to a different location where opportunities might exist, this is akin to nomadic behaviour where a nomad takes his herd from one region to other in search of fresh pasture.

Geographic Expansion: This approach involves expanding a firm's business from its original location to one or more additional geographic sites, and is particularly well suited for firms that cannot expand in their present location but believe that their products or services may be appealing to consumers in other markets.

Organic Expansion: Organic expansion involves growth in an enterprise from within based on its skill base, core competency and on the perception of the owner manager who as at the helm of the enterprise; it has to do with expansion in terms of number and size of projects handles, number of services offered etc.

8. GROWTH RECIPE FOR MICRO ENTERPRISE IN THE UK CONSTRUCTION INDUSTRY

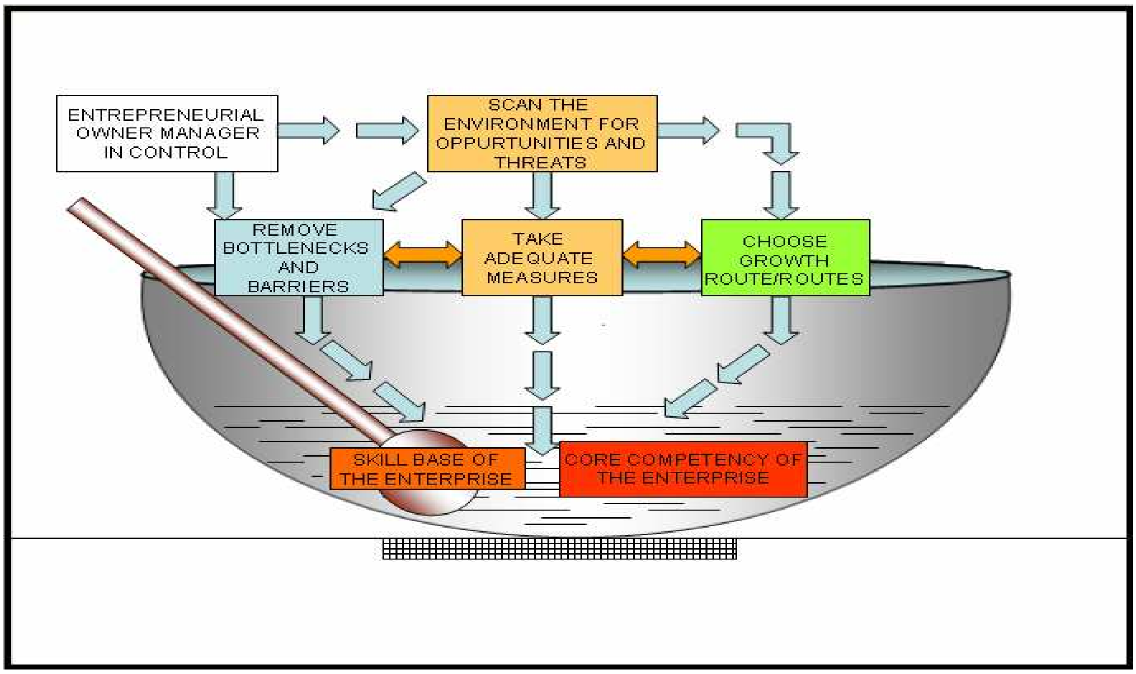

Fig 8.1: Recipe for Growth for micro enterprises in the Construction Industry

Fig 8.1 explains how akin to a master chef preparing a fine cuisine with the right balance of ingredients, an entrepreneurial owner manager of a micro enterprise in the construction industry needs to mix all the ingredients for growth properly and constantly monitor and supervise so as to achieve growth. There is a great degree of similarity between the two situations; if the chef does not oversee the whole process then the result would be a failure which is very similar to how an owner manager of a micro enterprise needs to address the issue of achieving growth in his firm or else suffer failure.

8. CONCLUSION

This study has attempted to look at the variable components which are integral for growth for a micro enterprise in the construction industry. This is a suggestive study and does not claim to have found the panacea for treating the high failure rate of micro enterprises instead has tried to address the issue and hints that there is definitely a way forward. Micro enterprises are essential for the survival and growth of the UK construction industry; and this multi-faceted study has tried identifying the essential components for achieving growth in micro enterprises. It should be noted that growth of a micro enterprise is not within the complete volitional control of the owner manager instead, is defined to a great extent by the external environment, in situations when the external environment is not conducive, growth could be an absent commodity. When presented with such a situation the owner manager should not loose focus instead should find alternative ways forward. This identification of an alternative way forward depends on the opportunism of the owner manager (Sanchez & Heene, 2004).

This study has only highlighted the issues surrounding growth and tried developing suggestive models; what is required is a long drawn out concentrated effort to develop a perfect recipe for growth; it could be argued that there is no such perfect recipe for growth as all enterprises devise their own strategies depending on their core competency and skill base.

Every micro enterprise in the construction industry has to try developing its own recipe for growth but what they have to remember is that the external environment is dynamic and thus any recipe which they develop would have to be flexible enough to cope with the dynamics of the environment.

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APPLICABILITY OF STRUCTURE CONDUCT PERFORMANCE PARADIGM TO THE UK PRIVATE FINANCE INITIATIVE MARKET

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Abstract: The Public Private Partnership/Private Finance Initiative (PPP/PFI) market in the UK has now increased significantly where the capital value of the projects has reached £ 42 billion from over 670 projects. Out of 550 projects, approximately 60% involve construction and/or property activity. As the PFI market matures and showing signs of high growth potential, the UK construction industry has inevitably experienced changes such as mergers and acquisitions of PFI intensive firms, involvement of external entities (such as financial firms) in the PFI construction market and some strategy changes within the industry. These activities and changes can be examined based on already established industrial organisation theories and conceptual models. One such model is the Structure, Conduct and Performance (SCP) Paradigm, which stresses that certain market conditions affect the structure of the firms within a market which later shape their strategic behaviour or conduct and finally decide the performance of the firms in the industry. This paper discusses the UK PFI market in relation to the overall construction investment, orientation of the UK construction market that are attributable to the PFI developments, some features of SCP paradigm and the applicability of the paradigm to measure the changes in the UK construction industry as a result of the introduction of PPP/PFI.

Keywords: Industrial organisation theory, Private Finance Initiatives, Structure Conduct Performance (SCP) Paradigm.

1. INTRODUCTION

The Public Private Partnership/Private Finance Initiative (PPP/PFI) scheme was introduced to tackle the deterioration and inadequacy of public built facilities and infrastructure for competitiveness of the UK economy in late 1970s and 1980s (Winch, 2000). The objective is to share the best resources possible and risks between public and private sectors in a contractual agreement in delivering services and infrastructures to the public and the economy. The public sector provides its initiative and authority, and the private sector brings the financial acumen and managerial and/or technological ability to the table. In doing so, the public sector transfers a significant amount of project risks to the private sector, which is deemed suited and able to manage (CIC, 1998). PFI is generally recognised as a long-term sustainable strategy for improving the social infrastructure and enhancing the value for tax payers' money (Akintoye et al., 2003) in competitive and innovative ways.

The value and utilisation of PPP/PFI schemes in the UK has now reached £ 42 billion from over 670 projects (PUK Database, 2005). Approximately 60% out of 550 PFI projects examined by Jordan and Dixon (2004) involve construction and/or property activity. The UK government's enthusiasm in using PFI as one of the major public procurement method is perceptible through its PFI usage trend within the last decade (see Figure 1, which shows the trend in terms of increasing value and number of signed

PFI schemes from 1987 to 2003). It is claimed that UK construction industry is in a more stable ground after the emergence of PFI schemes (Corporate Watch, 2004). Between 2001 and 2002, construction output is estimated to have increased by 9.7 % (Construction Industry Market Review, 2003; Corporate Watch, 2004).

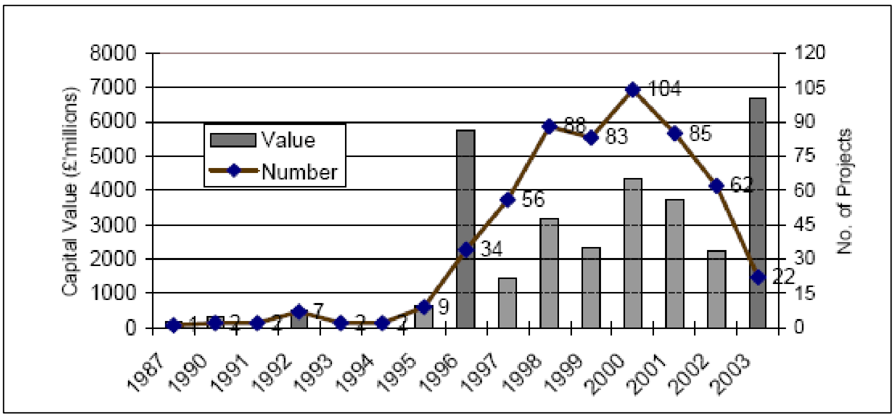


Figure 1: The number and capital value of signed PFI projects *(Source: Akintoye et al., 2005)*

The PFI market in the UK construction industry extensively involves financial advisors, investors, government departments, policy makers, legal advisory firms, risk management/insurance firms, technical advisory firms and waste management firms that are outside the construction industry. The implications of PFI to and from these stakeholders are apparent but the magnitude is less clear. There are great divisions of opinion and perception within government departments, industrialists and academics towards PFI and in some cases, these criticisms about PFI have been a subject of media debate and discussions. The perceived impact of PFI scheme is still regarded ambiguous and widely unknown after more than a decade since it was introduced. This paper aims to propose the SCP paradigm as a tentative tool for assessing the PFI market in the UK to provide means to address some of the criticisms of the PFI, particularly from the construction sector perspective.

2. MAINSTREAM ISSUES IN PFI SCHEMES

Despite the claim that the concept of PFI seems to produce the mutual benefits of both public and private stakeholders, it is never agreed that both sectors are maximising the benefits at the same time. Mainstream issues concerning PFI such as: increase in public expenditure because of PFI projects, whether PFI capital expenditure is additional or substitutional for the government, accountability of PFI projects, fiscal dilemmas, public sector comparator (PSC) usages, discount rates and expensiveness, effectiveness of risk transfer to the private sector, contract standardisations and whether PFI projects deliver overall value for money as expected are dominating problems for the public sector procurement system (House of Commons, 2001). For the private sector, issues such as high bidding costs, higher cost of borrowing and funding, long and cumbersome bidding time for PFI projects, market capacity, political and economical uncertainties, risks management and press/public perception are dominant (Robinson et al., 2004). Research into these areas have been currently explored and mostly dominate the PFI research fields and debates (Li, 2004; Robinson et al., 2004; House of Common, 2001).

3. EFFECT OF PFI ON THE UK CONSTRUCTION INDUSTRY

3.1 Domestic Market Implications of PFI

It is a general assumption that PFI schemes positively affect the UK domestic construction industry. For example, National Audit Office (NAO) reported in 2003 that 29 out of 37 PFI projects produced no construction related price increase after contracts were awarded. As shown in Table 1, 73% of non-PFI projects exceeded price agreed at contract compared to only 22% of PFI projects that exceeded the price agreed. In addition, 70% of non-PFI projects were delivered late compared to only 24% of PFI projects and only 8% of PFI projects were delivered over two months late (NAO, 2003). The main reason being that is the private sector consortiums would like to operate the facility faster to receive their payments with greater certainty. In addition, such results are mainly attributed to the need for the private sector to manage the risk transfer to it by the public sector effectively (Akintoye et al., 2003). The UK construction industry has also found that PFI projects produced cost improvements of 5 % to 10 % both on construction and subsequent operations or facility management (Public Account, Thirty-Fifth Report, 2003). Nevertheless, and importantly, the NAO (2003) is not able to judge whether the present performance by the construction industry in aforementioned PFI cases could also be resulted from using different procurement routes rather than PFI.

Table 1: Comparison of cost and time overrun on public construction project delivery

	Previous Experience (1999 Government Survey)	**PFI Experience (2002) NAO Census**
Projects where cost to the public sector exceeds price agreed at contract	**73 %**	**22 %**
Projects delivered late to public sector	**70 %**	**24 %**

(Source: NAO, 2003)

Given that early PFI schemes involved mainly infrastructure projects, the construction industry arm of the private sector is highly affected by the PPP/PFI schemes. As the risks involved in the PFI schemes are great, the incentives and opportunities are also immense depending on the level of involvement in the schemes; many construction companies were attracted by the opportunities offered by PPP/PFI rather than by the risks presented.

Through their involvement in PFI schemes, the construction companies can not only gain the financial benefits, but also gain the experiences, skills and knowledge to better manage their assets in an innovative and more efficient ways since PFI projects require more proactive financial management system than in traditional projects (CIC, 1998). Moreover, the strategy formulation for taking part in the PFI schemes particularly where new market opportunities or niche presents, plays a great role for the development of the construction companies. The experiences and the expertises gained in the PFI projects could also be used in the overseas markets of the industry. The current major players in the PFI market in the UK construction industry, ranked by the total net sales are shown in Table 2. The PFI market sector in the UK construction industry is largely dominated by these companies.

Table 2: UK's Top 12 leading PFI contractors in ranks by their total net sales until year 2004

Position	Contracting Firm	Total Net Sales (£ M)	Number of Projects
1	Skanska	2,973	23
2	Balfour Beatty	2,918	33
3	Laing O'Rourke	1,661	17
4	Carillion	1,613	22
5	Amec	1,193	13
6	Mowlem	1,192	14
7	Jarvis	1,167	33
8	Bovis Lend Lease	922	8
9	Sir Robert McAlpine	895	5
10	AWG	877	11
11	Alfred McAlpine	784	13
12	Bouygues	769	6

(Source: Hipperson and Gillman, Skanska, 2004)

3.2 International Market Implications of PFI

According to Crosthwaite (1998), it has been stressed by major construction firms in the UK that international market activities should be increased in order to tackle problems within the domestic construction market. From 1990 to 1996, UK construction firms actually increased their international activities. However, after peaking in 1996, still having a high volume of revenue on international market, their market share started to decline. Even though UK construction firms are among top international firms in terms of rankings with significant volume of global contracts, their market share and international involvement has significantly declined in recent years, and firms from countries such as China are gaining bigger market share globally.

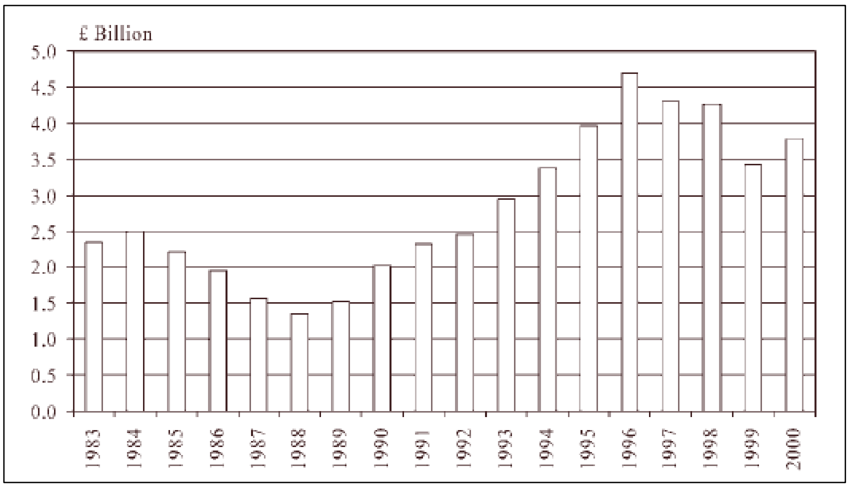


Figure 2: Value of work undertaken overseas by British construction firms in 1983–2000 (£ Billion in current prices) *(Source: DTI, 2001 in Pheng et al., 2004)*

A report from the Engineering News Records (ENR) in 1995 indicated that 12 UK firms with international revenue of US$ 11.444 billion which accounted for 12.4 % of total revenue were among the top 225 construction firms in the world (Pheng et al.

2004). The share decreased in 2002 to only 4 UK firms in the top 225 firms with international revenue of US$ 8.58 billion which accounted for 8.06 % of the total revenue. In the latest report of ENR in 2004, UK firms slightly increased in number from 4 in 2002 to 6 firms with the revenue worth of US$ 9.1 billion, but the market share has significantly decreased to only 6.5 %. Among these 6 firms, 4 of them declined in rankings from 2003 with one firm without previous ranking came in and one firm with only one ranking inclination. On average 47.3 % of the revenues of these 6 firms are from international contracts. In 2003 and 2004, the value of US dollar has decreased and yet, the UK firms could not sustain their market share of 1996. Figure 2 shows the trend in the UK construction firms' involvement in overseas construction activities in their value of work. Such decreasing global market share suggests a declining global competition of the UK construction firms. However, on the domestic front, these firms have witnessed increasing projects counts, sizes, revenues from involvement in the PFI markets after year 1997 when the labour government endorsed the schemes for a principle public procurement strategy. Development and trends of PFI projects that enjoyed a boom after year 1997 is significant to take account. The coincidence in the boom of the UK PFI market and the decline in the international market share could indicate the impact of PFI schemes on the UK construction industry. Other factors contributing to this decline may be the profit margins expected from international contracts which did not meet the high expectations under different risks involved in global construction market (Crosthwaite, 1998) and the economical declination of Middle East region due to poor regional stability in recent years.

3.3 Corporate strategy changes in the UK construction firms

There are clear indications that PFI schemes have greatly impacted the structure and conduct of the UK construction industry, significantly towards the corporate strategy changes of the construction firms. Prominent market factor contributing to this change of corporate landscape is identified by Morton (2002) as PFI scheme. Mergers and acquisitions of PFI intensive construction firms and non-construction firms especially in the firms of large scales and of greatly diversified business activities are some important examples. Involvement of external entities such as financial firms getting into the PFI construction market, shift of focus of construction firms towards services such as facility management and maintenance provide evidence of the impact that PFI schemes have toward the construction industry (Morton, 2002). Examples include Skanska's purchase of Kvaerner's construction arm in order to enhance its PFI expertise in 2000; Amec's restructuring in 1999 into three divisions namely investment, capital projects and services to move away from traditional work and shift towards more negotiated partnered work and PFI schemes; P&O, Bovis and Lend Lease merger-acquisition in 1999; Tarmac and Carillion, the firm which is extensively involved in PFI schemes, splitting in 1999; construction firm Laing's business focus change towards PFI in 1999, etc (Morton, 2002). All these firms are ranked as top firms within the UK PFI market sector (Table 2) as well as power houses within traditional construction market. Pheng (2004) pointed out that some numbers of recent takeovers were mainly prompted to acquire and access the expertise involved in the PFI schemes. The attractiveness of the PFI schemes has driven the construction firms into a trend of involvement in non-construction activities as part of their business lines which have emerged through horizontal diversification process and integrated business structure. These diversification and differentiation processes have created UK construction firms with subsidiaries engaged in areas such as financial services, investment, property, facilities management and international PFI developments. (Pheng et al., 2004).

UK construction firms also have the competitive advantage in the global market from the financial abilities or linkage with financial institutions and expertise in the financial sector rather than relying solely on its construction ability (Pheng et al., 2004). These firms have developed two corporate strategies when engaged in the global construction market; consolidation of core contracting business or specific contracting and importantly, differentiation of services in the areas of financial services and facilities management (Hillebrandt et al., 1995; Morton, 2002; Pheng et al., 2004); these have developed from extensive PFI schemes in the domestic market.

3.4 Market conditions

The PFI market in the UK seems to have become highly concentrated as the same major firms dominate the market. It is also noted that in some projects, only one or two bidders are involved in the bidding process. The nature of PFI schemes especially in the lengthy period of bidding, negotiation and high cost of bidding has also led the industry into high market concentration. According to Lend Lease (2004) in PFI healthcare projects, big deal size, prolong bidding timescales and high bidding costs lead to consolidation of "1st and 2nd Divisions" within PFI market competitors.

3.5 The Need for Analysis in PFI Construction Sector

Current mainstream research on UK PFI have explored the areas of public finance policy, risks, project performance, value for money and project finance options but none has looked into the impact of PFI on the construction industry. Since the PFI market has become an integral part of the UK construction industry, it is important that both tangible and intangible impacts of the PFI schemes are assessed empirically using the tools that have been developed for industrial organisation analysis. The Structure, Conduct and Performance (SCP) Paradigm has been used widely as a basic tool to analyse the cause and effect of the market conditions, market structure, its conduct and the resulting performance of industries (Scherer and Ross, 1990; Faulkner and Campbell 2003). To identify sets of attributes or variables that influence economic performance of a market sector and to build theories detailing the links between these attributes and end performance, the SCP Paradigm is commonly used as a broad descriptive model (Scherer and Ross, 1990). Introduced by Mason (1939), it explains the behaviour of the interlinking structures, conduct and performance of an industry where basic market conditions shape market structure, which influences market or firms' conduct and then the resulting conduct determines the performance of the firms (Bain, 1968). Within this paradigm, the classic testable hypothesis has been that industry profitability is significantly correlated with the concentration ratio and categorisation of the height of barriers to new entry (Scherer and Ross, 1990), i.e. the conditions of market structure. Since PFI market has emerged with its own attributes and market characteristics such as basic conditions within the construction industry affecting the market concentration, market attractiveness, barriers to entry, risks involved and cost structures, its effect on the structure of the industry is significantly unique and can be tested by the SCP paradigm.

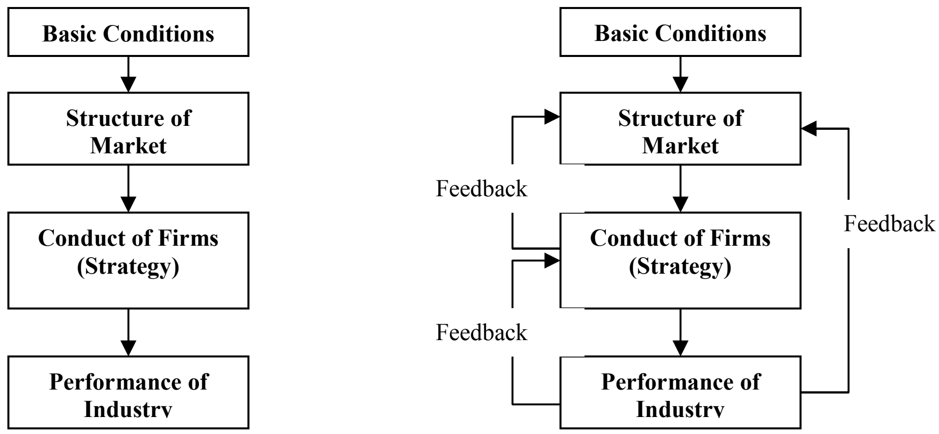
In 1980s, Game theory has emerged as a modern industrial organisation theory and replaced SCP paradigm (Froeb, 2004) in some aspects of the industry analysis, but the SCP paradigm is still significant particularly in measuring the industry structure and performance (Baye, 2003) resulting from the influential basic conditions. Moreover, Game theory emphasises mainly on the strategy implication of firms towards the performance; and implies that under same basic conditions such as supply and demand, public policy or same market structure, the conduct of the individual firms within the market greatly differs in their strategy to maximise the performance. Nevertheless, the SCP paradigm does not address the strategy of firms under same basic conditions (Scherer and Ross, 1990). As it is needed to measure the impact of PFI in terms of basic conditions affecting the market structure, the SCP paradigm shall be used as the primary tool in this study.

4. STRUCTURE, CONDUCT AND PERFORMANCE PARADIGM

To scale the impact of the PFI schemes on the construction industry, the use of a Structure, Conduct and Performance Paradigm (SCP Paradigm) seems plausible. It has been used in the manufacturing setting to analyse the causes and consequences of the market structure, the strategic behaviour of the organisations in the market with market power and the interaction or conduct between firm behaviours and the economic performance of markets (Shearer and Ross, 1990). The SCP paradigm has since been used for public or national policy analysis and has been standardized. However, the earlier model is said to be deficient of unilateral causality using static analysis frameworks among SCP models. In 1970s, Chicago theories emerged which imply bidirectional interactive relations among the structure, conduct and the performances of the market within the dynamic analysis frameworks.

The SCP model stresses that the analysis should focus on the critical determinant of the profitability, as it mostly determines the performance of the industry. However, Porter (1981) and Scherer and Ross (1990) insist that from the strategy and business policy point of view, it is the firms that structured the industry that should be assessed as this leads to the conduct which affects structure and performance in return (Faulkner and Campbell, 2003). The SCP paradigm can be used to analyse market performance as it also determines the market relationship with the clients (CFA, 2000). In the case of the PFI market, this will normally be public clients and end users of PFI projects. The theory generally predicts that profits and output prices would be higher because of greater level of concentration in a given market as a result of the greater ease of collusion in a more concentrated market (Polius and Samuel, 2002). However, the performance measurement should be comprehensive and multifaceted which will include both efficiency and fairness on the market (CFA, 2000).

The limitations of the SCP paradigm are particular in its deterministic slant, hence the need to consider the actions of each individual firms and their ability to alter the structure of the industry (Porter 1981, cited in Faulkner and Campbell 2003). Moreover, the competitive environment at industry structure and business unit level as well as internal strength of each firms play great impact on the SCP paradigm. Some interpretations, as Scherer (1990) pointed out, see the influences running from structure to conduct and performance as being weak, and the feedback affecting structure is so strong, that they doubt the predictive power of the structure-conduct-performance paradigm. The firm strategy, performance and the managerial strategic choice of firms, all of which influence the industry structure also break the deterministic hold of the industry structure on the performance in the SCP paradigm (Faulkner and Campbell, 2003). Figure 3 is the SCP model developed by Bain (1959) and Mason (1957), and the model suggested by Porter (1981).



(Earlier model by Bain (1959) and Mason, 1957)

(SCP model with feedback by Porter, 1981)

Figure 3: SCP models (Source: Faulkner and Campbell, 2003)

4.1 Market structure

Bain (1959) defined market structure as characteristics of an organisation of a market which seem to influence strategically on the nature of competition and pricing within that market. It determines the market concentration of which firms control the majority of the differentiated market and by what amounts. In addition, it determines the entry and exit barriers, and power distribution among the firms. The interaction among the firms in the industry includes relations and characters in the quantity, scale, share and benefit allocations between the market players. All the determinants of market centralization, product difference and market entry barriers and exit barriers play significant roles in the market structure. Faulkner and Campbell (2003) reaffirm the nature of market structure by indicating that the significant factors of market concentration are numbers of firms and clients, product or service differentiation, barriers to entry, cost structures, extent of vertical integration and diversification (Faulkner and Campbell, 2003). Table 3 shows four types of market concentration and the environment under which they are operated. They are categorised by calculating market concentration, low or high barriers to entry, level of product or project differentiation, number of suppliers and price determinants of the projects.

For the SCP model to be constructed in the PFI construction market context, it requires an understanding of the structure of a sector in relation to market concentration and competition. This can be determined by using the functions of all the individual firms' market shares as of top four firms (CR4) or eight firms ratio (CR8). The four firm concentration ration (CR4) is the sum of the market shares of the four largest firms and eight firm concentration ratio (CR8) is that of top eight firms within the same market. The Herfindahl-Hirschman Index (HHI), which is the sum of the squares of the percentage market shares of the firms in a market (Scherer and Ross, 1990), can also be used to analyse the competition level within the market sector. Content analysis of recent activities within the PFI construction sector can be used to provide the merger and acquisition movements of the key players in the sector. This analysis will reveal the market orientation, trend and the tendency of the PFI key players in relation with their activities in the sector.

Table 3: Types of Market Concentrations and their environment

	Perfect Competition	**Monopolistic Competition**	**Oligopoly**	**Monopoly**
Number of suppliers	Many	Many	Typically 2-10	One
Product/Project differentiation	Homogeneous (identical)	Some differentiation	Substantial differentiation	No close substitutes
Barriers to entry	None	None or Very Limited	Substantial scale and scope economies	Substantial
Concentration of market power	Zero concentration	Low	Medium to high	Maximum (perfect concentration)
Price determinants	Purely by supply and demand. No individual client or contractor can influence market price	Price as function of supply and demand, and the ability of a firm to charge more due to product/project differentiation	Ability to influence market price by restricting output	Ability to set market price by restricting output

(Modified: Department of Public Works, Queensland Government, 2002)

4.2 Market Conduct

Market conduct is a set of competitive strategies that firms adopted as a result of other factors, especially market structure. The conduct of a market includes pricing behaviour, product/project strategy and advertising, research and innovation, market investment, and legal tactics (CFA, 2000; Bain 1959, 1968). These enable competing firms to coordinate and adapt to each other to eliminate the potential entry or existing competition. The market conduct simply describe the behaviour of the firms in order to make profit and increase their market share in their relevant markets based upon the supply and demand condition. Content analysis coupled with a comprehensive analysis of the UK database of PFI projects such as the one produced by the Partnerships UK should provide some information on the conduct of major players in the PFI market sector .

4.3 Market Performance

The performance of a market is a multi-dimensional concept which encompasses effectiveness, productivity, efficiency, equity, profitability, quality, pricing and technological progress of the firms in the industry together with job opportunities and employment (Stern et al., 1996; Scherer and Ross, 1990). In other words, it refers to economic results; project delivery in relation to customer specification (effectiveness); rate of profits in relation to marketing costs and margins; price flexibility and price integration between markets (efficiency). It also refers to the impact of structure and conduct as measured in terms of variables such as prices, costs, and volume of output (Bressler and King, 1979). By analyzing the level of marketing margins and their cost components, it is possible to evaluate the impact of the structure and conduct characteristics on market performance (Bain, 1968). PFI performance and the performance of the key players involved in PFI should be capable of being measured in terms of the extent to which PFI projects are delivered within targeted time frame and contracted cost, compliance with the output specifications and long term sustainable operation. Attractive profit margins, growth and positive stock market performance will also show the market performance of the firms within the sector.

4.4 Cutomisation of the SCP Paradigm

The overall aim of the research is to develop a SCP paradigm customised to the UK PFI construction market to measure the direct impact of PFI schemes upon the UK construction industry. It is expected that the paradigm, with a set of matrixes and factors important to a SCP model in the context of the strucutre, conduct and performance of the PFI construction market, will provide some answers to the changes that have taken place in the UK construction industry and identify the attributes of PFI schemes on the industry. Analysis of the market structure of UK PFI sector coupled with an understanding of the associated market orientation and market strategy will enable us to understand the market conduct of the sector. The conduct of the PFI sector resulted from its structure, coupled with the assessment of the market performance, will facilitate the understanding of the impact of PFI schemes on the industry and the stability of the market in the long term.

5. CONCLUSION

The UK PFI procurement route for the delivery of public projects will certainly continue to increase in terms of the number and value of projects. It is difficult to say if the number of firms that will continue to participate in the PFI market will continue to increase or not given the current decline in the number of the key players' involvement in tendering for new PFI projects.

As the current market is dynamic and competitive, understanding PFI influence on construction firms and its impact on the industry is imperative. However, no research investigations on PFI have addressed the impact of PFI schemes on the UK construction industry. It is crucial to understand the impact of a significant public procurement method upon one of the biggest contributing sectors of the economy.

The UK construction industry has changed significantly in terms of its global market share, domestic market and involvement in non-construction activities, since PFI was introduced. Hence, an understanding of the impact of PFI on the construction industry based on an empirical investigation could bring positive outcomes to the public perception of this procurement system and bring more awareness of the market drivers and strategy. An evidence based approach to current PFI market is essential to deliver successful PFI projects. An understanding of the structure and conduct of the PFI sector may also provide an incentive for new firms within the construction industry to enter the market.

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MODELLING IN RANKING PROCEDURES; A CASE STUDY: INFRASTRUCTURE FAILURES IN NIGERIA

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Abstract: The lack of a scientific approach as to which factors are considered or chosen in a decision-making process can seriously influence the effectiveness of that process. Using the example of infrastructure failures in Nigeria, this paper presents a severity index in matrix order (SIMO) model that unambiguously ranks factors and also defines a threshold that demarcates between major variable factors that should not be compromised in policy and less important ones. Infrastructures failures in Nigeria have hindered economic processes which were meant to alleviate poverty. Constraints responsible for this situation are identified from a carefully conducted survey in Nigeria. Severity of these constraints is empirically ranked using a developed severity index in matrix order (SIMO) model. However, the investigation reveals that corruption, misallocation of investments, inadequate maintenance, lack of transparency and accountability, insufficient funding for infrastructure, lack of supportive institutions, inconsistent political, social and economic policies and the lack of suitable technical and managerial skill are the major variable factors responsible for infrastructure failures in Nigeria.

Key words: Modelling, Ranking, Severity-index, Failures, Infrastructure, Nigeria

1. INTRODUCTION

Decision-making processes need a clear understanding of factors involved and how they affect the process being considered (Levine et al., 1999). A ranking procedure is an effective way of knowing the relative importance of these factors (Clarke and Cooke, 1992; Levine et al., 1999). Various ranking techniques for example severity index, prioritisation technique and frequency counts have been used in previous studies (Aniekwu, 1995; Mansfield et al., 1994; Foster, 2001).

However, when factors are identified and ranked according to severity, policy makers are often left in a dilemma as to how to identify the point of demarcation between the major variable factors that can not be compromised in policy and those to be considered minor. This is because it is practically impossible to make provision that is proportionate to the level of severity for each factor during policy formulation. Nevertheless, an arbitrary selection of "relevant" factors - as is common in the decision-making process - could be considered an interference in a due statistical process and thus could be classed as a "bias". It is the view of the authors that an unscientific selection of factors and the exclusion of a demarcation point in ranking procedure leave the process inconclusive. Making a demarcation point that is unbiased leads decision makers to an impartial, systematic conclusion.

Generally, ranking procedure is affected by frequency count, the order of priority made by respondents and occasional multiple occurrences of factors in different ranking positions as explained in the methodology of this study. However, if these aspects are not adequately accommodated in the ranking procedure, it becomes unreliable and at best inconclusive. Thus, it is the objective of this paper to present a developed Severity Index in Matrix Order (SIMO) model that can cater for the identified anomalies in ranking procedures using a case study of infrastructure failures in Nigeria (a part of an ongoing PhD research in the School of Architecture, De Montfort University). However, a brief definition of infrastructure is necessary at this stage to adequately introduce the case study.

Infrastructure is an encapsulation of social overhead capital with subsequent potentials for economies of scale and huge externalities i.e. its ability to decrease unit cost of production with increasing output over a wide range and the tendency to spillover its effects from users to non users (World Bank, 1994; Yoshino and Nakahigashi, 2000). The foregoing gives credence to the general understanding of Infrastructure as being the underlying framework which enhances the effective functioning of any system or organization (Ostrom et al., 1993; Webster.s Reference, 2002).

Nonetheless, what constitutes effective functioning of an organisation or system is the extent to which growth and economic development is sustainable (Ostrom et al., 1993; World Bank Document, 2002). Moreover, the impact of infrastructure on economic development has been critically evaluated and validated empirically, especially as it relates to the interactions between private and public investment. (Aschauer, 1989a; Aschauer, 1989; Easterley and Ravelo, 1993; Pinnoi, 1994; Buffie, 1995 ; Barro, 1997; Looney, 1997; Canning, 1998 ; Rioja, 1999; Delorme et al., 1999 ; Sagales-Roca and Pereira, 2001; Voss, 2002; Otto and Voss, 1998). However, most literature on the impact of infrastructure on economic development, particularly the interface between public and private infrastructure, has mainly been concerned with developed economies (Pinnoi, 1994; Buffie, 1995 ; Wang, 2002) with very little attention paid to the developing world.

Lately, the new partnership for Africa's development (NEPAD) has recognized the vital role of infrastructures in economic growth and development; basically this is due to the present fragile economic base of sub-Saharan Africa and the obvious global strident shift towards effective consistence in infrastructure delivery (NEPAD, 2004). The fragile economic base of the region is notable for its frequent high inflation rates, heavy debt overhang, its monoculture economies, uncontrolled population growth and the wasteful expenditure profile of many sub-Saharan African countries. For example, over a third of the roads built in the sub-Saharan Africa are now obsolete (World Bank, 1994; Zawdie and Langford, 2001). Another example of waste is the Nigeria natural gas project, where the gas flaring annually amounts to about four billion cubic meters. This is equivalent to 60% of the total thermal-based power generation in the whole of sub-Saharan Africa. Nigeria is currently producing 2500 megawatts of electricity, which is just 30% of its installed capacity (World Bank Document, 2002).

Consequently, the majority of the population in countries within sub-Saharan Africa - specifically Nigeria – has little or no access to potable water, decent shelter and healthcare, decent education, electricity, assessable roads, sanitation and telecommunications. These predicaments are further exacerbated by the fact that most of the existing infrastructures and projects are misallocated and this has led to low percentage cost recovery and poor spin-off for social economic development (World Bank, 2000). These problems regarding infrastructure delivery have raised strong doubts about the investment priorities and appropriateness of present infrastructure projects (Ostrom et al., 1993; Ostrom, 1996; Ogu, 2000; Kessides, 1999). Thus, the need to identify and empirically rank unambiguously notable factors responsible for the frequent infrastructure failures and dearth is overwhelming as this will facilitates the formulation of key policies for effective infrastructure and service delivery.

To this end, an extensive literature search was carried out in this study in order to identify the causes of inadequate infrastructure delivery and subsequent failures. In addition, a questionnaire survey was carried out in order to validate and rank the factors identified. These factors include the lack of suitable managerial and technical skills (Wells, 1986; World Bank, 1994; Aniekwu, 1995; Alutu, 2000); lack of effective and supportive institutions (World Bank 1994; Ebohon et al., 2002; Ostrom et al., 1993; Ostrom, 1996); inconsistent social, political and economic policies (Alutu, 2000; Filani, 1993); corruption and the lack of transparency and accountability (World Bank, 1994; World Bank Document, 2002; Ostrom, 1993); misallocation of investments (Ostrom et al., 1993; Ostrom, 1996; Ogu, 2000; Kessides, 1999); high construction and equipment procurement cost (Betts and Ofori, 1994); and poor consideration for maintenance (Wells, 1986; Filani, 1993; Betts and Ofori, 1994; Ofori, 1994; World Bank, 1994; Aniekwu, 1995; Ostrom, 1996; Alutu, 2000; Ebohon et al., 2002; World Bank, 2002).

After ranking these variable factors successfully, the threshold value or demarcation point was finally established using the SIMO model.

2. METHODOLOGY

A structured interview with the aid of a questionnaire was employed using the stratified random sampling technique. The questionnaire method of data collection was chosen because it is cost effective and ensures anonymity. The six geopolitical zones in Nigeria constitute the first specified stratum; afterwards respondents were randomly selected from the second specified stratum which was the sector / organisation of respondents. To this end, the subdivisions for the first stratum are as follows: south-west zone; south-south zone; south-east zone; north-west zone; north-central zone; north-east zone to cover respondents from the public sector, private sector and non-governmental organisation and those not willing to respond. Please see Table 1 and Table 2 for questionnaires distribution and responses in the appendix.

Respondents were asked to rate the stability of infrastructure and service delivery in Nigeria and this was cross tabulated with geopolitical zones to ascertain the relative cross-section of views across the country (see Table 3 in appendix). Further, respondents were requested to identify and rank factors in order of importance from a list of 18 identified to be likely causes of infrastructure and service delivery failures (see Table 3.1). In addition, Table 3.2 comprises the frequencies of factors in their various ranking positions in the order of priority accorded by respondents. This order of priority in the horizontal direction is in a decreasing arithmetic pattern where the factor with the highest severity is ranked as 1. Thus, the number of times a factor is ranked under a particular position is represented as its frequency counts for that ranking position. Moreover, the index factor column in the table is relevant due to prioritization by respondents and the many cases of multiple occurrences of variable factors in different ranking positions.

The effects of multiple occurrence of a factor in different ranking positions i.e. "corruption" appearing in twelve different factor ranking positions cannot be accounted for by mere frequency counts of one ranking position independently of the others (see Table 3.2). For example, in ranked position number 1 (see Table 3.2), the highest frequency count for a particular variable factor was 142 and this factor reappeared in ranked position numbers: 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 13 with the following frequency counts of 63, 19, 13, 13, 9, 3, 6, 4, 4, 1, 3 respectively (see Table 3.2). Thus, ranking this factor solely with the highest frequency count magnitude of 142 without considering the effects of its frequency counts in other ranking positions absolutely negates the true severity of this variable factor.

However, to consider all frequency counts in all the ranking positions for a particular factor without due consideration for the preference of ranking or ranking positions accorded it by respondents negates the actual severity of this variable factor. As a way of tackling this notable problem or observation in this type of survey, a severity index in matrix order (SIMO) was developed and applied in this investigation using notable existing mathematical and statistical tools like 'index values', 'matrix' and 'midhinge'. After ranking effectively, the model further demarcates without prejudice the major or critical variable factors from the minor variable factors by defining a demarcation point termed the 'threshold value'. The processes are carefully explained in the subsequent section.

2.1. Severity Index in Matrix Order (SIMO):

The following are the steps employed in building the model:

- The factors were coded from 1 to 18 i.e. F(1), F(2), F(3),….,F(18) (see Table 3.1).
- Ranking positions are created in decreasing order of severity corresponding to the number of factors under consideration i.e. P1, P2, P3,...,P18 (see Table 3.2).
- The frequency counts of each factor are entered under the various ranking positions respondents have given them (see Table 3.2). Thus, it is expected that a particular factor could have frequency counts in multiple ranking positions.
- The column of index factors as shown in Table 3.2 is derived by each of the numbers or items in the inverse array of arithmetic numbers i.e. 18, 17, 16, 15, 14,…,1 multiplied by the inverse of 18 or (1/18).
- The severity of all factors is calculated by multiplying the matrix of frequency counts under the various ranking positions (i.e.18 X 18 matrix) by the column of index factors (i.e. 1X18 matrix) to give an the array of severity magnitudes in first matrix as shown in Table 3.3.
- The variable factors and their severity magnitudes as explained above are re-arranged in a decreasing order of severity i.e. p(1), p(2), p(3),….,p(18) (see second matrix in Table 3.3 and Table 3.4).
- The threshold value or demarcation point is the midhinge of Table 6 (see equation 7 to 10)

These processes could also be represented in a mathematical format (see equation (1))

$$F(j) = \sum_{i=1,j=1}^{i=n,j=n} \mu_{ij} \frac{\sigma_i}{n} \quad \text{.....................................}(1)$$

Where: $\sigma_i = (n + 1) - i$

j is the variable factor under consideration: for j = 1,2,3,…,n-1, n
σ_i is the factor for ranked position of the variable factor under consideration: for i = 1, 2, 3,….., n-1, n

Thus:
σ_1: represent variable factor position 1; σ_2: represent variable factor position 2…, σ_n: represent n^{th} variable factor position.

$\frac{\sigma_i}{n}$ = Severity index factor, for i = 1, 2, 3,….., n

μ_{ij} = is the frequency of variable factor j under ranked variable factor position i. Thus, equation (1) becomes

$$f(1) = \mu_{11}\frac{\sigma_1}{n} + \mu_{12}\frac{\sigma_2}{n} + \mu_{13}\frac{\sigma_3}{n} + \text{----} + \mu_{1n}\frac{\sigma_n}{n} \quad \text{............}(2a)$$

$$f(2) = \mu_{21}\frac{\sigma_1}{n} + \mu_{22}\frac{\sigma_2}{n} + \mu_{23}\frac{\sigma_3}{n} + \text{----} + \mu_{2n}\frac{\sigma_n}{n} \quad \text{............}(2b)$$

$$f(3) = \mu_{31}\frac{\sigma_1}{n} + \mu_{22}\frac{\sigma_2}{n} + \mu_{33}\frac{\sigma_3}{n} + \text{----} + \mu_{3n}\frac{\sigma_n}{n} \quad \text{............}(2c)$$

$$\vdots$$

$$f(n) = \mu_{n1}\frac{\sigma_1}{n} + \mu_{n2}\frac{\sigma_2}{n} + \mu_{n3}\frac{\sigma_3}{n} + \text{----} + \mu_{nn}\frac{\sigma_n}{n} \quad \text{............}(3)$$

transfering from equations (2) to equations (3) gives :

$$\begin{bmatrix} \mathbf{f(1)} \\ \cdot \\ \cdot \\ \mathbf{f(n)} \end{bmatrix} = \begin{bmatrix} \boldsymbol{\mu_{11}} & \cdot & \cdot & \boldsymbol{\mu_{1n}} \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \boldsymbol{\mu_{n1}} & \cdot & \cdot & \boldsymbol{\mu_{nn}} \end{bmatrix} \begin{bmatrix} \boldsymbol{\sigma_1/n} \\ \cdot \\ \cdot \\ \boldsymbol{\sigma_n/n} \end{bmatrix} \quad \textbf{................................(SIMO)}$$

Actual variable ranking position matrix (AVARP)

$$= \begin{bmatrix} P(1) \\ \cdot \\ \cdot \\ P(n) \end{bmatrix} \quad \text{............................}(4)$$

And :

$$\begin{bmatrix} P(1) \\ \cdot \\ \cdot \\ P(n) \end{bmatrix} = \begin{bmatrix} f(1) \\ \cdot \\ \cdot \\ f(n) \end{bmatrix} \quad \text{............................}(5)$$

$$\Leftrightarrow f(1) \geq f(2) \geq f(3) \geq \ldots \geq f(n)$$

$$\text{Otherwise}: \begin{bmatrix} P(1) \\ . \\ . \\ P(n) \end{bmatrix} = \begin{bmatrix} f(1) \\ . \\ . \\ f(n) \end{bmatrix} \uparrow \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

where :

$$\text{" } \uparrow \text{ " implies an ascending order of magnitude in} \begin{bmatrix} f(1) \\ . \\ . \\ f(n) \end{bmatrix}$$

p(1) is the highest severity position

p(2) is 2nd highest severity position

.

.

.

P(n) is the least severe position.

Stage 2 : Threshold value (Demacation point) :

$$\text{The Threshold value (Midhinge) in the matrix of equation (6)} = \left[\frac{h_1 + h_2}{2} \right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

where:

h_1 is the corresponding value to D_1

h_2 is the corresponding value to D_3

$$D_1 = \frac{n+1}{4} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

$$D_3 = \frac{3(n+1)}{4} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9)$$

n is the total number of observations or variable factors under consideration in equation (6)

D_1 and D_3 are specified observations within the matix of equation (6).

Rules for D_1 and D_3 :

1. If D_1 or D_3 is an integer, the numerical observation or item corresponding to the position of that integer in the matrix is chosen for either D_1 or D_3
2. If D_1 or D_3 is halfway between two integers, the average of the corresponding items or observations is chosen.
3. If D_1 or D_3 is not an interger or halfway between two intergers then the resulting value should be approximat

to the nearest interger
and the corresponding item or observation is chosen.

N.B: All the variable factors (elements) in the matrix of equation (6) above cannot be accounted for in policy formulation as most severe at the same time. In order to over come this problem, variable factor's magnitude greater than or equal to the threshold value are to be considered most severe.
See equation (10)

Thus : $\left|P(a)\right|_{a=1,2..}^{n}$ = Threshold value.............(10)

3. RESULTS

Table 3.1: Variable factors under consideration

Variables	Variable factor [*F(j)*]
The lack of supportive institutions	F(1)
Misallocation of investments	F(2)
Lack of effective competition	F(3)
Inadequate maintenance	F(4)
Inconsistent billing strategy	F(5)
Inadequate cost recovery strategy	F(6)
Lack of suitable technical and managerial skill	F(7)
Lack of financial and managerial autonomy	F(8)
Corruption	F(9)
Lack of transparency and accountability	F(10)
Poor wages and remunerations	F(11)
High construction and equipment procurement cost	F(12)
Weather and difficult environmental terrain	F(13)
Inconsistent political, social and economic policies	F(14)
Insufficient funding for infrastructure	F(15)
Hostile communal conflicts	F(16)
Too much pressure on existing infrastructure	F(17)
All of the above	F(18)

Table 3.2: Frequencies of ranked variable factor positions and index factor

Variable Factors F(j)	Frequencies of ranked variable factors position (μ_{ij})																		Index Factor
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	$\sigma_i / 18$
F(1)	36	19	15	10	14	15	11	14	10	7	8	10	1	6	2	1	4	1	1.00
F(2)	101	41	33	17	13	19	14	9	10	6	3	4	4	2	4	1	0	0	0.94
F(3)	3	6	16	12	14	12	8	10	6	10	8	5	10	4	3	1	2	0	0.89
F(4)	22	55	39	41	25	11	14	9	9	1	3	4	1	1	1	1	2	1	0.83
F(5)	0	5	9	16	20	18	9	5	9	9	13	7	9	1	2	0	1	0	0.78
F(6)	0	4	9	11	14	16	12	8	9	10	10	6	2	14	3	1	0	0	0.72
F(7)	3	9	11	18	9	17	22	23	16	12	10	4	4	2	2	3	1	0	0.67
F(8)	0	17	12	7	11	9	11	19	18	12	5	10	6	4	2	5	0	0	0.61
F(9)	142	63	19	13	13	9	3	6	4	4	1	0	3	0	0	0	0	0	0.56
F(10)	5	35	35	30	33	20	19	7	9	10	1	2	1	0	0	1	0	0	0.5
F(11)	0	5	10	11	21	20	10	7	7	11	11	2	4	1	2	1	1	0	0.44
F(12)	1	1	7	8	10	19	10	7	9	8	4	13	8	4	3	1	1	0	0.38
F(13)	3	1	13	7	12	7	9	12	6	5	1	3	7	8	9	7	2	2	0.33
F(14)	4	10	12	23	15	24	28	25	11	5	2	4	2	7	3	1	0	0	0.27
F(15)	6	19	33	27	21	14	20	11	15	8	6	4	5	2	6	2	0	0	0.22
F(16)	0	1	1	3	6	6	10	6	8	7	7	6	3	6	8	6	4	2	0.17
F(17)	1	5	11	19	10	6	6	10	3	7	8	4	2	1	4	8	4	3	0.11
F(18)	59	14	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0.06

Table 3.3: Array of severity magnitudes in a decreasing order

$$
\begin{bmatrix} f(1) \\ f(2) \\ f(3) \\ f(4) \\ f(5) \\ f(6) \\ f(7) \\ f(8) \\ f(9) \\ f(10) \\ f(11) \\ f(12) \\ f(13) \\ f(14) \\ f(15) \\ f(16) \\ f(17) \\ f(18) \end{bmatrix} = \begin{bmatrix} 132.62 \\ 236.06 \\ 83.07 \\ 194.38 \\ 85.34 \\ 78.25 \\ 108.02 \\ 92.92 \\ 256.88 \\ 162.83 \\ 81.81 \\ 67.66 \\ 64.49 \\ 120.60 \\ 142.62 \\ 42.97 \\ 67.51 \\ 63.71 \end{bmatrix} \text{ arranging in decreasing order gives } \begin{bmatrix} p(1) \\ p(2) \\ p(3) \\ p(4) \\ p(5) \\ p(6) \\ p(7) \\ p(8) \\ p(9) \\ p(10) \\ p(11) \\ p(12) \\ p(13) \\ p(14) \\ p(15) \\ p(16) \\ p(17) \\ p(18) \end{bmatrix} = \begin{bmatrix} f(9) \\ f(2) \\ f(4) \\ f(10) \\ f(15) \\ f(1) \\ f(14) \\ f(7) \\ f(8) \\ f(5) \\ f(3) \\ f(11) \\ f(6) \\ f(12) \\ f(17) \\ f(13) \\ f(18) \\ f(16) \end{bmatrix} = \begin{bmatrix} 256.88 \\ 236.06 \\ 194.38 \\ 162.83 \\ 142.62 \\ 132.62 \\ 120.60 \\ 108.02 \\ 92.92 \\ 85.34 \\ 83.07 \\ 81.81 \\ 78.25 \\ 67.66 \\ 67.51 \\ 64.49 \\ 63.71 \\ 42.97 \end{bmatrix}
$$

Table 3.4: Actual variable factors ranking positions

p(1)		f(9)= corruption
p(2)		f(2)=misallocation of investments
p(3)		f(4)=inadequate maintenance
p(4)		f(10)=lack of transparency and accountability
p(5)		f(15)= insufficient funding for infrastructure
p(6)		f(1)= Lack of supportive institutions
p(7)		f(14)=inconsistent political, social and economic policies
p(8)		f(7)=lack of suitable technical and managerial skill
→←		→......................***Threshold (demacation point)***......................←
p(9)	=	f(8)=lack of financial and managerial autonomy
p(10)		f(5)= inconsistent billing strategy
p(11)		f(3)=lack of effective competition
p(12)		f(11)=poor wages and remunerations
p(13)		f(6)= Inadequate cost recovery
p(14)		f(12)=high construction and equipment procurement cost
p(15)		f(17)=too much pressure on existing infrastructure
p(16)		f(13)=weather and difficult environmental terrain
p(17)		f(18)= all of the above
p(18)		f(16)=hostile communal conflicts

Thus : $D_1 = 5$; and $D_3 = 14$; $h_1 = 142.62$ and $h_2 = 67.66$

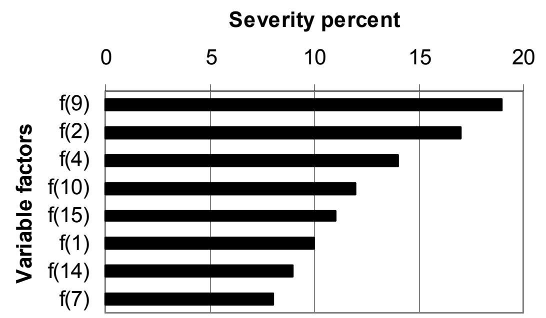
Thus : The "Threshold value" = 105.14

N.B. In applying equation (10) Variable factors in the matrix having severity magnitudes greater than or equal to the Threshold value are to be considered critical in policy formulation.

4. CONCLUSION

From the results received for Nigeria shown in Figure 1 after applying the threshold value, the following variable factors were identified as critical to the causes of infrastructure and service delivery failures in Nigeria: corruption [f(9)]; misallocation of investments [f(2)]; inadequate maintenance [f(4)]; lack of transparency and accountability [f(10)]; insufficient funding for infrastructure [f(15)]; lack of supportive institutions [f(1)]; inconsistent political, social and economic policies [f(14)]; lack of suitable technical and managerial skill [f(7)]. The proportion of severity of each of these factors is represented in Figure 2 below.

Figure 2: Critical variable factors in order of severity



The Severity index in matrix order (SIMO) model developed in this investigation would empirically assist in the unambiguous ranking of notable variable factors in future investigation of this kind. Its application assisted the authors to identify effectively the core variable factors responsible for infrastructure and service delivery failures in Nigeria.

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APPENDIX:

Table1: Questionnaire distribution and responses within each Geopolitical zone

	Number of questionnaires	Number of respondents	Valid Percent	Cumulative Percent
No response	0	2.0	.5	.5
South west	100	59.0	14.6	15.1
North west	100	70.0	17.4	32.5
South east	100	61.0	15.1	47.6
North east	100	54.0	13.4	61.0
South south	100	99.0	24.6	85.6
North central	100	58.0	14.4	100.0
Total	600	403.0	100.0	

Table 2: Questionnaire distribution and responses within each Sector / organization

	Number of questionnaires	Number of respondents	Valid Percent	Cumulative Percent
no response	0	6.0	1.5	1.5
Public	210	133.0	33.0	34.5
Private	210	130.0	32.3	66.7
Non Governmental Organization	180	97.0	24.1	90.8
Not applicable	0	37.0	9.2	100.0
Total	600	403.0	100.0	

Table 3: Crosstabulation of Geopolitical region and Stability of Infrastructure in Nigeria

			Stability of Infrastructure and service delivery in Nigeria					Total
			No response	Very Stable	Stable	Unstable	Very Unstable	
Geo-Political Region in Nigeria	No response	Count	2	0	0	0	0	2
		% within Geo-Political Region in Nigeria	100.0%	.0%	.0%	.0%	.0%	100.0%
		% of Total	.5%	.0%	.0%	.0%	.0%	.5%
	South west	Count	1	4	3	20	31	59
		% within Geo-Political Region in Nigeria	1.7%	6.8%	5.1%	33.9%	52.5%	100.0%
		% of Total	.2%	1.0%	.7%	5.0%	7.7%	14.6%
	North west	Count	1	0	19	26	24	70
		% within Geo-Political Region in Nigeria	1.4%	.0%	27.1%	37.1%	34.3%	100.0%
		% of Total	.2%	.0%	4.7%	6.5%	6.0%	17.4%
	South east	Count	0	0	2	18	41	61
		% within Geo-Political Region in Nigeria	.0%	.0%	3.3%	29.5%	67.2%	100.0%
		% of Total	.0%	.0%	.5%	4.5%	10.2%	15.1%
	North east	Count	1	3	2	24	24	54
		% within Geo-Political Region in Nigeria	1.9%	5.6%	3.7%	44.4%	44.4%	100.0%
		% of Total	.2%	.7%	.5%	6.0%	6.0%	13.4%
	South south	Count	1	0	3	57	38	99
		% within Geo-Political Region in Nigeria	1.0%	.0%	3.0%	57.6%	38.4%	100.0%
		% of Total	.2%	.0%	.7%	14.1%	9.4%	24.6%
	North central	Count	0	0	5	25	28	58
		% within Geo-Political Region in Nigeria	.0%	.0%	8.6%	43.1%	48.3%	100.0%
		% of Total	.0%	.0%	1.2%	6.2%	6.9%	14.4%
Total		Count	6	7	34	170	186	403
		% within Geo-Political Region in Nigeria	1.5%	1.7%	8.4%	42.2%	46.2%	100.0%
		% of Total	1.5%	1.7%	8.4%	42.2%	46.2%	100.0%

DEVELOPING AND REHABILITATING SOCIAL HOUSING FROM THE PERSPECTIVE OF INSTITUTIONAL MODEL: STRUCTURE OF PROVISION

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Abstract: Social housing development may involve the provision of new dwellings or the refurbishment/rehabilitation of existing buildings. The term social housing means housing provided and managed by local authorities as well as by housing associations and other organisations regulated by government. Institutional model is a model of development process which can elaborate the interaction between structure and agency's interests in the fabric of society. Structure of provision is one of the methodologies used in the institutional analysis. Detailed processes in initiating the development, preparing detailed designs, and constructing the development are the stages of the traditional process of social housing development and rehabilitation. This paper seeks to understand the significance of structure of provision model in the process of social housing development in the United Kingdom (UK). In addition, the events of social housing development will also be mapped in order to understand the processes involves in the social housing development and their agents interaction. Finally, this paper will examine main institutions and their roles in the development of social housing in the UK.

Keywords: Social housing, development process, institutional models, structure of provision

1. INTRODUCTION

The social housing industry is vast and still growing. There are very few countries in the world where some form of subsidised housing does not exist, and the total number of social housing is likely to grow worldwide, as there are challenges of the sector (Reeves, 2005). Some of these countries do believe that the elements of social housing already existed with the different name, context, strategies, governance and procedural of implementation (Sulaiman *et al*., 2005). In terms of the theory of development process, new institutionalism has grown rapidly since 1985 and has produced an extensive literature (Lowe, 2004). Originally, Healey (1992) has proposed to develop an approach known as *institutional model* of development process as an attempt to establish link between *structure* and *agency* (in Healey, 1990) empirically through relating the construction of roles, and the strategies and interest of agencies, to the material resources, institutional rules and organising ideas. This approach has been arguing by many housing scholars which cited that it is not relevant for the certain social phenomenon (Hooper, 1992; Ball, 1998). On top of that, Ball (1998) has surveyed approaches to study of institutions and revealed that instead of structure and agency approach, institutional analysis can be approached from mainstream economics, power, and structure of provision. Ball (1986) has appeared with his structure of housing provision model and continued cited that structure of provision model is most applicable to the other forms of building provision as well (in Ball, 1998). The aim of this paper is to understand the concept of social housing development in the UK through the reviews of development process models. This paper then will emphasise to discuss specifically on the structure of provision approach and its relationship for social housing development in the UK. In order to respect the principal aim of the paper, it also adopts an *even sequence* approach to clarify and identify the sequence and social agents roles in the development of social housing in the UK.

2. SOCIAL HOUSING IN GENERAL

In the UK, the basic objective of housing policies are reflected in the phrase a decent home for every family at a price within their means (Stephen et.al, 2005). By 2010, in achieving good quality of housing, government's aim is to bring all social housing into decent condition with most of the improvement taking place in deprived areas, and increase the proportion of private housing in decent condition occupied by vulnerable groups (ODPM, 2004). In the UK, social housing can embrace public housing (often called 'council housing') and also the dwellings of housing association (Whitehead, 1994; Perry, 1995; Best, 1996; Herriot and Matthew, 2004). According to ODPM (2003), presently, social rented sector in UK comprises council rented housing managed by local authorities (approximately 5 million dwellings) and social rented housing managed by housing associations (approximately 635,000 dwellings). Traditionally, social sector has housed a wide range of households, including skilled and semi skilled working households as well as households in priority need – those accepted as homeless and having one or further characteristics such as dependent children, expectant mother, elderly or otherwise vulnerable (Monk,2004). Sulaiman *et al.,* (2005) summarised the characteristics of social housing in the UK as in the Table 1 below.

Table 1: Characteristics of Social Housing in United Kingdom

Characteristics	Component of Provision
Development Driven	Do not exist to make profit
Provider	Local authorities, Housing Association (non-profit society, body of trustees, or company established to develop and manage housing)
Stock of Housing	Regional Housing Boards (RHBs) advise on investment priorities for housing in each region through the development of Regional Housing Strategies (RHS)
Ability to pay	Ability to pay is not criterion
Financial for Housing Provider	Own resources (mainly rental income and receipts from dwellings sales) and partly from support provided by central government (ODPM). Regional Housing Pot through Regional Housing Board (RHB) will be allocated to LAs(the Housing Investment Program (HIP)) and HAs (the Approved Development Programme, the Starter Home Initiative and the Challenge Fund managed by Housing Corporation)
Financial Support to the renters	Qualified households may obtain housing benefit which pays some or all of the property's rental costs
Housing needs	Housing to be developed is either for general family needs or specialised for certain types of household.
Allocation or letting policies	The selection of households depend on allocating and letting policies by housing organisation
Subsidies for housing provider	Capital Subsidy (for LA's and HA's) and Revenue Subsidy (for LA's only)
Subsidies for households	Capital Subsidies, or ownership (Right to Buy, Right to Acquire, Homebuy, Cash Incentive Scheme; Do It Yourself Shared Ownership (DISYO), and Conventional Shared Ownership) Revenue Subsidy, for Renters (Housing Benefit) and for Mortgagors (Mortgage Benefit –Income Support)
	Source: Adapted from Sulaiman *et.al* (2005)

Social housing unit will continue to be given to people in the greatest housing need and for whom suitable private sector housing is not an affordable option (DETR,2000). In general, only those households considered to be in *housing need* will be offered a social housing dwelling, which may, or may not meet with their desire or aspirations (Harriot and Matthews, 2004). Local authorities and registered social landlords currently allocate housing to people on their housing registers in accordance with their assessment of people's needs. Potential applicants who may need to be considered for social housing allocation are slum clearance applicants, homeless applicants, refugees and asylum seekers, transfer applicants, applicants who are sick and disabled, applicants with social reasons for moving, mortgage repossessions applicants, National Mobility Scheme applicants, waiting list applicants and keyworkers (Harriot and Matthews, 2004). Instead of households housing needs, in general, local authorities also need to draw up strategy or needs assessment for the identification of future housing needs in their local authority area. Most needs fall within one of the three categories: need for work on the existing housing stock, need for more dwellings and need for care and support (ODPM, 2005).

3. OVERVIEW OF THE MODEL OF DEVELOPMENT PROCESS

The concept of development process has been discussed in many literatures before. Development is a process involves the dynamic and complex interaction of land, labour and capital (Adams *et.al*, 1998). In general, the development might be taken either to modify the existing building through refurbishment, redevelopment or new development (Harvey, 2003). So that, undoubtedly, the development process is the response to such changes may itself be dynamic, one development generating development elsewhere. In the UK, by the mid 1980s, the policy shift taken placed which emphasised the role of the private sector in property development, reflected a rapid increase in the study of the development process (for review see Healey and Barrett, 1991; Gore and Nicholson, 1991; Healey, 1991; Healey, 1992; Ball, 1983; Ball and Harloe, 1992; and Ball, 1998).This has been directed from a variety of perspectives, and the models of the development process produced later. Five different approaches to the conceptualisation have been identified:

1. *Equilibrium model,* which assume that development activity is structured by economic signals about effective demand, as reflected in rents, yields, etc. In the real estate adage, *at the right place, the right time and the right place*.
2. *Event-sequence model,* which focus on the management of stages in the development process. These derive primarily from an estate management preoccupation with managing the development process.
3. *Agency model,* which focus on actors in the development process and their relationship. These have been developed primarily by academics seeking to describe the development process from a behavioural or institutional point of view.
4. *Structure model,* which focus on the forces which organise the relationship of the development process and which drive it dynamics. These are grounded in urban political economy.
5. *Institutional model,* which focus the land development process is viewed as not only the physical process of creating and transferring building to occupier but also as a social process dominated by economic interests involved. Interaction between structures and agencies are emerged in this model.

As mentioned earlier, Ball (1998) revealed that instead of structure and agency approach, institutional analysis can be approached from mainstream economics, power, and structure of provision. However, this paper only refers to the structure of provision model to be discussed. This approach has been chosen for the purpose of identifying social agents, their economic interest and how they interact in the structure of housing provision. Very simply, housing provision approach is a social construct, that there are combinations of social agents involved in housing provision that relate to each other in empirically observable ways (Ball and Harloe, 1992). Any narrowly conceived examination of the agents and social relationships implicated in housing provision and its development only leads to some equally narrow and misleading answers to the 'when, how and why' questions in the production of theories of housing development (Harloe, 1995). Initially, Ball (1983) has came out with his extensive works with the argument that social aspects of housing provision is necessary to comprehend the social relations of housing provision. The core of his works is that the production and consumption (that is provision) of building are not only the physical process of creating and transferring such artifacts to their occupiers, but are also a social process dominated by the economic interests involved (Gore and Nicholson, 1991). This model appeared when he believed that consumption oriented approach has neglected the social relations involved in provision. Thus, in terms of residential property *a structure of housing provision describe a historically given process of providing and reproducing the physical entity, housing; focusing on the social agents essential to the process and the relations between them* (Ball,1986). This model emphasised that;

1. A social relation is part of a structure of provision. This offers a criterion by which to include or exclude social relations from a structure of provision.
2. Failure to understand the inner workings of a structure of provision can lead to faulty analysis about what causes particular problems in housing phenomenon.
3. Without considering social relations in housing provision, major issues in housing sphere (consumption, exchange and production) will be denying on their necessities (class struggle and social conflict in the nature of housing provision-*internal dynamic*).
4. The internal and external division of factors creating change, but should not be regarded in stylised ways.
5. Actual inter-connections within the actors are likely to be complex; some of it might not have direct communality of interest between struggles.
6. Any alliance between social groups in the structure generated their link over areas of mutual interest and not because of taken for granted.
7. It is necessary to be quite precise about which social agents are actually involved in a particular form of housing provision.
8. Physical factor, obviously influence the nature of provision such as locationally specific land is required.
9. Finance in the forms of money capital or credit, can intervene at various points in structure of provision and most likely all the actors involved.
10. If the state agencies and capitalist agencies are necessity part of structures of provision they must be included, all other and actions are excluded. This is applicable even to the housing which developed by local authorities.
11. The state intervenes into all structures of housing provision in one way or another from setting of legislation (building regulation, planning control, and employment legislation), policy framework (taxes and subsidies-*capital* or *revenue*), and political of landownership to outright ownership of stock and control over all aspects of provision can effect the structure of provision as a whole.

12. There might be some pressure as particular reactions to state from politician and government administrations.

Ball and Harloe (1992) added that we should not ignore the *institutional* and other *structures* within which it takes place nor should we forget the social agencies engaged in such structures. In fact, it involves the whole physical process of creating and transferring a dwelling to its occupiers, its subsequent use and physical reproduction and at the same time, a social process dominated by the economic interests involved (Ball and Harloe, 1992). In relation to that, *structuration* theory developed by the British social theorist Anthony Giddens made Ball's argument more strong. Giddens revealed that *structures* are not something external to social actors but are rules and resources produced and reproduced by actors in their practices (Dictionary of Sociology, 1998). *Structure* shapes people's practices, but these practices constitute and reproduce social systems in a society. The word *society* means *a group of people who share a common culture, occupy a particular territorial area, and feel themselves to constitute a unified and distinct entity* (Dictionary of Sociology, 1998). Structures, for Giddens, are not something external to social actors but are rules and resources produced and reproduced by actors in their practices. He also argued that structure and agency cannot be conceived of apart of another. Structures are neither independent of actors nor determining of their behaviour. Rather, they are a set rules and competencies on which actors draw and which, in the aggregate, they tend to reproduce over time (Sulaiman *et al*., 2005). Lowe (2004) also summarised his idea about the definition of the whole institution as refers to a *wide range organisation, social groups and settings and value systems, encompassing relationship within and between agencies (government department, central-local relations), election and voters, political parties, the structure and organisation of key economic groups (such as trade unions) as well as social structures (social class) and social norms and values.*

4. SOCIAL HOUSING DEVELOPMENT PROCESS

Ratcliffe *et.al* (2004) agreed that structure of provision model in the development of real estate may be seen as a set of interrelated processes and not merely a single sequential process. It can be seen through the Figure 2. In a way to identify the stages of social housing development process, this paper essentially adopts an *event sequence* approach as well. It should also be appreciated that there are many number of ways in which the development process can be described as a sequence of events or series of stages from the start to the finish of the project. There might be slight variation but according to Harriot and Matthews (2004) there are three main stages in the processes of social housing development as follows;

Stage 1: Initiating the Development. This stage includes all of activities which need to be undertaken before there is a form decision to go ahead with the project. This involves the concern about the type of development needed, sustainability of assessment, planning consent, feasibility study, and site acquisition. *Stage 2: Detailed Design.* This includes all of the activities which contribute to the final detailed plans for the project, generally produced by the consultant and guided by a briefing fro the client. This stage will determine whether the organisation achieves the sort of new development or refurbishment that it requires, because the outcome is the final design, which will be constructed. *Stage 3: Constructing the Development.* This final stage is concerned with getting the project built. The client must first appoint a contractor to undertake the work, and there are several possible approaches to this. The consultant oversees the process of constructing the properties, with close supervision provided by the clerk of works. Figure 2 shows the stages of social housing development and the agent's interest likely to be involved in the project taken by social housing's client.

5. NATURE OF ACTORS IN THE DEVELOPMENT PROCESS

Specifically, housing development process includes all activities, which are necessary to achieve the construction of a new housing scheme or the refurbishment of existing dwellings (Harriot and Matthews, 2004). Generally, the provisioning of housing involves the whole physical process of creating and transferring a dwelling to its occupiers, its subsequent use and physical reproduction and at the same time, a social process dominated by the economic interests involved (Ball and Harloe, 1992). Introducing the social aspect of housing would involve the *structure* and *agents* role in the provisioning of housing. As Ball (1986) revealed a structure of housing provision describes a historically given process of providing and reproducing the physical entity of housing, focusing on the social agents essential to that process and the relation between them. Colton and Dunlop (1999) cited that there is wide variety of actors which competing their interest in the world of housing and urban policy. Some housing scholars referred to these agents as *actors* for the development process. As an example, Fisher and Collins (1999) cited that housing development is undertaken by variety of *actors* each also distinguished by their *aims*, *status* and *roles.* Social agents are associated with creating and sustaining a particular set of housing conditions, costs and benefits (Ball and Harloe, 1992).

6. KEY AGENTS IN SOCIAL HOUSING DEVELOPMENT PROCESS

Many parties are involved as agents in the development and rehabilitation process of social housing in the United Kingdom (UK). However, in order to understand the structure of provision model, even there are a wide variety of agents involved in the social housing development process, this paper has examined main agents and institutions involves as follows;

6.1 Office of Deputy Prime Minister (ODPM)

Office of Deputy Prime Minister (ODPM) was created as central department in May 2002 to responsible for local and regional government, housing, planning, fire, regeneration, social exclusion and neighborhood renewal put the Office at the heart of the Government's ambition to create sustainable communities for all. ODPM's Communities Plan includes major investment in housing, transport and regeneration, changes in planning, design and construction and a new regional approach to tackling the different housing problems across the country (Varady, 1996). ODPM establishes national priorities and the policy framework for new investment by identifies the key national level outcomes it is pursuing (e.g decent homes, homelessness, key workers recruited/retained).

6.2 Housing Corporation (HC)

Housing Corporation is a Non-Departmental Public Body (NDPB) which oversees the registration and operation of housing associations in England. Wales has a separate body which performing the functions of the housing corporation known as Welsh Office and Scottish Homes has the functions of the housing corporation in Scotland. In Ireland the central agency for managing and producing social rented housing in Northern Ireland is the Northern Ireland Housing Executive (NIHE) (Gibb *et. al*, 1999). It has responsible to pay grants, lend money, and monitor and regulate housing associations (Lomax, 1996). It invests in housing associations and protecting that investment and ensuring it provides decent homes and services for residents (Housing Corporation, 2005).The board of Housing Corporation has overall responsibility for the running of the organisation, make sure it will meet the performance delivery targets and gives advice to Ministers on housing issues, policy and its implementation. It will collaborate with RHBs (Regional Housing Boards) in the development of Regional Housing Strategies (RHS) by informing with its knowledge and experience of regional and sub regional market/data/trends, the full range of housing needs, the practical delivery of housing investment, and the strategic projects being developed by LAs, RSLs and other bodies (ODPM,2005).

6.3 Regional Housing Boards (RHBs)

RHBs were established following the publication of the Sustainable Communities Plan in February 2003. The boards identify and propose housing investment priorities within regions for achieving the regional outcomes quantified by ODPM. It also gathers knowledge from Housing Corporation on local housing markets to ensure that practicable investment plans for Registered Social Landlords (RSLs) sector can be delivered through the preparing of Regional Housing Strategy (RHS). According to DETR (2000) the RHBs roles are also to identify for sub regions their relative needs in relation to national level outcomes, establish an overview of investment and other action to address housing in the region and propose a split of Regional Housing Pot investment (whether in demolition, new social build, low cost home ownership) by sub region and type of product that best achieves the outcomes.

6.4 Local Housing Authorities (LAs)

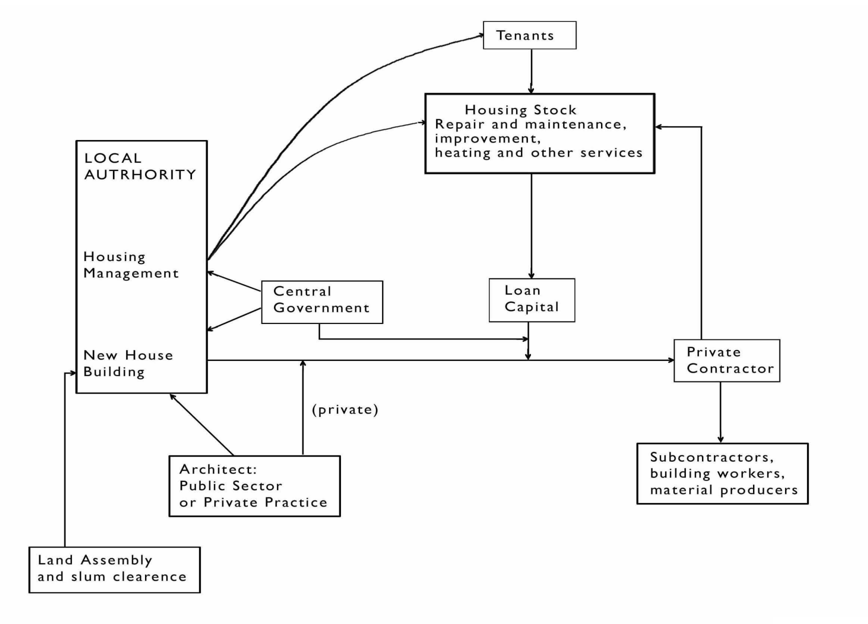
A local authority is a local administration run by elected councillors and paid officers responsible for local services including housing, planning and education. The 1985, Housing Act requires local authorities to provide housing for certain categories of homeless people, such as families, the elderly and disabled, and pregnant women. The Green Paper: Quality and Choice: a decent home for all, published in 2000 set out a series of aims and objectives which laid the foundation for subsequent policy initiatives (Harriot and Matthew, 2004). Under Best Value regime local authorities need to examine critically the range and detail of their service provision, together with service standards, carefully specified, and accounted for as local authorities are subject to inspections by the Audit Commission's Housing Inspectorate. However, not all local authorities have housing responsibilities. Harriot and Matthews (2004) drawn the key responsibilities of local housing authorities include:

1. Developing and keeping up to date a strategy for dealing with all the major housing issues-public and private-in their area;
2. The assessment of housing needs in the area and the development of plans to meet those needs;
3. The provision of rented accommodation and the management of that housing stock, including the letting of dwellings, rent collection, arrears recovery and the enforcement of tenancy conditions;
4. Assisting housing associations and private developers to provide housing within their area: the enabling role;
5. The provision of accommodation and other services to the homeless;
6. Exercising powers to tackle disrepair in private sector housing and in relation to houses in multiple occupation;
7. The administration of housing benefit for both private and public sector tenants.

6.5 Housing Association

A housing association is a nonprofit society, body of trustees, or company established to develop or manage housing receive large capital grants from central government (Whitehead, 1994). Since 1988, housing associations have been regarded as wholly private sector bodies (Lomax, 1996). They are the main providers of new social housing and technically known as Registered Social Landlords (RSLs) registered and regulated by the Housing Corporation, whose regulatory code requires them to meet the Decent Homes Standard by 2010 (ODPM, 2005). Housing associations are run as businesses but they do not trade for profit. Any surplus is ploughed back into the organisation to maintain existing homes and to help finance new ones. A large housing association might have paid staff; a committee or board of management made up of volunteers and has overall responsibility for the work of the organisation. A board might include tenants, representatives from local authorities and community groups, business people and politicians. The basis for public funding of housing associations has remained the same which is provided a capital grant toward the cost of development called Housing Association Grant (HAG)/Social Housing Grant (SHG). However, the total amount of capital grants available (the Approved Development Programme (ADP)) and the rate at which grants may be offered to associations are reviewed annually by the government.

Ball has done his first attempt to structure two example of structure of provision taken from the contemporary British context one is shown in the Figure 1. This figure is adapted from the structure of council housing provision developed by Ball (1983). This figure reflects to nature of a structure of housing provision which concern that the various social agents intervene in the physical process of provision. A social relation is part of the structure of provision if it is a component of the physical process of housing sphere which consisting production, allocation, consumption and reproduction of housing.



Source: Ball (1983)

Figure 1: The structure of council housing provision.

The important elements are the relationships between the social agents in the provision of council housing. It showed by the interaction between the arrows. The ways in which relations between two types of agent work and deliver their interests is like to have repercussions throughout the rest of the structure. The other feature is the considerably degree of latitude within the structure, courtesy of the vacillating relations between human agents that provide their driving force. Agents are seen as having certain amount of discretion, albeit within the confines of structure the provision (Gore and Nicholson, 1991).

7. CONCLUSION

Based on the structure and provision model, the sets of social agents are defined by their economic relationship to the physical process of provision, which includes the production, exchange, distribution and use of the built structure. This model has a series of interconnected social relations between the agents and institutional involved. It needs a legal framework in regulating such activity and the financial arrangement that allow it to proceed. Detailed processes in initiating the development, preparing detailed designs, and constructing the development are the stages of the traditional process of social housing development and rehabilitation. Even there are a wide variety of social agents which competing their interests in the social housing development but the main ones are ODPM, Housing Corporation, RHBs, LAs and HAs. This main agent’s interests and actions are intrinsically dynamic mainly because of the pressure brought about by the way in which social relations within them operate. The exact content of this structure of provision can be identified only by studying the real world, focusing especially on the social agents that are central to the process and on the relations between them. Moreover, due to the external forces in the wider economy and society as a whole, may also bring about further adjustments in a structure of provision in the future.

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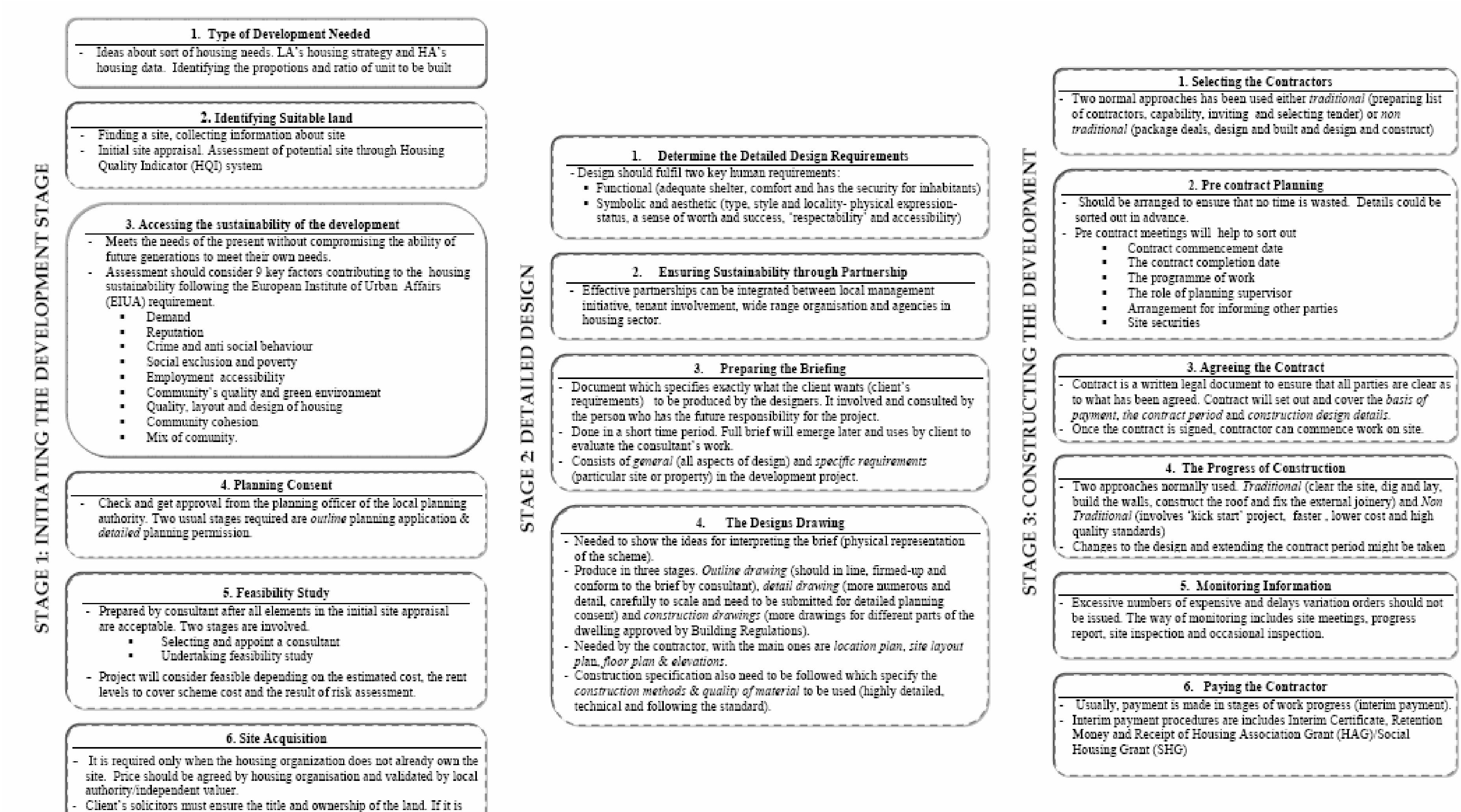

Source: Adapted from Harriot and Matthews (2004)

Figure 2: Social Housing Development Stages in the United Kingdom

A CONTENT ANALYSIS APPROACH TO COMPARE DIFFERENT TYPES OF SERVICE PROVIDERS IN THE CONTROL OF HEALTHCARE ASSOCIATED INFECTIONS IN DOMESTIC SERVICES

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Abstract: The paper is based on an on-going PhD research project which aims to develop a performance management framework for domestic services in the control of HAI. The paper mainly focuses on explicating the content analysis approach used to analyse the data collected from two case studies conducted. The case studies were conducted as part of the research study. The main idea of carrying out a case study approach was to identify the present context of control of HAI in domestic services. The two case studies were selected from two different service providers, i.e. an in-house service provider and a Private Finance Initiative (PFI) contractor. The paper first explains the research process in-detail to identify the reasons for adopting a case study. It then describes the data analysis process. The paper discusses in-detail the reasons for using a content analysis method and the way it has been applied in this study. Summary of the findings derived are also given at the end of the paper. The content analysis method suffers from some disadvantages. Considering the context of the research and some of the advantages of content analysis, it is concluded that the advantages outweigh the disadvantages.

Keywords: Case study approach, Coding, Content analysis, Domestic Services, Healthcare Associated Infections

1. INTRODUCTION

The research study on which the paper is based specifically focuses on Healthcare Associated Infection (HAI) in domestic services. HAI by definition means "infection which was neither present nor incubating at the time of admission but has developed during the course of a stay in hospital or other healthcare facility" (Scottish Executive Health Department, 2002). Healthcare Associated Infection (HAI) is a major cause of morbidity and mortality. There is a growing recognition that domestic services have a dominant role in the control of HAI. Herein, for the purpose of this study, cleaning is considered as the prime area of domestic services (Scottish Executive Health Department, 2003). Hence, one of the main objectives of this research study was to explore the issues related to control of HAI in domestic services. A case study approach was carried out during the mid-stages of the research study in order to achieve this. The idea of this paper is to explicate the research process of the said case study approach in-detail.

1.1 Focus of the research – domestic services in the control of HAI

Even though leading writers and researchers in the field of HAI such as Prof. G A J Ayliffe, and Prof. Emmerson (Emmerson and Ayliffe, 1996; Ayliffe et al, 1988; Ayliffe, Babb and Taylor 1999; Meers, Ayliffe and Emmerson, 1981), as well as reports published by health service organisations and its related organisations worldwide (NHS Estates, 2004; NHS, 2004; Clinical Standards Board for Scotland, 2002; Department of Health, 2004; WHO, 2002; Communicable Disease Network of Australia, 2002; Centers for Disease Control and Prevention Healthcare Infection Control Practices Advisory Committee, 2001) have affirmed the role of domestic service in the control of HAI, there is a paucity of evidence-base literature which suggests the association between domestic services and control of HAI. According to a systematic literature review carried out by Dettenkofer et al (2004), it was found out that about 236 articles have highlighted the importance of environmental disinfection or cleaning in HAI rates. According to Dettenkofer et al's classification of the strength of evidence available, none of the articles described a published meta-analysis, systematic review, or randomized controlled trial. Majority of these articles have only had expert judgments or consensus statements about the association of cleaning with HAI, which Dettenkofer et al have categorised as the lowest level of evidence. Of the 236 articles, only 4 have described completed cohort studies with concurrent or historical controls meeting the criteria for final inclusion.

Some of the reports published by the NHS (UK) suggest that there is an association between domestic services and HAI rates. For examples; 'towards cleaner hospitals and lower rates of infection' by the Department of Health, UK (2004), 'healthcare facilities cleaning manual' by the NHS Estates (2004), 'code of practice for domestic services' by the NHS in Scotland task force groups for infection control (2003), 'the Matron's charter – an action plan for cleaner hospitals' by the NHS (2004) and 'Healthcare Associated Infection (HAI) - Cleaning Services Standards' by the Clinical Standards Board for Scotland (2002). However, as Florence Nightingale has mentioned domestic services was the 'Cinderella' of infection control (as cited in Dancer, 1999), and still, on the main, it continues to be. Although the aforementioned NHS reports have highlighted the significance of domestic services in the control of HAI, the problem of HAI still persists. Identifying the reasons for this, could only be fulfilled by examining the real context and issues associated with the control of HAI in domestic services. The idea of the case study approach was, therefore, to identify some of the issues of control of HAI with regard to the current context of domestic services.

2. THE CASE STUDY APPROACH

The process of the case study approach is given in figure 1. As the figure depicts, the idea of the case study approach was to scrutinize the existing issues of the control of HAI in domestic services. This was mostly in terms of what is currently happening in domestic services and how the players endeavour to address the issue of control of HAI. Therefore, a qualitative method was employed to enhance in-depth investigation. The unit of analysis was the control of HAI in wards in the domestic services. The study was undertaken to examine five research questions (refer to figure 1).

Deciding on the research questions then led to the enquiry of type of qualitative strategy to be chosen; a research strategy which has to be good enough to probe the research questions and to be appropriate in fulfilling the aims and objectives of the research. Even though there are several research strategies under the qualitative paradigm which can be chosen to explore a research subject, an in-depth case study approach was selected as the appropriate method as, by definition, it is an in-depth investigation of an event or series of related events (Hammersley, 1989). As Rowley (2004) explains, case studies are a useful research approach for answering why and how questions, or when it is useful to seek to understand a situation. As for Rowley, case study research starts with an analysis and description of the situation in one organisation. Using a case study approach was useful in this study as it has the capability of providing richness of detail and also has the capability of uncovering the realities that exist. Deciding on the research strategy was also strengthened through the research questions. In this research study, the researchers started with developing a set of questions, worked out the type of research strategy, i.e. a qualitative methodology using a case study approach, and then revisited the research questions according to the type of research strategy. As Robson (1993) suggests, this approach is important to ensure consistency between the questions and the research strategy.

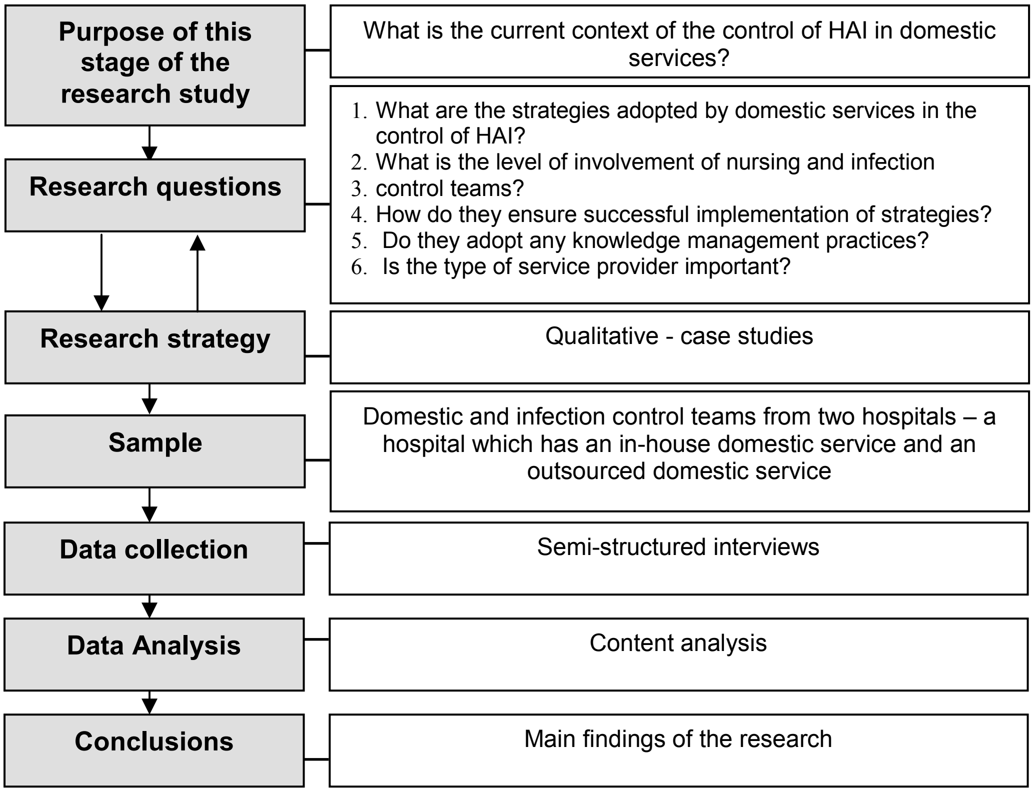

Figure 1: The research process of the case study approach

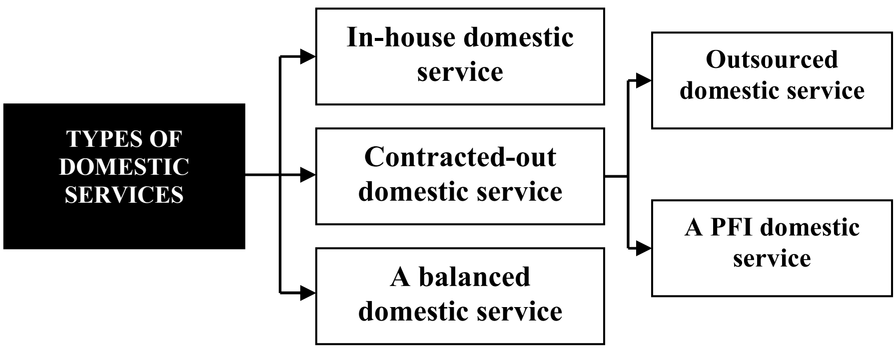

Figure 2: types of domestic services (Adapted from NHS Estates, 1998)

For the case study approach, two cases were chosen instead of a single case, to help establish cross-case conclusions. Choosing more than one case study, provided the researcher with the means to identify patterns and trends to gain insights into potential differences or similarities between case studies (Yin, 1994). Miles and Huberman (1994) affirms that cross-case analysis enhance generalisability. As they further explain more fundamental reason for cross-case analysis is to deepen understanding and explanation. Organisational characteristics such as the size of the hospital (more than 100 beds), type of the hospital (acute hospitals) and more importantly the type of domestic service (the service provider) were taken into consideration during the case study selections. For the purpose of this study, domestic services in hospitals were categorised into three broad types as shown in figure 2.

Using the above classifications two different types of domestic services were chosen for this study. The two cases were chosen from an in-house domestic service and a PFI domestic service. Choosing an in-house and a PFI domestic service (contracted-our service) was strengthened by the increase concern given by the NHS for such type of services. As UNISON (2005) claims, 'if anything the NHS is a growing area for the private sector, partly because of the increased use of NHS PFI schemes and other attempts to bring in private sector provider' According to UNISON, domestic services often form part of PFI schemes or is covered in wider support services or FM contracts within a PFI. Information on the number of contracted-out domestic services across the NHS is not held centrally (Hansard, 2000) although Unison estimates it to be 30% of domestic services (Unison, 2005). UNISON (2005) reports that there is a growing number of PFI contracts in the NHS. However, as the UNISON alleges, the cleaning standards of such hospitals seemed to be lower. A review by the Patient Environment Action Team (2001; as cited in Butler and Batty, 2001) shows that the four of the five trusts running the ten hospitals identified as having the worst standards of cleanliness in the NHS employed PFI schemes. In the Auditor General, Scotland (2003) report on 'hospital cleaning', the average staff turnover was found to be higher amongst contracted-out services (i.e. outsourced and PFI contracts) than in-house services. Therefore, according to Murphy (2002), in the UK, strategies to improve hygiene standards have included bringing domestic services in-house, employing additional cleaning staff, and increasing frequency of cleaning.

All the above reasons, therefore, prompted the need to select a PFI domestic service and an in-house service to check and compare the level of standards of the domestic services between the two services. The two domestic services were selected from two hospitals in the NHS in Scotland. The data collection of the case studies was done using semi-structured interviews. Altogether 26 interviews were conducted across the two cases. The data collected was recorded using a digital dictaphone. The recorded data was then analysed using a content analysis method and the findings of the analysis are presented as a form of a cross-case synthesis. Details of the content analysis method adopted for the study will be discussed in the following sections.

3. CONTENT ANALYSIS

Content analysis can be defined as a systematic, replicable technique for compressing many words of text into fewer content categories based on explicit rules of coding (Krippendorff, 1980). Holsti (1969) offers a broad definition for content analysis as 'any technique for making inferences by objectively and systematically identifying specified characteristics of messages'. The content analysis method was used to analyse the data collected from the case study approach mainly due to the following reasons:

- it enables to organise large amounts of data into codes and categories (GAP, 1996 as cited in Stemler, 2001; Junginger, 1996)
- it identifies systematically the properties of categories (Zhang and Kuo, 2001)
- it enables to identify the relationships between the categories (Wikipedia, 2005)

As explains above, what makes content analysis particularly rich and meaningful is its reliance on coding and categorising of the data. Content analysis can be divided in to two different types, i.e. conceptual analysis and relational analysis (Colorado State University, 2003). In conceptual analysis, a concept is chosen for examination, and the analysis involves quantifying and tallying its presence. Relational analysis, like conceptual analysis, begins with the act of identifying concepts present in a given text or set of texts. However, relational analysis seeks to go beyond presence by exploring the relationships between the concepts identified. Relational analysis has also been termed semantic analysis (Palmquist, Carley, & Dale, 1997). Considering the type of data to be analysed conceptual analysis was adopted for this particular study.

Derivation of results

Idea of this section is to highlight the derivation of results using the content analysis method. The method adopted allowed to explore the context of domestic services in the control of HAI, as well to investigate the similarities and differences between the two cases. During the semi-structured interviews, apart from the case study questions, a matrix was used to explore the question in depth. Developing this matrix at the initial stages of the semi-structured interviews allowed to further elaborate the questions to be asked from the interviewees. According to FAO (1990), developing a matrix also provides a framework for the semi-structured interviews. This process of developing a matrix made it possible to triangulate the data and add internal consistency to the interviews (Miles & Huberman, 1994). The main idea of this matrix system was to depict the main issues/ areas to be considered in a particular question as perceived by the interviewees' views.

Categories and codes were then developed using the questions and the matrix used for the semi-structured interviews. Developing categories and codes provided the following advantages such as condense the content in to analysable units (Junginger, 1996); and generate concepts from/ with data (Wikipedia, 2005). Manual coding was used in this research study instead of computerised coding. Manual coding entails reading text and extracting user-specified information deemed relevant to its content and/ or context (Carley, 1990). However, as Morris (1994) claims manual coding in content analysis is more reliable and time consuming. In this research study, as there were not any large volume of data it was easier to code the content of the interviews manually. Manual scrutiny was more suitable for coding since there were interviewees from different types of professional/ staff categories. The infection control team members and nurses used more clinical words to describe issues of control of HAI, whilst domestic services teams used non-clinical terms to express similar issues. The categories and codes developed were modified progressively using the data gathered from the semi-structured interviews. Modifying the list of categories and codes step-by-step through out the stage of the interviews allowed the researcher to have flexibility on investigating new issues/ matters raised by the interviewees. Most of the findings were presented according to the type of professional/ staff categories and according to the type of case. The contents of the interview transcriptions were then coded using the developed codes. The occurrence of the number of words (in a form of text analysis) was used to obtain an estimation of the main issues discussed by the different categories of professionals/ staff in the control of HAI in domestic services. An example of frequency of word counts during the content analysis method is given in table 1.

Table 1: Frequency of word counts – an example

Number of interviewees presented issues/ areas under the particular question

Staff/ Professional category code

Total number of interviewees presented issues/ areas under the particular question

Number of interviewees in the particular staff/ professional category

Case study code

Total number of interviewees asked about the particular question

Question

Question: Strategies adopted for control of HAI in domestic services					
Description	**Case study 1**		**Case study 2**		**Total**
	FMGR (CS1)	**FMGR, SUP (CS1)**	**FMGR (CS2)**	**…..**	
	2 / 3		**2 / 2**		**4 / 5**
Set up standards	18 (2)	…..	10 (1)	21 (2)	**125 (3)**
………………..	….	…..	…..	…..	**105 (4)**
………………..	13 (3)	…..	…..	…..	**…**
Set up guidelines	6 (1)	…..	…..		**…**
………………		…..	…..		**…**

Frequency of words in the particular staff/ professional category

Number of interviewees talked about the particular issue/ area under the question

Total word occurrence under the issue/ area under the question

Total number of interviewees talked about the particular issue/ area under the question

The importance of frequency of word count is to identify the issues or important areas to be considered in the control of HAI in domestic services according as perceived by the interviewees. These areas, as aforementioned, are tabulated in a matrix form during the interview process. An example of derivation of results from the matrix one professional/staff category is elaborated in table 2 in the following page. All these results are then substantiated with interviewees' comments/ arguments to strengthen the overall findings of the analysis.

Table 2: Example of derivation of results

Staff/ Professional category code

Case study code

Number of interviewees presented ideas under this particular question/ issue

Description / Case study		Case study 1			Case study 2		
		FMGR (CS1)	FMGR - SUP (CS1)	ICT (CS1)	FMGR (CS2)	FMGR - SUP,OUT (CS2)	ICT (CS2)
		2	1	3	2	2	2
Impact of domestic services on HAI rates		Y (1)	Y (1)	-	Y (2)	N (2)	-
Priority given for control of HAI in domestic services		-	Y (1)	Y (1)	-	-	N (2)
Awareness of domestic teams in the control of HAI	Dometic managers	-	-	Y (3)	-	Y (1)	-
	Domestic staff	-	-	Y (1), S (2)	-	Y (1)	-
Change of work practices in domestic services due to the high priority given for control of HAI in recent years		Y (2)	-	-	N (1)	-	N (1)

Sub-issues as identified by the interviewees under particular question/ issue

The level of agreement for the particular sub-issue regarding its existence in the particular domestic service (i.e. yes – Y, to some extent – S, no – N)

Total number of interviewees agreed on the particular sub-area

A summary of results derived from the aforementioned analysis is given below. The findings are presented according to the research questions investigated (refer to figure 1 for research questions). The two cases are named as 'in-house case' (i.e. case study 1) and 'PFI case' (i.e. case study 2), for easy reference.

1. <u>What strategies do domestic services adopt in the control of HAI?</u> The in-house case adheres to service specifications while the PFI case adheres to output specifications to carry out control of HAI practices. There is a need to update these specifications since both in-house case and PFI case specifications are not up-to-date. The PFI case specifications are fairly nebulous and are very wide. As findings of the review of literature reveal, a poorly specified service can lead to greater costs as it may result in some areas being cleaned too often or in the wrong way (Ayrshire and Arran Acute Hospitals NHS Trust, 2004); besides, this also increases the risk for HAI. Therefore it is essential to have properly defined specifications to carry out domestic services including control of HAI tasks. The PFI case does not adhere to national policies and guidelines. Also there is no involvement from the infection control team when developing local policies and procedures in the PFI case. This, as infection control teams view, is a major limitation in successfully carrying out practices in the control of HAI.

2. What is the level of involvement of infection control and nursing teams in operationalising the strategies of control of HAI in domestic services? Infection control team's involvement is comparatively higher in the in-house case. However, the nursing team's involvement in the in-house case is lesser than the infection control team's involvement in. The ward managers/ matrons believe that they should be involved more in control of HAI in the in-house case in terms sharing responsibilities. Neither the infection control nor the nursing teams are involved in control of HAI practices in the PFI case; although, both parties believe that their involvement is crucial. However, the domestic managers in the PFI case believe that the infection control teams partake in making decisions in control of HAI practices to some extent. The in-house case being an internal service to the hospital can be a reason for having a higher integration between the domestic and infection control teams.

3. How do the domestic services ensure the successful implementation of strategies in the control of HAI? Monitoring and supervision is carried out in both cases. However, the matrons in the in-house case believe that they should be involved in monitoring and supervision to a greater extent. Regular performance audits are also carried out by the domestic teams and infection control teams in the in-house case. In the PFI case regular audits are carried out by the PFI consortium as well as by the Property and Support services department of the relevant NHS Trust. If the required level of performance is not achieved the PFI contractor is penalised by the relevant Trust. Audit Scotland also carried out audits in both cases normally once in two or three years. However, there is a need to have a comprehensive performance management programme in both cases which sets out what is required, how should they be achieved, what is being achieved and how should they be rectified (if the required levels are not achieved) or maintained in future (if the required levels are achieved). It was also identified that no feedback is given to the domestic staff regarding the outcomes of the audits, which is a drawback in both cases.

4. Do domestic services employ any knowledge management (KM) practices in the control of HAI in domestic services? In terms of KM, knowledge sharing practices occur among the domestic services managers in both cases. In the in-house case infection control teams and domestic managers also share their knowledge during monthly infection control committee meetings. There is a need to establish this in the PFI case as well since acquiring knowledge from infection control teams is important to successfully carry out control of HAI practices. In both cases domestic supervisors and domestic staff are given induction training. Other training and education programmes are conducted occasionally when the need arise. But the infection control team in the PFI case believe that the PFI contractor does not cover infection control training comprehensively. There is an infection control champion in the in-house case selected from nursing team to mentor both nursing and domestic teams. This is an excellent opportunity for knowledge dissemination. This has to be established in the PFI case as well. Less Information Technology facilities are available, both in cases, for the domestic teams to acquire knowledge, especially from internet sources.

5. Is the type of service provider of the domestic services a major contributor in achieving the required levels of standards in the control of HAI in domestic services? Overall, it was identified that the in-house has more established practices

than in the PFI case in terms of strategies adopted, involvement of infection control and nursing teams and knowledge sharing and dissemination. However, irrespective of the type of service provider, it is only a matter of developing the appropriate strategies to carryout control of HAI and operationalising the strategies. Also, the domestic service managers should ensure that they get adequate input from the infection control and nursing teams while ensuring appropriate knowledge sharing among the parties involved. Conducting sufficient training and education programmes on control of HAI practices for domestic staff as well as for domestic managers is also vital.

The following implications and inferences could be made from the aforementioned findings:

- According to most of the participants of the case studies (domestic service managers and infection control team members) having an authority in planning, monitoring, taking corrective actions and changing infection control practices is necessary for effective control of HAI in domestic services. This is also evident from the report published by the Department of Health (2004) on *'towards cleaner hospitals and lower rates of infection'*. In both case studies the domestic service managers have sufficient authority in all the aforesaid categories. In one of the Department of Health report's (2002) on *'getting ahead of the curve: a strategy for combating infectious diseases including other aspects of health protection'*, it was put forward that the NHS trusts have to fully involve infection control teams throughout the FM operations (including domestic services). However, most of the infection control team participants of the case studies, especially participants from the PFI case, revealed that they have limited or no authority in the control of HAI in domestic services. This is a significant issue to be addressed if it is the case elsewhere across the NHS.
-
- As Parliamentary Office of Science and Technology (2005) state, infection control teams need to be working closely with facilities managers, producing actions plans, adopting good guidelines and protocols and implementing local-focused surveillance for control of HAI in FM services (including domestic services). The case study results, however, highlighted that there is a major rift between the domestic and infection control team members in the PFI case in terms of integration between the two parties in the control of HAI in domestic services. This prompts the need to investigate the issue of integration further, mainly to find out whether it has an association with the type of domestic service, i.e. whether the level of integration is low when the domestic services are managed by an external contractor (out-sourced).
- The case study findings also have important implications for assessment of the different performance management approaches used by different service providers.

4. DISCUSSION AND CONCLUSIONS

The content analysis method adopted for this study allowed the researcher to do a comprehensive cross-case analysis and to derive robust results in the control of HAI in domestic services. However, as in most of the data analysis method/s, content analysis also has problems of reliability and validity. As Weber (1990) notes, reliability problems usually grow out of the ambiguity of word meanings, category definitions, or other coding rules. Yet, it is important to recognise that the people who have developed the coding scheme have often been working so closely on the project that they have established shared and hidden meanings of the coding (Stemler, 2001). The obvious result is that the reliability coefficient they report is artificially inflated (Krippendorff, 1980). As Stemler (2001) explains, in order to avoid this, one of the most critical steps in content analysis involves developing a set of explicit recording instructions. These instructions then allow outside coders to be trained until reliability requirements are met. Gottschalk (1995; as cited in Colorado State University, 2003) points out that the issue of reliability may be further complicated by the inescapably human nature of researchers. For this reason, he suggests that coding errors can only be minimized, and not eliminated (he shoots for 80% as an acceptable margin for reliability).

Validity of a content analysis study refers to the correspondence of the categories to the conclusions, and the generalizability of results to a theory (Colorado State University, 2003). Shapiro & Markoff (1997) assert that content analysis itself is only valid and meaningful to the extent that the results are related to other measures. As Colorado State University (2003) they state, the overarching problem of content analysis is the nature of conclusion reached by its inferential procedures.

Content analysis also suffers from several disadvantages, both theoretical and procedural. In particular, content analysis (Colorado State University, 2003):

- can be extremely time consuming
- is often devoid of theoretical base, or attempts too liberally to draw meaningful inferences about the relationships and impacts implied in a study
- is inherently reductive, particularly when dealing with complex texts
- tends too often to simply consist of word counts
- can be difficult to automate or computerize

However, considering the context of this research and considering the advantages of content analysis method given in the previous sections, it can be concluded that the advantages outweigh the disadvantages.

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IMPROVING CONSULTATION AND WORKER ENGAGEMENT IN THE CONSTRUCTION INDUSTRY

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Abstract: The industrial revolution has resulted in the traditional construction craft organisational model being replaced with one that precludes most site operatives from planning the work they will do. Worker engagement has been found to have a positive impact on worker performance, including safety, in many industries. Despite this not enough construction employers properly involve and consult their workers on health and safety. This paper reports on a 12 month, Contract Research Report on behalf of the United Kingdom's Health and Safety Executive. The aim of the research is to research the practice of worker engagement in the management of construction health and safety. The primary hypothesis to be tested is: Operative engagement in health and safety management has a direct and positive impact on health and safety performance. This is being tested through a series of case study, intervention strategies, using various approaches to worker engagement. Initial findings from four industry workshops are discussed along with the implications of these for the fieldwork stage of the research.

Keywords: Consultation, Engagement, Health, Safety, Worker

1. INTRODUCTION

Historically, construction has been performed using a craft model of organisation in which the planning of the work process in terms of determining what is to be produced; how it is to be produced, where it is to be produced; when it is to be produced; who is to produce it; and what constitutes acceptable quality and quantity output is integrated with the actual performance of the work. The Industrial Revolution resulted in the separation of these activities in industries other than construction in the early nineteenth century. It wasn't until late in that century and the early twentieth century that the separation occurred in the construction industry. This shift resulted in construction organisations (other than the very smallest ones) being divided into three functions: business, production related staff, and field production. As a result of differences in education, training, and experience, production staff personnel have very different perspectives on the work and its accomplishment than that of the field production staff (site operatives).

Consequently, construction planning is accomplished with little input from site operatives. This process may be ignoring the wealth of knowledge and experience possessed by site operatives, which is a tremendous waste. In the United States, many older construction managers refer to operatives as "hands." However, when a firm hires an operative for his hands, it also hires his brains. The operative has the knowledge and experience to contribute to an improved process plan for the accomplishment of the work.

This paper reports on a 12 month, £98,500 Contract Research Report on behalf of the United Kingdom's Health and Safety Executive. The aim of the research is to research the practice of worker engagement in the management of construction health and safety.

Worker engagement does not occur within a vacuum; it occurs within an organisational environment that is strongly influenced by the management beliefs, structure, and processes of the organisation. Worker engagement will not occur when the management of a firm employs a command and control approach to management. Management commands and workers comply. It is imperative that management is receptive to and desirous of worker engagement. The Keil Centre developed a model of safety culture maturity model that represents the necessary transformation of management to a style that honestly cultivates worker engagement, and facilitates a step change (Fleming 2001).

It is necessary at this point to recognise that in the construction industry management exists at two levels: home office management and project management including foremen. The top management of the firm operates at the home office level. In many cases, top management has given unqualified support to worker engagement and then charged project management with implementing it. Many times this has resulted in failure because worker engagement is threatening to many project management level people (Walters et al 2005, ECOTEC 2005). They perceive it as giving up control or even question the value of it. It is crucial to assess management's beliefs, structure, and processes to determine whether it promotes and encourages engagement or, whether it frustrates it.

In the past twenty years, industry, adopting Japanese manufacturing methods, has begun to integrate the planning and doing functions again. High performance and self-managing are terms applied to integrated work teams. The common thread running within these approaches is worker engagement. Organizations employing worker engagement tend to experience greater productivity, lower absenteeism and turnover, fewer accidents and fatalities, and all around better performance (Biggins et al 1991), see also: Grunberg (1983); Quinlan (1996); Simard & Marchand (1995).

Recent history reveals effort in the UK to advance worker engagement in health and safety. Beginning with legislative efforts in the 1970s, worker engagement has been advanced as an approach to improving health and safety performance in industrial settings. Namely the Safety Representatives and Safety Committees Regulations (1977) and the Health and Safety (Consultation with Employees) Regulations (1996) have been promulgated by the Health and Safety Executive (HSE) to directly address involvement, consultation, and the sharing of information with regard to health and safety. Despite this "not enough employers properly involve and consult their workers on health and safety and there are not enough workers who feel able to come forward and take on health and safety responsibilities" (HSC 2004). In addition to this the Construction Design and Management Regulations (Regulation 18) requires management to obtain "views of workers". Similarly, only 3 improvement notices have been served regarding CDM Regulation 18, which would indicate that guidance on "what constitutes improved worker engagement" would benefit HSE inspectors greatly in this respect.

Evidence shows that union safety representatives often lead to higher levels of compliance and better health and safety performance than non-trade union systems (Litwin 2000), although the vast majority of the UK workforce is non-union. Recent developments include the 'Worker Safety Adviser Fund' which has seen greater involvement from trade unions, however this may be tending towards 'worker representation' rather than 'direct' worker engagement. Furthermore, due to the low representation of unions in construction, no more than 15% (Walters et al 2005), other mechanisms need to be in place to drive this legal requirement. The two approaches of union representation and direct worker engagement are not mutually exclusive; they can complement one another with each being effective in particular situations.

The question that prompted the research being reported in this paper flows directly from the Construction Industry Advisory Committee (CONIAC) declaration for worker engagement in the construction industry, which is "Can worker engagement be employed in construction to secure improved performance?" (HSC 2004). The construction industry has very different product, production, and employment characteristics than other industries. Consequently, techniques and approaches utilized with success in other industries have failed when employed in construction. Given the unique characteristics of the industry, its products, and its workforce, the primary problem of interest is whether approaches or techniques of worker engagement can be developed for the construction industry that will secure improved H&S performance.

2. RESEARCH OBJECTIVES & METHOD

The objectives for the research are to:

1. Review the literature to identify approaches, models, and techniques of worker engagement.
2. identify the characteristics of construction that influence the effectiveness of worker engagement
3. to develop approaches of worker engagement for the construction industry
4. to evaluate these approaches for viability in the industry
5. to test the effectiveness of these approaches in securing worker engagement
6. to determine the impact of the various approaches for securing worker engagement on health and safety performance (Risk Reduction) as well as on other measures of performance such as productivity, absenteeism, turnover and reputation**.**
7. determine the impact of the approaches on worker perceptions of engagement and well-being
8. To assess whether the management structure and processes impact on the viability of worker engagement (management maturity), with particular focus on the commitment of middle management at site/project level.

The methods to be employed in the research, subsequent to a literature review and initial industry consultation, will involve the development of 'intervention packages' to implement on several case study projects. These will be based on existing examples of best practice observed elsewhere out with and within the industry. Collaborating industry partners have agreed to implement the intervention packages on their projects. Each partner organisation will implement one package and will also provide access to a second project of similar size, scope and nature which will represent a 'control' project being run using existing processes. In order to test the effect of each intervention package 'before' and 'after' measures will be taken. Similar measures will also be taken at the control site.

A key measure will be the impact of each intervention on how H&S issues are dealt with, how management responds and what perceptions the workers have of management's attitude to H&S. in addition to this, each collaborating organisation will also collect H&S performance measures on an ongoing basis as part of their own Safety Management System e.g. site audits, measures of near misses, accidents, injuries etc. follow-up interviews will also be carried out where evidence shows existence of improvements elsewhere e.g. productivity or quality.

The industry partners are main contractors appointed to undertake refurbishment and new-build works for an international bank throughout the UK. The fieldwork will involve several steps in order to implement each intervention package. These steps broadly fall into five categories:

1. A short training programme on the approach to be used;
2. Implementation of the approach, by contractor staff;
3. Worker participation during the implementation;
4. "Before and after" interviews of workers and managers, to determine perceptions of the worker engagement safety programme and its impact on all health and safety issues;
5. Group interviews with management in "before" and "after" measures of safety performance.

2.1 Training programme

The training in the approach to be used will be given by a member of the research team to the site management team. This initial training will take no more than 1 ½ hours per site management team.

2.2 Implementation

Management will make whatever arrangements required for implementing the approach. This will be part of the initiation of normal site safety systems and should not require significant additional duties. The manager responsible for site induction will then introduce the approach to new workers as part of each site induction meeting. Communication of the instructions for workers will take less than 30 minutes per induction.

2.3 Worker participation.

The actual participation by workers during the course of each project will be designed to integrate with normal worker communication and the safety input will not normally require more than a few minutes at regular intervals, depending on the approach used.

2.4“Before” and “after” interviews

These will cover perceptions of the workers before and after the intervention. The worker will complete a questionnaire at the beginning of the induction, and then again, sometime after exposure to the new approach. The exact questions will be developed through the course of the research; however, an upper limit of 15 minutes to complete the questionnaire will be set.

2.5 Discussion of safety performance

Records of safety performance, probably using existing measures, will be collected, to test whether there has been any direct impact of the intervention on site safety. Use of existing measures will avoid any additional burden on site management. However, a final close-out meeting with the site manager to discuss the overall impact of the intervention will be sought. This should take no more than 1 hour per site.

3. PROGRESS TO DATE

The literature search yielded a number of approaches to worker engagement as shown in Figure 1.

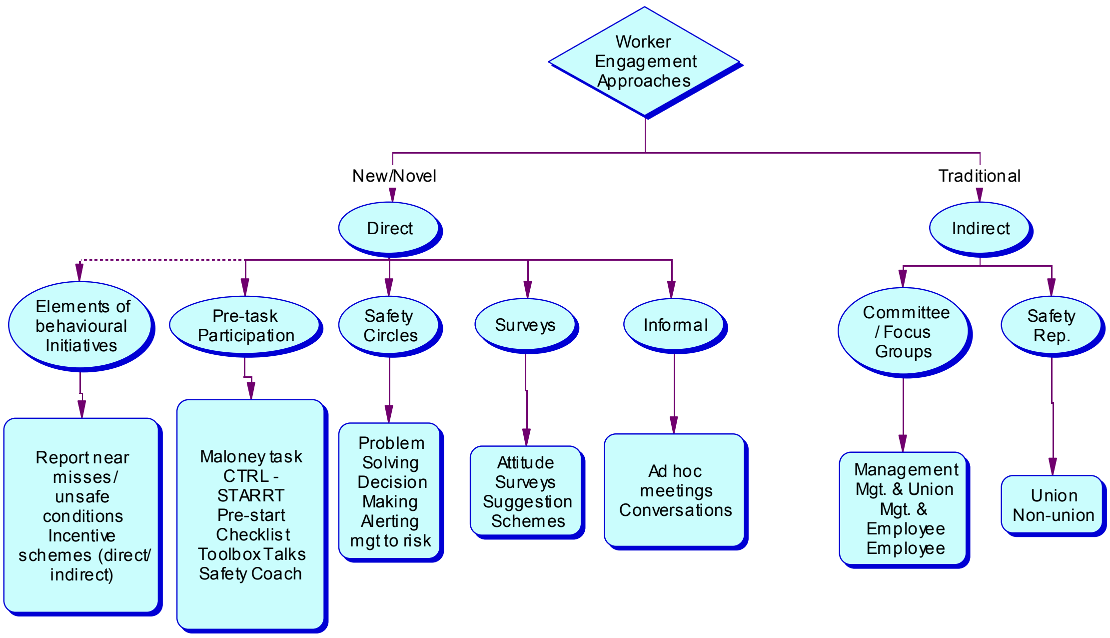

Figure 1: Approaches to Worker Engagement

Traditional approaches to worker engagement are enshrined in the legislation regarding consultation with employees as described earlier. These are namely safety representatives, who may or may not be appointed by a union; and safety committees, these can have several permutations of management and employee representation. These have been termed ‘indirect’ as shown in Figure 1. Other approaches identified inclued informal; surveys; safety circles; pre-task briefings; and elements of management lead behavioural initiatives.

Informal approaches consist of ad-hoc meetings or conversations, usually initiated by management when walking through the site, at break-times or even during conversations regarding the work to be done.

Surveys have been used to collectively describe any means of communication through paper-based media, usually without direct contact, but, none-the-less has the ability to reach every worker and can provide anonymity.

Safety circles consist of volunteers who come together for the purpose of solving specific problems. They differ from a safety committee in that they do not have to meet at regular intervals. They are subsequently 'dissolved' after each meeting until another problem arises that needs a solution. This is essentially a reactive approach but could be developed to be more proactive.

Pre-task briefings are instigated at the beginning of a shift or task or when something changes that will affect the worker. It essentially consists of discussing the work to be done and asking the worker to compare the risk assessment controls and method of work with the actual task in hand. Feedback is not restricted to the task in hand and the worker is invited to also discuss any H&S issue they desire.

There are certain elements of behavioural initiatives that can also be considered as worker engagement. For example incentive schemes to encourage workers to get involved in H&S and requirements to report unsafe conditions, near misses etc. are also useful.

These various approaches were presented at an industry workshop, held September 2005 in Glasgow, to gain feedback on specific issues uncovered during the literature search. This involved over 80 participants from a varied cross-section of the industry and although the event was held in Scotland there were a number of delegates from all over the UK. Issues were discussed in four workshop groups:

Table 1: Findings of industry workshop on worker engagement

	WHAT WORKS	BARRIERS	MEASURES
Safety committees	Workers Union sites Client commitment Empowered	Lack of trust/apathy Fails to work Intimidation Small Sites	Resources Influence decisions Who Outstanding issues
Union Safety Representatives	Soft approach Local Government TU Training Team approach	Migrant workforce Finance exclusive Combined approaches	Was not discussed.
Direct Management approaches	Training Feedback Demonstration Communication skills Motivation	Workers reluctance Trade Union Blame Culture Traditional Contracts	Test Whistle blowing Survey Feedback
Informal approaches	Workers self ownership Non-financial rewards Listening Self Policing/Auditing	Reluctance Suspicion of management Peer Pressure	Suggestions Responses

1. Safety committees
2. Union Safety Representatives
3. Direct Management approaches
4. Informal approaches

The results of this exercise were categorised into ‘what works’ ‘barriers’ (and where possible solutions) and ‘measures’ (what could be measured to determine success). The results are summarised in Table 1 and discussed further below.

Safety committees

It was agreed by this group that improved communication was the greatest single potential benefit of H&S committees. The act of “getting people talking” was thought to be very positive. Therefore giving everyone an equal voice was seen as paramount. The group agreed that the more workers that attend the better. A preferred ratio was agreed to be at least 4 workers to 1 manager. Union sites were noted as having more workers willing to volunteer compared to non-union sites. Client commitment i.e. money and a willingness to co-operate with issues that the client has influence over was discussed. Although it was commented that there are good clients that do not get involved with H&S committees. Empowered committees work best, this could be via management commitment.

Barriers discussed included a lack of trust or apathy, especially when concerns and issues “fall on deaf ears” and “nodding dogs” fail to act. This can be overcome through delivery of results by management when issues are raised i.e. closing out issues. The committee may fail to work; either the committee achieves nothing (as mentioned above) or is frustrated by individuals with other agendas, including “general complaints”. A solution put forward by the group to combat this was to measure performance. This is discussed in more detail below. Intimidation was seen as a problem, whether real or only perceived, it was acknowledged that workers can sometimes feel intimidated by managers on committees. As discussed above, it was suggested that the 4:1 ratio of workers to managers could help alleviate this problem. Small Sites were seen as needing a slightly different approach; at a certain level a formal committee is too cumbersome (the level of this “threshold” could not be determined by the group); it was suggested that an “open door” policy works better on small sites; as well as informal meetings, possibly as part of a “site walk”.

Several issues were discussed regarding ‘measurement’. Outstanding issues were seen as the most vital unit to measure. More specifically, percentage of outstanding issues to those closed out and type, as well as number of issues e.g. are just minor issues being dealt with? The influence on decisions was seen as an indicator of success. It was suggested that evidence of an audit trail from issues being raised to final decisions could be part of a review. There is invariably someone within effective H&S committees who drives it and champions H&S. the personality of the individual is key. If someone is identified to hold responsibility for the committee they can be measured to ascertain the committee’s performance. Resources were discussed, as mentioned earlier regarding clients; the group acknowledged that support (such as administration) is required to assist the committee. The level of resources in relation to the job could be measured.

Union Safety Representatives

Discussion covered "soft" approaches, which have been successful in getting people involved in safety. Local Government have been seen to promote worker participation, however experience of main contractors and SME's was far less evident. TU Training of Safety Representatives (SR's) was seen as best practice. However the decline of TU membership in recent years has not helped. A team approach, (TU working in partnership with management) has been successful. This was recommended as a way forward.

Regarding barriers the group discussed migrant workers as a concern with regard to safety. The issue was the question "Do they need representation more than others?" Finance seamed relevant where SR's are concerned, it was claimed that there is not enough finance in budgets for SR's. Union SR's were seen as being somewhat exclusive. The issue of representation being held with one person places more emphasis on the character of that individual. Some group members commented that combined approaches (TU and non-TU) tend to lead to conflict, due to different objectives of each. Possible measures were not discussed by this group.

Direct Management approaches

Training was discussed as a key issue, provision of information was agreed to be the first step to training and educating the workforce. The information needs to be relevant. It was agreed that a feedback loop is required and a mechanism needs to be in place for this. This involves both the direct and indirect forms of communication and the means to act on it. Other issues included a demonstration of what is required; use of live case-studies has worked on previous projects; communication skills are essential for the delivery of any management lead initiative, this is an area commonly overlooked in construction. It was also suggested that there should be less use of jargon. Motivation of the workers was seen as essential, including use of incentives "carrots".

Barriers discussed included workers reluctance to get involved in initiatives instigated by management; Trade Union suspicion of management lead initiatives; a blame culture where senior management and/or peers, who believe the programme and budget or cost are the main drivers for a project over people issues; and traditional contracts that "normally assist in transferring the risk from the main employers (Client's and Principal Contractor's) to the sub and sub-sub contractors".

Things to measure discussed by this group included testing the workers and their supervisors individually on the process through demonstrations, basic written tests or observations. Also just as important is higher up the chain their senior management, who should be measured on their attitudes and values. Whistle blowing was also discussed, i.e. number of safety failures reported by workers, although this has failed in the past due to workers 'staging' an unsafe condition to report it for praise or incentives. Surveys were discussed i.e. survey and sample the means of Communication, Consultation, Co-operation, Collaboration, the Climate, the Culture, the Commitment, the Competency, the Control and Reporting from and with all levels of the workforce. The group also agreed that feedback could be measured as an indicator of success. This could be both quality and quantity measures.

Informal approaches

Workers self ownership of H&S was discussed by this group as helping them to be more pro-active and get involved on interventions where management merely provide support. Non-financial rewards were seen as a far better way of maintaining sustained performance. This should not be confused with 'no financial commitment' by management. In the case discussed financial support was given to reward favourite local charitable causes, in return for sustained H&S performance. Listening was seen as a key issue. Workers need managers to actively listen, understand and respond to what they are saying. This highlighted a need for "soft-skill" training for managers. Self policing or auditing, which is similar to self ownership, was seen as a good way of gaining worker commitment.

Barriers discussed by this group included reluctance of workers to get involved, possibly stemming from a 'not my job' attitude; suspicion of management having ulterior motives; and peer pressure from other workers unwilling to participate.

Measures discussed by this group echoed those above. Suggestions made by workers (number and quality) were discussed. Responses of workers to safety interventions and by management to worker suggestions (number and quality) were also discussed.

4. DISCUSSION

The findings from the industry workshop groups highlight both specific and generic issues. The specific issues have already been covered above; however, there are some obvious overarching issues that can be seen in the findings of each group.

Training will need to be part of any intervention. This has already been identified in the fieldwork design. However, specific reference has been made to 'soft' skills, which will need to be addressed. Therefore reference to communication skills and man-management skills will need to be a feature of the management training exercise.

Suspicion from all quarters e.g. workers, management and trade unions was clearly evident from the workshop findings. A challenge for the research team will be how to create an open environment on the case study projects. This is being addressed through initial meetings with key personnel from the industry partners.

The reluctance of some workers to be engaged needs to be acknowledged. Although every effort will be made to allow workers to get involved it has been established that no coercion should be used by management.

A key issue that every intervention package will need to address is the ability to facilitate two way communication. This was evidenced in the responses to 'measures' in particular the repeated reference to a need for recording numbers of worker suggestions, recommendations or general issues; and the number of responses by management, issues closed out or outstanding etc. Further, it was obvious that the type of issues, i.e. important or superficial, should be recorded.

These findings will now feed into the next stage of the research, which is the fieldwork case studies. At present four 'intervention packages' have been identified for implementation these are:

1. Pre-task briefings with elements of behavioural safety initiatives
2. Suggestion schemes with safety circles
3. Safety representative with H&S committee
4. Informal approach using 'safety coaches'

The fieldwork will take place over the next six months and a final report will be submitted to HSE by the summer of 2006.

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UNDERSTANDING CULTURE, SKILLS AND R&D INVESTMENT AND THEIR RELATIONSHIP TO INNOVATION IN THE CONSTRUCTION INDUSTRY

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Abstract: It is widely held that for a business to become universally proactive and to remain successful, the top priority should be the development of a culture of innovation. This paper reviews specific areas within innovation management in the construction industry, reporting on key literature on culture, R&D investment and Skills requirements as they relate to innovation. The objective is to investigate barriers to the development of a culture of innovation in the construction industry. The construction culture is a major factor in many of the ills faced by the industry, the mismatch of skills supply and demand could prove to be serious for the construction industry and the amount of investment funding available for construction research has also been steadily declining in recent years. This research will explore ways of promoting a culture of innovation and research within the construction industry, developing strategies and best practice guidelines to enhance the industry's competitiveness through the implementation of technological innovation.

Keywords: Construction industry, Culture, Innovation management, R&D investment, Skills.

1 INTRODUCTION

In the UK, the construction industry has been characterised as slow to adopt technological innovation, which has been said to contribute to low productivity and poor performance. This has often been attributed to the conservative nature of the industry, which in turn is attributed to a number of features that set it apart from other industries like aerospace, automotive and pharmaceutical industries, which appear to have stronger, more visible innovation cultures (Gesey et al., 2005). Close-to-industry research is needed to identify more effective ways of identifying, managing and promoting innovation in construction. The Centre for Innovative and Collaborative Engineering (CICE) at Loughborough University is undertaking research on innovation in construction as part of an Engineering Doctorate project. The research will explore ways of promoting a culture of innovation and research within the construction industry, developing strategies and best practice guidelines to enhance the industry's competitiveness through the implementation of technological innovation and advanced business practices. A number of research methods will be used including interviews, survey questionnaire, focus groups, and case studies with a range of companies within the construction industry to map the existing culture of innovation/research and establish appropriate method(s) to devise and implement improvements.

What is innovation?

There is no generally accepted definition of innovation at the present time. However, there has been a noticeable convergence as to its principal characteristics. In the context of this paper this point can be illustrated by a sample of general definitions. An innovation is "an idea, practice or an object that is perceived as new by an individual or unit of adoption" (Rogers, 1995). The Department of Trade and Industry (DTI) have acknowledged the work of Rogers, (1995), Fairclough, (2002) and Jones et al, (2003) defining innovation as a 'successful exploitation of new ideas' (DTI, 2003).

Why innovate?

The construction industry has been described as slow in the adoption of technological innovation and new ways of working and it is commonly characterised as a 'backward industry' and in particular, one that fails to innovate in comparison to other sectors (Winch, 2003). There are many reasons for construction firms to innovate, most of which are known and understood, e.g. to improve competitiveness. Most stakeholders expect innovation to offer benefits in one or more of following areas; capital and operational expenditure, quality, performance, market share, competitiveness, customer service and value etc. (Barrett and Sexton, 1998; Glass, 2002). Tatum (1991) points out that construction firms need to innovate to win projects and to improve the financial results of these projects. Westbury (2004) argued that innovation is best facilitated through a blend of methodologies, work practices, a supportive culture, the right business infrastructure and also business environment. The construction industry needs to innovate more frequently to boost its competitiveness so it can meet the ever increasing client demands of both national and international marketplaces (Larsson, 2003). These factors are closely linked and will be explored in turn.

2 CULTURE IN CONSTRUCTION AND ITS IMPACT

Culture is a difficult concept to identify and is as complex as innovation, but is generally understood to mean the personality and behaviour of an organisation. 'It can help to bind people together through a sense of belonging and a sense of common purpose and can also generate an environment conducive to competitiveness through joint learning and innovation' (Jones and Saad, 2003). Culture can also bind people together outside the work environment through their belonging to ethnic groups, religious or social organisations etc (Cooper, 1994), see Table 1 below. Organisational culture can be seen as unity of the characteristics of the organisation together with the norms, values and traditions (Dikmen et al., 2003), whereas innovative behaviour and creative thinking have different components (Tatum, 1987; Egbu, 1999; Girmscheid and Hartmann, 2001).

The existence of a particular culture in construction is cited by several sources (Banwell, 1964; Latham, 1994; Egan et al, 1998) as a major factor in many of the ills faced by the industry (Ankrah and Proverbs, 2004). There is distrust between clients, consultants, contractors, subcontractors and suppliers leading to conflicts of interest and to relationships that are predominantly short term (Luiten et al., 2000). Therefore, understanding that this results in a particular 'construction culture' is likely to be a significant step towards identifying why management of innovation in construction can pose problems. There is of course the view that this culture produces constructive conflict and it would be neither easy nor desirable for it to be managed in practice.
Egan (1998) identified that the UK construction industry is fragmented in nature. Each category of professional has a distinct background, culture and learning style (Powell

and Newland, 1994) and even goals (Kalay et al., 1998). The industry is also said to be adversarial (Anumba & Evbuomwan, 1996) with a culture of intimidation, where pressure is continually applied to those at the next level down in the hierarchy (Greed, 1997). Kuramswamy (1994) observed that where there is a proliferation of human relationships, as in the construction industry, then there is potential for conflict. Therefore, the potential worst case scenario for a construction project is to be under constant threat of conflict due to the fragmented and adversarial nature of the industry.

Table 1: Diverse definitions of culture (Source: Bodely, 1994)

Topical:	Culture consists of everything on a list of topics, or categories, such as social organization, religion, or economy
Historical:	Culture is social heritage, or tradition, that is passed on to future generations
Behavioural:	Culture is shared, learned human behaviour, a way of life
Normative:	Culture is ideals, values, or rules for living
Functional:	Culture is the way humans solve problems of adapting to the environment or living together
Mental:	Culture is a complex of ideas, or learned habits, that inhibit impulses and distinguish people from animals
Structural:	Culture consists of patterned and interrelated ideas, symbols, or behaviours
Symbolic:	Culture is based on arbitrarily assigned meanings that are shared by a society

The fragmented nature of the UK construction industry inhibits performance improvement (Egan, 1998), leaving project stakeholders having different goals. For example, Engineers become focused on providing optimal technical solutions, whereas Contractors becomes focused on minimum cost, with client value not considered to a significant degree in either case (Mitropoulos and Tatum, 2000).

There is evidence that inter-disciplinary boundaries originate within construction higher education departments. Gale (1992) suggested that lecturers bring such attitudes with them into the classroom, and begin to define the interfaces between those involved within the construction process. Students can then be seen to adopt divisive attitudes based on professional territories (Moore and Dainty, 1999). Also, new recruits to the professions do not take long to adopt the structured (in terms of attitude) views of their peers. These views can encourage division and inhibit communication in the solving of complex problems requiring genuine collaboration (Moore and Dainty, 1999) such as construction projects.

Bodely (1994) claimed that culture has several properties: it is shared, learned, symbolic, transmitted cross generationally, adaptive and integrated. Such a definition of culture implies that it is defined and ingrained by the professional sphere in which its members operate. If this is the case then changing the current construction industry culture would be a substantial task. However, there is evidence (Egan, 1998) to demonstrate that either it and/or government is trying to facilitate such a change.
Egbu et al. (1999) examined the management of innovation in construction by surveying a number of companies which were identified as 'innovative'. They highlighted certain characteristics shown by all innovative organisations. These are:

people are open-minded, willing to accept change, flexible in lines of communication, structure that allow top-down bottom-up and risk tolerant climate where it is accepted that lessons can be learned through mistakes. Other characteristics or conditions favourable to innovation included: a 'knowledge-friendly culture' where people are not inhibited about sharing knowledge and do not fear that sharing knowledge will cost them 'power and influence' or even their jobs; a climate where people genuinely feel valued and where people feel some sort of 'ownership' or involvement with the innovation; and a climate where people feel some job security. Clearly many of these characteristics would be difficult to engender in an industry based on adversarial, entrenched relationships.

It may appear that the frequency with which culture is mentioned and in some cases blamed for the ills of the industry has become something of a cliché, but the fact that it continues to be mentioned should be respected; what is missing is a systematic and thorough interpretation of the various elements of culture that could be manipulated to improve the effectiveness of innovation.

3 R&D INVESTMENT IN THE CONSTRUCTION INDUSTRY

Research and Development (R&D) is an input to the innovation process and it contributes to innovation in many ways (Salter et al, 2000) for example: increasing the stock of useful knowledge, supplying of skills graduates, creating new instrumentation and methods, developing new networks, and enhancing technological problem solving capacities.

In the UK, R&D in construction has a relatively low profile compared to other industries like aerospace, automotive and pharmaceutical industries (Dikmen, 2003; Winch, 2003). The amount of investment funding available for construction research has been declining steadily in recent years and is estimated to be less than 0.5% of the construction sector's spending. By comparison aerospace invests 11%, automotive over 9% and pharmaceutical up to 13% of their revenues on research (ICE, 2003). A lack of continuing investment in R&D in the construction industry may be preventing innovation starting and continuing (Glass, 2002).

There are many reasons to explain the low level of R&D investment in construction, they include: in accurate or invalid reporting of R&D expenses, small sizes of professional service firms, lack of risk capital, conservative behaviour of clients, unsuitable government policies and many more factors (Seaden and Manseau, 2001).
Furthermore, the construction industry itself has clearly struggled with the notion of R&D as a tangible benefit, which may relate to the fact that the industry has traditionally been very slow to exploit innovation. At present, no construction organisations have been placed in the top 250 R&D investors list (Steele and Murray, 2001). Since the publication of the Egan report 'Rethinking Construction'(1998), it has been accepted that for future growth within the construction industry to be sustainable it will become increasingly reliant on its R&D capabilities.
This notion was again endorsed by the Fairclough (2002) report, 'Rethinking Construction Innovation and Research', which reviewed current construction research competencies and facilities. The report clearly spelt out the inadequacies of the industry and further highlighted the central role of research to the construction industry and

subsequently society as a whole. In that review Fairclough (2002) asserted: 'The potential lack of high calibre personnel being trained to work in UK construction is the greatest threat to the long-term health of the research base'. He presented a powerful explanation for the continued fragmentation and collapse of construction R&D, based on the limited horizons and modest rewards of careers within the industry, declining numbers of new entrants on construction-related degree courses, and subsequent decrease in graduates entering the profession. Fairclough (2002) critically suggested that it is important that a better mechanism be developed for defining the industry's long term research needs.

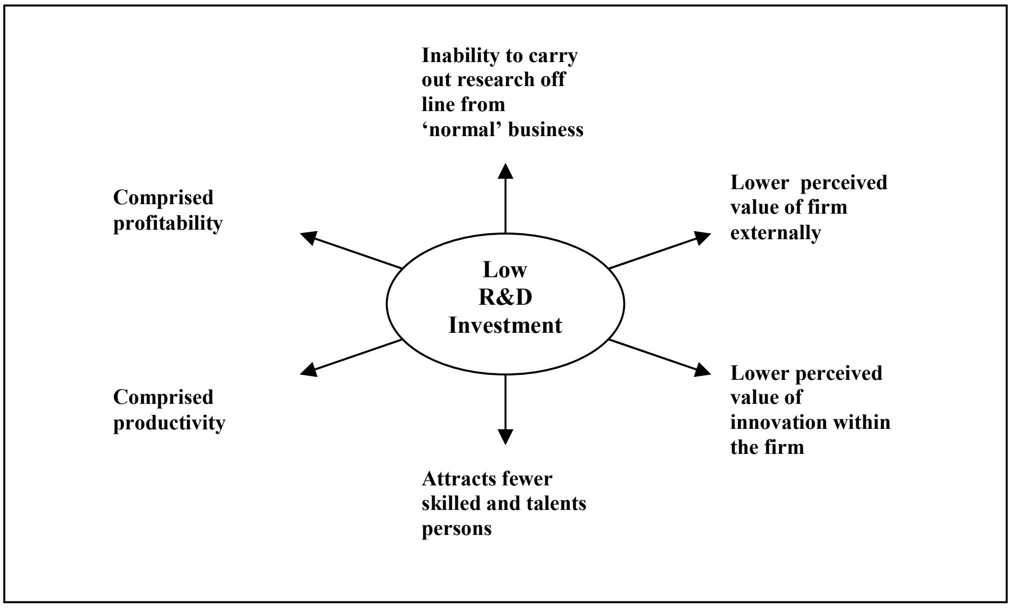

Figure 1: A proposed model of the effects of low R&D investment

Figure 1 above shows that lack priority given to R&D investment could be explained by the lack of recognition of a number of key determinants of innovation in the construction industry, such as; investment, strategic vision, mechanisms for change and research base structure etc.

4 SKILLS IN CONSTRUCTION

The construction industry faces a serious problem in matching the supply of available skills and its demand for labour (CITB, 2002). The greatest challenge facing the construction industry today is the shortage of skilled labour. Studies reveal a number of factors, which have combined to influence the construction skills shortage (e.g. Dainty, 2004). These include:

- the demographic downturn and resulting reduction in the number of entering the labour market (Druker et al, 1996);
- the poor image of the industry, which adversely affects its popularity as a career choice (Dainty, 2000; Fairclough, 2002);
- the high number of jobs shed during the recession of the early 1990s (Churchill, 1997);

- the introduction of technologies, which have reconstituted the skills required (Agapiou et al., 1995);
- failure to develop multi-skilling as a route to overcome skills shortages (Scott et al., 1997);
- the growth in self-employment and the use of labour-only sub-contractors, which have reduced the commitment and investment in training within the industry (Harvey, 2001).

All the above factors have led to the skill shortage for the industry (Dainty, 2004). This is not a new phenomenon within the construction industry and has been a recurrent problem in the UK over the past three decades (Department for Education and Employment, 2000). The problems of demands for, and supply of, skills arises partly because of the declining employment of younger and the right calibre of people in the industry, but also because the construction has to compete with other sectors for the skills that it needs. It is interesting and disturbing that more construction professionals such as engineers, architects and surveyors etc are employed outside the construction industry than in it (CITB, 2002). There is considerable concern that the supply of professional skills required in the production and maintenance of the built environment has not matched the changing needs of the sector (Fairclough, 2002). Moreover, there has been a dramatic decline in the numbers of new entrants on construction-related degree courses such as Building and Civil engineering degrees which show quite marked falls (DTI, 2003). It is very important for construction industry to develop an internal culture for innovation that will attract the right calibre of employee and the most innovative individuals to facilitate a self-sustaining rise in levels of innovation and focused R&D (Steele and Murray, 2004).

5 PROMOTING A CULTURE OF INNOVATION IN THE CONSTRUCTION INDUSTRY

It has been well documented that current construction industry culture is adversarial: professions are fragmented (Anumba and Evuomwam, 1999; Egan, 1998; Lottaz et al., 2000) and information insensitive (Gajendren, et al., 2004; Thomas et al., 2001; Tam, 1999), creating divisions in background, culture, learning styles and goals. The R&D base is fragmented, patchy in quality and in size, and because of these above reasons, the industry will find it difficult to attract and retain talented people in the future (Fairclough, 2002). To improve the situation the development of a culture of innovation is of utmost importance if a business is to become universally proactive, and remain successful (Steele and Murray, 2001). It is clear from the literature that investment (both human and financial) in a knowledge-based innovation management method that facilitates both top-down and bottom-up approaches could be an appropriate option for construction companies (Gesey et al., 2005). UK Construction Industry needs to understand Culture, Skills and R&D investment and its relationship within innovation if they want to be successful. Figure 2 below represents the overall skills, culture and R&D investment and its relationship within innovation in the construction industry.

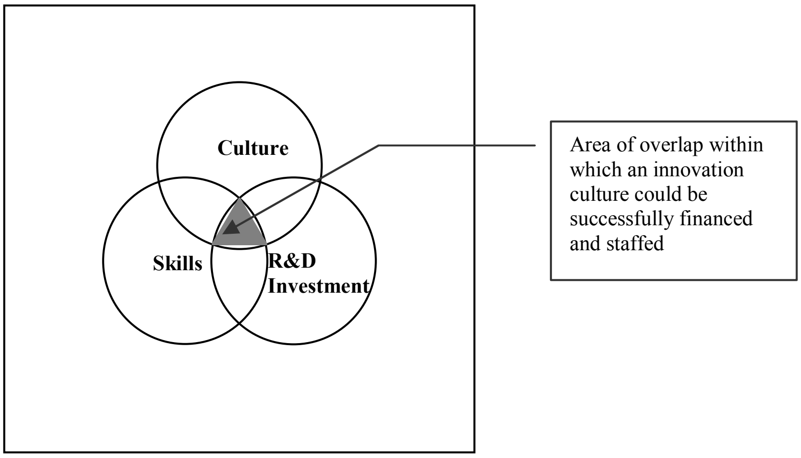

Figure 2: A proposed model in search of 'Innovation Chemistry' (after Nicolini).

Areas where all three elements overlap represent the opportunities where innovation can be exploited. A good understanding of the relationship between culture, skills and R&D investment is fundamental to practical application of innovation in the construction industry. The successful innovation culture can arguably be financed and staffed at this overlap, i.e. the successful formula or chemistry (Nicolini, 2002).

6 CONCLUDING REMARKS

There is evidence that the industry is attempting to move away from its adversarial and fragmented nature but it is a slow process with many traditional attitudes currently remaining. The culture within the construction industry is a major factor in many of the ills faced by the industry. Therefore, understanding this culture is likely to be a significant step towards identifying why management of innovation in construction has so many problems. To improve the situation, the construction industry needs to recognise that the development of a culture of innovation, when complimented with a strategy of recruiting right calibre of employee and developing talent, together with focused R&D investment, can deliver productive rewards.

Fairclough (2002) critically suggested that it is important that a better mechanism be developed for defining the industry's long term research needs. This lack of innovation and research can be explained by the lack of recognition of a number of key determinants of innovation in construction industry, such as; investment, strategic vision, mechanisms for change and research base structure etc. Against this background a self-assessment tool is proposed as part of this research to help construction companies assess their innovation capabilities. The objective of the tool is to initiate a process leading to the effective implementation of a strategy/best practice guidelines and allow construction companies to: assess their innovative performance; help them to focus on the areas where they want to make progress; integrate innovation related strategies into overall competitive strategies; and benchmark their innovation performance with peers and within the construction industry etc.

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INTEGRATION OF HEALTH AND SAFETY PLANNING IN CONSTRUCTION PROJECT MANAGEMENT THROUGH A BEST PRACTICE "GATEWAY" MODEL

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Abstract: It was widely believed that implementation of the CDM Regulations had lead to a bureaucracy, parallel to, but detached from, normal project management practice and adding little value to the management of construction projects. The authors have engaged in extensive industry consultation, including several group meetings and a number of interviews with experienced practitioners. This has resulted in the development of an integrated Gateway model for construction projects, incorporating the management of health and safety risk. Health and safety risk is part of overall project risk and the use of Gateways can provide the mechanism to manage the risk of cost and time overruns as well as health and safety risks. If the model is to be implemented issues such as iterative design processes and construction beginning before completion of design needs consideration.

Keywords: Gateway, Health, Integration, Planning, Safety.

1. INTRODUCTION

When the UK's Health and Safety Executive (HSE) implemented the Construction Design and Management Regulations 1994 (CDM), they intended them to "encourage the integration of health and safety into project management" (HSE 2001). Almost ten years on these very regulations are under review as many in the industry still struggle to properly integrate the management of health and safety throughout the planning lifecycle of construction projects. In construction, planning can cover a vast number of activities from pre-project planning, through design, to planning specific site activities (CIOB 1991). It is estimated that up to 90% of accidents could be prevented (HSE 1988). Recent studies have found that planning and control failures were related to 45.4% of accidents (Duff and Suraji 2000), and designers could have contributed to the prevention of up to 47% of accidents investigated as part of an HSE research project (HSE 2003).

Effective planning for Health and Safety (H&S) is therefore essential if projects are to be delivered on time, without cost overrun, and without experiencing accidents or damaging the environment or the health of site personnel (CIOB 2002; Teo, F et al. 2005). For projects in the UK, the initial planning has to also consider the needs of those maintaining and cleaning the structure (HSE 2001). These are not easy objectives as construction sites are busy places where time pressures are always present and the work environment ever changing (HSE 2002).

Today's construction project planning seriously challenges the old triangular model of time/cost/quality trade-off, which suggested that an improvement in one must lead to deterioration in at least one of the others (Atkinson 1999; Westerveld 2003). It now extends the total quality management philosophy that quality is free (Crosby 1979) and embraces the premise that delivery in one area, safety, can actually lead to benefits in other areas, such as time and cost (Hinze and Parker 1978). The importance of effective construction planning and control in the communication and avoidance of health and safety risks cannot be overstated but the fundamental premise postulated by the authors is that this need not, and should not, be a separate exercise aimed solely at health and safety. Effective management will embrace all production objectives, as an integrated process, and deliver construction which satisfies all these objectives and not one at the expense of the others.

2. RESEARCH METHOD

The research problem was posed by the authors as a submission to the UK's Health and Safety Executive (HSE), who funded the project over an 18 month period. This problem was "how best to promote the effective integration of health and safety management into construction project planning, communication and control". The method employed was adopted in response to the research problem. This problem is industry based. This invariably means the solution requires an applied research approach which attempts to resolve practical problems or improve on accepted, traditional thinking (Holt 1998). To solve this particular problem the method needs to deal with the perceptions and views of industry experts. Therefore a qualitative method of action research suits the needs of the research problem well (Fellows and Liu 1997; Naoum 2001). The type of action research required should facilitate feedback to allow improvements of the solution. Field interviews provide a useful method for data collection and satisfies this requirement (Naoum, 2001). Semi structured group interviews are suitable for exploratory data and structured one-to-one interviews are more useful for objective data collection, such as that of validation exercises (Naoum, 2001). These methods were adopted in line with the research objectives:

1. Consult experienced practitioners to ascertain current practice and improved methods of integrating health and safety within construction project management.
2. Produce a model of construction project management, integrating H&S.
3. Validate the model in order to improve it

In order to achieve these objectives a programme of work was devised and carried out in five overlapping phases which incorporated both group and individual interviews:

Literature search into construction project management; health and safety management, and CDM. Information on Gateways was also investigated.

Industry Steering Group; to advise on strategic direction, review progress and outcomes and obtaining access to current "best-practice" construction organisations.

Expert (Brainstorming) group interviews; covering maintenance; construction; and planning and design; to investigate critical "Events" or "Tools" that would both ensure compliance with CDM and add value to the management of the project.

One to one interviews; with industry practitioners, to assist in the development and validation of the model, based on their industry experience. This consisted of 12 in-depth interviews with senior professionals responsible for H&S within contractor, design, maintenance and client organisations.

The remainder of the paper discusses the model developed as a result of this process. In most cases the interviewees agreed on general points, where differing points of view were expressed this is accounted for by qualifications in the text. This also helps increase the robustness of the findings.

3. PROCESS MODEL FOR CONSTRUCTION PROJECTS

Process models for construction projects have been in use for some time. For example, there is the traditional RIBA Plan of Work (RIBA 2000), the Association for Project management guidance (APM 2002) and more recently Salford's Process Protocol (Kagioglou, Cooper et al. 1998). Although these make useful guides, any attempt to be this prescriptive reduces flexibility and creates problems when trying to apply them to different procurement methods (Winch and Carr 2001). The UK Office for Government Commerce (OGC) model for construction procurement (OGC 2003) has been the main source of the model's structure, having two major advantages. Its flexibility allows various procurement routes to be adopted; and it is primarily for general project management purposes, rather than promoting additional, health and safety specific, gateways and procedures. The OGC describes a gateway review as "a review of a procurement project carried out at a key decision point by a team of experienced people, independent of the project team" (OGC 2001). Whether the team is internal or independent, the process facilitates consideration of the critical aspects of a project at key points through its life, providing assurance that everything is in place prior to progressing to the next stage. The gateways can also be moved or repeated to align with the procurement method.

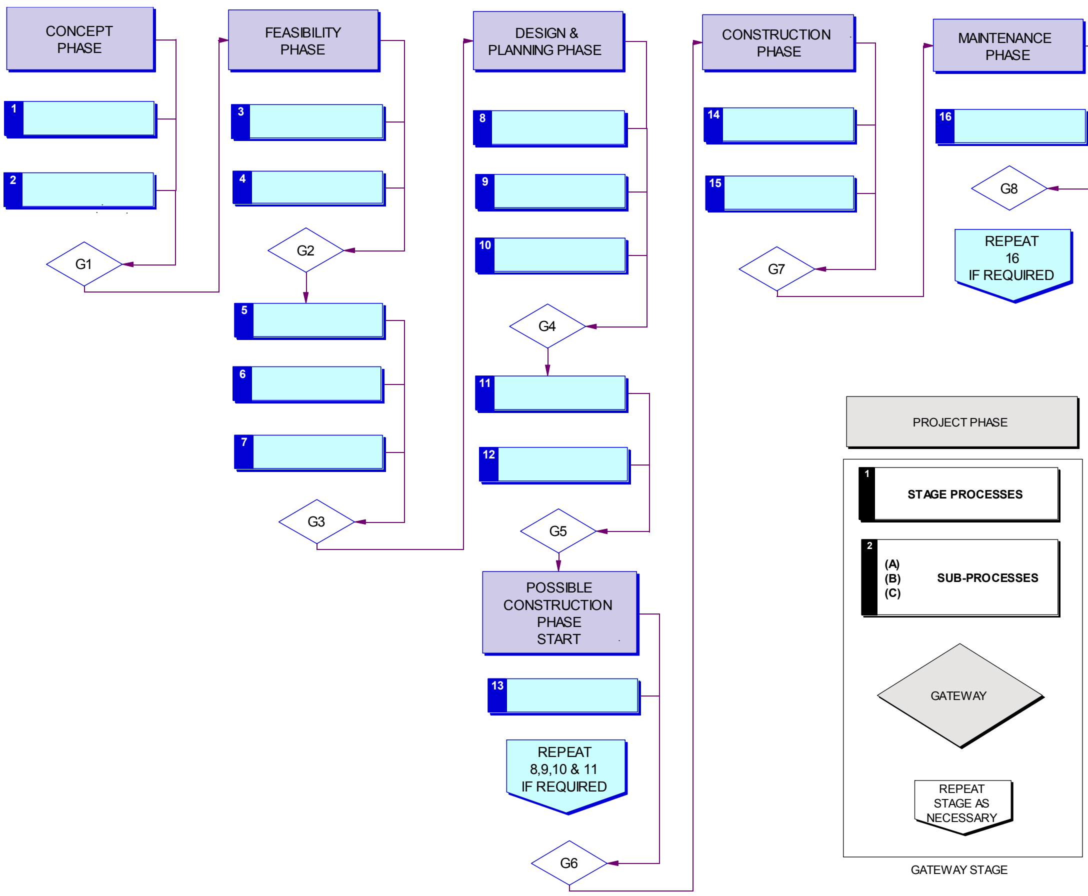

Figure 1: Gateway model for integration of health and safety

The model (Figure 1) shows a total of 8 gateways. Tables 1 to 5 show in more detail the processes required for each gateway phase, aligned to their project management processes.

4. PROJECT PHASES

4.1 Concept Phase

Table 1 shows the processes leading to Gateway 1. At this stage it is recommended that the client appoint a competent Planning Supervisor (PS) or health and safety advisor. Early appointment at this gate ensures compliance with the requirement to have the PS in place before commencement of design, which includes concept design. At gateway 1 it is expected that the strategic objectives have been set and strategic decisions taken.

4.2 Feasibility Phase

Table 2 shows the processes leading to Gateway 2 - Project Risk Assessment and Gateway 3 - Procurement Strategy. Whole life costing is seen as best practice when considering options for construction procurement. At this stage the maintenance and cleaning budget should be included in cost analysis. This is clearly an issue for the cost consultants. However, there will need to be an interface with the Planning Supervisor.

A key issue within Value Management is evaluating and choosing the best option. A tool used for this purpose is the Option Evaluation Chart. This takes the form of a matrix in which various options are compared, including risk to health and safety.

Table 1: Concept Phase

1	**Possible Need for Project**	
A	Initiated by client: "informed" client – appoint owner "naïve" client - appoint consultant.	Appoint a competent Planning Supervisor to assess designers and contractors.
B	Consider if construction project is required.	Consider client's role in H&S throughout project: supply of information; time allowed and budget required for project.
2	**Define User Needs**	
A	Policies and procedures	Align Health & Safety (SHEQ) policies for project; how supply chain will be informed of H&S requirements; expertise required; criteria for evaluating competence, resources and commitment; how to measure & monitor performance. Copy to H&S Plan.
B	End users' needs	Issues for safe operation and maintenance. Consult end user/maintenance/FM (if known).
C	Identify threats and opportunities (Risk Register)	Identify S.H.E. hazards (Risk Register)
GATEWAY 1 STRATEGIC ASSESSMENT		
CDM: Construction (Design and Management) Regulations H&S: Health and Safety SHEQ: Safety Health Environment and Quality SHE: Safety Health and Environment FM: Facilities Management ACoP: Approved Code of Practice		

The preparation of the business case will require more detailed health and safety input. Key CDM milestones should be integrated into the programme at this point. Gateway 2 is a point when the business case is confirmed. It will be successful if it is robust, which will require the team to confirm that the project is technically feasible, financially viable, plans are in place to manage the risks identified and timescales are realistic. All of which impact on health and safety.

Table 2: Feasibility Phase

3	**Options to Meet User Needs**	
A	Performance Specification to allow flexible approach.	Include H&S performance, materials and components specified by output performance can meet functional and H&S requirements.
B	Whole life Costing	Compare whole life cost of high risk O&M/cleaning, i.e. abseiling to clean glass panels.
C	Value Management	Ensure best choice = safe choice. Option Evaluation Chart to include H&S.
D	End user's operation and maintenance (F.M.).	Input from end user at this stage; include format for H&S File and budget for maintenance strategy.
E	Initial/Concept Designs	Initial S.H.E. Box information e.g. highlight where complicated designs will require extra planning to develop.
4	**Prepare Business Case**	
A	Objectives	H&S Objectives, copy to H&S Plan.
B	Project Critical Milestones	CDM/H&S milestones copy to H&S Plan.
C	Project budget	Evaluate cost of specific CDM/H&S items e.g. P.S., H&S advice, worker participation schemes, safe maintenance.
D	Decide procurement route	Assess procurement route e.g. will it be traditional or combine design and construction in one contract (for CDM milestones).
E	Decide project control procedures	Assess risks. Decide SMS (or SHEQ) control procedures, update Risk Register.
	GATEWAY 2 PROJECT RISK ASSESSMENT	
5	**Project Brief**	
A	Define what the project needs to achieve	CDM/H&S objectives included, update H&S Plan
B	Decide what will be measured to define success	Decide Project H&S Performance Indicators, update H&S Plan, agree format for H&S File.
C	Communicate any known risks	Update Risk Register; new risks.
6	**Feasibility Study Options**	
A	Consider sites and select	Consider H&S/Environmental risks on each site via Option Evaluation Chart. Copy information for site selected to H&S Plan.
7	**Procurement Strategy**	
A	Confirm procurement strategy	Progress H&S Plan in accordance with procurement strategy. Where construction commences prior to completion of design agree "Construction H&S Plan Milestones" also.
B	Agree criteria for selection of supply chain.	Agree H&S criteria for selection of supply chain.
C	Involve supply chain and end users in design options and selection of materials (Design and build options facilitate this)	Seek specialist advice on residual risks (Risk Register). Seek advice on maintenance and access issues during O&M period to prevent H&S problems.
	GATEWAY 3 PROCUREMENT STRATEGY	

The Procurement Strategy Gateway stage sees development of the project brief. Health and safety Key Performance Indicators for the project can help focus attention. Best practice is now embracing behavioural indicators where concentration on safe acts will help facilitate continuous improvement. Gateway 3 marks the end of the concept and feasibility phases.

4.3 Design & Planning Phase

Table 3 shows the processes leading to Gateways 4 - Team Selection, 5 - Outline Design and 6 - Detailed Design. The Team Selection phase allows various options to be incorporated for the selection of the whole project team, which may include appointments, negotiation or tender processes and can involve designers, consultants and contractors. Careful supply chain selection will always be a feature of well-managed construction projects and health and safety criteria should be seen as a key factor. OGC use a flow-chart which is an excellent guide to this process (OGC 2002). Gateway 4 is a critical point as it marks the move into the main design phase. Its main purpose is to confirm that the earlier plans are being implemented. This particular gateway can be repeated several times. The H&S Plan will need to be developed to a suitable degree before this gateway is signed off and sufficient time must be allowed for adequate completion.

Just as the terms of the contract need to be acceptable to all parties concerned, the level of health and safety performance expected from each must be considered. If everything is satisfactory, the next step will be to create a climate conducive to co-operation and good communication, along with affirmation of responsibilities. A team building, health and safety workshop can both create a team spirit and aid hazard identification. Creating a Responsibility Chart will communicate the roles and responsibilities of each party, integrating health and safety responsibilities in a concise and transparent manner.

The design phase is one which can vary in complexity. Regardless of this, the key CDM functions to consider are design hazard identification and risk management. CIRIA Report C604 (CIRIA 2003) is a useful guide, HSE's new CDM website for designers features Red-Amber-Green lists (HSE 2003). These can highlight the main generic hazards to eliminate or avoid, as well as suggest good practice. It must be acknowledged that design is an iterative process. It is therefore recommended that several review points are included in the project programme to review buildability and maintainability. Gateway 5 may lead into the construction phase. Analysis of the method of construction goes hand in hand with the contractor's Risk Assessment. This Gateway should confirm that the design has progressed enough and no major client changes will be made. Changes are sometimes inevitable but a deadline for this goal is better than none at all. At detailed design the overall design should be well established, therefore the emphasis will be on development of specific details and the co-ordination of specialist contractors. This co-ordination that is necessitated by the design process should also lend itself to a **collaborative approach** to hazard identification and risk management.

In many respects Gateway 6 is similar to Gateway 5 applying the same rules for outline design to detailed design, but will yield a greater level of detail. Also, if the construction phase has already started the review should consist of separate design and construction portions. Guidelines for site audits can be taken from publications such as HSG65 (HSE 2003).

Table 3. Design & Planning Phase

8	**Contract Preparation**	
A	Develop project programme	Develop H&S milestones for project programme.
B	Develop output performance based specifications	Review specifications for prescriptive items that may generate H&S risks during construction/O&M.
9	**Expressions of Interest / Vetting**	
A	Use criteria previously outlined to vet supply chain.	Use H&S criteria previously outlined to vet supply chain. CDM requirements: competency and resources.
10	**Partner/Contractor Selection**	
A	Collate and despatch project information/tender documents	Complete and despatch Pre-Construction H&S Plan, including specific feedback requirements regarding residual risks from the site and/or design. Include current H&S File.
B	Negotiation/Tender correspondence.	Co-operation between parties involved in negotiation/tender process with regard to H&S issues.
C	Decision via cost/performance criteria.	Ensure H&S criteria sufficiently weighted in decision.
GATEWAY 4 TEAM SELECTION		
11	**Award Contract**	
A	Issue and complete contract documents. Accept, change or decline contract.	Confirm health and safety duties. Each party may accept or decline contract depending on its commitment to H&S, project risks and contract requirements.
B	Partnering / Team Building Workshop	H&S hazard workshop, action outputs.
C	Confirm Responsibilities	Integrated responsibility chart with H&S included
12	**Outline Design**	
A	Assess functional brief and commence iterative design process.	Initial Red-Amber-Green list analysis. On-going CDM reviews, Buildability, Maintainability.
B	Outline design, co-ordinate services & consultants. Produce drawings, schedules, information.	Co-operation & Co-ordination of design team; Buildability and Maintainability of design challenged; site issues regarding residual risk should have been addressed by the contractor, if appointed, ahead of completing the Construction H&S Plan. Identify H&S hazards/risks on drawings, DRA to Risk Register. Update H&S File
C	Possible construction phase start after this gateway. Detail method of construction. Develop Construction Programme.	Possible Construction Phase H&S Plan; contractor risk assessment; cross reference H&S Plan to programme; H&S milestones on programme.
GATEWAY 5 OUTLINE DESIGN		
13	**Detailed Design**	
A	Detailed design process.	On-going CDM reviews, Buildability, Maintainability.
B	Detailed design, co-ordinate services & consultants. Produce drawings, schedules, information.	Co-operation & Co-ordination of design team; Buildability and Maintainability of design challenged; site issues regarding residual risk have been addressed by the contractor ahead of completing the Construction H&S Plan. Identify H&S hazards/risks on drawings, DRA to Risk Register. Update H&S File
C	Possible construction phase start after this gateway. See 12 (C)	Per 12 (C)
14	**Initial Works Contract**	If Construction Phase started after Gate 5, see process 14 for details.
GATEWAY 6 DETAILED DESIGN		

4.4 Construction Phase

Table 4 shows the processes, during the construction phase, leading to Gateway 7 – Project Handover. At this stage the emphasis will change to short term planning and operational issues. Although the contractor is responsible for this the client, or his representative is required to ensure work is being done competently and safely. The contractor's performance will be checked regularly in terms of time, quality and cost, health and safety is no different and the previously agreed health and safety performance indicators need to be monitored. The client ultimately has this responsibility, but may choose to delegate it to a health and safety advisor.

Gateway 7 marks the end of the construction phase. At this stage contractor and supply chain performance will be reviewed. The outputs of the construction phase, including Operation and Maintenance (O&M) manuals and the H&S File, should be reviewed to confirm that they were completed satisfactorily.

Table 4: Construction Phase

14	**Works Contract**	
A	Site establishment	Display HSE Notice, site inductions – confirm operatives have received and understood method statements, communicate site rules. Confirm contractor's supply chain input to Construction H&S Plan & H&S File.
B	Contractor's own design process. Change management process.	DRA required, P.S. input required – copy residual risk to Risk Register. Update H&S Plan.
C	Site Management & Control – implement management system, monitor progress & resources, report feedback.	Implement SMS, ensure site-specific training, monitor H&S performance & resources, facilitate feedback from operatives and worker consultation.
D	Execute works packages, monitor progress & resources, report feedback.	Safety inspections, continue to monitor H&S performance & resources, report incidents & accidents.
E	Pre-handover meeting agree procedures for commissioning & testing.	Identify potential H&S/Environmental Risks at commissioning and during use. Ensure contractor's supply chain have submitted information for H&S File.
15	**Handover**	
A	Check completed structure with specifications and drawings	Final inclusions and completion of H&S File.
B	Testing and commissioning	Include safety issues in testing of M&E equipment; testing of safety and maintenance equipment, including rescue procedures.
C	User familiarisation, Handover Management Documents	Communicate H&S residual risks (H&S File). Training
GATEWAY 7 PROJECT HANDOVER		

4.5 Maintenance Phase

Table 5 shows the processes leading to Gateway 8, Monitor and Review. In order to benefit fully from this feedback point it should be carried out during the maintenance phase. This will allow the end users, operating staff and maintenance contractors to evaluate the success of the project in operation and as such is an ongoing process. It is recommended that the lessons learnt should be recorded in the Health and Safety File. In this way future work can benefit from any mistakes and initiate improvements in project planning, design and construction practice. Some more sophisticated clients may wish to use a knowledge management system for this purpose. This can aid organisational learning.

Table 5: Maintenance Phase

16	**Feedback**	
A	Lessons learnt communicated to knowledge management database. Success of project and Performance measurements recorded for future use.	Any incidents and accidents included in lessons learnt along with details of best practice witnessed. H&S performance of supply chain recorded for future tendering purposes.
B	Feedback from users, assess and implement changes	H&S and maintainability issues raised and assessed. Implement changes. Copy to H&S File
GATEWAY 8 MONITOR & REVIEW		

5. CONCLUSIONS

Views and experience of interviewees and discussion group members were gathered during the course of the research to develop and validate the model. It has been based on the OGC framework which has been recommended by *Accelerating Change* (Egan 2002) and *Revitalising Health and Safety in Construction* (HSE 2002). As such, the OGC model has already seen successful use in its application to construction projects. However, exploitation of the framework for improvement of health and safety planning has still to be fully realised.

Gateways, in general, have been proven to improve commercial success. The health and safety benefits of low contingency projects are obvious. It must be remembered, however, that the model is reduced from reality, and as such, can never be perfect.

With regard to the practical use of the Gateway model, a *conditional go* option at Gateways is not advisable. Although the incorporation of this as an option makes the process more flexible, there were concerns that weak managers would abuse it. Without good leadership the process will be in danger of becoming bureaucratic. Supporting tools, mentioned in the above text, have also been developed.

There are several factors peculiar to construction projects that need to be considered when implementing the model. Firstly, the procurement of all the construction services for a project is not usually all done at the same time. The process of appointing project members is more likely to be repeated throughout the life-cycle of the project and several aspects need to be revisited, therefore the model needs to be flexible. Secondly, the design process is often described as an iterative one. Furthermore, the construction phase almost invariably starts before the completion of the design and to assume that site works only commence after the conclusion of design is unrealistic. The model attempts to address these issues through its ability to repeat and overlap phases but only a full field trial will confirm its practical application.

Subsequent to the completion of this work HSE have incorporated gateway elements from this research into their proposed guidance for the new CDM Regulations and OGC have drafted new guidance for health and safety with their gateway model which also incorporates elements of this research.

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MAPPING THE COMMUNITY-BASED ACTION MODEL FOR PROFESSIONAL SKILLS AND COMPETENCES IN HOUSING MARKET RENEWAL

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Abstract: The UK government's Housing Market Renewal (HMR) programme, implemented through the Pathfinder organisations, has been central to recent attempts to deal with the problems of housing market failure. It has become clear that the problem is not only an issue of the physical condition of housing. Rather it is about non-physical intervention factors such as social deprivation, economic and environmental issues that cause housing to become unpopular and deteriorate. The aspirations of the local community are central to this recent protests by the local residents within the Pathfinder scheme in the North England suggesting a gap between professional intentions and community expectations. The conflict between the aspirations of the local community and the objectives of the HMR Plan suggests that HMR professionals need to focus on skills necessary for community-based actions. This paper aims to look at what building sustainable communities really means for low housing demand in the Pathfinder areas. It leads to the development of community-based action model that recognises additional skills needs for delivering HMR from the Pathfinder organisation perspective. The development of the proposed model may answer the question: What are the additional skills and competences that need to be acquired by the employees of Pathfinder organisation necessary to deliver Housing Market Renewal?

Keywords: Community-based action skills and competencies; Professional competences; Housing Market Renewal; Sustainable Communities

1. BACKGROUND TO RESEARCH

This paper aims to investigate additional skills and competences that need to be acquired by the relevant professionals in the process of delivering Housing Market Renewal (HMR). HMR via its Pathfinder organisation is part of many strategies in the UK government's Sustainable Communities Plan (2003) with its main task being to tackle low housing demand and in some case abandonment across North and Midlands of England. The related concepts of Sustainable Communities and their relation to HMR have been reviewed. Some potential research pertaining to the skills and competencies in the process of delivering HMR by the employees of Pathfinder organisation has also been identified. The main research focus that emerges from this work is centred on the question: *what are the additional skills and competences that need to be acquired by the employees of Pathfinder organisation in the process of delivering HMR?*

2. HMR AND SUSTAINABLE COMMUNITIES PLAN

Around one million homes in England are affected by low demand and around 440,000 of these are in North West (ODPM, 2003a). Migration from towns and cities has meant more people living in suburbs and rural locations. Such a trend is unsustainable, as it will force the existing housing market to collapse. The challenge now, is to revitalise the affected towns and cities with people, green spaces, safe streets and good design so that they become places people choose to live. There is also a need to create communities that are capable of absorbing social change and renewing themselves where existing housing are recycled and reused to provide a range of goods and services for modern life.

2.1 HMR Pathfinders and the Sustainable Communities Plan

The main policy initiative by which the Sustainable Communities Plan aims to tackle low demand is via nine Housing Market Renewal Pathfinders (Pathfinder) areas in the North and Midlands of England. In 2003, a large proportion of Government funding is being allocated to the Pathfinder areas: £500 million has been made available for the task in three years. The East Lancashire Pathfinder (Elevate) is one of four Pathfinders in the North West. It covers seven intervention areas known as Area of Development Frameworks (ADFs), containing approximately 85,000 properties across five local authorities of Blackburn with Darwen, Hyndburn, Burnley, Rossendale and Pendle Borough Councils (Elevate, 2004).

By 2005, the Government expects strategic actions to be in place for all Pathfinder areas, envisaging large-scale clearance, refurbishment and new build work to be underway, complemented by improvements in local services. In line with the improvements of the physical aspects of housing, the Pathfinder with its partnerships are also crucial to addressing non-housing requirements of Sustainable Communities, in particular, customer focused public services and a pride in the community and cohesion within it (Audit Commission, 2003).

2.2 Factors Contributing to Low Demand in Pathfinder Areas

Low housing demand appears in number of ways. The government used a broad range of indicators in both private and social sectors to define low demand. According to the DETR (1999), in the social housing sector the following low demand symptoms occur: *a small or non-existent waiting list; tenancy offers are frequently refused; high rate of voids available for letting; high rate of tenancy turnover*. In the private sector, low demand has been concentrated in areas where: *private property value is particularly low and/or falling in absolute terms; high private sector void rate; high turnover of population; significant incidence of long-term private sector voids or abandoned properties; visibly high number of properties for sale or let.* In addition, a set of other possible factors that might contribute to the problem of low demand as collected from the literature (particularly Nevin et al., 2001 and Leather et al., 2003) are:

- *Deprived areas and anti social behaviour*- bad image/reputation of area; crime and anti social behaviour; litter and vandalism; physical appearance of housing and surrounding area
- *Type and condition of housing*- rooms sizes/layout; density; lack of parking/garden; availability of new houses elsewhere which are more attractive; type of housing
- *Location, availability of services and amenities and accessibility*- poor road

Unquestionably, low demand for housing cuts across environmental, social and economic aspects of sustainability (CPRE, 2004). These low demand factors include not only on the physical aspects of housing but, also other non housing related factors that contribute to low housing demand. These non-housing issues require professionals to diversify their skills and competences in the process of delivering HMR. It is strongly recommended that relevant professionals involved in tackling low demand in the Pathfinder areas, have to address other skills that might be needed, especially in meeting local community needs and aspirations. Skills for community-based action that are not directly related to housing are among many skills that are required necessary to effectively deliver HMR and Sustainable Communities.

Community-Based Action in the Process of Delivering HMR

The Government has promoted the idea of community strongly (e.g. by encouraging community involvement), making it a key requirement of urban regeneration programmes, a driver of local government reform and a key feature of its Strategy for Neighbourhood Renewal (Brickell, 2000). The author further emphasised that the Government's overall approach to community regeneration is failing because of its inability to engage communities in a dynamic, entrepreneurial and widely inclusively way. But, this raises the question of what is the community that the professionals need to get involve and engage with in the process of delivering HMR? As defined by Poplin (1979) community is "the place where people maintain their homes, earn their livings, rear their children and carry on most of their life activities". Long and Hutchins (2003) define community as "a grouping of up to several thousand households, whose occupants share common experiences and bonds derived from living in the same locality". Thus, community consists of the persons or people living within the same geographical area, carrying on their social interactions and activities with one or more common ties and shared values. This is the community that needs to be engaged by the professionals in the process of delivering HMR.

Secondly, why do the professionals need to engage with the community in the process of delivering HMR? According to the Sustainable Communities Plan (2003), communities need to be sustainable over the long term: "people continuing to want to live in the same community, both now and in the future" (Long and Hutchins, 2003). Only local people know what the best is for them and can help creating communities they feel proud of and to become much more involved in how local areas are run.

Lastly, how do professionals engage with the local community in the process of delivering HMR? This new approach no doubt becomes a challenge to the professionals involved in the process of delivering HMR. To be effectively delivering HMR, the local community need to be engaged in significant issues such as participatory planning for public space. Within the Pathfinder areas, communities have different ethnic backgrounds, faiths and cultures. Only the local community know what their common value is. By allowing local people to be involved and participate in the process of delivering HMR can the conflict between the government objectives and local community aspirations and interests be prevented. The key objective is how professionals strengthen community involvement in the process of delivering HMR. These are the skills that need to be highlighted by the professionals.

3. NATURE AND EXTENT OF SKILLS SHORTAGES IN THE PROCESS OF DELIVERING HMR AND WHY THEY EXIST

3.1 Understanding Skills and Competencies

Skills are the ability to demonstrate a system and sequence of behaviour that are functionally related to attaining a performance goal that requires multiples skills from the persons or employees (Boyatzis, 1982). Skills can be assessed by examining the difference between the skills needed by employers and those are currently available in the market. These differences show up as s*kills shortages, skills gaps* or *latent skills* (Giles and Campbell, 2003; SSDA 2003).

Dench (1997) identified three broad areas of skills need that can be summarised as *Personal attributes and attitudes:* these relate to a person's character and innate feelings. *Personal skills:* these relate to an individual's innate abilities that can be developed and built on, such as communication, being capable of working with others, taking responsibility, making decisions, negotiating and problem solving. *Technical skills*: these relates to basic technical skills, specific technical knowledge that is acquired through the educational system and experience. Dench further argued that personal skills are important in influencing the effectiveness with which an individual is able to operate in a workplace, as well as being of particular importance in certain occupations. *Good technical skills will be necessary, but not enough to enable people to operate effectively.*

Meanwhile, a competence is defined as an *ability to do, for a task (*Concise Oxford English Dictionary) or an *ability to do something well or effectively* (Collins Cobuild English Dictionary). Boyatzis (1982) described a job competency as *an underlying characteristic of a person* in that it may be a motive, trait, skill, aspect of one's self-image or social role, or a body of knowledge which someone uses. The existence and possession of these characteristics may or may not be known to the person. In this sense, these characteristics may be unconscious aspects of the person (i.e., the person is not aware of them or is unable to articulate or describe them). Conventionally, competence is taken to be a combination of *knowledge, skill* and *awareness* or *attitude* (Dingle, 1995). A competence that recurs across many different jobs and organisations can be classified as a 'generic competence' and classified into one of four broad bands: *Cognitive; Influencing; Managing* and *Personal* (Bethell-fox, 1982) or summarised into five competences areas as: Task competences; Professional competence; Political competence and Ethical competence (Virtanen, 2000).

The Construction Industry Council (2004) has differentiated between skills and competences and concluded that: *a skill is an ability to perform a task and is generally* *transferable across occupations* whereas *a competence is an ability to perform a technical task that is related to a specific occupation*.

3.2 Understanding the Existing Professional Practice

In order to map a community-based action model for professional skills and competences in the process of delivering HMR, it was necessary to examine previous work on modelling professional competence.

Table 1: Understanding the existing models of professional competences

The UK occupational standards models (Cheetham and Chivers, 1996)	Competences are recognised in the form of job-specific that are required through a '*functional analysis'* process of determining: *Key purpose*; *Key role* (the level below 'key purpose'); *Units of competences*; *Elements of competence*- encompassing of 'performance criteria' describes the characteristics of competent performance and 'range statements' specifies the range of situations or contexts in which the competence should be displayed. *Behaviour or personal competence* (particularly in the area of management) is important in professional roles to effective performance. *Ethics and values* are increasing important especially within the care sector.
The job competence model (Mansfield and Mathews, 1985),	Competence comprises of three basic components: *Tasks* – consist of skills which are used in a routine way to achieve defined outcomes; *Task management* – involves the use of skills that may be needed when a number of tasks are required to be performed together in a particular way; *The role/job environment* – consists of those skills which are needed to cope with a particular working environment (e.g. working with others – fellow team members, customers, clients, etc.) or those needed to cope with highly critical situations.
Behavioural/personal competence models (Boyatzis, 1982; Klemp, 1980 and Schroder, 1989)	A number of American researchers, especially within the management areas, have focused heavily on *behaviours*. *Personal competence* may be a better predictor of capability (i.e. potential to perform in future posts) than *functional competence*, which attests primarily to competence within a candidate's current post. However, there is no guarantee that a person who apparently has the right mix of personal competencies will be able to 'put it all together' and deliver the desired outcomes
The reflective practitioner approach (Schon, 1983)	Schon (1983), has offered a new epistemology of professional practice based on *'knowing-in-action'*(a form of acquired tacit knowledge) and *'reflection'* (the ability to learn through and within practice). He argues that reflection (both 'reflection-in-action' and 'reflection-about-action') is vital part of the process.
Meta-competencies (Reynolds and Snell, 1988; Hall, 1986 and Nordhaug, 1990)	Reynolds and Snell (1988) identify *'meta-qualities'*, (creativity, mental agility and balanced learning skill). Hall (1986), uses the term '*meta-skills'* which are defined as 'skills in acquiring other skills'. Nordhaug (1990) offers as examples: *communication, problem-solving and analytical capacities.*
Core skills (Cheetham and Chivers, 1996)	They are generic and be fundamental to effective performance in all (or most) occupations. The units consist of: *Communication*; *Application to Number* (numeracy); *Information Technology*; *Personal Skills* – working with others; and *Personal Skills* – improving one's own learning and performance
Ethics and values (Eraut et al, 1994)	The authors identify four overlapping sets of values and they are: *Legal values* (operating within the law and other mandatory systems); *Professional values* (relationships with clients and other professionals); *Organisational values* (relationships with colleagues, staff, customers and general public) and *Personal values* (individual beliefs and behaviours)
Professional competence model (Cheetham & Chivers, 1996;1998)	Influenced by the existing models, four core competences are identified: *Knowledge/cognitive competence*- defined as 'the possession of appropriate work-related knowledge and the ability to put this to effective use'; *Functional competence*- defined as 'the ability to perform a range of work-based tasks effectively to produce specific outcomes'; *Personnel or behaviour competence*- defined as '*the ability to adopt appropriate, observable behaviours in work-related situations; Values/ethical competence*- defined as '*the possession of appropriate personal and professional values and the ability to make sound judgements based upon these in work-related situations'*
Model of professional framework for RICS (Kennie and Green (2001)	Four components of competence which combines: *Knowledge Competence*- defined as 'the possession of appropriate technical and/or business knowledge'; *Cognitive/Problem Solving Competence*- defined as 'the ability to solve using high level thinking skills technical and/or business related problems effectively to produce specific outcomes'; *Business Competence*- defined as '*the ability to understand the wider business context within which the candidate is practising and to manage client expectations in a pro-active manner'*; *Ethical/Personal Behavioural* (which is core to the previous three areas) Competence- defined as *the possession of appropriate personal and professional values and behaviours and the ability to make sound judgements when confronted with ethical dilemmas'*

This required the review of the extensive literature of existing models and protocols for describing competences. The aim was to seek out coherent elements within different approaches and if possible bring them together in a single model. It was also necessary to explore the extent to which existing models recognise the important of soft, community-based skills development in addition to technical competences. Some differing views of competence and approaches to professional practice are listed in *table 1* below;

Study the existing models as described above suggests that each of the models and approaches has its own strength and weakness within the context of their own professions. However, the purpose of this paper is to study the ability of the existing models to deal with the demand of skills and competencies in the process of delivering HMR. An outline model for mapping the Community-based action model for professional skills and competences in the process of delivering HMR is developed in section 4. Before this can be done it is also necessary to review the extent to which the current professional skills and competences within Pathfinder organisations meet community needs and aspirations for creating Sustainable Communities. Understanding the existing models of professional competences also leads to the identification of shortcomings skills that need to be acquired in order to deliver HMR and create Sustainable Communities. This can be realised by reviewing the extensive literature on skills needs for delivering Sustainable Communities and in particular HMR.

3.3 Skills Needs in the Process of Delivering HMR

Professional skills are important in achieving the objectives of HMR as well as Sustainable Communities. The concept of HMR requires an active engagement from all participants involved in the delivery process and plays an essential role in making local communities attractive, safe places to live and work. This approach requires additional professional skills and new ways of working for the participants involved. But *why do professionals need a new approach in delivering HMR?* Local residents are very clear about what they want from their communities but, in many places the current approach fails to deliver what people want. For example protest by the local residents on the scale of the clearance and compulsory purchase of thousands of unfit houses within the East Lancashire Pathfinder area have been claimed as creating forced migration and preventing the creation of Sustainable Communities (Clover, 2004). The local residents want actions that encourage people to continue to live and work in the pathfinder areas and not to be forced to move elsewhere. The conflict between the aspirations of the local community and the HMR Pathfinder suggests that the relevant professionals involved need a new approach in addition to their technical expertise that enable them to understand exactly what people want from their own communities. Meanwhile, a study by CPRE (2004) in East Lancashire and Merseyside Pathfinder areas reveals that housing market failure is not just about the physical aspects of housing but is also about non-physical factors such as social deprivation and bad image that cause residential environment to decline. These non-physical aspects of housing within the social, economic and environmental context are very important in tackling low occupancy and empty houses. Thus in the process of delivering HMR, the professionals need to acquire not only the core, harder and technical skills, but also other skills that are more *generic, softer, people and community-based skills*.

A broad range of terminology exists in relations to skills, all with different meanings including attitudes, behaviour and competencies. However, in this paper the focus will be on skills and competencies reflecting those activities that relevant professionals in HMR might be expected to undertake and consequently the skills that they might need to successfully deliver HMR. This paper started by reviewing relevant literatures within the Sustainable Communities context to investigate what other skills that might be needed and considered significant in delivering HMR. Some of relevant literatures on skills for Sustainable Communities and HMR are summarised below.
The Egan Review Report (2004) suggest that the delivery of sustainable communities and the skills/competences necessary to support delivery have much in common with the way that successful organisation operate and the skills that they display. The Egan Task Group has further concluded that lack of generic on skills and knowledge in regeneration are a perceived barrier to the delivery of sustainable communities. The Egan Report (2004) also described the generic skills that are considered as being essential for delivering Sustainable Communities. These are summarised as:

> *Inclusive visioning; Project management Leadership; Breakthrough thinking/brokerage; Team/partnership working within and between teams, based on shared sense of purpose; Making it happen given constraints; Process management/change management; Financial management and appraisal Stakeholder management – including ability to work with local residents and residents/community group; Analysis, decision making, evaluation, learning from mistakes; Communication-including intelligent*

A study by the Turner and Townsend Group (2004), reinforced the Egan conclusions concerning the need for skills in Sustainable Communities and summarised their findings as;

> - *Society has not necessarily been well served by the existing professions operating in the built environment*
> - *The professions are either unwilling or unable to engage with communities*
> - *Knowledge about 'what works' is, inconsistent and poorly managed*
> - *The skills and knowledge relating to strategic planning, project*

These arguments have in turn been subject to a great deal of criticism, though the focus on skills and knowledge has been broadly welcomed by regeneration professionals as part of a balanced approach to the better delivery of regeneration. Furthermore, the complexity and diversity of responsibilities and providers of skills and knowledge in regeneration cannot be overstated as the real issues for the delivery of sustainable communities concern the interaction of people and partnerships through appropriate and effective processes (Turner and Townsend Group, 2004).

The Learning Curve (ODPM, 2002) has introduced three main elements to a regeneration-learning framework in three different audiences of residents, professionals and civil servants/policy makers. However, for the purpose of this paper it is only necessary to summarise the skills needed by the *professionals and practitioners.* These are:

- *Analytical skills -* *Analysing possibilities, creating opportunities; evaluating alternatives*
- *Interpersonal skills -* *Strategic leadership**;** Management of people**;** Valuing of diversity**;** Working with partners**;** Working with the community**;** Communication**;** Conflict resolution, consensus building*

Research finding by Hartley (2002), emphasised the concept of community leadership for local authorities, as part of the culture shift required that aimed to empower individuals, groups and communities and build their capabilities. A number of key skills were seen as important for this and they are:

Putting people at their ease; Learning to think about services from a user's perspective; Listening to interests as well as voices; Recognising the different pace and processes of community groups and individuals; Capacity building; Managing conflict and difference; Managing expectations; Influencing skills; Detailed local knowledge; Professional skills; Maintaining a strategic focus and Working constructively with councillors.

There is no doubt that to deliver HMR effectively, relevant professionals have to acquire additional skills for community-based action as an addition to their core and technical professional competences. Although the existing models of professional competences (as listed in *Table 1*) do recognise these soft and people-focused skills, they are not clearly stated either in terms of skills for the employees interacting among themselves within an organisation or for their employees interacting with their customers. These multiple responsibilities and diversified skills are across social, economic and environmental context of Sustainable Communities.

4. COMMMUNITY-BASED ACTION MODEL FOR PROFESSIONAL SKILLS AND COMPETENCES IN THE PROCESS OF DELIVERING HMR

Before the empirical work can begin, it is necessary to construct a model of community-based action for professional skills and competences. This will form a conceptual framework to be tested during the empirical phase of the research.

In constructing the model, a number of related key influences have been considered. The proposed model as illustrated in *figure 1* is based on the previous arguments developed in section two and section three. The three dimensions of Sustainable Communities: Social, Economic and Environmental and the existing model of professional competence: Technical, Cognitive, Business and Ethical/Values have been integrated into the proposed model.

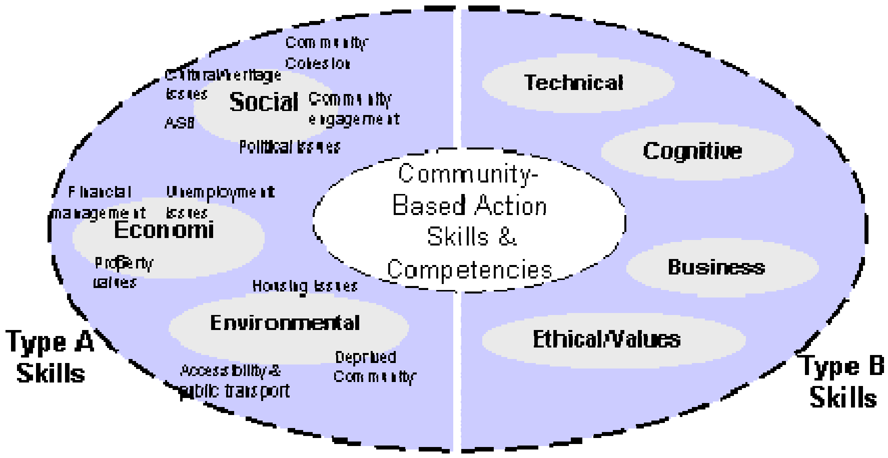

Figure 1. Mapping the Community-based action model for professional skills and competences in the process of delivering Housing Market Renewal

The model falls into two headings:

- *Type A Skills*: comprise of softer, generic skills, people-based (additional potential skills need to be acquired by the professionals in the process of delivering HMR.
- *Type B Skills*: comprises of harder, technical and core professionals competences

In mapping this model, this paper only focuses on type *A Skills.* Type B Skills are recognised as necessary to successful delivery of HMR but are insufficient in themselves. The potential type *A Skills* will be grouped and clustered around under the same themes. Each of the identified skills that might be needed in the process of delivering HMR is clasified into the main themes of Society, Economy and Environment.

The next step of this study will be to conduct an empirical phase. This will investigate the validity of the proposed model with relevant professionals involved in the process of delivering HMR. The insights of experienced professionals are being sought out on whether they have recognised the need for additional skills and competences and the extent which these skills are required. It is hope that the development of this model will assist the professionals in recognising the additional skills that are necessary to deliver HMR.

5. CONCLUSIONS

Delivering HMR and Sustainable Communities require not only the technical skills and competences but also a broad range of generic skills, behaviour and knowledge. There is a clear need to focus on skills and competencies for community engagement within the three dimensions of society, environment and economy in the context of Sustainable Communities. These additional skills are required by the relevant professionals in the process of delivering HMR. Although professional practitioners do recognise these people-based skills it is not clear whether they consider those skills are necessary for their employees interacting among themselves within an organisation or for their employees interacting with the customers/clients. The challenge of mapping the community-based action model for professional skills and competences is how the professionals could integrate additional skills that are required for effectively delivering

HMR as well as Sustainable Communities and meets social, economic and environmental objectives. The paper proposes a provisional model for mapping the skills necessary for skills for community based action, and constructive comments on it is invited from those with experience in similar areas.

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LITERATURE REVIEW ON THE STATUS OF "RESEARCH AND DEVELOPMENT" IN CONSTRUCTION AND ITS PERFORMANCE MEASUREMENT

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Abstract: Due to the changing market needs, customer demands and government regulations on environment, health and safety issues, organisations are keen on improving their performance by means of innovating new products and methodologies. In this context, research and development (R&D) plays a major role acting as a main driver for innovation. Further, to gain the competitive advantage in the market, organisations are interested on developing their R&D work. Within construction, prioritising the R&D activities, creating longer term R&D programmes and increasing investments on R&D activities have been identified as vital factors for its growth. In order to identify whether the R&D objectives are properly met and also due to the accountability of R&D expenditure, attention has been paid on measuring its performance. Accordingly, this paper provides a literature review of the need of R&D applications for the construction industry. This discussion will be further supported by a discussion on its performance measurement applications and its current status within construction.

Keywords: Construction industry, Performance measurement, Research and development

1. BACKGROUND

The contribution of the construction industry towards the economy is significant in most of the countries and the UK construction industry is not an exception. Yet many studies have shown that the industry is behind its optimal performance (Kagioglu et al 1999; Lee et al 2000; Smith 2001). Expectations from the construction projects such as value for money, free from defects, reasonable running costs, durability etc. are not achieved to a satisfying level (Latham, 1994). Due to the unpredictability of delivery of the product in terms of time, cost, and quality parameters, clients are dissatisfied regarding the performance of the industry (Egan, 1998). Hence, construction industry is being criticised by various government and institutional reports for its inefficiencies and under-performances (Latham, 1994; Egan, 1998; Fairclough, 2002).

One of the main reasons behind the under performance of the industry is being recognised as insufficient research and development (R&D) activities and innovations (Dulaimi et al, 2002). Macmillan (2002) and Fairclough (2002) argue that research and innovation in the construction industry have a significant role to play in performance improvement while providing benefits to the industry as well as to its stakeholders. Due to the changing market needs, customer demands and government regulations on environment, health and safety issues, organisations are keen on improving their performance by means of innovating new products and methodologies (Kerssens-van

Drongelen, 1999). In this regard, R&D plays a major role acting as a main driver for innovation (Fairclough, 2002). Prioritising the R&D activities, creating longer term R&D programmes and increasing investments on R&D activities have been identified as vital factors for the growth of the construction industry (Hampson and Brandon, 2004; Fairclough, 2002). Further, according to Bremser and Brasky (2004), competitive advantage of organisations largely depends on their commitment to on going R&D.

Even though the contribution from R&D activities towards the development of the industry is significant, UK construction R&D intensity is lower than the other sectors such as manufacturing (DTI, 2004). In their reports, Egan (1998) and Fairclough (2002) identify the low investment for construction R&D in UK. This situation is not only limited to UK but also can be found in other countries such as Australia, Hong Kong (Building for growth, 1999; Construct for excellence 2001). Further, the spending on construction R&D is comparatively less in UK than its competitors such as USA, Japan, Denmark, and Finland.

"R&D have become more complex, as they involve many parties and have a wide range of, often interrelated, technological, market and organisational options to choose from under constrained conditions" (Kerssens-van Drongelen et al , 2000). R&D activities require many resources ranging from human side to technical side which requires proper utilisation. In this context, accountability of these resources is being questioned by the management as well as by the shareholders (Wood, 1998; Nixon, 1998). These factors arise the need of performance measurement of R&D activities.

This paper is focused on identifying the need of R&D for the construction industry. In doing so the paper briefly identifies the challenges faced by the construction industry and highlights the importance of innovation and R&D activities for its development. The importance of performance measurement of R&D activities is then discussed.

2. CHALLENGES FACED BY THE UK CONSTRUCTION INDUSTRY

According to Manseau (1998), construction industry is undergoing major challenges due to the rapid changes in the both demand and supply sides. Consumers demand more functional buildings and sophisticated equipment with lowered capital and operational cost. In terms of the supply side, advanced technologies such as automated equipment, intelligent materials, off-site manufacturing, and integrated building automated systems are developing which will have a grate impact on the industry (Manseau, 1998).

Further, construction industry is under pressure to meet the sustainable goals by optimising the use of natural resources (Faireclough, 2002), designing energy efficient buildings, reducing the construction waste (Plooij-van Gorsel, 2000).

Laing (2001) identifies several issues which the UK construction industry has to face

- Requirements by the global trends and competitive forces on changing the nature of the construction product, service and industry organisation, work practices and relationships
- Greater need for standardisation and prefabrication

- More consideration on health and safety of the industry
- Pressures to manage the risk effectively
- Need of new materials and advanced construction techniques
- Growing concern on sustainable development and work practices
- Need of proper planning, development and regeneration of construction activities with adequate provisions for transportation, social services, training and jobs
- Growing concern on the life cycle performance of buildings rather than on the initial capital cost.

Besides, material and component and design and engineering services are becoming global markets (Manseau, 1998). The demand for housing facilities, renovation of infrastructure, preservation of cultural heritage, reduction of traffic congestions require construction industry to innovate more (Plooij-van Gorsel, 2000). The increased competitiveness in the industry demands the construction organisations to up lift its efficiency by reducing construction cost and whole life cycle cost of buildings, minimising site activities, construction time, and increasing quality of the product (Hampson and Brandon, 2004; Foresight Construction Associate Programme Panel, 2001)

Further, construction has been identified as an industry where higher number of accidents occurs. Thus, providing a safer environment and increasing the health and safety of the industry via safe construction processes, use of appropriate tools and equipment and implementing new safety rules and regulations have been recognised to provide a good image for the industry (Plooij-van Gorsel, 2000).

The above mentioned challenges are forcing the construction industry to change its traditional approaches to design, construction, refurbishment, and maintenance (Faireclough, 2002). Further, these challenges demands innovation and effective R&D activities for construction organisations to compete in the market and to meet the social need (Laing, 2001). The following section briefly discusses the important of innovation and R&D for the development of the construction industry.

3. R&D AND THE CONSTRUCTION INDUSTRY

3.1 R&D as a Driver for Innovation

"Efficiency" was the dominant tool in industrial competitiveness in 1970s (Omta and Engelen-van, 1998). In the late 70s and early 80s, quality oriented firms took the major market share by competing well against their opponents. After mastering the efficiency and quality, organisations tried to get hold of another tool to be competitive in 1990s. This new weapon is nothing but the "innovation" (Omta and Engelen-van, 1998; Osawa and Murakami, 2002). Pospisil (1996) and Reed et al (1996) identify innovation as the last remaining preventative measure in the business environment which leads the companies to achieve least cost, high performance, and to develop new products and services. Further, it is argued that innovation as one of the main drivers of improved productivity which helps the long term health and viability of organisations domestically and internationally (HM Treasury, 2002).

In terms of the construction industry, there is no exception; innovation has been identified as a major weapon to compete and to improve the performance of organisations. Plooij-van Gorsel (2000) argues that competitiveness of the construction industry largely depends on its capacity to innovate new construction processes and techniques, in product development, and in organisation of construction workforce. However, R&D has been identified as one of the vital factors behind the progression of innovation (Roberts, 2002; HM Treasury, 2002; DTI, 2004). Accordingly R&D is an input to the innovation process and contributes to innovation in various ways (Salter et al. 2000);

- Increasing the stock of useful knowledge
- Supplying skilled graduates
- Developing new net works
- Enhancing technological knowledge solving capacities
- Generating new firms
- Providing social knowledge

The innovation gained through the active participation of R&D work embedded in the construction organisations well (Fairclough, 2002) as such innovations are aligned well with the environment, work practices and procedures of the organisation. Thus, Fairclough (2002) stresses the need of encouraging the construction organisations to actively involve in the R&D work.

Accordingly, the following section analyses the critical role of R&D in assisting innovation towards achieving the challenges and goals of the construction industry.

3.2 Importance of R&D to the Construction Industry

As the contribution from the construction industry towards the national economy and the quality of life of the general public in UK is immense, Fairclough (2002) argues that "a narrow definition of construction research cannot properly serve the future needs of the sector and its stakeholders". Thus, a wider definition covering the construction contribution to the UK economy and the quality of life have to be included in the R&D research agenda (Fairclough, 2002).

Research in construction industry ranges from highly technical studies (development of new materials) to "soft" issues such as management relationships (Courtney, 1999). The demand for construction research arises due to three main reasons Fairclough, 2002);

- Solving the scientific, technical, social, economic and environmental problems where there is some degree of predictability about future trends and requirements
- Those in which there is little predictability, but where government and industry need capabilities to respond quickly to unforeseen problems or events
- Development of new ideas and knowledge

Accordingly, construction research is carried out for one of the four reasons (Courtney, 1999);

- To underpin and extend generic knowledge, with the aim of improving the final product type (building, bridge etc) or the process leading to it

- To support the development or implementation of public policy (notably public health, safety, environmental or consumer protection policies)
- To secure competitive advantage by a firm or industry sector
- To understand or address the requirements of a particular project

The nature of buildings and construction related services itself creates opportunities for R&D activities (Fairclough, 2002). The contribution from R&D for the development of the construction industry is immense as it leads the path to enhance the effectiveness of construction organisations and to raise the international competitiveness through technological advances and managerial developments (Hampson and Brandon, 2004; Gustavsson et al, 1999; Ernst, 1998). To remain competitive in the market, organisations should make sure their customer needs are properly met, and future demands of the customers are properly addressed specially to keep ahead from the competitors. In this respect R&D acts as a valuable "input" for the development of the organisations (Business Link, 2005).

In the Australian construction industry, the growing interest in R&D work and creating a R&D culture to maximise the efficiency and effectiveness of activities have been identified (Hampson and Brandon, 2004). Thus, one of the visions for the Australian construction industry has been set out as the leadership in R&D (Hampson and Brandon, 2004). Further among the nine visions identified for the development of the construction industry "leadership in R&D" has been considered as the "overarching vision" which is crucial to achieve and facilitate the remaining visions. This it self indicates the significance of R&D in the construction industry in accomplishing the overall goals and objectives and facing future challenges.

In the rapidly changing world, performance remains as one of the critical success factors for any organisation (Edelheit, 2004). Edelheit (2004) argues that, "speed to market" is as important as "performance" to challenge the competitors and to safe guard the market share. In addition to that, increased quality and the ability to produce the products with lower prices have become vital factors to compete in the market (Karlsson et al, 2004; Edelheit, 2004; Omta and Engelen-van, 1998). Hence, R&D activities are needed to find new ways to produce goods and services with lowered time, cost, and increased quality and R&D is a major driver to develop new products, materials, construction methods, and processes (DTI, 2004).

Fairclough (2002) identifies several reasons to develop R&D in the construction industry.

- Contribution from the construction industry to the national economy is significant
- The need of delivering better value for money while becoming profitable
- Innovation is essential to competitiveness and effectiveness
- R&D is a driver for innovation
- Innovation occurs in construction but, not captured well and fed forward
- Industry does not give the same priority or level of funding given for other sectors
- Public investment for R&D in construction is inadequate when compared with size and importance of the sector

In the UK construction industry, R&D lays the foundation to achieve the objectives of Rethinking Construction, Accelerating Change and the successful operation of Government's strategy for sustainable construction (DTI, 2004) while providing maximum value for clients, end users, and stakeholders through quality products and services (DTI, 2005). Further, the dissemination of research results benefits the construction industry as a whole as well as its clients (Seaden, 2002).

According to Hampson and Brandon (2004) and Roberts, (2002), positive relationship has been identified between the investment of R&D work and productivity of organisations. Further, survival is challenged in the global market in organisations which lack the investment in R&D (DTI, 2004). Fairclough (2002) highlights the need of developing a strategic vision to improve the performance of the construction industry, and supporting the vision with a R&D framework. Further, he argues that appropriate R&D is needed to achieve the targets set out to the construction industry such as annual improvement of 10% in value (Egan, 1998).

Kerssens-van Drongelen, (1999) identifies several reasons behind the need of R and D performance improvement in organisations;

- The change of the business environment from "seller's market place" to "buyer's market place"
- Rapidly changing customer needs.
- Increasing government regulations and social pressures regarding environmental, safety and health issues.

The situation is very much similar in the case of construction industry as the business environment of construction also has been turned to a "buyers market place" with highly increased customer needs (Manseau, 1998), government regulations and health and safety issues (Laing, 2001). Hence, it can be argued that construction R&D work also needs to improve its performance.

The importance of R&D activities for the development and performance improvement of the construction industry is well highlighted in the previous sections. The following section justifies the need of a performance measurement for effective and efficient R&D activities in the construction industry.

4. CONSTRUCTION R&D AND PERFORMANCE MEASUREMENT

To get involved in high quality research, organisations require resources such as necessary equipment, and skilled individuals (Seaden, 2002). Investors in R&D work provide the necessary funding to undertake efficient and effective research. Thus, the role played by the R&D investors cannot be ignored at all as it is vital for the development of R&D in construction industry. Construction research activities generate little profit and most of the organisations who undertake R&D work are not for profit organisations (Seaden, 2002). Thus, in the point of view of the investors, what ever the money spent on R&D work should be used to its maximum capacity and to yield the utmost out come. Consequently the argument which says "financial constrains negatively affect the freedom of and the creativity of R and D activities" (Roussel et al, 1991) has been challenged due to the need of efficient and effective results from the R and D activities (Werner and Souder, 1997). Further, shareholders are keen on knowing the contributions from R&D activities towards the performance of the organisation (Institutional Shareholders' Committee, 1992) and this has increased the accountability of R&D managers on their spending. Therefore, such external pressures have forced the management to find ways of measuring the return on R&D expenditure and to evaluate the performance of R&D activities (Nixon, 1998).

Identifying new ways to access technical solutions, and creating new and improved products requires not only sufficient investments, but also necessary time (Building research establishment, 2005). Thus, what ever the time devoted for construction R&D should be justifiable. In addition to that, if the resources spent on construction R&D do not generate the expected goals, it will result in waste of money, equipment, and valuable time of people. Therefore, careful monitoring of the successfulness of R&D work is needed to justify the resources allocated for R&D activities.

Print (1999) argues that some of the money spent on R&D activity is wasted. However, R&D managers are unable to identify and locate the area where the money is wasted (Print, 1999). This problem can be avoided by having a R&D performance measurement system. Further, Cooper (1995) and Griffin (1997) identifies that companies that are performing well utilise R and D performance measurement techniques.

"If you can't measure something, you can't understand it. If you can't understand it, you can't control it. And if you can't control it you can't improve it" (Oxman, 1992). Thus, the first step of an improvement process can be identified as the measurement. Accordingly, the above section discussed the necessity of R&D performance measurement system to improve the construction R&D and thereby to improve the performance of the whole industry.

5. CONCLUSION

Construction industry faces various challenges both from the demand and supply side where the industry have to be adjusted to meet the new social demands, while reducing the long term impact on the environment. Therefore, in order to face these challenges while raising the profile of the construction industry, it is essential to invent new ways to deliver the construction out put in an economical and socially and environmentally acceptable manner. In this regard R&D plays a key role as it is the back bone to innovate effective and efficient construction processes, new materials, advance technologies, new procurement route and managerial structures to suite the requirements of the stakeholders. Further, successful implementations of R&D activities create the opportunity for the construction organisations to be competitive in the international market. More importantly R&D has been considered as the base which helps to achieve the overall goals and objectives of the construction industry. Therefore, it is widely accepted that proper investment should be done in the construction industry to uplift the R&D activities and thereby to improve the performance of the industry.

Further, it was identified that the nature of R&D work has become complex. Due to the rising cost, time and other resource constraints, much attention is paid on the successfulness of R&D and the managers are under pressure to monitor and improve the performance. Further, it is equally important to show that the results obtained through R&D activities are properly aligned with the expected objectives of the organisation. This has demanded proper controlling and monitoring of R&D work. Thus, performance measurement of R&D can be considered as an important aspect for the construction industry.

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PRODUCTIVITY, SKILLS, AND TRAINING: A PROBLEM OF DEFINTION?

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Abstract: There appears to be no agreement on a common framework for defining productivity, skills and training. Accordingly, the relationship between skills and training with respect to productivity remain unclear. This is important to ensure that the industry's skills base and training needs are geared towards improving productivity in the construction industry. This paper seeks to achieve this through an overview of the existing literature to map out the current understanding of productivity, skills and training then attempt to define a domain, where a relationship could be established. The analysis reveals a wide range of definitions that could result in potential confusion in adopting these terms by different stakeholders, which presents an obstacle for collaborative action. As such, this research provides a starting point for investigating this discrepancy and demonstrating that a clear understanding of skills and training is an important step towards inducing productivity gains to the industry.

Keywords: Discrepancy, Productivity, Skills, and Training.

1. INTRODUCTION

The construction industry can be seen as a multi-layered and multi-faceted sector. It is made up of projects, which includes: house building, heavy civil works, repair and maintenance, and refurbishment. The workforce employed on these projects includes: skilled and semi-skilled tradesmen, administrators, managers and professional experts. Governance of the industry is provided by institutes (e.g. CIOB, RICS), training providers and funding bodies (e.g. CITB-ConstructionSkills), industry improvement forums (e.g. Constructing Excellence) and a number of government departments. Clearly, given the sheer number of stakeholders and organisations involved, it is unlikely that a single definition of productivity, skills and training will exist. However, this is required to give guidance to policy aimed at enhancing the skills base of the industry which in turn will influence the performance and productivity of the sector. Without having a precise definition of skills, terms like 'upskilling' becomes somewhat meaningless unless one is clear as to what 'skills' are actually being enhanced (Keep and Mayhew, 1999).

A starting point is to identify the existing definitions and highlight that different understanding has an implication in terms of the actions adopted by different stakeholders. This would help to resolve definitional chaos, which exists between stakeholders, thus providing clearer distinction between different terminologies (Mansfield, 2002). The next step is to define potential links between these concepts and how a common framework of understanding can aid in achieving this goal. Thinking with diagrams (TWD) will be a useful tool used in this paper, where appropriate, to aid in the process of visualising information and easing cognition (Moore, 2002).

2. DEFINING TERMINOLOGIES

2.1 Productivity

A common definition of productivity is output per unit input (Horner and Duff, 2001; Olomolaiye *et al.*, 1998; Oglesby, 1989; Quambar, 1999). However, it is more accurate to describe it as a relationship between output and input which varies in terms of the context and objectives behind measurement (Flanagan *et al.*, 2003). For example, measuring productivity at the operational level will require different sets of input and output as opposed to the firm, project and industry levels. Olomolaiye (1998) considered productivity to be conceptually different than a simple output/input ratio, which should further include the capacity to produce and the effectiveness of the production process. This means that productivity, generally, is an indicator of effective utilisation of inputs to produce maximum output, at the same time, higher productivity levels could be a result of having more inputs, which are not necessarily being used effectively. Indeed, wasteful utilisation of resources could actually be a symptom of poor performance.

This lack of agreement on a single productivity definition leads to confusion in the assessment of the state of productivity at the operational, firm/project, and industry levels respectively. Goodrum *et al.* (2002) described the overall construction productivity at the industry level as declining, whilst the average activity productivity (measured by individual work activities) was increasing over the same time period. Bernstein (2003) argued that this view is flawed as some projects/firms are under-performing and others are performing well. Therefore, the task of defining productivity and capturing it through a single measure is elusive and oversimplifies the performance of a highly fragmented and complex industry.

Koskela (2000) emphasised the importance of promoting a common language or framework to act as a medium or solid base for collaborative action between different stakeholders in the construction industry. In striving for such a definition, Abdel-Wahab and Moore (2005) suggested a three level hierarchical model for productivity; operational, firm/project, and industry-wide. Basically, the model attempts to draw lines of demarcation between different productivity levels and minimises the likelihood of confusion and inherit discrepancy when referring to productivity. It is recognised that there could be various indicators/measures for productivity at each level which are not necessarily consistent. Nevertheless a common domain/framework has been defined for perceiving the same productivity. At the same time, this will provide focus for stakeholders to address each level independently and a common starting point for collaborative action, which is a necessary ingredient if the industry is to remain sustainable and realise its maximum potential.

2.2 Skills

"Despite the enormous interest in how skills in Britain have changed over time, how they are distributed, and how these trends and patterns compare with competing nations, there is surprisingly little agreement on what 'skills' actually refer to" (Felstead *et al.*, 2002). Skill is a term variously defined as qualifications, broad skills (Payne 1999) or as part of an overall competency model (Spencer and Spencer 1993) within construction, it is commonly cited synonymously with trades or crafts, such as bricklaying, plastering (e.g. Clarke and Wall, 1998).

Historically, the term 'skill' is used to refer to the manual craft worker and technologist (Ainely, 1993; Keep and Mayhew, 1999). According to the Further Education Unit (1982), "the skill concept was widening to include 'the ability to perform a specific manipulative occupational task' and which now embraces: Language (reading, writing, speaking and listening); number (calculation, measurement, graphs and tables); manipulative dexterity and co-ordination; problem solving; everyday coping, interpersonal relationships; computer literacy and learning". Payne (1999) considered skills to cover everything from reading, writing reliability, communication, reasoning, problem solving and motivation to assertiveness, judgement, leadership, team working, customer orientation, self-management and continuous learning.

Furthermore, to add to the confusion, skills change with time; some vanish and new skills emerge and this will continue as businesses strive to seek innovations to be more competitive. Felstead *et al.* (2002) ascertain that people coming from different backgrounds perceive skills differently, for example in economics the workforce is regarded as a human capital and investment in skills in the same way as physical capital should yield positive results; whereas in sociology skills are more regarded in the social context as a status.

Notwithstanding the differing emphases in definition, the key question is not whether the quantity and variety of skills acquired by the workforce, but whether they are relevant and effective for a particular job, or not. In other words, it is about the workforce having the right mix of skills at the right time to act as a support for doing their job productively. Johnson (1983) argues that "Skills , formerly understood by many as complex social processes, were now de-contextualised and de-constructed into finite, isolable 'competencies' to be located as the property of the individual, who then carried them, luggage-like, from job to job". This means that the notion of having more and more skills to guarantee better productivity is flawed, as this ignores the effect of other factors as well as disregarding the job-context for applying these skills.

It is evident that the term 'skill' refers to a wide range of disparate definitions, which may result in confusion. So, in an attempt to setting a common framework, Figure (1) is an application of the 'thinking with diagrams' concept (mentioned above) to differentiate between skills with respect to job context.

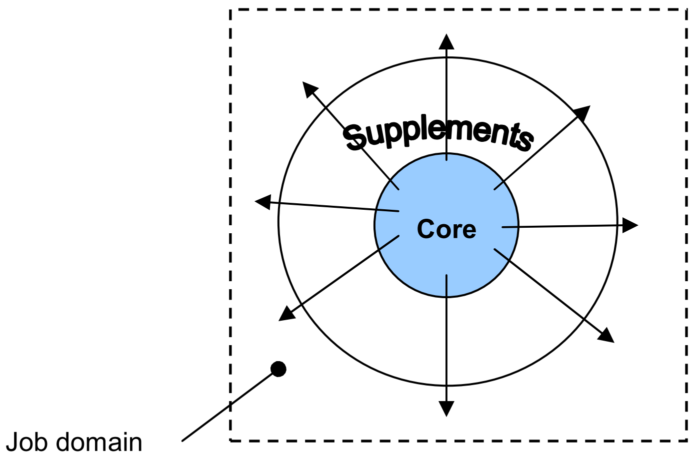

Figure 1: Core and Supplement Skills

This is a schematic diagram which classifies skills into core and supplements. The supplement skills will be acting as vital supporting elements for the core, where the extensions of lines outside the circle demonstrate the importance of the job context in determining these supplements. Therefore, core and supplement skills should be viewed as one mesh which varies across the job domain. Stasz *et al.* (1996) reinforced this view by describing the characteristics of problem solving, teamwork, communication, and disposition (in that case supplements skills) as being related to job demands, which in turn depend on the purpose of the work, the tasks that constitute the job, the organisation of the work, and other aspects of the work context.

At the same time, core skills will be the fundamental skills required for doing the job, for example, a blue collar work core skill would be joinery, whereas skill supplements would include communication and team working skills. The core skills could be easily identifiable as they directly relate to doing the job, but skill supplements are vital for boosting productivity levels. For example, Owens (1987) identified effective managerial communication skills (regarded as a supplement) as an essential part for increasing productivity.

It follows that a holistic view is needed to address both the core and supplement dimensions of skills (see Grugulis, 2003). In most cases, qualifications underpin core skills and are regarded as a proxy for skill. So, this is just an approximation for the type of skills that has to be possessed by the workforce. Yet, the capacity of the existing training infrastructure to respond and cope with the increasing demands and expectations of skills structure at the workplace remains questionable. This stems from the difficultly to incorporate all these skills in one or even multiple qualifications. So, living in a high tech society where the only constant is change, then skill will boil down to the ability of learning to learn (DfEE, 1998).

Then, it will be important in that respect to look at each job independently, though there might be similarities with other jobs, to identify opportunities for productivity improvements. For example, this framework is essential to realise distinctions between sub-sectors in the construction industry, which differs in their job content, thus they require different mixes of skills in terms of core and supplementary skills – in particular.

2.3 Training

The Oxford English Dictionary (2004) defines training as teaching (a person or animal) a particular skill or type of behaviour through regular practice and instruction. Armstrong (1996) mentioned that training usually refers to learning a specific task or job, the skills and behaviours of which are specifically defined, whereas development is an ongoing process involving changing people. This implies that training is a more of a mechanistic process, which is job-centred; meanwhile, development involves educating the workforce, which is person-centred (Fryer, 2004). It is important to note this distinction in order not to use the terms interchangeably resulting in confusion of what is actually meant. It follows that combination of both training and development is essential to attain the required skills to do the job. At the craft level, jobs lean more towards training to perform specific tasks, whereas managerial level positions are more of a development process for changing behaviour. Nevertheless, managers might need training in some instances to use new IT systems or to apply health & safety practices.

Ashworth (2000) recognises this characteristic of training when mentioning that "the emphasis at building craft level is now only training specific, with little attention or attempt paid towards any aspects of education. This provides a level of skill but outside of a framework or context". He added that "there is a need to revitalise the image through better education and training". This is an example showing that the same perception of training, with reference to the definition above, is a cornerstone for common understanding and thus supporting collaborative action.

At the same time, there has to be consistency between the meaning of training and its mode of delivery, and not regarding all training as involving lectures and classroom learning. This is important as different modes of training have an implication in terms of productivity. For example, Zwick (2002) mentioned that on-job training and participation at seminars or talks do not have an impact on productivity at the firm level. He added that the highest productivity impact can be obtained by more structural approaches, like formal internal and external training courses. This treats the training function as a mixed basket of managers and workers, without accounting for differences between 'training' and 'development' needs as described above. It is vital to realise this distinction, as training comprised of seminars and workshops is a more of a development process that should be aimed towards managers, whereas workers will be more interested on practical issues for doing their job on-site.

Therefore, training and development should be viewed as a human resource management tool for inducing productivity and performance gains. As such, the decision to train or develop staff should be aligned with other business processes, for example, 'Rover Group' invested heavily in training to be regarded as a learning organisation, which was not enough for maintaining the survival of the business (Keep and Mayhew, 1999).

They concluded that training should not be regarded as the only means for boosting skill levels, and accordingly pay-back on investment may take long time and may only be realised in conjunction with other changes, such as investment in new plant and machinery.

3. KNOWLEDGE BASE AND PRACTICE

The above discussion has suggested a lack of consensus among academics, in addition to an obvious gap between the body of knowledge and practice, and therefore it is important to explore the nature of this gap in order to identify opportunities for collaborative action.

There could be a widening gap between the body of knowledge and practice, which is supported by Hemsley-Brown (2004) view that management research fails to communicate with practitioners and does not reach sufficiently wide audiences. At the same time, actions by decision makers are insufficiently informed by research, and dissemination is viewed as problematic (Hillage *et al.*, 1998). This highlights the blame-game between researchers and practitioners and how the body of knowledge and practice tend to drift away from each other.

On the other hand, there is a need to move towards collaborative working, where both academics and practitioners will be co-operating to ensure their practice goes in-tune with the existing body of knowledge. "Unless practitioners can identify both the distinctions and the connectivity between management concepts, there is a real danger that the natural cynicism of the industry towards things seen either as modish or quasi-intellectual, will predominate and that what we will see is token rather than genuine commitment to cultural change" (McGeorge and Palmer, 2002, p. 226).

The current situation, as further explained by McGeorge and Palmer (2002), is that there is very little case-study material available in the public domain in terms of the application of the existing concepts in construction management. Hopefully, this paper attempts to close this gap by first identifying the existing body of knowledge with regards to the definitions of: productivity, skills, and training. The next step is to consult with practitioners in order to align their views with the existing body of knowledge and thus identifying possible opportunities for collaborative action. It is critical in that respect to deliver management research for the consumption of practitioners, which is at this point, is failing according to Peters and Howard (2001). Therefore, having discussed the definitions of productivity, skills and training; it is now necessary to explore the domain where links between the three concepts could be drawn.

4. PRODUCTIVITY, SKILLS, AND TRAINING

There is a lot of evidence to suggest that training and accordingly better skills, results in improved productivity levels. For example, Naoum and Hackman (1996) found that lack of experience and training among the top three factors reducing construction productivity. Rojas and Aramvareekul (2003) confirmed that improving training programs were among the top factors for improving construction labour productivity. Furthermore, the Institute of Management and Administration (2003) considered both incompetent managers and the lack of qualified trained workforce to be amongst the top five factors affecting a firm's productivity. At the same time, variations in productivity figures at the industry, firm/project, and operational levels suggests that there is a considerable potential for improvement. Then, it is not clear how exactly influencing skills through training and development could contribute to realising this potential; Campbell (1988) explained that "training and development can influence performance, but the effects are several steps removed from productivity".

Whilst some studies might have pointed direction to the importance of certain skills, e.g. Dainty *et al.* (2003) identified 'team building' and 'leadership' amongst the important skills for project managers; it still remains unclear to quantify the productivity gains realised from training and development towards acquiring these skills. Part of the problem is the confusion in terminology when discussing productivity, skills and training (development), as discussed above.

This demonstrates that the impact of skills in relation to different productivity levels (hierarchy) varies from the macro-level down to the micro-level. It is envisaged that the influence of skills materialise at the activity level, where the composition of core and supplement skills become more visible, thus the relevance of training and development becomes more apparent. Albriktsen and Førsund (1990) explained that a micro-level analysis of the construction industry is essential to provide an explanation of lower productivity levels at the macro-level. At the macro-level, skill proxies (qualifications) are used, which may not represent the elements of skills required at the micro-level in order to perform the job productively. Given the expanding nature of skills, Keep and Mayhew (1999) refer to the current vocational and educational training (VET) structure as failing to accommodate for these new skills. This could represent a considerable obstacle for productivity as certain skills may be blocked and not attainable by the workforce. In that respect, Ford's (1990) view about 'skill formation', as 'an emerging holistic concept that embraces and integrates formal education, induction, continuous on-the-job learning, recurrent off-the-job learning and personal development', is necessary for identifying opportunities for productivity gains. However, the core of the problem is that improvement in productivity at the macro-level might not be superimposed on the whole construction industry due to its very nature of being highly fragmented.

In fact, there is a divergence of productivity measured at the industry level as opposed to the activity level (Goodrum *et al.*, 2002). Nevertheless, an analysis is required at each level independently to define this link; at the operational level it will be required to correlate time and money invested in training disparately skilled operatives in relation to productivity levels on-site; this analysis will be essential at the firm level to distinguish between companies which invest in training as opposed to the ones who do not; finally it is essential to have a correlation between the pattern of overall industry investments in training and gross productivity levels. This three-tier analysis has to be distinctive as each level is concerned with providing information within certain level of detail to aid the decision making process. For example, at the industry level it is important for governing bodies to see the bigger picture and develop policies in pursuit of a more productive industry. At the same time, there has to be a consideration for this policy at the operational level to ensure sound representation of the workforce needs at large.

The measurement of skills at each level remains a daunting task, but correction indexes could be employed to account for factors, such as, experience, age, and type of qualification. This presents the future plan of this research in order to provide the necessary support for further development and progression in the construction industry particularly when it comes to top-up training in areas like sustainable development (e.g. waste management) or accommodating other innovations, which may include Modern Method of Construction (MMC). The ultimate goal is to ensure sound responsiveness to the demands of the industry at each level, which necessitates the analysis at each level independently in order to develop a possible link between productivity, skills, and training. This research will contribute partially towards the achievement of this goal, but it remains the task of researchers to deliver solutions for the disposal of the industry's best practice.

5. CONCLUSION

There is no doubt that having a consistent terminology is important in terms of understanding and communicating different views within a highly fragmented industry as construction. By the same token, lack of consistency depicts discrepancies between the body of knowledge and practice. It is important not to take the variations in definitions of these terms at face value, but rather look at the implications or interpretations made and establish whether the actions taken match this understanding.

This paper has mapped the definitions of productivity, skills and training. While the list is certainly not exhaustive, it is used as an illustration for possible discrepancies and confusions when referring to these terms. This relied on consulting the existing literature and therefore, it will be important to research this further through discussions with different industrialists and academics to develop a common understanding. Finally, getting the definitions right is a critical first step for collaborative action between key industry stakeholders. Eventually, establishing a clear and coherent relationship between skills and training with respect to productivity, to inform policy making.

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IMPACT OF SOCIAL AND ENVIRONMENTAL FACTORS IN THE PROCUREMENT OF HEALTHCARE INFRASTRUCTURE

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Abstract: Construction investments contribute significantly to the development and growth of local and national economies, as well as adding social value. However, both the construction and operation of built facilities can have negative impacts on both the society and the environment. For example, healthcare infrastructures can consume large amounts of resources and energy, accommodate wide range of activities and attracts many visitors. In the UK, the NHS attends to the healthcare needs of over 50 million customers using its 1.2 million staff. The impact of NHS activities on the surrounding environment and local people is large and diverse. The identification and assessment of these issues is important in: providing better working environments and better services to the community; reducing environmental impact; achieving cost savings; and ultimately delivering best value from healthcare investments.

This paper discusses the importance of activities within the healthcare sector to sustainable economic growth and explores how the sector impacts on sustainable development, socially and environmentally. In achieving this, the paper identifies and highlights the impact of relevant social and environmental issues in the procurement of healthcare infrastructure using the project procurement life-cycle as its base, thus covering design, construction and operational phases.

Key words: Environmental, Healthcare, Procurement, Social, Sustainability.

1. INTRODUCTION

Construction investments contribute significantly to the development and growth of local and national economies, as well as adding social value. According to Roodman and Lenssen (1995), the construction industry directly or indirectly utilises around 40% of the material flow entering the world economy while Cooper and Curwell (1997) estimated that the UK construction industry uses about 6 tonnes of building materials annually for every member of the population. The extraction, processing and transportation of these materials create environmental impacts in the forms of noise, visual amenity, congestion, pollution, etc. Vale and Vale (1991) measured the UK energy consumption related to buildings and building construction services to be up to 66% (inclusive of mining and manufacturing of building materials, transport, construction and operation) of the total energy consumption. Bonini and Hanna (1997) quoted a similar level of energy consumption (54%) in the US construction industry. Construction also creates wastes at the construction and demolition stages. According to Levin (1997), the contribution of buildings to the total environmental burden ranges between 12 - 42% for the eight major environmental stressor categories: use of raw materials (30%), energy (42%), water (25%) and land (12%), and pollution emission such as atmospheric emissions (40%), water effluents (20%), solid waste (25%) and other releases (13%). Thus, construction generally affects communities and businesses as it makes heavy demands on the limited natural resources, and it can also lead to positive outcomes when planned successfully by raising the aesthetic profile of towns and cities.

In particular, healthcare infrastructures, such as hospitals and primary care trusts, support a wide range of activities, attract many visitors, use large amount of resources, and generate large amount of clinical and other wastes. The roles of healthcare facilities are not limited to the treatment of illnesses but are crucial to ensuring progress towards sustainability. They also improve people's wellbeing through promotion of healthier lifestyles by reducing factors that lead to ill-health and minimising environmental harm. The National Health Service (NHS) is the largest employer in the UK and one of the most complex property portfolios in Europe (NHS Estates, 1999). It is responsible for maintaining the health of the over 50 million population with an annual budget of around £40 billion, and provides working environment for over one million people in around 11,000 general practices. The NHS's proactive work to improve public health has a major social impact on individuals and communities by enhancing their quality of life. These impacts vary according to the size of the healthcare facility; for example, a large hospital can be a significant source of jobs and influence the associated local economy, while the main impacts of a smaller facility will be its relationship with the immediate neighbours and its catchment community.

Owing to the variety of activities undertaken, the cumulative impact of healthcare infrastructures on the society and environment are large and diverse. For example, Building Research Establishment reported in 1993 that energy consumption in UK hospitals results in an annual emission of around 7.5 million tonnes of CO_2 (BRE, 1993). In 2000, the Department of Environment, Transport and Regions reported that around 100,000 tonnes of clinical wastes with an additional 100,000 to 200,000 tonnes coming from other sources are generated in the UK predominantly GPs and dentists, nursing homes and private sources (DETR, 2000). A more detailed analysis in 2004 identified the quantity of waste generated by NHS as 384,698 tonnes, with 261,086 tonnes (68%) being domestic waste, 120,547 tonnes (31%) being clinical waste and 3,064 tonnes (1%) of special waste (Barratt *et al*., 2004). The previous major review of hospital waste was in 1997, and this demonstrated a composition of 47.04% clinical to 52.96% domestic waste (Audit Commission (AC), 1997). It is assumed that this reduction in the proportion of clinical waste generated (16% since 1997) is due to the adoption of more sustainable practices through segregation driven by initiatives such as those in "Health Waste Minimisation, A compendium of Good Practice" (NHS Estates, 2000). However, Woolridge *et al*. (2005) showed that the cost of domestic and clinical waste disposal has been increasing as are the tonnages of waste generated. They reported over 20% increase in the amount of total waste generated between 2001 and 2004.

Thus, in order to ensure better working environments and better service to the community, as well as reduce environmental impacts during the operation of healthcare infrastructure, there is need for the identification and integration of sustainability issues in the design and construction process. This paper aims at illustrating the importance of activities within the healthcare sector to sustainable economic growth and how the sector impacts on sustainable development, socially and environmentally. This will be achieved by identifying and highlighting the impact of relevant social and environmental issues on the procurement of healthcare infrastructures during the design, construction and operational phases.

2. WHAT IS SUSTAINABILITY?

The term 'sustainability' is often used interchangeably with 'sustainable development'. Sustainable Development is the achievement of a better quality of life through the efficient use of resources, in order to realise continued social progress while maintaining stable economic growth and caring for the environment. It has been defined in many ways by many authors. The following are the two most commonly cited definitions in the UK:

The United Nations World Commission on Environment and Development (UNWCED) (1987) define sustainable development as "*…development which meets the needs of the present without compromising the ability of future generations to meet their own needs*". This definition is popularly known as the Bruntland definition.

The Department of Environment, Transport and Regions (DETR) (1999) publication 'A Better Quality of Life' explained that "*at the heart of sustainable development is the simple idea of ensuring a better quality of life for everyone, now and for generations to come*". The publication lays out four key objectives that need to be met to bring about long-term improvements in people's quality of life:

a. social progress which recognises the needs of everyone;
b. effective protection of the environment;
c. prudent use of natural resources; and
d. maintenance of high and stable levels of economic growth and employment.

DETR (1999) further stressed that the health of the population is a key component of sustainable development. This view was echoed by the Director General of World Health Organisation, Gro Harlem Brundtland: "*… if people's health improves, they make real contribution to their nation's prosperity. In my judgement, good health is not only an important concern for individuals, it plays a central role in achieving sustainable economic growth and an effective use of resources*" (Brundtland, 2000).

In the context of construction, sustainability has been a growing trend and the opportunities for complete integration into the design and construction process is a great challenge for the industry. Hobson (2000) defined sustainable construction as "*a process by which a profitable and competitive industry delivers built assets (building structures, supporting infrastructure and immediate surroundings), which enhance the quality of life of people and offer customer satisfaction; provides flexibility and supports desirable natural and social environments; and maximise the efficient use of resources while minimising wastage*".

2.1 THE THREE PILLARS OF SUSTAINABILITY

All sustainability decisions involve balancing seemingly conflicting needs across what is known as 'The Three Pillars of Sustainability'. These pillars take account of the specific requirements and constraints of a particular project. The three pillars are:

1. Social sustainability

This identifies the needs of individuals and considers their well-being. In the context of construction, social sustainability covers a wide range of issues from health and safety, education and training through to social inclusion and poverty eradication. It is often the least considered area but it has the potential to bring the most benefits.

2. Economic sustainability
This focuses on the importance of stable economic growth. It means working within the capacity of the natural environment, adopting measures from fair and rewarding employment through to competitiveness and trade.

3. Environmental sustainability
This is most recognised of the three pillars. It is concerned with protecting and conserving both biodiversity and the environment, by reducing waste, preventing pollution and using water and other natural resources as efficiently as possible.

3. LIFECYCLE APPROACH

The project procurement lifecycle considers the whole life of a project from inception through to design and construction, operation and final re-use or disposal. It is a process which identifies where and when key decisions are to be made and determines the critical outputs that should be delivered at each stage of the project. Although there are many classifications regarding the various phases of a project procurement lifecycle, this article would consider only the main phases; design, construction and operational phases.

4. SUSTAINABILITY ISSUES AT DESIGN STAGE

Although the initial design cost of a building may represent only a fraction of its total construction cost, and even less of its lifetime operational cost, up to 80-90% of its lifecycle economic and ecological costs are usually sanctioned at this stage (Miles, 1972). Devoting sufficient time and resources to the design phase of a project can yield huge benefits in building quality and overall performance (Dell'Isola, 1997). It can also enable savings to be made in other aspects of the construction process, so that total construction time and cost are kept low. Key sustainable development issues that should be considered at the design stage of a healthcare infrastructure include the following.

4.1 Building and site layout

The building shape is the spatial attribute that defines the outline of the building. It informs the areas and sizes of the vertical components such as walls and associated finishes, windows, partitions and associated finishes, etc., as well as the perimeter detailing such as ground beams, fascias, and the eaves of roofs (Seeley, 1996). In general, Seeley asserts that "the simpler the plan shape, the lower its unit construction cost". The reason being that a building with a simple plan shape uses less external wall to enclose the same floor area and also for the fact that external wall is usually a cost significant element of a building. Thus, the building with the smallest perimeter for a given amount of accommodation offers the cheapest option as far as the enclosure elements are concerned (Ibrahim, 2003). However, Ferry and Brandon (1999) consequently argued that although circular shape provides the smallest perimeter in relation to area, it does not often provide the cheapest solution due to difficulty in setting out; high cost of achieving curved surfaces since non-right angled internal arrangements are generated, standard joinery and fittings based upon right angles will not fit against curved surfaces or acute-angled corners; and inefficient use of site space.

The key constraints influencing decisions on the outline of a building shape include the shape of the site (plot); functional requirements such as natural lighting and good views; and manner of use such as coordination of manufacturing processes, and the forms of machines and finished products in a factory building (Seeley, 1996). Thus, the aspects of building and site layout that has potential impact on the sustainability of healthcare facilities are:

a. low-rise construction (less than four floors) in order to reduce the need for vertical movements (which are energy intensive) and offer increased protection against heat loss through wind chill;
b. clustering of the buildings to reduce space requirement and connectivity (roads and paths) and increased protection against wind chill;
c. irregular building arrangement will ensure that high winds do not generate in corridors between buildings in consideration for care needs;
d. location of related services (having similar usage and service requirements) and departments together will reduce the amount of on-site transportation required and use of lifts;
e. where possible, separation of pedestrian and vehicular access routes will result in safer and more peaceful environment for pedestrians;
f. reduction in areas of hardstanding in order to minimise their contribution to surface water runoff;
g. minimising area covered with hardstanding or using porous pavement surfaces in order to downsize and reduce pressure placed on storm drains;
h. easy accessibility for deliveries and storage pending distribution throughout the facility;
i. ways of facilitating access of public transport and provision of disembarking point for public transport users;
j. building orientation to ensure the optimum use of solar energy;
k. using existing topography, trees (deciduous) or man-made windbreaks in protecting building surfaces from prevailing winds in order to reduce heat loss; and
l. provision of natural areas in order to increase health and wellbeing of staff and patients and reduce stress levels. Baines (2000) reported that hospital patients experience more rapid post-operative recoveries, require less medication and are more amenable if they have a view of green space from their beds.

4.2 Flexible and standardised design approaches

Because a huge amount of energy and resources is used in the construction of a building, insufficient flexibility in design may mean that the benefits of the investments may not be maximised if the building cannot adapt to changing requirements, or to alternative uses if it is no longer required for its originally planned use (Ferry and Brandon, 1999). The continuously evolving nature of healthcare needs, either as a result of feedback from performance indicators or demographics change, makes it important to ensure that a sufficient degree of flexibility in the infrastructure use be incorporated to assure that existing facilities can adapt to the changing requirements. The following factors should thus be taken into consideration:

a. designing some rooms slightly smaller or larger than is required in design specifications so that flexible interior layout can be achieved. For example, an office can be turned into a consulting room or a consulting room into an overnight room;
b. use of outer supporting frame in construction in order to eliminate the need for interior supports and thereby enabling re-design of the interior at a future date.

4.3 Integrated energy-efficient design approaches

Although traditional building styles take advantage of the use of sun as source of light and heat or use of walls and floor as heat sinks to reduce the size of internal temperature changes, the following technical innovations will enable higher performance and more sustainable healthcare buildings:

a. effective insulation will help in moderating internal environment and maintain comfortable temperature in either cold or hot weather. The areas where high levels of insulation can significantly improve performance are as follows (NHS Estates, 2001):
    i. windows, which accounts for around 20% of energy loss from a building, can be improved by using low emissive windows (double-glazed, with a surface coating that reflects heat back into a room);
    ii. walls, accounting for 8% of heat loss from a building, can be improved by using cavity insulation or thicker walls to provide thermal mass that absorbs heat during the day and releases it into the building at night; and
    iii. roof, which accounts for around 9% of heat loss from a building, can be improved through use of high insulation specification in the roof (to reduce energy use particularly on upper floors) in low-storey buildings.
b. use of passive solar design (PSD), involving the location of services in areas where they can achieve most benefit or are least affected by solar energy. This can reduce the need for artificial lighting, increase the quality of internal environment with more tranquil, natural and open atmosphere, and reduce the need for heating, cooling and ventilation services. Some important aspects of PSD include (NHS Estates, 2001):
    i. facing of the main façade to the south maximises heat and light gain;
    ii. siting of building to avoid overshading by another;
    iii. glazed areas to have external shading to reduce overheating and glare;
    iv. shallow planning of buildings, and deeper planned "light shelves" to be used to reflect light deeper into the building;
    v. use of operable windows, vents, and atria to increase natural ventilation;
    vi. circulation of hot air in the atria throughout the building to achieve solar heating during colder nights; and

vii. use of atria that is controllable with vents, blinds and shading.

c. the initial and operating costs of building services can be significantly reduced through the use extra insulation in windows, walls and roofs (as explained in section 4.3a above), necessitating the use of smaller plants;

d. use of whole-systems thinking, including whole-life costing to minimise the operational, maintenance and replacement costs over the facility lifetime and cost-effectiveness analysis such as the consideration of cost of increased insulation (windows, walls and roof) against heating and ventilation costs;

e. selection of building materials that require less energy to produce, are easier to recycle, require less transportation or use less non-renewable resources can significantly reduce the impact of buildings on the environment. CIRIA (1993) stated that the production of building materials in the UK accounts for around 10% of national energy consumption annually and thus the efficiency of different materials in use should be an influencing factor in its selection.

5. SUSTAINABILITY ISSUES AT CONSTRUCTION STAGE

Sustainable construction involves both the minimisation of environmental impacts of construction through specification and monitoring of construction activities and the maximisation of the social benefits that can be achieved from construction projects. Construction involves a large number of people and affects a locality in many ways. Similarly, although many of the environmental impacts arising from construction are predetermined by the design specification, management of site activities and materials sources can significantly reduce the impacts from these processes.

Major construction activities, such as the building of a new hospital or the renovation of existing healthcare centre, can have a significant impact on the local economy over the construction period, both directly through the creation of employment and indirectly through the procurement processes. Ways of maximising the social benefits of a healthcare infrastructure construction to the local communities include:

a. employing local people to work on-site and providing them with training opportunities;

b. using local suppliers for non-specialist services without undermining the delivery of value for money or contravening the rules and regulations governing public procurement;

c. working with local groups who may be able to make use of site waste materials or contribute to the development of the site; and

d. involvement of the local people in the planning and decision-making process in order to create sense of belonging.

The environmental aspects of construction processes relate to manufacture and transportation of construction materials, use of the materials on-site, ecological and nuisance impact in the vicinity of the construction site and pollution incidents. Ways of minimising environmental impacts during construction include:

e. re-using existing buildings will reduce the amount of energy and resources used for new buildings (manufacture and transportation of which account for around 12% of total UK industrial energy consumption (CIRIA (1993)). If new buildings are inevitable however, environmental impacts from material use can be minimised by management of the construction process and materials suppliers;

f. lean construction, which is concerned with ways of minimising waste and ensuring that all construction activities add value to the finished building, can be achieved in the following ways:
   i. bringing to site only those materials that will be needed immediately as stockpiling of materials on-site increases the likelihood of damage and waste of resources;
   ii. ensuring that delivery vehicles carry full loads when visiting the site thereby minimising transportation impacts and nuisance;
   iii. recycling of wastes through suppliers or specialists recyclers; and
   iv. on-site composting of organic wastes (paper, cardboard, wood, etc) and used to supplement topsoil in landscaping the finished site.
g. sustainable sourcing of building materials while ensuring that the value for money criteria are met;
h. taking appropriate steps to reduce local impacts of construction on both the environment and people as recommended by the Local Government Association (2003); and
i. use of risk assessment procedures to identify substances or activities that have potential to cause harm to the environment and estimate the likelihood of such an event occurring. Potential sources of pollution on a construction site include fuels and oils, construction materials, construction wastes, noise and light. Risk management procedures to minimise any incident include:
   i. secure storage of hazardous substance;
   ii. operating procedures for safe working with hazardous materials;
   iii. control over noise and light sources on-site.

6. SUSTAINABILITY ISSUES AT OPERATION PHASE

Sustainability issues during the operational phase of a healthcare infrastructure can be considered from the following perspectives (NHS Estates, 2001):

a. energy management;
b. waste management;
c. water management; and
d. transport.

6.1 Energy Management

Healthcare facilities use considerable amounts of energy on daily basis for a wide range of purposes such as heating, lighting, cooling, ventilation or powering appliances. A sustainable building must consider how it can minimise its energy use and source its energy requirements in the most cost-effective and environmentally beneficial manner. The benefits include financial savings, a more controllable and better quality internal environment, and reduced emissions of atmospheric pollutants arising from heat and power generation. Whether generated on-site or at a local power station, there are significant environmental and social costs associated with energy production such as:

a. emission of greenhouse gases, which contribute towards global climate change;

b. emission of particulate matter with associated chronic health impacts;
c. emission of oxides of sulphur and nitrogen, which contribute towards acidification; and
d. depletion of non-renewable resources.

The most effective way of reducing the impact of energy generation on-site is to reduce demand. Ways of minimising energy use and optimising energy sourcing include:

a. use of combined heat and power technologies, in which case the waste heat generated from on-site electricity production is used to provide heating;
b. use of natural sources of energy such as solar and wind, whenever possible;
c. use of heat recovery system, in which case the waste heat from hot water pipes or ventilation shafts are used to preheat the incoming ventilation air;
d. use of insulation to minimise heating requirements as detailed in section 4.3a
e. use of thermostatic radiator valves for wet central heating systems to minimise unnecessary heating and to increase local control and comfort;
f. insulation of pipework associated with the heating distribution system;
g. use of mechanical ventilation only when necessary, as this can account for up to 30% of electricity consumption in modern hospitals;
h. in addition to optimising cooling and ventilation equipment, minimise heat sources such as sterilizers, medical and laboratory equipment;
i. use of artificial lighting during the day by using PSD techniques detailed in section 4.3b;
j. using high efficiency fluorescent tubes rather than traditional filament bulbs to achieve huge energy savings and significant reduction in cooling load; and
k. use of dimming systems that adjust the level of artificial light according to the level of natural light, or occupancy sensing systems or timed lighting controls.

6.2 Waste Management

Healthcare facilities are a major source of both clinical and municipal wastes. With a disposal cost of between £180 and £320 per tonne, disposing these wastes costs the NHS Trusts around £34 million to £60 million a year (Audit Commission (AU), 1997). The budget for waste disposal in a typical 600 bed UK General Hospital is in excess of £225,000 per annum (Woolridge *et al.,* 2005). Thus, reducing the amount of waste arising from healthcare operations has become increasingly important in order to reduce unnecessary expenditure, while ensuring compliance to legislation.

Audit Commission (1997) recommends the following ways of reducing, re-using and cycling wastes:

a. reversing the growing tendency to use disposable equipment by re-introducing more re-usable equipment;
b. careful categorisation and segregation of the waste to ensure that household waste is not mixed with the clinical waste;
c. use of gas rather than coal as a source of fuel can eliminate the need to dispose coal ash to landfill; and
d. removal of recyclables or re-usables from waste stream and selling them to dealers.

6.3 Water Management

Water management involves reduction of overall level of water consumption and the recycling of grey-water. Greywater is water that has been used for a domestic purpose such as bathing, showering or hand-washing. Good water management can reduce costs if careful management practices are put in place which reduces water usage and encourage the re-use of grey-water for secondary purposes that do not require water of drinking-quality, such as WC flushing. However, the re-use of grey-water has its drawbacks as it could be a source of potential health risk and thus on-site partial treatment would be necessary.

6.4 Transport

Ease of access to hospital sites is essential to ensure access to healthcare for the whole society. Thus, healthcare infrastructures should be sited at a location with the greatest accessibility to the majority of the members of the society. However, access by car in particular is unsustainable and the increasing road traffic causes:

a. congestion, delays, unreliable journeys and road casualties;
b. emission of pollutants, affecting local air quality and community health;
c. emissions of carbon dioxide contributing to global warming;
d. noise and negative visual impacts; and
e. reduced levels of physical activity in the population related to a greater reliance on the car, and increased stress levels whilst driving, resulting in poorer health.

7. CONCLUSION

Procurement of constructed facilities have impact on the environment and also plays significant economic and social role, such as provision of employment, procuring of goods and services, investing in capital infrastructure, and (in some areas) contributing to the research and development process. The variety of activities undertaken within the facilities has necessitated the consideration of their economic, social and environmental impacts on both individuals and the communities they serve. Thus, NHS is significant not only because of the number of people it employs, but also indirectly through the consumption patterns of its employees, which contribute to local economies. One regional study (Yorkshire Forward, 2003) suggests that the greatest impact of rising health spending on the local economy was through employees' spending patterns, rather than through increasing NHS demand for goods and services. As a buyer of goods and services, the NHS can minimise its environmental impact by greening its supply chain and strengthening the local economy by opening its contracts to local small and medium-sized enterprises (SMEs). Similarly, substituting local supplies of goods and services currently sourced elsewhere could help build niche markets. Other economic prospects could come from allying the NHS with universities and businesses to commercialise research into new products and services.

This paper identified the inter-related sustainable development issues that require careful consideration when formulating strategy for establishing a healthcare infrastructure and also suggested ways of sustaining them. It has identified the key design issues for ensuring a sustainable healthcare infrastructure in terms of building and site layout, flexible and standardised design approaches, and integrated energy-efficient design approaches. The paper further highlighted the social and environmental impacts on people and environment as a result of construction and operation of healthcare infrastructure.

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CONCEPTUALISING A CONTINUOUS IMPROVEMENT FRAMEWORK FOR LONG-TERM CONTRACTS: A CASE STUDY OF NHS LIFT

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Abstract: One of the most crucial issues in today's business milieu is the achievement of excellence in customer satisfaction and competitive advantage through continuous improvements of processes, products and services. However, when organisations adopt new business improvement philosophies, they are usually faced with difficulties in measuring or quantifying the contribution that the new approach has made to the overall performance of the organisation But while the temporary nature of construction projects may be accepted as a disincentive for structured data gathering and analysis, when compared to the mass production characteristics of the manufacturing and service industries, the argument can not apply to long-term contracts.

In the last five years, the UK National Health Service (NHS) has been committed to a programme of sustained investment in the health sector. This has resulted in the proliferation of a number of initiatives, one of which is the Local Improvement Finance Trust (LIFT). But given the contractual and relationship complexities in the arrangements coupled with the duration of the contracts (15 to 20 years), the client's expectations, needs and requirements would continuously change throughout the contract period. Consequently, there is a need for a system that identifies, measures and continuously improves the processes, both tangible/intangible products and services provided by the parties responsible for the design, construction and operation of the health infrastructure. This paper proposes a conceptual framework for achieving the desired continuous improvement under long-term relationships, using the NHS LIFT scheme as case study.

Key words: Continuous improvement, Long-term, Healthcare, NHS LIFT.

1. INTRODUCTION

From the late 1980's, the construction industry on a global scale has been under intense scrutiny and this is set to continue as owners and users demand better value for money from a more sustainable built environment. In the UK, government reviews (Latham, 1994; Egan, 1998) showed that the sector was underachieving, bogged down with claims and disputes, had low profitability, many of its clients were dissatisfied with its overall performance and invested too little in capital, research and development, and training. Consequently, Latham (1994) advocated improvements in the efficiency and competitiveness of the industry through reforms in contracting, tendering, design process, quality management, productivity, training, education and other areas. Egan (1998) similarly exposited that substantial improvements in quality and efficiency were possible. The main actors in the construction industry have been responding to the challenges implicit in the resulting drive for greater competitiveness and social responsibility. This led to steady flow of research, reports and analyses on the nature of the industry, its various components, systems and structures. Many new management techniques, new forms of procurement, innovative programmes, knowledge management, CAD-supported processes and many more initiatives have evolved to help in transforming the sector, but their success depends upon appropriate contextualisation, a good match between process and organisational culture, and quality of the people involved (Slater 1998).

The cross-section of previous studies indicate that the major obstacles to implementing new management techniques includes changing the behaviour and attitude of people, lack of expertise/resources, lack of employee commitment/ understanding, lack of education and training to drive the improvement process (Bennett and Jayes, 1995, 1998; Bresnen and Marshall, 2000). Besides, when organisations adopt new philosophies, they are usually faced with difficulties in measuring or quantifying the contribution that the new approach has made to the overall performance of the organisation (Giunipero and Brewer, 1993). This was the main driver for the evolution of benchmarking; to provide measures for continuous improvement as part of the evolving TQM process etc. However, construction industry lacks solid data gathering history resulting in its poor reputation when it comes to performance measurement (Choi and Ibbs, 1990). The erratic fluctuation in productivity creates inconsistencies in structure and compilation of construction data. But while the temporary nature of construction projects may be accepted as a disincentive for structured data gathering and analysis when compared to the mass production characteristics of the manufacturing and service industries, the argument can not apply to long-term relationships.

The UK construction industry-wide survey (ECI, 2003) showed that the traditional arrangements for delivering long-term contracts seldom achieve best value and repeatedly fail to facilitate continuous improvement in both client and contractor performance. This is because cost and performance are driven by market forces rather than a sharing of risks, opportunities and objectives between the parties. Similarly, the fragmentation of responsibilities under the UK traditional healthcare delivery arrangements has been recognised as a key factor inhibiting the achievement of co-ordinated planning, service delivery and investment (Grimsey and Graham, 1997). ECI (2003) suggested that the impediments to improved performance could be removed or overcome by working together to achieve a greater understanding and management of the influencing factors. The current drive for sustained reform has led to the introduction of many initiatives, one of which is the NHS LIFT (National Health Service Local Improvement Finance Trust) scheme, aimed at bringing together the various local stakeholders, interests and users that comprise the local health economy. Although, the scheme is still in its infancy and it may take some time before historical performance data can be gathered, the process needs to commence now.

However, given the contractual and relationship complexities surrounding the scheme arising from the considerable potential for ever-changing clients'/users' expectations and requirements over the life of the scheme. Besides, the LIFT scheme includes a contractual requirement for continuous improvement not only from the supply side but also from the demand side. This creates the need for a system for identifying, measuring and continuously improving both tangible/intangible products and services through the life of NHS LIFT scheme and other long-term relationships. This paper focuses on the NHS LIFT scheme under the UK healthcare system and proposes a conceptual framework for achieving the desired continuous improvement in the processes, products and services in long-term relationships.

2. THE NHS LIFT

After years of under investment, attention is currently shifted to ensure that the UK primary care sector enjoys sustained and huge investment (the biggest since creation of NHS in 1948). This will help to improve both the quality of care provided and the environment in which it is delivered. The NHS LIFT scheme is focussed at developing and encouraging a new market for investment in primary care and community-based facilities and services, leading to long-term contract arrangements. One of the key objectives of the scheme is to bring together the various local stakeholders, interests and users that comprise the local health economy with a contractual requirement for continuous improvement from both the demand and supply sides. The scheme aims to deliver a step change in the quality of the primary care estate, remedy some of the deficiencies in the existing arrangements; and contribute to delivery of the investment targets identified within the NHS plan. Under the scheme, NHS plans to attract up to £1 billion of investment in primary care, refurbishing or replacing up to 3000 GP premises and establishing 500 new one stop care centres. The plan is a reflection of the views expressed by patients, visitors and staff, on how hospitals and healthcare facilities could and should be improved.

Like the Private Finance Initiative (PFI), LIFT is a way of accessing private money for public projects. But while the former is simply a contract to build and finance a building or group of buildings, LIFT involves a much deeper partnership. Under the LIFT scheme, the Department of Health (DoH) has established a national joint venture, *Partnerships for Health* (PfH), with Partnerships UK plc (PUK) which is itself a public-private partnership (PPP), with 49 per cent ownership by Her Majesty Treasury and the Scottish Executive, and 51 per cent by a range of private sector interests. Figure 1 shows the structure of the national joint venture company.

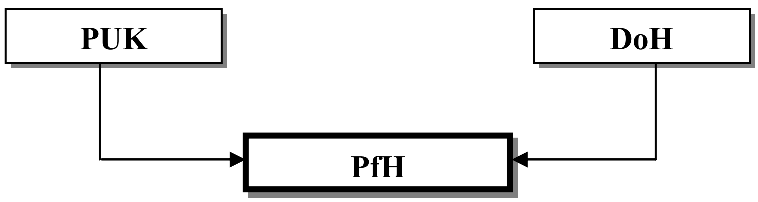

Figure 1: Structure of the national joint venture company (DoH, 2001)

Subsequently a *private sector partner* (PSP), a consortium of diverse specialties, is identified through a competitive procurement and then a local joint venture (LJV) established between the local health bodies, PfH and the PSP. The LJV (local *LIFT Company*) enjoys the benefits of a long-term partnering agreement to deliver investment and services in local care facilities over contractual period of between 15 to 20 years. The recommended local shareholding proposed by DoH/PfH is a local public shareholding of 20%. Figure 2 shows the structure of local LIFT.

The local LIFT companies are set-up as public-private partnerships in the form of limited liability companies. Each local LIFT is run by a management board comprising of directors nominated by the shareholders; the PSP, local NHS and PfH. However, they are structured to enable GPs or groups of GPs to be shareholders. A public sector Strategic Partnering Board (SPB), formed between the core statutory bodies in the local health and social care community (i.e. PCTs, LAs, voluntary sector, etc.), through a strategic partnering agreement to develop strategic service development plans, incorporating local primary care service needs and relationships with, for example, intermediate cares and local authority services. The SPBs are also responsible for monitoring the performance of the local LIFT companies and for identifying their future workloads.

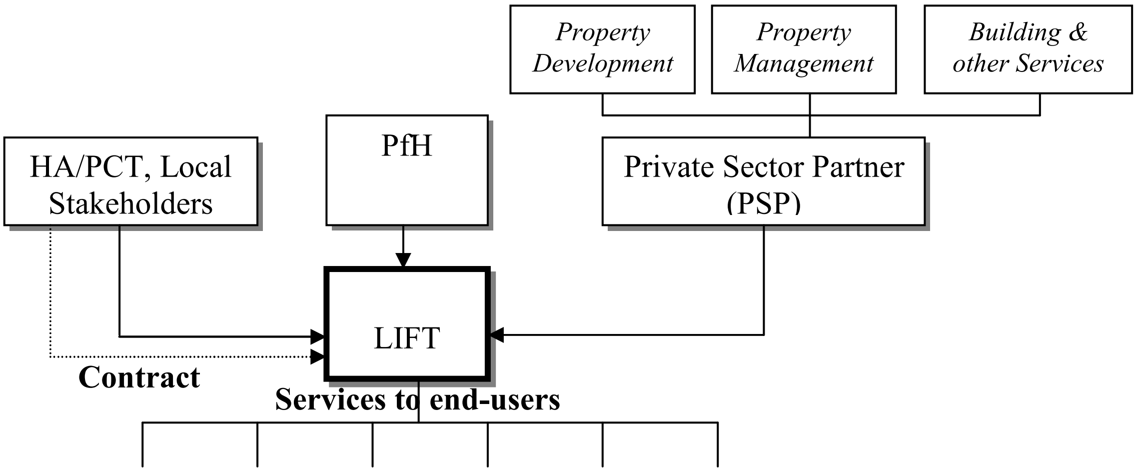

Figure 2: Structure of Local LIFT (DoH, 2001)

The local LIFT Company is responsible not only for managing and implementing agreed investments and services, but also for planning future estate and services requirements to meet the local health economy's needs and developing opportunities identified by the private sector partner.

All LIFT schemes are assessed to demonstrate that they offer value for money, partly through the competition in the selection of PSP and partly through District Valuer's endorsement during reimbursement of rentals. To date, 51 projects have been approved under the NHS LIFT scheme in a total of four waves.

3. CONTINUOUS IMPROVEMENT CONCEPT

The goal of continuous improvement is common to many managerial theories such as partnering, lean construction, sustainable construction and TQM and is applicable to various facets of the construction process. Shearer (1994) defined continuous improvement for professional services providers as the achievement of "*breakthroughs in productivity by improving the way that the work is done (process), by improving the way people communicate, and by facilitating operational consistency*." Lillrank *et al.* (1996) defined continuous improvement as a "*purposeful and explicit set of principles, mechanisms and activities within an organisation adopted to generate continuous and systematic improvement in deliverables, operating procedures and systems by the people who actually perform these procedures and operate the systems*". Therefore, a major underlying principle of continuous improvement process requires the establishment of constant self-assessment techniques to regularly evaluate key systems, processes and outcomes (Juran and Gryna, 1993; Stahl, 1998). Such a strategy ensures a realistic, proactive and measurable approach to performance. These improvements may take any one of several forms:

1. enhancing value to the customer through new and improved products and services;
2. reducing errors, defects, waste, and their related costs;
3. increasing productivity and effectiveness in the use of all resources; and
4. improving responsiveness and cycle time performance for such processes as resolving customer complaints or new product information.

ECI (2003) recommended that collaborative working can achieve a greater understanding and management of the project influencing factors and would remove the impediments to improved performance in long-term relationships. Cain (2004) further identified some of the numerous benefits that can be derived by integrating the project team and working within long-term collaborative relationships (such as long-term partnering arrangements) to include:

- improve design, including operational efficiency and health and safety performance,
- minimise the need for costly design changes,
- identify ways of driving out inefficiency in the construction process,
- repeat good practice learned on earlier projects,
- minimise the risk of costly disputes,
- identify incentives to deliver tangible improvements in the quality of the construction and reductions in time and whole-life cost, and
- integrate the whole supply chain.

In emphasising the importance of performance measurement to the achievement of continuous improvement, Egan (1998) cautioned that "*if you don't measure, you will never know how much improvement is possible or desirable. High level targets are the starting and are necessary to start improvement – but need to be broken down into a series of lower level targets that will enable everyone involved in a project to see how their daily work contribute to the overall improvement target. Measures are therefore required in all these areas of activity of the critical processes so that improvement targets can be set and progress to their achievement monitored*". The concept of continuous improvement stands for the idea of improvement as a problem-solving process and has the explicit purpose of improving the employees. It is built on the important presumption that every step of the process of an organization, of a service, and of an operation has room for improvement. Furthermore, it has been argued by Atkin *et al*. (2003) that *process* and the resulting *product* are inextricably linked, such that consideration of one in isolation of the other is a recipe for failure. The concern for construction process and how it is expected to align with the demands increasingly placed upon it has led to its redefinition.

3.1 CONTINUOUS IMPROVEMENT IN NHS

The importance of healthcare has been increasingly recognised by governments and the populations at large but standards that were acceptable a few years ago are no longer acceptable and this has necessitated a substantial drive for continuous improvement.

The design, construction and operation of healthcare buildings involve complex concepts that are difficult to measure and evaluate. In order to ensure that the industry works with a common framework, the NHS has worked closely with Commission for Architecture in the Built Environment (CABE), the Construction Industry Council (CIC) and Sheffield University to develop design evaluation criteria and an evaluation toolkit, *Achieving Excellence Design Evaluation Toolkit* (AEDET) Evolution. The functions of the toolkit include:

- assists Primary Care Trusts (PCTs) and NHS Trusts to develop design specifications for their schemes,
- a methodology for evaluating and assessing the design of healthcare building proposals,
- assists NHS Estates in performing their approval role on behalf of the Department of Health, and
- the basis for a national benchmarking system of design quality for healthcare buildings.

The basic framework and criteria of the toolkit is shown in figure 3, which involves the main criteria and the sub-criteria for determining performance improvement. The evaluation methodology of the toolkit is by posing a series of clear, non-technical statements, encompassing the three key areas and the ten sub-criteria.

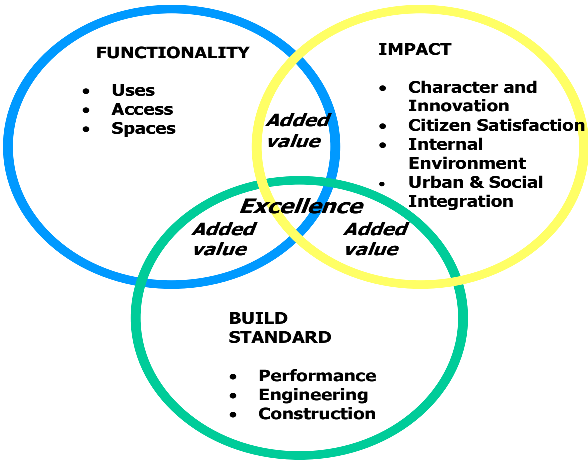

Figure 3: Basic framework and criteria for AEDET Toolkit (NHS Estates, 2005)

Literatures have shown that the interactions and interrelationships between the various project stakeholders greatly affect the overall performance and success of construction projects (Smith and Wilkins, 1996; Soetanto and Proverbs, 2004). Long-term contracts, such as PFI and LIFT schemes, involve diverse stakeholders, and thus require a wider and longer view and context. The multiplicity of participating parties poses serious challenge to the projects in terms of efficiency, effectiveness and interface management. Therefore, a comprehensive set of criteria is needed to cover the design, construction and operation phases, along with consideration of the impact on local communities and the external environment. The proposed framework will address all the issues highlighted above and attempt to investigate other sub-criteria that will properly define the main areas of the AEDET toolkit.

4. CONCEPTUALISING CONTINUOUS IMPROVEMENT FRAMEWORK FOR LONG-TERM RELATIONSHIPS

There have been many attempts at bringing about change in the way buildings are produced (process) but most have remained unsuccessful because they often ignored the product (built facility) and what it means to those who have to use them. Atkin *et al*. (2003) comprehensively summarises the various views of process improvement experts in a process definition that emphasizes three product-related phases; definition, manufacture and use, as shown in figure 4.

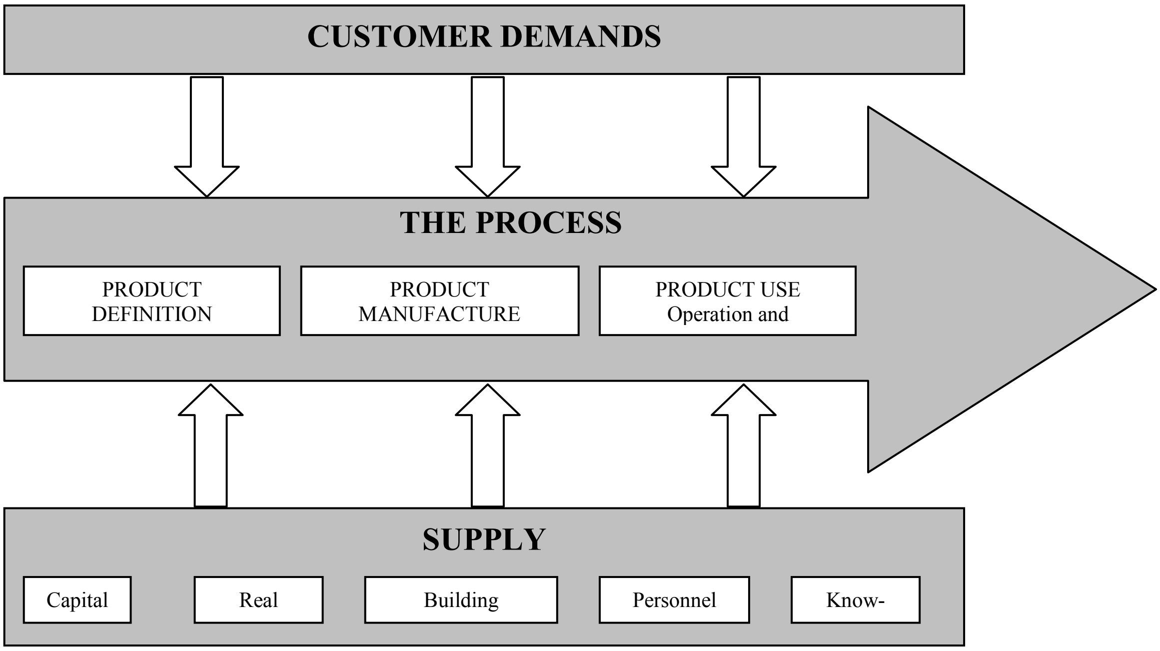

Figure 4: A process view of improvement (Atkin *et al*., 2003)

Cain (2004) further suggested that in order to drive out inefficiency and waste in the utilisation of resources and continuously improve the performance of construction projects under long-term relationships, attention should be given to the following:

- customer-focussed design,
- integrated processes and teams,
- long-term strategic partnership across the supply chain,
- industrialised and sustainable construction methods, and
- customer use and satisfaction.

The development of a conceptual model would facilitate clearer understanding and diagnosis of processes. For example, Belassi and Tukel (1996) developed a conceptual model of Critical Success Factors (CSFs) for project performance, and this helped to group the CSFs so that their effects at different phases of a project life cycle were determined and clearly explained. The proposed conceptual model of continuous improvement is shown in Figure 5.

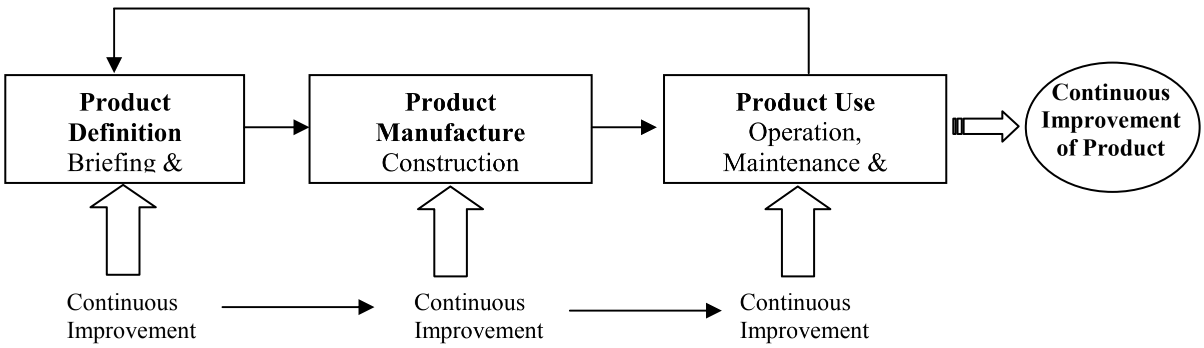

Figure 5: A conceptual model of continuous improvement

This conceptual model uses a three-stage process as suggested by Atkin *et al*. (2003), and this forms the basis for determining what factors lead to the continuous improvement at each stage of the construction process. The three stages are in a sequential process flow from left to right, and the loop indicates the commencement of another cycle, to distinguish a one-off relationship from a long-term cooperation. This three-stage process is proposed based upon two fundamental concerns. First, the construction process is similar to an organizational change process (Wilson *et al*., 1995). It is common that a change process consists of three stages (i.e. unfreezing, process and re-freezing). For another cycle to occur, the re-freezing stage will unfreeze again. The adoption of a change cycle is popular in other concepts such as total quality management (Love *et al*., 2000). Secondly, there is a common premise in the area of strategic alliance that the process should be composed of three key stages (i.e. creation, implementation and evaluation) (Das and Teng, 1999).

At each process stage, we propose the following 8-step cycle in the sequential order shown in Figure 6:

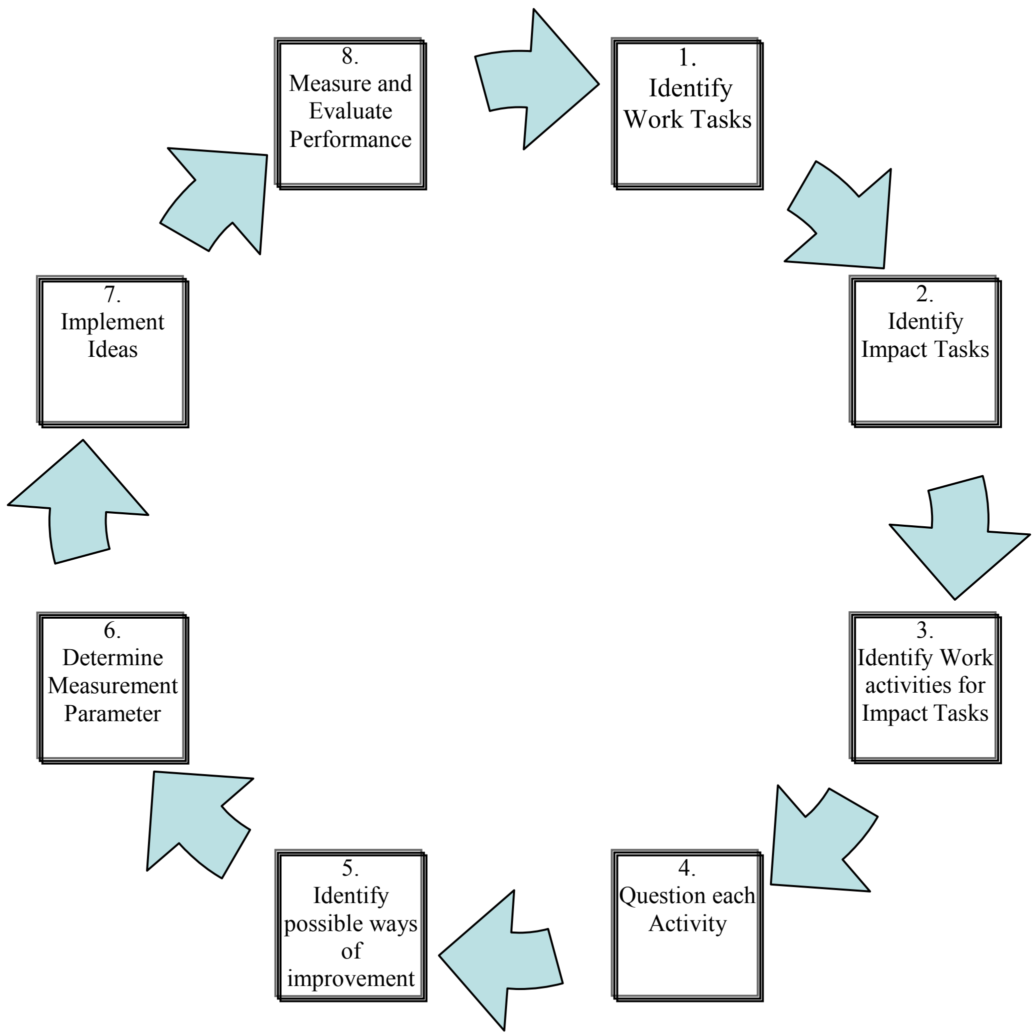

Figure 6: Proposed Continuous Improvement Cycle

1. *Identify Work Tasks* – this involves identifying large tasks categories that are necessary to get a project complete.

2. *Identify "Impact" Tasks* – this involves the identification of major task categories that offer the greatest opportunity for improvements in cost, schedule and quality.

3. *Identify Work activities for the Impact Tasks* – in this step, the large task categories identified in step 1 above are further broken down into discrete work activities. Organise these work activities in some logical using activity diagrams, affinity diagrams, flow charts, etc. and the potentials for improvements may become glaring.

4. *Question each Activity* – this involves focusing attention on improvement of the work process and elimination of wasted work effort. Some pertinent questions at this stage include:
    a. What are the goals of the particular task?
    b. How does this activity add value to the task?

c. How does this activity increase product quality?, and
d. Can this activity be eliminated without impacting quality or schedule?

5. *Identify possible ways of improvement* – this may entail brainstorming by a specialised group to identify ways to carry out activities faster, better and cheaper, and ways to implement them. These however, need to be specific.

6. *Determine measurement parameter* – any suggestions for improvements should be coupled, to the extent possible, with a measurement parameter such that the magnitude of the improvement over the baseline (current) can be clearly seen.

7. *Implement Ideas* – this involves the practical application of the suggested improvement ideas and may require specific assignments made to individuals or teams.

8. *Measure and evaluate performance* – the success of the continuous improvement process rests on the ability to objectively evaluate the impact of the implemented changes, and then factor successes and failures into the framework for another cycle of the continuum.

But because construction is a project-oriented industry, it would be natural to focus the performance measurement on the project work more than at the organisational level (Kagioglou *et al*., 2001; Love and Holt, 2000). The performance of construction projects are typically evaluated in terms of cost, time and quality (Ward *et al.* 1991; Kagioglou *et al.* 2001). These three have been described as insufficient by Ward *et al.* (1991) and they argued that other factors such as quality of relationships amongst participants and flexibility could influence customer satisfaction and thus affect the success/failure of projects. Furthermore, as explained by Ward *et al*. (1991), what remains in the minds of participants after project completion is not so much of the financial success or early completion, but memories of harmony, goodwill and trust, or conversely arguments, distrust and conflict. In addition, productivity has been a dominant issue in project management, promising efficient usage of resources and cost savings, and ultimately affecting the bottom line of every effort in the construction process (Olomolaiye *et al.*, 1998).

Eccles (1991) and Senge (1990) argue that, in today's complex and highly competitive business world, organisations must learn how to adapt and cope with continuous change in order to be successful. This has resulted in the regular evaluation and modification of performance measures to ensure that they reflect continuous change (Meyer and Gupta, 1994; Ghalayini and Noble, 1996; Dixon *et al*., 1990; Wisner and Fawcett, 1991). Lynch and Cross (1991) and Bititci *et al*. (2000) identified the need for performance measurement systems to: be dynamic and reflect changes in the internal and external environment; review and prioritise objectives as the environment changes; deploy changes in objectives and priorities; and ensure gains achieved through improvement programmes are maintained. However, there has been little evidence of the extent or effectiveness with which this takes place. Bassioni *et al*. (2004) also argued that although the design of measures/indicators has been covered by many publications, measures specific and appropriate to construction have not been well addressed. They also recommended further research on vertical cascading and aggregation of measures between the organizational and project levels of construction projects.

In developing and cascading performance criteria for construction facilities, a process of three converging levels is proposed. The first level identifies the life cycle of facility evaluation phases; the second level identifies performance categories; and the third level defines the elements of performance and equates them to the needs and goals of the users.

Level 1:

At this level, the life cycle of facility evaluation phases which should encompass the components of the facility development process follows the phases proposed by Atkin *et al.* (2003) as shown in Figures 4 and 5. This includes the briefing and design phase; construction phase; and operation, maintenance and disposal phase.

Level 2:

At this level, the evaluation components are identified for each of the process phase, and this includes the following broad components:

1. Functional System – involving the evaluation of the attributes of the physical setting that affects the user's activities.
2. Physical System – involving the evaluation of the physical elements used to create the completed facility, such as materials, equipment, and components.
3. Environmental quality – addressing the impact of the individual physical systems on the environment in which the occupants live or work.
4. Behavioural Factors – addressing the user's response, psychologically and sociologically, to their environment and the facility.

Level 3:

At the third level, the individual elements of performance are identified within the categories of performance and are equated to the needs and goals of the facility occupants. Facility performance criteria are then developed and the degree to which the facility supports the occupants' needs and accomplishment of their goals measured. These criteria can further be used to aid with the development of the facility evaluation instrument which can subsequently be used as a continuous improvement tool that can measure the success of the facility as determined by user satisfaction and how well the needs and goals have been supported.

4.1 APPLICATION OF PROPOSED FRAMEWORK TO NHS LIFT

For the NHS LIFT scheme, the AEDET Evolution toolkit already in use for evaluating proposals offers a viable potential platform for the proposed continuous improvement framework, if expanded and restructured. The expansion should recognise the operational phase and the intricacies and dynamisms of long-term relationships amongst the stakeholders whilst the restructuring should ensure more in-depth exploration of relevant issues. The major stakeholders include Partnership for Health (national joint venture between DoH and Partnerships UK), the local health authorities/PCTs and private sector partners. The key driving objectives of these parties are quite diverse and could be conflicting.

In expanding the AEDET toolkit for use in the proposed framework, it is imperative to investigate both reactive as well as proactive strategies (Shiba *et al*., 1993) that are unique to long-term healthcare procurement projects at each of the identified process stage. This would involve the use of both lagging and leading performance indicators. Whilst the lagging indictors would show the final outcome of an action usually after it has been completed such as time/cost growth, the leading indicators predicts, with certain degree of confidence, a future outcome such as process cycle times. Although most of the information provided by lagging indicators may have come far too late to allow any immediate changes to be made, they may still be useful under long-term relationships. However, leading indicators can be argued to be far more effective in driving forward continuous performance improvement. It is important to note that the leading indicators are a result of a measurement process that is driven by the organisation itself and is entirely within their span of control.

The identification of these performance elements and facility performance criteria, which were reported in the third level described in the preceding section, forms the heart of the futures works in this research.

5. CONCLUSIONS

In modern business parlance, the achievement of excellence in customer satisfaction and competitive advantage through continuous improvements of processes, products and services is an essential ingredient to business success. This is especially true when new initiatives and techniques are introduced, and the challenges of quantifying their impact on performance improvement arise. The complexity of the evaluation increases with duration of the relationship and when there is multi-party involvement in the procurement. This paper discusses continuous improvement concept in the context of construction and proposes a system to identify, measure and continuously improve both the tangible/intangible products and services provided by the parties responsible for the design, construction and operation of the health infrastructure.

The paper recommended further studies aimed at exploring the described performance indicators and the practical implementation of the proposed framework.

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COST AND TIME OVERRUNS OF PROJECTS IN MALAYSIA

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Abstract: Malaysia is a fast developing country in the Asian region and has undergone rapid economic growth since the seventies. The construction sector has being one of the main contributors to the gross domestic product (GDP) since then. However, there is a general impression that the construction industry in Malaysia is associated with time and cost overruns which is affecting the amount of physical infrastructural development that can be undertaken. Many factors may have impacted upon construction time and cost overruns in Malaysia. This paper reports part of an on going PhD programme with the overall aim to develop a system of risk management to proactively minimise cost and time overruns in public sector projects in Malaysia. The objectives of the PhD programme are: to determine cost overrun in Malaysian public sector projects in comparison with the private sector projects; to investigate the contributory factors for cost overrun, to investigate the nature and extent of the risk factors associated with construction projects; to evaluate the links between risk and cost overrun; and to develop risk management system for dealing with cost overrun in Malaysian public sector projects. This paper reports an evidence-based analysis on the time and cost overruns of the private sector and public sector projects in Malaysia and the impact of such project factors as procurement methods, types of projects and, project size.

Keywords: cost overruns, construction, time overruns, Malaysia, procurement.

1. INTRODUCTION

Malaysia is a fast developing country in Asian region and has undergone rapid economic growth since the seventies. The construction industry (CI) has played an important role in the Malaysia economic growth. The industry has been consistently contributed approximately 3% to 5% of the national Gross Domestic Product (GDP) (Shari, 2000, Takim, 2005). The growth in construction has been increase from 6% to 15% since the seventies until middle nineties. (Raftery et al, 1998, Shari, 2000). There are two main sector for construction projects in Malaysia; public and private sector. Most of the public sector projects are handled by Public Works Department (PWD). In Malaysia, the Construction Industry Development Board (CIDB) is a body with the main function of developing, improving and expanding the Malaysian construction industry and is involved with the public and private sectors project development (Takim, 2005).

This empirical study on the time and cost overruns of construction project in Malaysia is undertaken because of a lack of previous study of the causes of cost and time overrun in the Malaysian construction industry. Chan (2001) investigated the relationship between times and cost of building projects using Bromilow's model. The study concluded that the Malaysian public sector project contract costing RM 1 million takes about 269 days to complete and produced a best predictor of average construction time as $T=269C^{0.32}$. This study does not represent the whole of Malaysia, because the data used was based on one state out of fourteen states in Malaysia. Other studies undertaken have investigated factors affecting construction labour, construction safety and constructability implementation by Abdul Kadir et al. (2005), Abdul Aziz & Hussin (2003) and Nima et al. (2001) respectively. Adnan & Morledge (2003) and Takim, (2005) conducted research related to success factors in Malaysia construction industy. In view of the importance of the construction industry to the Malaysian economy, the study of the time and cost overruns in the Malaysian construction industry and the factors influencing these overruns has become important. These influencing factors can come from all project stakeholders in the construction development such as owners, contractors, consultants, financial and government authorities.

To establish the extent of time and cost overruns of construction projects in Malaysia, the first primary data collection were conducted in early 2005. This paper presents an evidence-based analysis on the time and cost overruns of the public and private sectors projects in Malaysia based a questionnaire survey conducted in early 2005 in Malaysia as part of a PhD research schedule for time and cost overrun in of construction projects.

The premise for the paper is that a construction project can be regarded as successful when the project is completed on time, within budget and with appropriate technical performance or quality (William, 2003). According to Chimwaso (2000), projects completed within budget are rarely found compared with cases of projects with cost overrun. Cost and time overruns are major problems in project development and are regular features in construction industry especially for developing country. This makes projects costly for the parties involved in construction especially for contractors and clients. The same holds for time overrun. Impact of project time overrun or delays for contractors include increased costs, reduced profit margin and battered reputation. Clients are also affected by additional charges and professional fees and reduced incomes because of late occupancy. As part of the factors responsible for delays in construction completion, Ng et. al. (2001) noted that most contractors assume that duration set by the client is realistic and prepare their bid accordingly.

2. OVERVIEW OF COST AND TIME OVERRUN IN CONSTRUCTION INDUSTRY

Construction project time overrun can be defined as an extension of time beyond the contractual time agreed during the tender and cost overrun as an extra cost beyond the contractual cost agreed during the tender. Many previous studies have identified cost and time overruns as general problems in the construction industry worldwide (Kaka & Price, 1991, Elinwa & Buba, 1993, Ogunlana & Promkuntong, 1996, Okuwoga, 1998, Abd. Majid & McCaffer, 1998, Shi et. al., 2001, Ng et. al., 2001, Aibinu & Jogboro, 2002, Choudhury & Rajan, 2003, Koushki et. al., 2005)

A study undertaken by Odeck (2004) for Norwegian Public Roads Adminstration showed that cost overruns ranged from -59% to 183% and this was more predominant on smaller projects compared with larger ones. Aibinu & Jogboro (2002) study indicated that Nigerian construction industry experienced a mean percentage cost overruns of 17.34% Kaming et al (1997) found cost overruns to be more common than time overruns on high-rise projects in Indonesia and consequently suggested a need for method studies and dissemination of the research results to both large and small firms, so that the most productive working methods can be adopted by all operatives. They saw this as a means to increase operatives output, without necessarily exerting more physical effort.

Research by Flyvberg et. al. (2002) concluded that nine out of ten transportation infrastructure projects costs are underestimated and that for all project types the actual costs are on average 28% higher than estimated costs. Forty four percent (44%) of the respondent in the research undertaken on the Nigerian construction industry by Elinwa & Joshua (2001) indicate that, time overrun often occured. Another research conducted by Barrick, cited by Jackson (2002) on the United Kingdom construction industry found that nearly one third of the clients complaints that their projects generally overran budget. Creedy (2004) is of the view that identification of the existence and influence of cost overrun risk factors in a project can lead to a better control on project cost overrun and also can help in proposing solutions to avoid future overruns.

Scott (1993), Alkass et. al. (1995 and 1996), Abd. Majid and McCaffer (1998), Al-Khalil and Al-Ghafly, (1999) have all show that time overruns occur on the majority of major civil engineering contracts and that this is a most common problem. Completing projects within the time is an indicator of an efficient construction industry (Chan and Kumaraswamy, 1997). According to Chan and Kumaraswamy, (1995), the ability to estimate the completion time is normally dependent on the individual intuition, skill and experience of the planning engineer. Mezher & Tawil, (1998) however noted that time overruns in Lebanon construction industry are costing the country a lot of money and that there is a need to find more effective methods to over come the problem.

3. METHODOLOGY

Data for this study were collected through a survey questionnaire to 150 quantity surveyor consultants in Malaysia. A survey packages containing a covering letter and project data collection form for the firms to provide cost and time information on up to 5 or more projects that they have undertaken. Only 8 consultants returned the questionnaire. Telephone contacts were made to the companies but still the response was poor. Given the situation personal contacts had to be made with public government officials and quantity surveyor consultants to encourage more respondents. This tactic improved the amount of response rate collected. Discussions with the establishments show that the main reason why they did not respond to the questionnaire is because the request is for data on previous projects undertaken which are not readily available. This would demand that they open the previous file to get the data. Pressure from work and lack of time to search for the data were some reasons for not responding to the questionnaire.

The respondents were asked to provide information on previous projects in relation to name of project, starting and completion date, location, numbers of storey and gross floor area for building project, contractual and actual duration, pre-contract budget, contract sum and final account cost (after Pearl et. al, 2003). Specific features of the projects such as type of project (new build or refurbishment), nature of work (sector), procurement methods, nature of works and tendering methods were also requested.

4. DATA COLLECTION

Table 1 shows the project summary and characteristics. Data were collected on 359 projects comprising very small, small, medium and large projects. The procurement methods involved are: traditional, design & build, construction management, management contracting and project management. The nature of works range from residential, infrastructure, commercial, office, educational, health, industrial and recreational. Three tendering methods were considered: open tender, selective and negotiated. All the projects were completed between years 1994 to 2005.

Table 1: Summary of project characteristics

Category	Classification	Number	%
Type	New Build	301	83.8
	Refurbishment	58	16.2
Sector	Public	308	85.8
	Private	51	14.2
Procurement Method	Traditional	291	81.1
	Design & Build	58	16.1
	Management Contracting	1	0.3
	Project Management	9	2.5
Nature of works	Residential	52	14.5
	Infrastructure	139	38.7
	Commercial	13	3.6
	Office	29	8.1
	Educational	111	30.9
	Health	11	3.1
	Industrial	1	0.3
	Recreational	3	0.8
Tendering method	Open tender	176	49.0
	Selected	118	32.9
	Negotiated	65	18.1

The average cost deviation of the project was 2.08%, the minimum cost deviation being -80.38% and the maximum was 80.76%. For the time deviation, the average was 49.71%, the minimum was -19.30% and maximum 440.00% as shown in Table 2. Table 2 also illustrate that the project cost and duration are extremely low as compared with the maximum value. The minimum cost is RM 0.1 million and the duration is 2 weeks.

These wide ranges in the time and cost overruns on projects in Malaysia suggest this is a major problem to the nation. However this is not unusual in the construction industry given Norwegian Public Roads Administration experienced cost overrun between of between -59% and 183% (Odeck, 2004) , 17.34% mean cost overrun of Nigerian projects (Aibinu & Jogboro, 2002) and 90% cost overrun of Denmark transportation infrastructure.

Table 2: Summary of projects' cost and time overruns

	Cost (RM)		Duration (weeks)		Cost Deviation		Time Deviation	
	Contract	Actual	Contract	Actual	RM (m)	%	Weeks	%
Mean	18.46	19.17	55.66	78.81	0.71	2.08	23.15	49.71
Minimum	0.1	0.1	2	3	-16.42	-80.38	-18.00	-19.30
Maximum	563.3	567.3	229	260	128.7	80.76	156.00	440.00

5. ANALYSIS AND DISCUSSION

Public and private construction projects

Table 3 compares cost overruns on public sector and private sector projects. The table shows that overall 8% of public sector projects did not have cost overruns compared with 37.3% private sector projects. In terms of cost overruns of 10% or below, 76.0% of public projects experience cost overruns compared to 84.3% o private projects. Figure 1 shows the comparison of the private sector and public sector projects cost overrun. Both the Table and Figure show little difference in terms of pattern of cost overruns between the public sector and private sector projects. These figures are similar to cost overrun statistics for Bostwana where 7 out of 10 projects had incurred cost overrun (Chimwaso, 2000).

Table 3: Comparison of public sector and private sector projects cost overruns

Range of cost deviation	Public Projects			Private Projects		
	Frequency	%	Cum. %	Frequency	%	Cum.%
<30.1	6	1.9	1.9	0	0.0	0.0
-(20.1)-(-30)	14	4.6	6.5	0	0.0	0.0
(-10.1)-(-20)	39	12.7	19.2	0	0.0	0.0
(-5.1)-(-10)	30	9.7	28.9	5	9.8	9.8
-(0.1)-(-5)	48	15.6	44.5	9	17.6	27.4
0	7	2.3	46.8	5	9.8	37.2
5-0.1	61	19.8	66.6	10	19.6	56.8
10-5.1	29	9.4	76.0	14	27.5	84.3
20-10.1	50	16.2	92.2	3	5.9	90.2
30-20.1	11	3.6	95.8	2	3.9	94.1
40-30.1	6	1.9	97.7	1	2.0	96.1
50-40.1	4	1.3	99.0	1	2.0	98.0
>50.1	3	1.0	100.0	1	2.0	100.0
Total	**308**	**100.0**	**100.0**	**51**	**100.0**	**100.0**

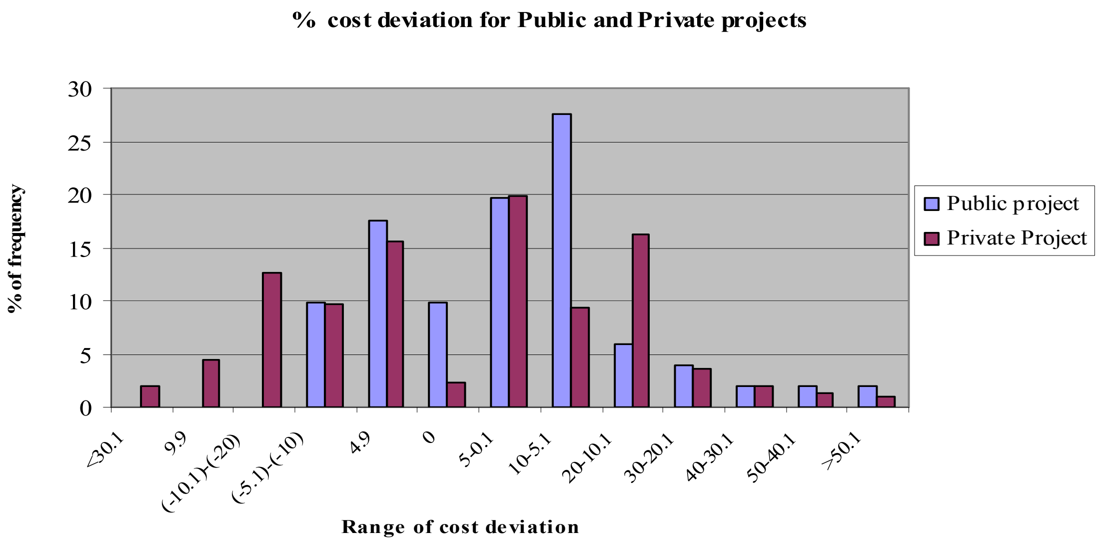

Figure 1: Comparison of cost overruns between public sector and private sector projects

Time overruns in public sector and private sector projects are shown in Figure 2 and Table 4. The Table shows that 18.2% of the public sector projects and 29.45% of private sector projects have 0% time deviation. The Table also shows that 20.5% and 33.3% of the public sector and private sector projects respectively are completed within not more than 10% of the projects duration specified in contract suggesting that 79.5% of public sector projects and 66.7% of private sector projects are not completed at 10% time overruns. This compares with Saudi Arabia construction industry time overruns study by Zain Al-Abedien (cited by Al-Khalil & Al-Ghafly) that 70% of projects undertaken by the Ministry of Housing and Public Works experienced time overruns. According to World Bank (1990) cited by Bordoli & Baldwin (1998), 1627 projects completed between 1974 and 1988 had time overruns of between 50% and 80%.

The figures presented from the analysis of the Malaysian construction industry projects shows that time overruns of Malaysian projects is higher compared with cost overruns. This finding contradicts the research done by Kaming et al, 1997 on Indonesia projects where it was found that cost overruns occur more frequently than time overruns on high-rise construction. This presents the need to investigate further whether the nature of the project, as the case in Indonesia, has influence on the results. In addition, the need to identify the factors influencing time overruns as shown in the level of time overruns experienced on the construction projects in Malaysia has become necessary to ensure that projects can be completed within the time frame specified and at the same time reduce the cost overruns.

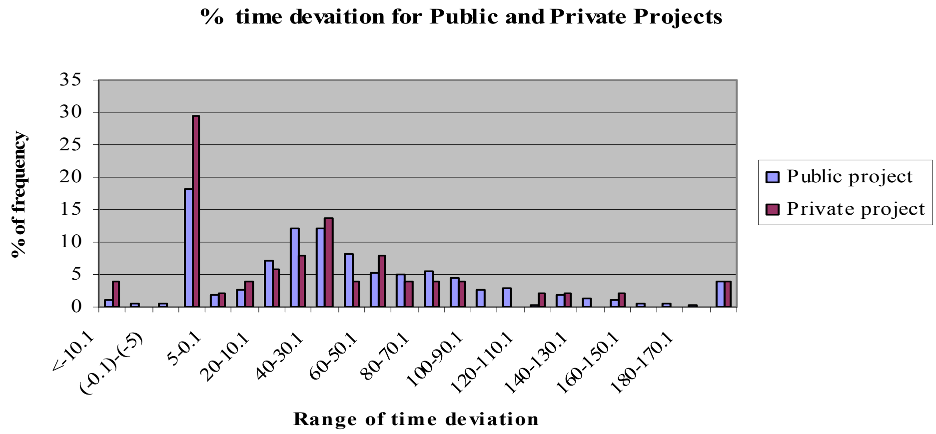

Figure 2: Comparison of time deviation of public and private projects

Table 5 shows that there is not much difference below 0% time and cost deviation based on tendering methods suggesting that tendering methods may not be an influencing factor on time and cost overruns of construction projects in Malaysia. This is not the case with the procurement method which shows cost deviation at below 0% is only be achieved on 11.1% of projects based on project management procurement methods. This tends to suggest that although the use of project management procurement method in Malaysia is growing particularly for large size and complex projects, this is not helpful in achieving project completion within the budget. However, project management procurement method has best results in relation with time overruns with 33.3% of projects completed at below 0% time deviation compared with 21% from traditional procurement method and 27.6% of Design and Build procurement method. Only these three types of procurement methods are considered in this analysis because the other two had few than five projects: the small number of projects made their inclusion in the comparative analysis of the procurement methods unjustifiable. .

Table 4: Comparison of public sector and private sector projects time deviation

Range of cost deviation	Public Projects			Private Projects		
	Frequency	**%**	**Cum. %**	**Frequency**	**%**	**Cum.%**
<-10.1	3	1.0	1.0	2	3.9	3.9
(-5.1)-(-10)	2	.6	1.6	0	0.0	3.9
(-0.1)-(-5)	2	.6	2.3	0	0.0	3.9
0	56	18.2	20.5	15	29.4	33.3
5-0.1	6	1.9	22.4	1	2.0	35.3
10-5.1	8	2.6	25.0	2	3.9	39.2
20-10.1	22	7.1	32.1	3	5.9	45.1
30-20.1	37	12.0	44.2	4	7.8	52.9
40-30.1	37	12.0	56.2	7	13.7	66.7
50-40.1	25	8.1	64.3	2	3.9	70.6
60-50.1	16	5.2	69.5	4	7.8	78.4
70-60.1	15	4.9	74.4	2	3.9	82.4
80-70.1	17	5.5	79.9	2	3.9	86.3
90-80.1	14	4.5	84.4	2	3.9	90.2
100-90.1	8	2.6	87.0	0	0.0	90.2
110-100.1	9	2.9	89.9	0	0.0	90.2
120-110.1	1	.3	90.3	1	2.0	92.2
130-120.1	6	1.9	92.2	1	2.0	94.1
140-130.1	4	1.3	93.5	0	0.0	94.1
150-140.1	3	1.0	94.5	1	2.0	96.1
160-150.1	2	.6	95.1	0	0.0	96.1
170-160.1	2	.6	95.8	0	0.0	96.1
180-170.1	1	.3	96.1	0	0.0	96.1
>180.1	12	3.9	100.0	2	3.9	100.0
Total	**308**	**100.0**	**100.0**	**51**	**100.0**	**100.0**

Table 5: Comparing percentage of projects at below 0% cost and time deviation

Tendering Methods	0% cost deviation	0% time deviation
Open Tender	41.8%	20.6%
Selected	54.8%	17.9%
Negotiated	49..2%	23.7%
Procurement Methods		
Traditional	45.4%	21.0%
Design & Build	51.7%	27.6%
Project Management	11.1%	33.3%
Nature of Works		
Residential	59.6%	26.9%
Infrastructure	38.8%	24.5%
Commercial	30.8%	38.5%
Office	24.1%	17.2%
Educational	53.2%	16.2%
Health	63.6%	27.3%

Project Cost and Time Deviation: Analysis based on Tendering Method, Procurement Methods and Nature of Work

Residential, educational and health projects produced 59.6%, 53.2% and 63.6% respectively less than 0% cost deviation compared to other types of project in the

Table suggesting that the nature of work has an influence on the cost overruns. This is not pronounced in case of time deviation where projects delivered at below 0% time deviation on the basis of nature of projects ranged between 16.2% and 38.5%. What would appear to be outlier time deviation based on the nature of projects is commercial works with 38.5%. Again, industrial and recreational projects were not included in the analysis because less than five projects of these types were involved.

6. CONCLUSION

Time and cost overruns of construction projects occur as a result of many factors: some of which are related to each other. An analysis of the cost and time overruns of the construction projects in Malaysia based on cost and time mean deviation, produced an 2.08% average cost deviation compared with 49.71% average time deviation suggesting that time overrun is more critical in Malaysia construction projects.

The results of the analysis show that both the public sector and private sector projects have similar pattern of cost overruns. Only 46.8% and 37.2% of public sector and private sector projects respectively are completed within the budget. However, 84.3% of the private sector projects are completed within the 10% cost deviation compared with 76.0% of the public sector projects.

Time overrun of public projects was more critical with only 20.5% of the projects completed within the time specified in the contracts compared with 33.35% of the private sector projects. The findings suggest there is a need to investigate further factors responsible for the level of time and cost overruns of the Malaysian construction projects. Hence, further planned data collection will concentrate on the factors contributing to the time and cost overruns in Malaysian construction industry. By doing so it is expected this will ultimately lead to better control of project cost and time and help in identifying alternative solutions to avoid future cost and time overruns.

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THE PRIVATE VERSUS PUBLIC INFRASTRUCTURE IN SUB-SAHARAN AFRICA: AN EMPIRICAL VALIDATION

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Abstract: The macro-economics of the relationship between the private and public infrastructure in sub-Saharan Africa has been very unpredictable due to the region's ineffective planning and policy formulation for infrastructure and service delivery. This paper examines the relationship between public and private infrastructure in sub-Saharan Africa. It also demonstrates that sub-Saharan Africa consumes more and invests less when compared to the industrialised world and that the present domestic investments in sub-Saharan Africa is actually more in the hands of the private sector. Lastly, an inference relationship for measuring and comparing economic stability between countries and regions was formulated, with the industrialised countries as reference value.

Keywords: Infrastructure, Private sector, Public sector, sub-Saharan Africa Investments, Macro-economics.

1. INTRODUCTION

In many developing countries, particularly countries within sub-Saharan Africa, public ownership is considered one means of avoiding the degradation of infrastructure services and the effects of market fluctuation (Nwoye, 2002; World Bank, 2002; World Bank, 2004). This has encouraged policies hostile to private ownership of national infrastructure and service delivery, policies which sometimes result in outright nationalization of some infrastructure enterprises (World Bank, 2002). These policies notwithstanding, the performance evaluation of public infrastructure in sub-Saharan Africa have shown that the public infrastructure services often used by the poor are of low quality, inadequate and sometimes exhibit very severe low percentage cost recovery and poor spin-off for social economic development (World Bank, 1994; World Bank, 2000; World Bank, 2002; World Bank, 2004).

It has also been observed that there are some deficiencies in the performance evaluation criteria used to assess the public sector in the region. Among these is an inability to quantify social objectives, or to separate them from the economic objectives set for public enterprises (Alexander, 2002; Nwoye 2002; Fischer et al., 2003). Thus, it is intrinsically wrong to assess the public sector by criteria relating to profitability alone (Independent policy group, 2003). The performance of the private sector has even been used as a major indicator of confidence in the economy and of the effectiveness of public policy (Nwoye, 2002; Independent Policy Group, 2003). Thus, a comparative assessment of the effects of each sector on the domestic economy subject to these constraints would be very difficult. Therefore, the need to critically examine this problem is overwhelming. Nonetheless, the authors are of the view that such study can be critically analysed from two dimensions namely: the quantum of investments in the region and the quantum of social objectives. It is the primary aim of this paper to empirically investigate partly this major concern from the perspective of the quantum of investments from both sectors in the domestic economy in order to ascertain the dominant sector. Such an investigation might provide an insight into the macro-economics of the region's infrastructure and more specifically a new direction to policies underpinning infrastructure. However, it would be useful to precede such a critical evaluation with an overview of the private and public sectors in sub-Saharan Africa.

It is important to note that private sector performance in any economy is usually monitored by actual and potential shareholders (Fischer et al., 2003). If poor performance is reflected in the stock market, share prices will be lower than they might have been, inviting buyers who will eventually install better management for capital gains when share prices subsequently rise (Fischer et al., 2003). Where this threat is not strong enough, shareholders can force managers to pay more attention to profit maximisation and cost reduction. Therefore, private sector managers are constrained by market forces through the performance of the stock market. (Fischer et al., 2003).

Conversely, the public sector faces no market pressures, because it tends to be dependent on the government's role as a watch dog. However, nationalisation in most cases results in poor management of the resulting enterprise, causing the government problems (Fischer et al., 2003). It appears that such political initiatives or policies are born from the need to serve effectively those for whom such services were intended. The sacrifice usually paid for fulfilling these needs could be enormous, as it is in sub-Saharan Africa, whereas, the fundamental reason for this sacrifice is the ease with which policy makers exercise power – an ease that could under-price public services. However, such under-pricing results in a pricing system that might exclude essential cost elements in production (Alexander, 2002). If services are under-priced, more of them will be consumed than if they were available at market cost (Alexander, 2002; Nwoye, 2002; Fischer et al., 2003), leading to an increase in demand that would be virtually impossible to meet (Alexander, 2002). It is thus one of the aims of this paper to also validate empirically the true extent of the region's increasing consumption capacity.

One reason often given for public involvement in infrastructure and service provisions is the fear of foreign dominance in the economy: multinationals could dominate key sectors of the economy if government does not participate in establishing business ventures in those areas (Nwoye, 2002). Others are to impede foreign dominance, to establish key industries crucial to the development of other sectors, to diversify the economy, and to satisfy the need to check the excesses of the private sector, especially in the welfare services sector (Nwoye, 2002; Fischer et al., 2003).

2. METHODOLOGY

The modified "adhoc conventional approach" model (Wang, 2002), based on the conventional neoclassical one sector aggregate production function in which public infrastructure constitutes a direct input to the production function, was employed for this study. It takes this form:

$$Y_t = f\left(L_t, W_t, X_t\right)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where Y_t is GDP per capita, W_t is public sector gross capital formation (Public Investments) and X_t, L_t private sector gross capital formation (Private Investments) and labor services respectively. The subscript *t* denotes time series. The application of this model is based on the assumption that L_t is of negligible effect on GDP in this function. Moreover, the primary concern of this investigation, to test the effect of public investments (X_t) on private investments (W_t) and that of private investments (W_t) on public investments (X_t), resulted in the exclusion of the variable "labour services" (L_t).

Data was collected from the Africa statistics year book (2003) and International Monetary Fund (IMF) (2003). The data collected from the latter was extracted from the International Financial Statistics. It was used to show the huge difference between the consumption and investments pattern in the sub-Saharan Africa (see Table 1, 2, 3 and 4) by means of some descriptive analysis and a bar chart plot showing both the sub-Saharan Africa and industrialized countries' gross capital formation as a percentage of GDP and final consumption expenditure as a percentage of GDP (see figs.1 and 2). The other data for sub-Saharan African countries, showing their average GDP per capita (1995-2000) in US$ tagged variable *Y* and public investment (1995-2000) tagged variable *X* (on proxy for public infrastructure) and private investments (1995-2000) tagged variable *W* (on proxy for private infrastructure) were empirically evaluated by regression analysis to develop an acceptable model. The average GDP per capita was the dependent variable while public investment and private investment were the independent variables (see Table 5).

To test the extent to which the independent variable predicts the dependent variable in the statistical model, several measures of variation were developed as illustrated in the works of Levine et al. (1999). The first measure is the total sum of squares (*SST*). The second is the explained variation or regression sum of squares (*SSR*), and the unexplained variation or error sum of squares (*SSE*). These measure of variation were used to develop the coefficient of determination (r^2) and correlation coefficient (r). The coefficient of multiple determination r^2 represents the proportion of the variation in *Y* that is explained by the set of explanatory variables selected (Levine et al., 1999). The coefficient of correlation *r* to test the strength of the relationship or association between two variables was carried out. (Levine et al., 1999).

Residual analysis was then carried out to be sure if the multiple linear regression model is appropriate for the available data. To determine whether there is a significant relationship between the dependent variable and a set of explanatory variables the F-test was also carried out. However, the F test as explained below was used to test the null hypothesis as it is the case for simple linear regression (Levine et al., 1999). Since there was more than one explanatory variable, the null (H_0) and the alternative hypotheses (H_1) were set up as follows: $H_0 : \beta_1 = \beta_0 = 0$

This means that the null hypothesis be accepted if $\beta_1 = \beta_0 = 0$ i.e. there is no linear relationship between the dependent variable and the explanatory variables. Where: β_0 is the intercept of the dependent variable and β_1 or precisely β_j is the slope of the dependent variable with one of the independent variables while holding the other constant. If H_1 : At least one $\beta_j \neq 0$ (reject the null hypothesis if $\beta_j \neq 0$ i.e. there is a linear relationship between the dependent variable and at least one of the explanatory variables).

In order to determine the contribution of each of the explanatory variable, the Partial *F test* criterion was applied. It involves determining the contribution to the regression sum of squares made by each explanatory variable after the other explanatory variable has been included in the model (Levine et al., 1999).

Moreover, to have a better understanding of the statistics of the numerical data for gross capital formation and final consumption expenditure for sub-Saharan Africa and the Industrial countries, the central tendency, variation and shape of the data were computed and examined for each set. For the central tendency the mean, median were of relevance while mode, midrange and mid-hinge were not necessary for this investigation.

To understand the variation within the data, the following computations were made: The first quartile, Q_1 , is a value such that 25% of the observations are smaller and 75% of the observations are larger. The third quartile, Q_3, is a value such that 75% of the observations are smaller and 25% of the observations are larger. The range, inter-quartile range, variance and standard deviations were also included in the computation, but the coefficient of variation was left out because it was not necessary for the investigation. All analysis carried out was through the use of a PH statistical software.

3. DISCUSSION OF RESULTS

The gross capital formation and final consumption expenditure data for sub-Saharan Africa and the industrial countries revealed a more concentrated or homogeneous data because the range, inter-quartile range, the sample variance and the standard deviation were relatively small. Despite the homogenous tendency in the data for sub-Saharan Africa and the industrial countries, the data showed that the final consumption expenditure for the former was more dispersed than that of the latter. For reasons of space the descriptive statistical result table for the data was not included in the result tables displayed. Furthermore, the shape, which reflects the manner in which the data is distributed (skewness), showed from computed values that both the gross capital formation and final consumption expenditure for sub-Saharan Africa is negative or left skewed. This has pulled the mean down so that the median becomes greater than the mean. The reverse is the case for the industrial countries as the manner of distribution is positive or right skewed, resulting in the mean being greater than the median. However, the homogeneity of the data had actually given credence to its reliability and use.

The first bar chart plot (see fig.1) shows sub Saharan Africa's gross capital formation and the final consumption expenditure over a period of time, and Table 1 revealed that the mean final consumption expenditure as a percentage of GDP is 4.4 times larger than the gross capital formation in sub-Saharan Africa. The second bar chart plot (see fig.2) shows the industrial countries' gross capital formation and the final consumption expenditure over a period of time, and Table 2 revealed that the mean final consumption expenditure as a percentage of GDP for industrial countries is 3.8 times larger than the gross capital formation for the industrial countries. By implication, sub-

Saharan Africa's final consumption expenditure over gross capital formation is 1.15 times larger than the final consumption expenditure over gross capital formation for the industrialised countries (see Tables 3 and 4).

The following multiple linear regression model for the data in Table 5 was developed for sub-Saharan Africa:

$$Y = 3.37X + 3.22W - 169.85 \quad (2)$$

Testing the linear relationship between the dependent variable and the explanatory variables with the F test, the null hypothesis H_0 was rejected since $F > F_U$ (critical value). Therefore, a linear relationship exists between the dependent variable and the explanatory variables in the model. The coefficient of multiple determination r^2 and the coefficient of multiple correlations computed for the model above were considered satisfactory. To provide an additional check on the validity of the model, the residual plots were examined and we observe from the residual plots that there appear to be little or no pattern in the relationship between the residual and the values of X; public investments (public gross fixed capital formation) and W; private investments (private gross fixed capital formation). Thus, it was concluded that the multiple regression model was appropriate.

In determining the contribution of the explanatory variable, the partial F-test criterion was used, and the stages employed are as follows:

- Two simple linear regression model partial outputs (see Tables 6 and 7) in each of which one of the mentioned explanatory variables was computed.
- To determine whether X significantly improves the model after W has been included:

  $$SSR(X/W) = 80568662.6 - 78949647 = 1619015.6$$

  $$F = \frac{1619015.6}{141999.4} = 11.40 > F_{critical}$$

  Therefore the addition of variable X after W has been included significantly improves the model.
- To determine whether W significantly improves the model after X has been included:

  $$SSR(W/X) = 80568662.6 - 68933355 = 11635307.6$$

  $$F = \frac{11635307.6}{141999.4} = 82 > F_{critical}$$

  In addition, variable W significantly improves the model after variable X has been included.

Thus, we have been able to show that each of the explanatory variables significantly improves the model. However, the proportion of W *(private gross fixed capital formation)* was significantly greater (since 82 > 11.40) by the ratio $\left(\frac{82}{11.4} = 7.1\right)$.

Further, with some assumptions, we were able to deduce an inference relation for measuring and comparing the economic stability of any country or region. These assumptions are as follows: we assumed a negative sign for final consumption expenditure as a percentage of GDP (*FCE*) and a positive sign for gross capital formation as a percentage of GDP (*GCF*). The inference relationship for economic stability is $S_E = GCF + FCE$.......................(3)

S_E is the inference relationship for economic stability, and the higher its value in comparison to that of the industrialized countries (reference value) the higher the economic stability of that region or country. The following examples should suffice to show this:

Industrialized countries:
$S_E = 20.8 - 79 = -58.2\%$
Sub-Saharan Africa:
$S_E = 18.7 - 81.5 = -62.8\%$
Since: -58.2 > -62.8
$\Rightarrow$ The Industrial countries are economically more stable than the sub-Saharan Africa with a 4.6% margin of stability.

4. CONCLUSION

This investigation was able to show empirically that private fixed capital formation (*W*) has a greater effect on GDP than the public fixed capital formation (*X*) in sub-Saharan Africa. The most striking revelation was that the effect of *W* was seven times greater than the effect of X on GDP. The implication of this finding is that the private sector invests seven times more heavily in domestic gross capital formation than does the public sector because $\left(\frac{82}{11.4} = 7.1\right)$. It inescapably follows that the private sector is more likely to have invested more in infrastructure. This no doubt contradicts the widespread notion that the region's domestic economy is in public hands. Further, our earlier findings using the descriptive analysis have shown that the sub-Saharan African region consumes much and invests little since sub-Saharan Africa's final consumption expenditure over gross capital formation is 1.15 times larger than the final consumption expenditure over gross capital formation for the industrialised countries.

Table 1: Gross capital formation and final consumption expenditure (1991-2001) for sub-Saharan Africa

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Gross capital formation as a % GDP	19.6	18.8	19.1	20	19.2	18.4	18.1	19.1	18.4	17.1	17.5
Final consumption expenditure as % of GDP	80.6	83.3	83.7	83.6	83.2	82.1	82.7	85.6	79.2	75.2	77.1

Source: International Financial statistics (2003)

Table 2: Gross capital formation and final consumption expenditure (1991-2001) for Industrial countries

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Gross capital formation as a % GDP	21.1	20.4	19.7	20.3	20.5	20.5	20.9	21.2	21.5	21.8	20.5
Final consumption expenditure as % of GDP	78.7	79.2	79.5	79	78.7	78.7	78.1	78.1	78.8	78.9	80

Source: International Financial statistics (2003)

Table 3: Industrial countries and the sub-Saharan Africa gross capital formation comparison

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Gross capital formation as a % GDP(industrial countries)	21.1	20.4	19.7	20.3	20.5	20.5	20.9	21.2	21.5	21.8	20.5
Gross capital formation as a % GDP(sub-Saharan Africa)	19.6	18.8	19.1	20	19.2	18.4	18.1	19.1	18.4	17.1	17.5

Source: International Financial statistics (2003)

Table 4: Industrial countries and the sub-Saharan Africa final consumption expenditure comparison

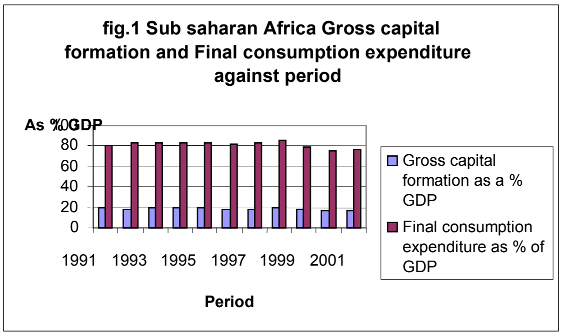
Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Final consumption expenditure as % GDP(industrial countries)	78.7	79.2	79.5	79	78.7	78.7	78.1	78.1	78.8	78.9	80
Final consumption expenditure as a % GDP(sub-Saharan Africa)	80.6	83.3	83.7	83.6	83.2	82.1	82.7	85.6	79.2	75.2	77.1

Source: International Financial statistics (2003)

Table 5: Average GDP per capita, gross public and private capital formation (1995-2000)

COUNTRY	Mean US$ GDP Per capita (1995-2000)(dollars)	Public investment(1995-2000)(dollars)	Private investment(1995-2000)(dollars)
	Y	X	W
Angola	498.7295495	41.39455261	122.1887396
Benin	392.0419387	28.61906153	41.94848745
Botswana	3206.614173	407.24	490.6119685
Burkina-faso	228.1555545	31.94177763	34.67964429
Burundi	151.1881268	10.88554513	3.32613879
Cameroun	638.8752103	8.944252944	95.83128155
Cape verde	1460.800529	132.9328482	235.1888852
Central Afr.Rep	345.185009	18.9851755	15.87851042
Chad	213.3588554	19.84237355	18.34886156
Comoros	357.6585873	21.10185665	28.97034557
Congo	810.5642496	51.06554772	176.7030064
Congo Dem.Rep	106.6730811	12.48075049	3.626884759
Cote d' Ivoire	817.1347746	39.22246918	69.45645584
Djibouti	1004.478554	41.18362073	70.31349881
Egypt	1071.46475	58.93056125	182.1490075
Equatorial Guinea	938.2704839	37.53081936	643.653552
Eritrea	160.571239	45.60223188	2.408568585
Ethiopia	112.7334717	10.3714794	8.229543435
Gabon	4396.137814	232.9953041	936.3773543
Gambia	354.5107735	24.81575414	36.86912044
Ghana	395.9858239	46.72632721	41.97449733
Guinea	527.1375906	39.0081817	80.65205136
Guinea Bissau	249.7976772	28.22713752	17.98543276
Kenya	329.0192881	21.38625372	38.4952567
Lesotho	521.9091828	174.8395762	84.02737843
Madagascar	232.457986	17.20189097	14.41239513
Malawi	160.1518682	13.93321253	7.84744154
Mali	259.8414207	23.9054107	32.74001901
Mauritania	175.6929618	23.54285688	12.82558621
Mauritius	4100.296766	299.3216639	815.9590564
Mozambique	163.3217786	19.59861343	25.47819746
Namibia	2305.613727	182.1434844	357.3701277
Niger	202.3215308	11.53232726	8.699825826
Nigeria	286.4141664	24.91803248	30.93272997
Rowanda	320.9098328	24.06823746	24.71005713
Sao T&Principe	364.1778007	94.68622818	83.03253856
Senegal	584.2628967	37.97708829	65.43744443
Seychelles	6630.44978	570.2186811	1604.568847
Sierra Leone	193.6179921	6.38939374	0.387235984
South Africa	3901.41724	101.4368482	554.0012481
Sudan	289.5349388	4.63255902	50.95814922
Swaziland	1703.922583	95.41966463	252.1805422
Tanzania	176.2188055	5.815220582	23.96575755
Togo	341	10.912	45.012
Uganda	322.2061964	18.68795939	37.37591879
Zambia	370.2680443	35.17546421	22.95661875
Zimbabwe	616.2899051	59.16383089	41.90771355

Source: African statistical Yearbook (2003)



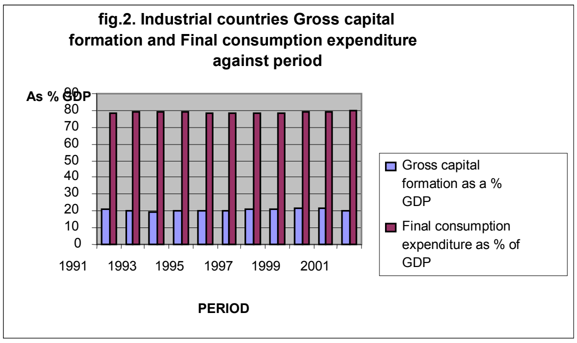


Table 6: Summary output of a linear regression with variable W as the only explanatory variable

Regression Statistics	
Multiple R	0.951285
R Square	0.904943
Adjusted R Square	0.902963
Standard Error	415.6568
Observations	50

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	78949647	78949647	456.9622	3.56E-26
Residual	48	8292989	172770.6		
Total	49	87242636			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	229.1154	68.0185	3.368427	0.001498	92.3551	365.8757	92.3551	365.875653
W	4.253019	0.198956	21.37668	3.56E-26	3.852992	4.653047	3.852992	4.653047039

Table 7: Summary output of a linear regression with variable X as the only explanatory variable

Regression Statistics	
Multiple R	0.88889471
R Square	0.7901338
Adjusted R Square	0.78576158
Standard Error	617.611002
Observations	50

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	68933355.33	68933355	180.7172	6.83202E-18
Residual	48	18309280.8	381443.4		
Total	49	87242636.14			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	175.402985	105.0758948	1.669298	0.101569	-35.86613706	386.6721	-35.86613706	386.672108
X	11.1399765	0.828675669	13.44311	6.83E-18	9.473813328	12.80614	9.473813328	12.80613958

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PROCESS IMPROVEMENTS OF CONSTRUCTION PROJECTS IN MALAYSIA: ANALYSIS OF CASE STUDIES

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Abstract: In the context of construction industry, improvement of project performance is crucial and to be uphold continuously. In this respect, the integration of process improvement strategies across project phases is vital to enhance project and organisational performance. This paper provides an analysis of the different forms of process improvements used in the development of construction projects in Malaysia. Six projects were selected as case studies by means of a semi-structured interview involving four project stakeholder groups: Government, private sector clients, consultants and contractors.

A total of 34 interviews were carried out. The data were analysed by means of statistical and content analysis methods. The results show that the integration of 'briefing, brainstorming and regular meetings' are essential at the initial project stage, followed by the 'correct selection of procurement and delivery strategy'. The use of 'standardisation and pre-assembly' in project implementation combined with the use of 'information and communication technology (ICT)' should help to speed up the construction process and disseminate of project information. 'Health and safety' process improvement is required at the construction stage and finally, 'commissioning and training programmes' for users and maintenance operators are important at project completion stage. The study disclosed that the Government of Malaysia should exercise their influence on project consultants and contractors to initiate process improvements in construction project development.

Keywords: Case studies, content analysis, Malaysia, process improvement, statistical analysis.

1. INTRODUCTION

In Malaysia, the construction industry plays a significant role in the economic growth (Government of Malaysia, 2001). Over the last 20 years, the industry has consistently contributed approximately 3% to 5% of the national Gross Domestic Product (GDP). Given this, under the Ninth Malaysian Plan (2006-2010), the Ministry of Works plan to inject an estimated RM 30 billion (US$12billion) to enhance the growth of the construction sector (Bernama, 2005). The contributions are more than just economic; the products of construction (whether directly or indirectly through provision of superior infrastructure and buildings) have contributed extensively towards the creation of good quality of life of the population.

However, despite the development of this industry, conservative attitudes towards the implementation of construction projects have hampered the adoption of new improvements tools and techniques for construction processes and methods, corporate structuring and administrative methods. To a certain extent the improvement process in construction is regarded as slow in nature (Raftery et al. 1998) particularly in the Government sector. The reasons for the slow improvement processes in construction project development are due to the lack of sufficient technical expertise and managerial skills apart from financial support (CIDB, 2000).

In addition, improving project and organisational performance requires the identification and implementation of suitable improvement programmes subjected to the construction business cycle. Tang and Ogunlana (2003) have identified some improvement programmes namely: collaborative arrangement, supply-chain management, the choice of procurement strategy, and the use of ICT, TQM and QA in construction. It is worth noting that the integration of improvement programmes in construction development may incur high cost and yet the benefit can only be realised after some time. Consequently, the project clients are often faced with the challenges of selecting the best options for their projects and organisations.

This paper documents an analysis of different forms of process improvements used in the development of construction projects in Malaysia across the different construction phases based on semi-structured interviewing of construction stakeholder groups.

2. CHARACTERISTICS THAT INFLUENCE IMPROVEMENT PROCESSES IN CONSTRUCTION

According to Koskella (1992), there is a strong separation between design and actual realisation of construction. In effect, construction companies tend to focus more the project at hand in terms of their contribution to the successful completion of project and pay little attention to the issues immediately outside a project such as learning and improvement issues, or transfer of individual learning into organisational learning. This position is noticeable in the public and government sectors construction project management in Malaysia.

Gieskes and Broeke (2000) have shown how management of construction projects is predominantly short-term oriented and the strategic component in decision making is often absent. Most improvements that take place are of a technological nature, while improvisation is more valued than organised. This is inline with the opinion of Culp et al. (1993), that failing in many quality management efforts is due to the lack of clearly defined and measurable goals. This all call for a well organised improvement process in construction project development.

A construction project is usually a temporary alliance of autonomous partners in which a project is 'organised-to-order'. As a result of this form of co-operation, participants such as consultants and contractors are partners for a particular project. A participating company in one project cannot be sure that improvement processes learnt and results achieved from their last projects will be applied in another project given that they may now be dealing with new partners unless specially demanded by client.

Furthermore, past experience in the development of construction projects in Malaysia have shown that some project clients are not inclined to the 'hard' and 'soft' process improvement issues in the management of construction projects. Reasons for this could be due to the budget constraints and lack of technical expertise to implement the improvement programme. Mostly, integration of improvement programmes in construction is considered to be associated with higher cost that needs to be minimised or removed in order to trim down the overall total development cost of a project: this is particularly during the economic slow down. Instead, impromptu or *ad hoc* improvement processes are deployed for the day-to-day management of projects depending on the needs and requirements.

Tay (1994) has argued that unlike other industries, the construction industry is characterised by activities which are discontinuous, dispersed, diverse and distinct. Consequently, process improvement in the construction setting is considered more difficult to implement and sustained. It is also claimed by Tay that for some reasons, process improvement in such areas as quality, risk and value managements and product development is difficult to achieve fully. In contrast, a study by Bajracharya et al. (2000) suggested that organisations should adopt a more balanced view of organisational and project performance that includes both short and long term improvement programmes in the discontinuous and dispersed construction activities to ensure successful project completion and for future success.

3. RESEARCH METHOD

In order to understanding the process improvement programmes used in the Malaysian construction industry, the research method adopted was a case study of qualitative research techniques. Six projects were selected as case studies from a representative sample of projects involving the same client organisation (Development Division of University Technology Mara (UiTM)) in Malaysia comprising: Hostel Buildings (Project A); Health Centre (Project B); College Buildings (Project C); Sport Centre (Project D); Corporate Buildings (Project E); and Academic buildings (Project F). The case studies approach by means of in-depth interviews was part of the strategy to tackle the PhD research objectives undertaken at Glasgow Caledonian University. The research objectives were to determine critical success factors, success measures, process improvements, stakeholders and performance measurement involved the Malaysian construction project development. For the process improvement in construction two questions were addressed: the types of process improvements that are used in the implementation of the government projects and; the level of and reasons for integrating process improvements in the six projects.

The selection of the client and cases were based very largely on pragmatic considerations: the availability of personal and professional contacts with the project client and the ease of access to information. Pragmatic consideration is considered essential by Bresnen (1990) in an investigation involving accessing confidential data particularly for case studies. In addition, the six cases were self-selected by the project client (Deputy Vice Chancellor, Development Division of UiTM) with whom initial contact was made, subject to agreement of other parties. The cases were selected at the onset on the basis of geographical proximity which is in line with Yin (1994) to include recent completed and problematical projects that need to be investigated as required by them. However, since no attempt was made by the author to select representative projects of a specific type, then the potential for bias in this respect was not an issue. Full guarantees of confidentiality and anonymity were given, and the independence and neutrality of the researcher was stressed.

Each case study involved an in-depth interview on the basis of the common methodology with six project stakeholders directly involved in the projects namely: project clients, architects, engineers (civil & structural and mechanical & electrical), quantity surveyors and contractors. The interview exercises were held in Malaysia in May 2003. Thirty four (34) respondents were interviewed out of 38 respondents, which bring the total response rate to around 89 %. In undertaking this task, every effort was made to minimise the threats to validity and reliability of the data that can occur in qualitative case study research (Yin, 1994). Considerable importance was attached to cross-checking the information that were obtained with the project information held by client on files in the form of minutes of meetings, monthly progress reports and reviews. The results were analysed by means of content analysis technique using the Statistical Package for Social Sciences (SPSS) software.

Content Analysis

The interviews outcomes of the case studies were processed by means of content analysis techniques. Soetanto et al. (2002) describes content analysis as a technique for extracting and categorising information from the text. Content analysis according to McBurney, (1998) is a research tool used to determine the presence of a certain words or concepts within the texts or sets of texts. Researchers quantify and analyse the presence, meanings and relationships of such words and concepts, and make inferences about the messages within the texts, interviews, discussions, essays, book chapters, articles, speeches or any occurrence of communicative language. According to Guthrie et al. (2004), for content analysis to be effective, certain technical requirements should be met. First, the categories of classification must be clearly and operationally defined. Second, the objective of the study should be clear. Third, the information needs to be able to be quantified and finally, a reliable coder is necessary for consistency.

In this study *conceptual analysis* was adopted due to its simplicity by looking and coding at the occurrence of selected terms within the interview texts. In this method, the data were analysing in five major steps: transcription of information, categorisation of concept; generalisation; organising the coding process; and analysing the results. The reliability of a content analysis study according to Soetanto et al. (2002) refers to its stability, reproducibility and accuracy. The *stability* refers to the tendency for codes to consistently re-code the same data in the same way over a period of time, *reproducibility* refers to the tendency for a group of coders to classify categories membership in the same way, and *accuracy* refers to the extent of which the classification of a text corresponds to a standard or norms statistics. The coding errors can only be minimised and not eliminated completely.

Response rate

Table 1 shows the projects selected and interviewees involved in the case studies. For projects A, B and D, all the respondents participated and the interview went on smoothly. For project C, the main contractor refused to participate. For project E, the quantity surveyor and the first contractor rejected this exercise totally despite many calls and attempts made for the interview arrangements. On project F, the client avoided the interview request.

The respondents for project A had an average construction experience of 8 years; Project B of 20 years; Project C of 16 years; Project D of 17 years; Project E of 18 years and Project F of 17 years. The majority of them held senior positions in their firm. In addition, the interviews were conducted among various project stakeholders within the case and thus give us some confidence that the responses are representative.

Table 1: Sample of Projects and Respondents

Projects/Interview Respondents	Project A (Hostel Buildings)	Project B (Health Centre)	Project C (College Buildings)	Project D (Sport Centre)	Project E (Corporate Headquarters (Re-Tender)	Project F Academic Buildings (Re-Tender)	Total
Client	√	√	√	√	√	X	5
Architect	√	√	√	√	√	√	6
C & S Engineer	√	√	√	√	√	√	6
M & E Engineer	√	√	√	√	√	√	6
Quantity Surveyor	√	√	√	√	X	√	5
Contractor 1	√	√	X	√	X	√	4
Contractor 2	N/A	N/A	N/A	N/A	√	√	2
Total	6	6	5	6	5	6	34

Note: N/A: Not applicable

Most of the projects listed in Table 1 are procured based on conventional type lump sum contracts with the exception of projects A and E. Project A used a 'Turnkey' form of procurement system by means of selective prequalification, while project E was initially a conventional lump sum contract but after it was re-tendered; the selection of contractor was done by negotiated tendering process. The overall project values are in the range of MYR 5.1M (£0.78M) to MYR 30.9M (£4.75M) indicating that these projects are registered under the Class A (no limit to the value of work that the contractors under this category are eligible to tender) and Class B (allow contractors to tender for projects of value greater or equal MYR 5M but less than MYR 10 M) of Construction Companies. The contract sum for Project A is RM 6.6M (£1.01M); Project B is RM 5.2M (£0.8M); Project C is RM30.9M (£4.75M); Project D is RM 16.9M (£2.6M); Project E is RM 25.3M (£3.89M) and Project F is RM5.3M (£0.81M).

4. RESULTS AND DISCUSSION

Usage and integration of process improvement

Table 2 shows the usage and the integration of process improvement programmes in construction project development in Malaysia. The results of the case studies show that out of seventeen types of process improvement areas listed, *briefing the team, brainstorming session and regular meeting* are most used with 71% score (24 out of 34), followed by *information and communication technology (ICT)*, *standardisation and pre-assembly*, *health and safety*, and *choice of procurement routes for construction*.

The fact that *briefing the team* was selected as the most important of process improvement area is evident in all the six cases with the exception of Project B. The possible reason for the selection is that *brainstorming session and regular meetings* are included in the phrase apart from *briefing the team.* These two components that Tan (1996) regarded as technical and administrative requirements are essentials to project management activities.

Table 2: Case Studies-Process Improvement Areas

	PROCESS IMPROVEMENT AREAS	PROJECTS						Total score
		A (N=6)	B (N=6)	C (N=5)	D N=6)	E (N=5)	F (N=6)	
1.	Briefing the team, brainstorming session & regular meetings	5	3	4	4	4	4	*24*
2.	Information & communication technology (ICT)	5	3	3	3	5	4	*23*
3.	Standardisation & pre-assembly	4	2	3	1	3	4	*17*
4.	Health and Safety Programmes	3	3	1	3	2	1	*13*
5.	Choice of procurement routes *(Design & build, Built-Operate-Transfer (BOT), Built-Operate Own (BOO), Turnkey, Management Contracting, Project Management Consultants (PMC), etc.*	6	-	1	-	3	1	*11*
6.	Integrated of Design & Construction	4	-	-	-	-	-	*4*
7.	Value management/value engineering	-	1	1	1	-	-	*3*
8.	TQM/QA	-	-	1	-	1	-	*2*
9.	Supply-chain management	-	1	-	-	1	-	*2*
10.	Benchmarking	-	-	-	-	1	-	*1*
11.	Collaborative arrangements *(Joint-venture, Partnering, Private-Finance Initiative (PFI), Public- Private Partnership (PPP), etc*							
12.	Risk management							
13.	Whole life Costing							
14.	Sustainable construction							
15.	Lean Construction							
16.	Culture and people							
17.	Product Development							

Information and Communication Technology (ICT) is ranked second with the total response rate of 68%. Detail investigation shows that advances in ICT are seriously being implemented in the government projects of Malaysia although this is not high compared to the private sector experience (Takim et al. 2003). The designing and estimating routine activities and processes are now regularly undertaken using computer technology. Nevertheless, the interviewees reported that construction project bidding through internet is still not widely used and if used at all, it is mainly for overseas projects and not for local projects. A study conducted by Mui et al. (2002) confirmed that businesses in the Malaysian construction industry are now utilises ICT in their business communication but reported that only 16% of the respondents in Malaysia were involved in bidding for projects through internet. Reasons for this low usage level could include security of data, difficulty to sieve information, and lack of confidence and working experience of the system. Nevertheless further research is required to confirm this.

Standardisation and pre-assembly is ranked third in the case studies with the total response rate of 50% (17 out of 34). The use of standardisation in design and product according to CBPP (1999), does not limit the scope for design innovation and one of the crucial benefits is to increase project efficiency and shorting lead time. At the same time, pre-assembly can help to ensure high quality standards although it requires more time at the initial project stage. In Malaysia, the concept of standardisation and pre-assembly could be associated with modular co-ordination and the Industrial Building System (IBS). Structural components are manufactured in a factory (on or off site), transported and assembled into a structure or building with minimal additional site work (CIDB, 2001c). These systems are currently being initiated and encouraged by CIDB Malaysia through workshops, seminars and standard manuals. Many construction projects in Malaysia are now considered for these systems of construction. All the case study projects, particularly Projects A and F used some elements of this process improvement.

Ranking in the fourth position is *health and safety* with the total response rate of 44%. Health and safety initiatives have now become a priority process improvement area by many contractors in Malaysia. The need to ensure a construction site is safe for workers and the general public is part of the government message for the construction industry in Malaysia (CIDB, 2000).

The fifth factor is the *choice of procurement route* for construction with the total response rate of 32%. 'Turnkey' contract following pre-qualification exercise was selected for Project A, while 'traditional' procurement with 'direct negotiation' was used for Project E, after the project was determined. The procurement route selected for Project F was 'traditional' based on 'open competitive' tendering procedure; the contract was terminated half way due to the failure of the first contractor to deliver the work according to the contract provisions. Most of the consultants were unhappy with the decision of the project client to have adopted this traditional procurement method at the initial stage. Nonetheless, they failed to convince project client about the consequences of the choice for the project because project client seems to be too fanatic with the belief (irrespective of the nature of the project) that this method is most useful to resolve the issues of fairness to all reputable contractors.

Two other process improvements that are less considered across the six cases by the interviewees are *Total Quality Management (TQM)/Quality Assurance (QA) and Collaborative arrangement.* Results in Table 2 shows that TQM/QA was implemented in Projects C and E but not on the other remaining four projects. The possible explanation is that although contractors in Malaysia have awareness, TQM/QA concept in construction, full implementation of the concept is perhaps at an infant stage. The results suggest that TQM/QA concept is not currently being seriously integrated into project development by many contractors and subcontractors in Malaysia. In case of Project C, the interview undertaken suggests that although ISO concept was used by project architect for the decisions whether to accept or reject materials brought to the site for quality assurance and quality control on site, the contractor and subcontractors failed to follow the requirements. The contractor is Class A Construction Company. This suggests that if TQM/QA could not be integrated into a project by a contractor of this calibre, more difficulties could be expected in implementing TQM/QA by small and medium size construction companies.

The fact that the interviewees on the six case projects did not mentioned *collaborative arrangement* may suggest that no form of alliance is implemented on the projects. However, this does not mean that *collaborative arrangement* is not sought by the government sectors in the delivery of construction projects in Malaysia. According to Price (1996), the most popular form of public and private sector collaborations in Malaysia is Build-Operate-Transfer (BOT). For instance, the North-South highway government projects were implemented using BOT through a concession period of 30 years after which the projects will revert to the Government at no cost.

Apart from the five process improvement areas, *commissioning and training programmes to users and maintenance operators* is repeatedly reported by the interviewees across the six cases with a total response rate of 38%. The need for this area to experience improvement is because users occupy the completed buildings and make use of the facilities; thus, it is practical and sensible for them to have a proper knowledge of the way the facilities are operated and maintained.

The interviewees did not mention integration of value and risk managements, supply chain concept, bench marking, whole life costing, lean construction, sustainable construction, and product development as areas of process improvement in the development of the six academic projects. Although the investigation is limited to six academics projects of UiTM (i.e. the same client organisation in which the projects were implemented based on the same missions, objectives, policies and political consideration), the results could be generalised to other government projects in Malaysia. The basis for the generalisation is that all government sector projects in Malaysia receiving funding and adhere to the similar policies under the 5-year Malaysian Plan with regards to the physical construction project development. The policies are prescriptive in a way construction projects are implemented in Malaysia.

In addition, value and risk management, supply chain, benchmarking, lean construction, sustainable construction, and product development concepts are very still rhetorical in the government and public organisations circle in Malaysia due to lack of sufficient knowledge of these management tools by those engaged in the delivery of projects at the public sector level. For instance, the interview with Development Division of UiTM respondents shows that the University is reluctant to integrate these areas in order to minimise the total development cost of projects. This is very misleading and this level of ignorance on these improvement areas can lead to negative impacts; in relation the need to achieve such client objectives for as: 'value for money' and 'client satisfaction with product development'. This may suggest that although the development division of UiTM is regarded a repetitive client and used to development of multi-millions physical projects of UiTM, continuous improvements (CI) and learning cycles concepts (as suggested by Bessant et al. 1994) are not one of primary concern of the department.

Reasons for integrating process improvement

The second part of the questions addresses the reasons for integrating process improvements on the six projects. Table 3 shows the reasons extracted from the interview. About 62% (19 out of 34) of the respondents indicated that process improvements are needed in order to deliver projects on *time, within budget and of good quality,* 55% wanted to *improve on project performance*, and for 26% are for *meeting client's/user's satisfaction*. These outcomes suggest that majority of the construction professionals in Malaysia are aware of the benefits of process improvements in construction. However, this does not suggest that they have sufficient knowledge on how to deploy the procedures and how behavioural patterns could generate improvements as pointed out by Samuelsson, (2003).

5. CONCLUSION

It is undeniable that process improvements in construction should be continuous and has a major impact on the way construction business is conducted, particularly for government and public sector organisations that are known generally for inefficiency and poor performance. The interview findings of project stakeholders involved in six case projects in Malaysia revealed that *briefing the team, brain storming and regular meetings* and the use of *ICT* are the most popular process improvements in the development of construction projects within the government sectors of Malaysia.

Table 3: Reasons for Integrating Process Improvements in Construction Projects

PROCESS IMPROVEMENT AREAS		*PROJECTS*						*Total score*
		A *(N=6)*	***B*** *(N=6)*	***C*** *(N=5)*	***D*** *N=6)*	***E*** *(N=5)*	***F*** *(N=6)*	
1.	Briefing the team, brainstorming session & regular meetings	5	3	4	4	4	4	*24*
2.	Information & communication technology (ICT)	5	3	3	3	5	4	*23*
3.	Standardisation & pre-assembly	4	2	3	1	3	4	*17*
4.	Health and Safety Programmes	3	3	1	3	2	1	*13*
5.	Choice of procurement routes *(Design & build, Built-Operate-Transfer (BOT), Built-Operate Own (BOO), Turnkey, Management Contracting, Project Management Consultants (PMC), etc.*	6	-	1	-	3	1	*11*
6.	Integrated of Design & Construction	4	-	-	-	-	-	*4*
7.	Value management/value engineering	-	1	1	1	-	-	*3*
8.	TQM/QA	-	-	1	-	1	-	*2*
9.	Supply-chain management	-	1	-	-	1	-	*2*
10.	Benchmarking	-	-	-	-	1	-	*1*
11.	Collaborative arrangements *(Joint-venture, Partnering, Private-Finance Initiative (PFI), Public- Private Partnership (PPP), etc*							
12.	Risk management							
13.	Whole life Costing							
14.	Sustainable construction							
15.	Lean Construction							
16.	Culture and people							
17.	Product Development							

In addition to these two process improvement strategies, *Total Quality Management/Quality Assurance Systems* are implemented in the government sector construction projects. Nonetheless, the use of these three process improvement areas is considered low compared with the private sector utilisation of process improvement strategies. Other important improvement areas identified in the case projects that were studied are *standardisation and pre-assembly* and *Health and Safety.* These two process improvement areas have developed in Malaysia to the extent that they now have their own operational framework and procedures. However, process improvement programmes in relation to supply chain, value and risk management and benchmarking are still new to the industry; hence they are not being deployed on projects. Obviously, these new strategies for process improvement in construction will need robust framework to assess and measure their performance on construction projects in Malaysia.

Despite the overwhelming supports from Government and construction consultants that the integration of process improvements are needed in order to deliver projects *on time, within budget and of good quality; and to improve on project performance,* government organisations are reluctant to implement the improvement strategies in the delivery of public sector projects. The Construction Industry Development Board Malaysia could have some role to play to sensitise government official in Malaysia responsible for construction project procurement through appropriate training on the various process improvement programmes in construction and the procedures for their implementation. This is important if government sector is going to champion the campaign for continuous improvement and efficiency of the Malaysian construction industry given that the government sector is the major client of the industry.

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A QUESTIONNAIRE STUDY ON PROJECTS IN THE CONTEXT OF BEST VALUE TOWARDS THE APPLICATION OF VALUE MANAGEMENT IN THE UK PUBLIC SERVICE SECTOR

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Abstract: Value management (VM) has been developed, applied and has reached maturity in the UK manufacturing and construction industries but its use within the service sector has been infrequent. This paper reports on doctoral research which investigates the application of value management in the public service sector and addresses the primary research question; 'Can value management be applied effectively and successfully to Best Value projects in the public service sector?' The research proposition is that value management is a service which can maximise the value of government services to achieve Best Value.

The research examines the procurement and management projects in local government within the context of Best Value and reviews local authority projects, project management tools, quality schemes, best practice and benchmarking practices. The results of a web-based questionnaire, distributed to all local authorities in Scotland to supplement; information gained from a literature review on Best Value and projects, and a previous research project on online learning in local government focussing on project management will be discussed. The output of this research will conclude on the procurement and management of projects in Scottish local government. This will address such issues as project stages and tools used to support project work.

Keywords: Best Value, local government, projects, value management

1. INTRODUCTION

Value management (VM) has been successfully applied in both the manufacturing and construction industries (Kelly and Male, 2002); however, application outside these two areas has been limited. This has presented an opportunity for doctoral research to investigate the application of value management to public sector projects, at an opportune time, in parallel with implementation of the Scottish Best Value legislation. This research defines value management as being 'an innovative project focussed service conducted in a workshop environment with the aim of adding value to a project to support continuous improvement.' This implies that if there is a project with a willingness to add value then VM may be applied.

Best Value is an emerging context for local government in improving the quality of public services, adopting the view that what matters is what works whether this is a service provided internally within the local authority or externally using a private, voluntary organisation or another local authority. It was introduced in 1997 by the Labour Government who made a manifesto pledge to abolish Compulsory Competitive Tendering (CCT) and introduce a new regime of Best Value.

2. BACKGROUND ON THE RESEARCH AREAS

The three key areas of this PhD research (value management, Best Value and projects) are illustrated in the Venn diagram in Figure 1. Value management is the area of research that is being developed with the incorporation of the public service sector as a new industry sector for the application of value management. The focus is also on Best Value due to the timeliness of its introduction as a statutory duty in Scotland in 2003 which recognises that value management and Best Value have similar objectives. And finally, projects because value management is a project focused service that relies on various interventions within the project life cycle.

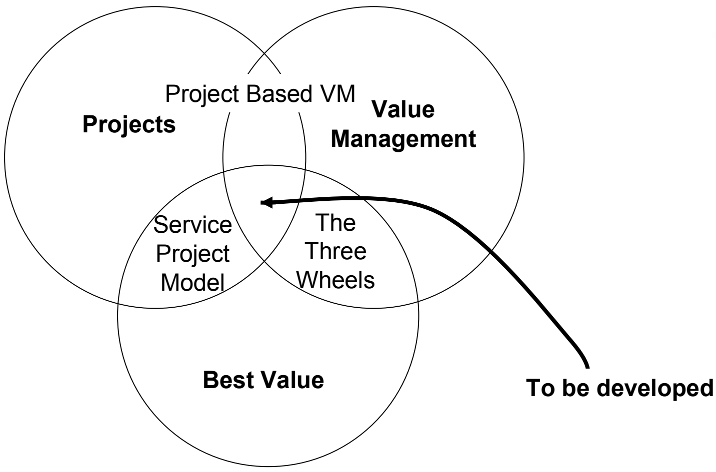

Figure 1 – Venn Diagram: Public Sector Implementation of Value Management

Value management has variously been applied in workshops to improve particular aspects of the project such as; operations and communications amongst the project team, partnering relationships, development of best whole life design solutions and procurement routes, the development of bid proposals, to aid the briefing process in client organisations, and the exploration of scope for business development. This scope for application highlights the diversity of the VM methodology and it should be noted that the types of application outlined are not all specific to the construction industry and could have been initiated elsewhere, such as in the public service sector.

Value management relies on interventions in the project life cycle. Male *et al.* (1998) highlighted six value opportunities in the project life cycle of a typical construction project that were derived through a benchmarking study, discovered to be the most common points in the application of value management in a construction project. This is primarily designed for use in construction projects and is therefore not suitable for use in this research for local government service projects. This led to the development of a generic project model applicable to service projects; 'The Three-Stage Project Model' (Hunter and Kelly, 2003b) which was to be further developed following analysis of the questionnaire results. The model as presented in the questionnaire is shown in Figure 4 and the developed model complete with VM opportunity points derived from analysis of the questionnaire results is shown in Figure 5.

A logical review of tools and techniques and measurement tools currently used in local government resulted in the service focused approach to the measurement of Best Value, termed; 'The Three Wheels of Best Value' (Hunter and Kelly, 2002). This was constructed from a review of government literature and tested through a case study. The research allows for a robust case to be made to the effect that value management is a service which can maximise the value of government services to achieve Best Value. 'The Three Wheels of Best Value' shown in Figure 2 includes a VM approach to achieve Best Value and to support continuous improvement. This research concluded that a process entitled; 'The Three Wheels of Best Value' is a logical framework that may be applied in local government to permit a practice of continuous improvement and to provide a system that may be adopted as the foundation for the measurement of Best Value.

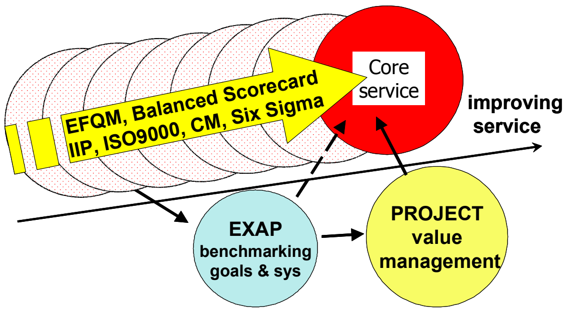

Figure 2 – The Three Wheels of Best Value

The framework illustrated its measurability by outlining a three-stage process that adopts a variety of methods to assess service effectiveness. Quality schemes are adopted in wheel one, which are used to assess the authority's score in achieving its objectives. In wheel two, benchmarking is conducted to monitor the service effectiveness in comparison to others. And in wheel three, robust KPIs are constructed that are fed back into the authority's core business in wheel one. The framework works as a continual measurement process to evaluate Best Value in the authority to ensure a practice of continual improvement.

3. THE RESEARCH AIMS AND OBJECTIVES

The paper addresses the primary research question; 'Can value management be applied effectively and successfully to Best Value projects in the public service sector?' The research proposition is that value management is a service which can maximise the value of government services to achieve Best Value. Value management is currently not well associated with the public sector and there are very limited publications in this area (Bone, 1993; Bone and Law, 2000; Bone and Robertson, 2003; Kelly and Male 2002). The literature review identified gaps in the knowledge of projects in local government; this research aims to fill these gaps.

To answer the research question, the secondary objectives specific to the questionnaire survey are:

(a) To determine the extent to which value management can support Best Value in local government.
(b) To develop an outline of what kinds of local government projects may be susceptible to the value management methodology.
(c) To determine the likely opportunity points for use of value management in a service and construct a new project model indicating the service value opportunities.
(d) To evaluate existing approaches to managing a project in the context of a service in local government.
(e) To collate the tools and techniques that may be used in a typical local government project and test on a local authority.

These objectives will be satisfied through the questionnaire survey which is the focus of this paper.

4. THE QUESTIONNAIRE

The purpose of the questionnaire is to examine projects in local government within the context of Best Value by investigating how local authorities in Scotland manage and define their projects. This involves research of local authority projects, project management tools and quality schemes used, as well as an exploration of best practice and benchmarking practices. The questionnaire was distributed to all local authorities in Scotland by email and post using contacts from the CoSLA (Convention of Scottish Local Authorities) Improvement Service, and supplements information gained from a literature review on Best Value and a research project conducted in 2002 on online learning in local government which focussed on project management (http://www.cosla.gov.uk/). The output of the research questionnaire will conclude on the procurement and management of projects in Scottish local government. This will address such issues as project stages and tools used to support project work.

4.1 Questionnaire Distribution

The questionnaire was initially sent by email prior to being distributed by post as it was considered the fastest and most cost-effective method for the targeted area which has a large coverage geographically and therefore rules out the interview as a possibility. Other methods considered were use of a web-page survey. However, difficulties were anticipated in attracting potential respondents to a website, therefore, this was disregarded as there may also be a tendency for people to quit in the middle of a questionnaire and thus fail to complete it. In addition to this, previous research work in local government found that local authority employees are 'timed out' (http://www.cosla.gov.uk/) when on the web and so only have limited time to spend on-line. All potential respondents were contacted by telephone first during the last week in May 2005 and given a background on the research study before questionnaires were distributed. E-mails were sent following initial telephone calls and postal questionnaires were then distributed during the first week in June. Responses were invited to be returned within two weeks. The questionnaires were accompanied by a

covering letter which detailed the study objectives, the reason for the study, by whom the study was conducted and gave confirmation of confidentiality.
To increase the response rate, respondents were asked whether they wanted to nominate other suitable persons to assist in the study and the questionnaire included the benefit to local authorities participating in the study and offered a copy of the final report upon completion.

The questionnaire was distributed to all thirty-two Scottish local authorities and has targeted those at a corporate level who oversee project management and the implementation of Best Value across the different service areas. Contacts for the questionnaire were sourced from the Improvement Network at CoSLA with the exception of four local authorities who were not part of the network. Contacts from these local authorities were identified from the corporate section of their website. The roles of respondents varies across local authorities from policy officers to service improvement managers, performance operations managers, strategic planning managers, and Best Value managers but all essentially have similar roles within their respective local authorities. The major limitation with the use of the questionnaire is that the researcher has little or no control over who completes it. However, a prior investigation ensured that the relevant person(s) was targeted in each local authority by locating their correct contact details and address which reduced the chances of the questionnaire being passed on. The fact that all respondents were contacted prior to receiving the questionnaire helped to ensure that the correct people were targeted and most completed their contact details at the close of the questionnaire which confirmed who they were.

4.2 Questionnaire Structure

The questionnaire is structured, containing a mix of closed and open questions. Although this mix is used, the closed questions are accompanied with open questioning to allow further explanation preventing restriction to a set of options. It was considered that a qualitative method would explore participants understanding of the subject area and more could be gained by finding gaps in the data. The quantitative data in the form of closed questions were included in the questionnaire to supplement other information and to test assumptions produced in the literature review.

The survey is of a cross-sectional nature which means that the information was collected at the one time to ensure that authorities were targeted in the same time frame and changes introduced through legislation or by other means did not affect the results as they would do if the survey was conducted over a longer time period. Questions were derived from a review of projects and their characteristics as well as local government literature. A pilot study for the questionnaire survey was conducted to ensure that the survey questions were appropriate and made sense to the target group. Denzin *et al.* (1998) highlights that there is a high degree of unpredictability and so a pilot study is a good means to add value to the research. Modifications were made as a result of the pilot study which improved the clarity, structure and presentation of the questions.

4.3 Questionnaire Analysis

Due to the small data set (thirty-two local authorities) the results were analysed manually. Strauss and Corbin (1998) describe the process of analysis as, 'the interplay between the researcher and the data.' Creswell (1994) highlights that there is no one right way to analyse the data and therefore the method that is most suited to the data at hand has been chosen. The measurement instrument will be the extent of agreement or disagreement with the questions relating to each of the four areas (1) projects, (2) project management tools, (3) Best Value, (4) best practice and benchmarking. The questions that permit an open response, depending on the type of response were recorded and compared with others.

5. QUESTIONNAIRE RESULTS

The questionnaire results are representative of thirty-one (31) local authorities out of a total possible thirty-two (32) giving a response rate of 97%. It should also be noted that the questionnaire was sent to forty-eight (48) local authority members from roles such as policy officers, service improvement managers, performance operations managers, strategic planning managers, and Best Value managers. Thirty-three (33) responses were received in total giving an overall questionnaire response rate of 69%.

Two local authorities chose to opt out of completing the questionnaire due to the following comments;
"We are a large and diverse authority… we have a range of approaches to project management… it would not be possible to give you some of the definitive yes /no responses as they would not accurately reflect the range of practice and approaches."
"We have a distributed management structure and no corporate approach… our authority is so diverse and there is no common approach. I cannot complete the questionnaire from a corporate or a departmental service level as the responses would have to be both yes and no."
These comments also reflect some of the other local authority responses where respondents have highlighted in the open questioning that there is diversity, the approach varies and there is not a consistent approach.

The questionnaire results are reported under the following four sections; (1) Projects, (2) Project Management Tools, (3) Best Value, (4) Best Practice and Benchmarking.

5.1 Projects

The first part of the questionnaire explores projects and seeks to discover if there are any project models used in local authorities as a framework for project direction. There is no report of any such project framework in the literature. Respondents were asked what project stages in 'The Three-Stage Project Model' they are familiar with, what stages need more time spent in their particular department and which project stages involve most problems. This will inform the VM 'opportunity points' in 'The Three Stage Project Model' (Figure 4). This section on projects determines if local authorities have a standardised project management approach, if project managers are employed for each type of service provision e.g. education, social work, leisure services etc. and identifies typical project constraints such as communication, unrealistic timescales and budget.

The first question asked how respondents would define a project to identify their level of understanding in relation to projects. 53% of respondents gave a satisfactory definition and 20% made reference to the PRINCE / PRINCE II definition. PRINCE stands for **Pr**ojects **in C**ontrolled **E**nvironments and is a project management method covering the organisation, management and control of projects (http://www.prince2.com). Throughout the questionnaire many references have been made by respondents to PRINCE highlighting its popularity.

Local authorities were asked to indicate what statement best describes project work in their authority. 46% of local authorities felt that they had a well thought out plan to project work compared to 54% who indicated that an ad-hoc approach is taken.

In response to use of project management models, it was discovered that 58% of respondents use PRINCE and 42% do not use any models. Local authorities were also asked whether they had a standardised project management approach; 43% do and 57% do not. Four local authorities made specific reference to the PRINCE methodology.

Respondents were asked if there were designated job roles for project leaders, 48% said no and 52% said yes. However, although this was a closed question there was some elaboration evident in the following remarks;
'Project managers are identified as required'
'We have no full time project managers'
'The individual undertakes their day job in addition to project management duties'
'It varies across the council'
Also asked was whether people were specifically employed as project managers; 21% said no and 79% said yes. Again, this was another closed question but some respondents elaborated and mentioned that this was only a temporary arrangement / secondment, or for certain jobs / short term contracts.

In a previous research project (http://www.cosla.gov.uk/) which involved setting up an online forum on project management, an area explored was the issues leading to problematic projects and what made projects a success. These issues were identified and reinforced through a literature review before being incorporated into the questionnaire. In total, ten constraints were identified that are common in projects. It is clear from the graph in Figure 3 that local authorities were familiar with all of them particularly resistance to change, budget constraints and unrealistic timescales which were ranked in the top three.

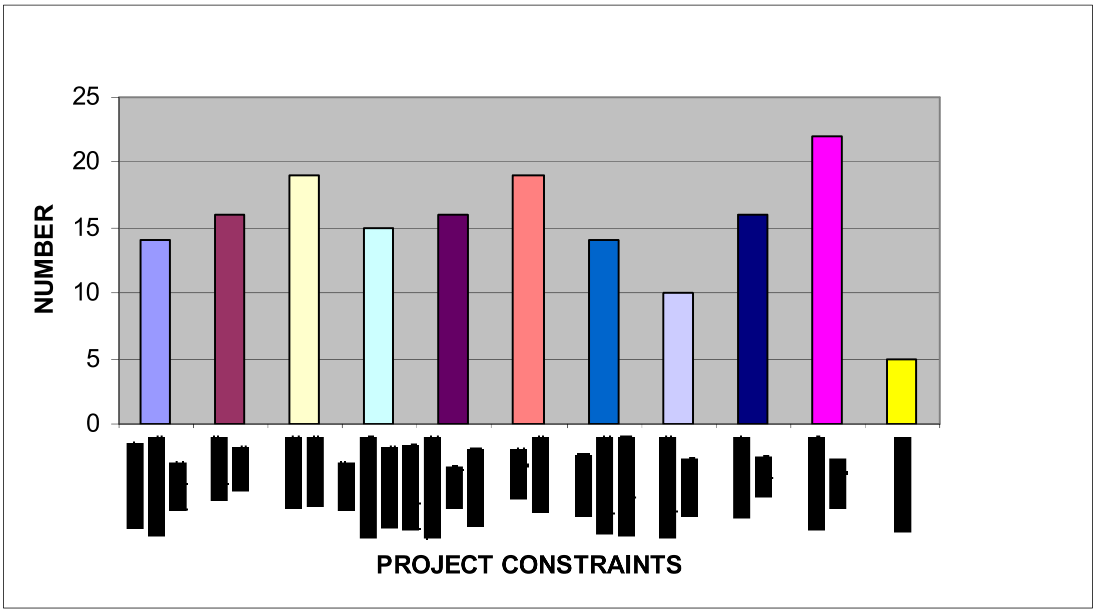

Figure 3 – Project Constraints (Source: Questionnaire Survey)

A review on projects highlighted a number of generic project stages that have been structured into; 'The Three-Stage Project Model' shown in Figure 4. The three stages can be described in broad terms as, the Pre-Project stage which is primarily discussion and paper based involves users and planners (Nicholas, 2001) and concludes with the termination of the pre-project stage when full budgetary approval is given. This signifies the point when the initial concept becomes an identifiable project known as 'project initiation' (Woodhead, 2000). The Project stage where a practical start is identifiable involves designers and builders (Nicholas, 2001). Finally, the Post-Project stage where the project is absorbed into the organisations core business involves users and operators (Nicholas, 2001). Respondents were asked to indicate their familiarity with project stages as shown in Figure 4 by checking box 1 if they were familiar with the project stage, box 2 to indicate which project stages need more time spent in their department and box 3 to indicate which project stages involve most problems.

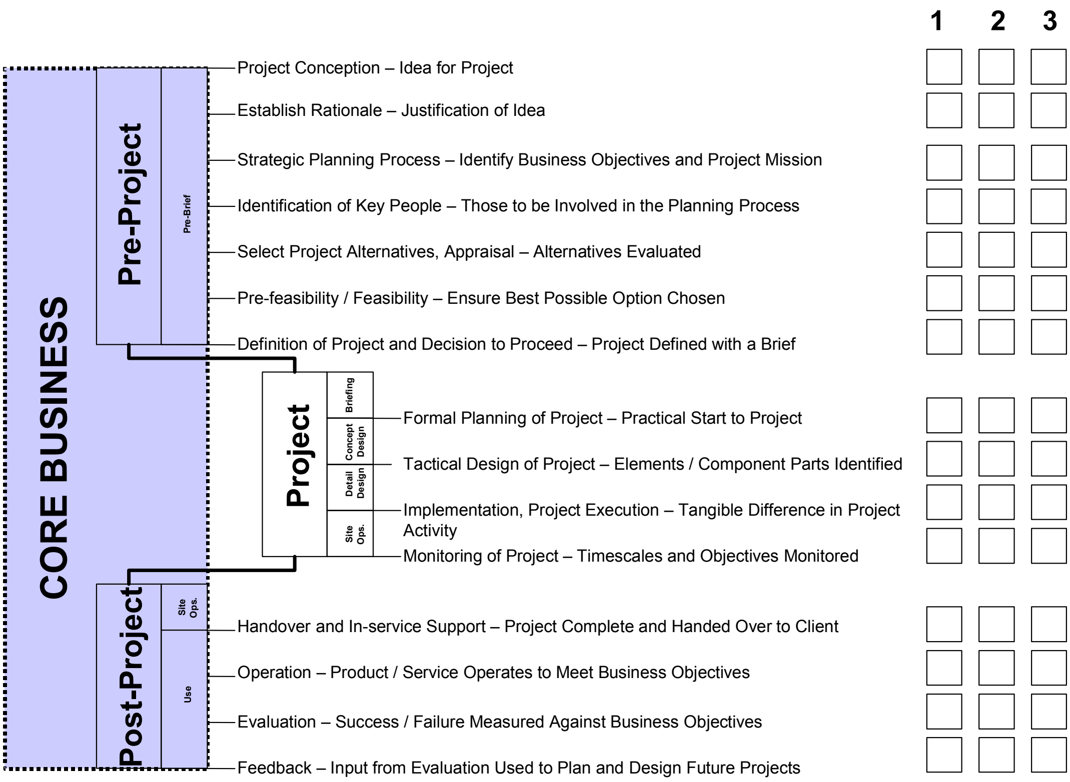

Figure 4 – The Three-Stage Project Model as Presented in Questionnaire Survey

It was clear that the majority of respondents were familiar with all project stages; however in the pre-project stage, the two least familiar stages were; select project alternatives and pre-feasibility / feasibility. In the project stage there was a high degree of familiarity, and in the post-project stage, the three stages; handover, operation and feedback had a low degree of familiarity indicating that little consideration is given to this final stage where the project is absorbed into local authority core business. Concurrently, it was discovered that in the pre-project stage, the same two stages; select project alternatives and pre-feasibility / feasibility were highlighted as requiring more time and were identified as the stages where most problems exist. In the project stage, respondents indicated that more time should be spent in the tactical design of the project. In the post-project stage, it was indicated that more time should be spent on evaluation and feedback and that most of the problems occurred undertaking the evaluation stage.

5.2 Project Management Tools

This part of the questionnaire asked whether local authorities use any project management software to guide their projects such as; Microsoft Project 2000, PACE (Projects in a Controlled Environment) and PRINCE which have been listed in the literature as tools for local authority use. The purpose of these tools is also examined such as whether they are for planning, monitoring, reporting, collating information, or indeed all of these. This section also determines whether software is chosen to suit the project or alternatively if project templates are moulded to suit the project.

The most common project management system in use was Microsoft Project 2000 used by 80% of local authorities, although principally for planning and monitoring only. PRINCE / PRINCE II was the next most common, used by 53% of local authorities and found to be used across the board for planning, monitoring, reporting, and collating information. Gantt Charts were also popular, used by 47% of local authorities and also used for all four mentioned functions. 20% of local authorities mentioned six other systems in place within their local authority.

Respondents were asked to indicate on the basis of their use of project management software whether project teams followed the template or if templates were moulded to suit the project team. It was discovered that the majority; 41% of local authorities moulded templates to suit the project team. 26% of project teams followed the template and the rest were either unsure or stated that it varied across the local authority.

In a previous research project (http://www.cosla.gov.uk/) which involved setting up an online forum on project management an area explored was approaches to project management in the workplace. It was clear that there was not a consistent approach to project management across local authorities. The following comments were made;

- *"There is no standardised project management approach."*
- *"An ad-hoc approach is taken."*
- *"Meetings are used to discuss the progress of projects; however, there is no current policy to use project management tools or systems."*
- *"There is no plan, process or system for managing projects, we do the job and sort out problems if they arise."*
- *"I am unaware of formal project management systems. We are using meetings to work on a current project as I feel direct communication is most effective."*
    - *"A central logging system would have been useful for a previous project where there were overlaps with other departments."*

5.3 Best Value

In the Best Value section, respondents were asked for their opinion on whether a Best Value Review is a project in its own right allowing a judgement on whether the value management approach could be applied in a review. The management tools used to support Best Value are questioned to determine what is in line with the Three Wheels Framework (Figure 2). These are items such as a PEST analysis, SWOT analysis and meetings. The survey explores the usage of tools outlined in the Three Wheels framework; local authorities are asked if they use the EFQM Business Excellence Model, Balanced Scorecard, Six Sigma, Investors in People, Charter Mark or ISO 9000 and how these quality schemes assist in Best Value Reviews.

Respondents were asked from four statements to indicate what best describes the resulting action plan from a Best Value Review. The purpose was to reveal how effective the current situation is with regards to reviews and presents an opportunity to test the techniques used for a Best Value Review in terms of effectiveness. It may result in the VM approach being a suitable option for a Best Value Review. This question is further supported by querying if roles are defined for the operational responsibility of the project in core business following the review. At the close of a VM study this part of the process would be assured supporting the case for a VM approach to Best Value Reviews.

When asked whether a Best Value Review was considered to be a project; 93% of local authorities agreed. Local authorities were also asked what management tools are used to support Best Value, the following results were found; meetings (87%), workshops (81%), SWOT analysis (71%), PEST analysis (61%). It was clear that most local authorities use a combination of methods. Other tools listed by local authorities and mentioned more than once were; consultation / stakeholder analysis, benchmarking, option appraisal, process mapping / gap analysis, scorecards, performance management, EFQM, and in-house guidance for conducting strategic and management reviews.

Likewise, local authorities were asked what quality tools they use, the following results were found; Investors in People (81%), ISO 9000 (77%), EFQM (71%), Charter Mark (55%), Balanced Scorecard (52%), and Six Sigma (6%). Other tools mentioned were specific to particular service areas within the local authority. Local authorities were asked if the use of quality tools assist in Best Value Reviews, 74% said they do and 26% said they do not. 30% of the local authorities that use quality tools to assist in Best Value Reviews specifically mentioned that the tools support reviews in highlighting gaps / areas / issues to be addressed. Other reasons offered for their use were to satisfy continuous improvement, for analysis, to address the four C's of Best Value (challenge, compare, consult and compete) and to strengthen skills.

Local authorities were asked to select from four options what statement best describes the resulting action plan from a Best Value Review. A breakdown is given; (1) A simple straight forward plan which is implemented to improve the service (25%), (2) Very supportive in outlining what improvement actions have to be taken, the people to implement and the timescales for completion (46%), (3) Moderately supportive by providing some information that outlines plans for improvement (25%), (4) Not supportive in taking action to improve the service (4%). It is clear that almost half of local authorities believe that their Best Value action plan is very supportive.

Local authorities were asked how their action plans were implemented. It was evident from the response that there are many similarities in how this is done. Most local authorities have a planning system in place which was referred to either as a service plan / improvement plan / performance plan / operational plan. Also referred to was the particular role of the person in charge of implementing this plan; the lead officers / responsible person / service manager. However, two local authorities stated that action plans were implemented *'badly'* and one stated that it was *'hard work.'*

Similarly, when asked how progress was monitored, many local authorities mentioned this was done through committees / boards / management teams. They also made reference to monitoring progress against performance improvement plans / service plans or through a performance management system. Again, the same two local authorities stated that progress was monitored *'badly'* and only *'sometimes.'* In addition, local authorities were asked how progress was reported which was similar to the response for how it was monitored; to a committee / board / management team and using a service plan performance report or through the performance management system / framework. Timing of reporting varied between local authorities with some reporting annually and others biannually.

5.4 Best Practice and Benchmarking

In the final section of the questionnaire respondents were asked if their local authority has used workshop based value management techniques, reviewed best practice data or conducted any benchmarking. These questions relate to the Three Wheels Framework and identifies the likely usage of the items within each of the Three Wheels. It was discovered that 28% of local authorities had used workshop based value management techniques.

The response to the use of best practice data revealed the following top five databases / sources used by local authorities; (1) Benchmarking, (2) Association for Public Service Excellence (APSE), (3) Improvement and Development Agency (IDeA), (4) Audit Scotland / Statutory Performance Indicators, (5) Professional Associations / Organisations.

In terms of how local authorities conduct their benchmarking, it was clear from the previous question that nine local authorities were members of a benchmarking club. In addition to this, other local authorities' benchmark with those that are similar, some mention that the approach varies dependent on the service and others mention various databases / sources.

6. QUESTIONNAIRE ANALYSIS

Only 53% of respondents gave an appropriate definition of a project by using words such as; resources, timescale, objectives and budget which suggests a lack of understanding of the components of a project amongst the other 47%. This could be as a result of only 58% of local authorities using a project management model and only 43% having a standardised project management approach. In addition to this, 54% of local authorities indicated that an ad-hoc approach is taken to project work. Value management is a project focussed management technique that may be used in public service sector projects and will particularly be of benefit to those projects requiring guidance and direction. The fact that the role of the project manager across local authorities tended to be a temporary, short term role may influence the approach to project management and the ad-hoc approach common in more than half of Scottish local authorities.

'The Three-Stage Project Model' explored familiarity with project stages, identified what stages problems existed, and the project stages where more time was required which resulted in the revised project model shown in Figure 5. Four value management opportunity points were identified. Two were located in the pre-project stage, however both of these stages; select project alternatives and feasibility which is the following stage, can be addressed in one VM study. The reason this was chosen as a VM opportunity point is that these stages were both identified as being least familiar, as stages where most problems exist and where more time requires spent. VM opportunity point two in the project stage was selected to address the requirement for more time in the tactical design of the project. The four stages in the post-project stage all required either a better degree of understanding to ensure successful absorption into local authority core business, were where most problems existed and were identified as stages where more time was needing spent. Therefore, two VM opportunity points have been located here to ensure the successful absorption of the project into local authority core business.

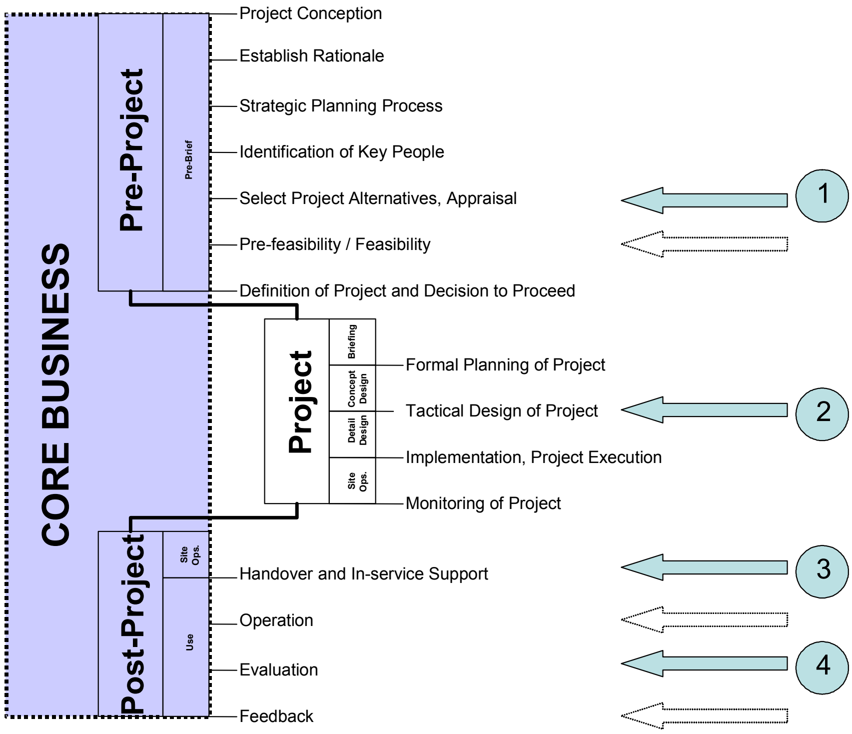

Figure 5 – The Three-Stage Project Model Adapted for the Public Service Sector

Almost all (93%) local authorities considered a Best Value Review to be a project. Value management is project focused and therefore can be used in a Best Value Review. It was also discovered that many management tools used to support Best Value; meetings, workshops, SWOT analysis, PEST analysis, are common in VM studies which are workshop based. The fact that local authorities are already using these tools would mean that VM would not be something entirely new to them. It was discovered that 28% of local authorities have actually used workshop based VM techniques. This suggests that there is some knowledge of the benefits of VM within local authorities but more would need to be done to ensure an adequate understanding on how VM may be used to support Best Value. Other tools mentioned by local authorities; consultation / stakeholder analysis, benchmarking, option appraisal, process mapping / gap analysis, scorecards, performance management, EFQM, and in-house guidance for conducting strategic and management reviews are all tools that are used and may be incorporated in the Three Wheels Framework. It was clear that local authorities use all the quality tools; Investors in People, ISO 9000, EFQM, Charter Mark, and the Balanced Scorecard with only a small minority using Six Sigma. 74% of local authorities agreed that quality tools assist in Best Value Reviews and almost a third specifically mentioned that the tools support reviews in highlighting gaps / areas / issues to be addressed.

It was evident that most local authorities have a planning system in place for implementing action plans. However, only 46% of local authorities described the resulting action plan from a Best Value Review as very supportive in outlining what improvement actions have to be taken, the people to implement and the timescales for completion. Two local authorities stated that action plans were implemented *'badly'* and one stated that it was *'hard work.'* The output of any value management study is an action plan, listing activities, timescales and people to implement. VM is a logical, systematic approach which will address these issues identified.

Local authorities monitor and report progress through committees / boards / management teams. This is similar to what goes on in the Three Wheels Framework where different teams at different stages monitor and report on how the local authority is performing. Again, two local authorities had stated that progress was monitored *'badly'* and only *'sometimes.'* Using a systematic approach such as VM will address this.

The questionnaire revealed the top five databases / sources used by local authorities for both reviewing best practice and benchmarking data. These will be incorporated into the Three Wheels framework to support Wheel two and the other sources may be listed as a reference to benefit local authorities.

This paper has reported on the questionnaire objectives, design and analysis, and the previous work involved in the doctoral research; 'The Three-Stage Project Model' (Hunter and Kelly, 2003b) and 'The Three Wheels of Best Value' (Hunter and Kelly, 2002). Other work has been carried out using grounded theory to determine commonality of project issues making the case for the application of VM in local government (Hunter and Kelly, 2003a; 2004). The final part of the doctoral research will be an action research study in local government using a value management approach.

7. CONCLUSION

There is a varied approach to how local authorities procure and manage their projects which was evident by the refusal of two local authorities due to the diverse nature of their authorities' and the response given by others in the open questioning. This was also supported by a previous research project conducted in 2002 by the research team which highlights a lack of consistent approach which is still apparent three years on.

The questionnaire study confirmed the use of tools and techniques currently used in the Three Wheels Framework and discovered other methods to promote a practice of continuous improvement and better project practice, particularly that of the PRINCE methodology that was discovered to be very popular amongst most local authorities. The Three Wheels Framework will be further developed in response to the questionnaire findings.

'The Three-Stage Project Model' is another model that has been further developed to incorporate a VM approach specific to the public service sector. When considering use of VM, local authorities may want to use this model to identify what stages of the project under consideration would value a VM approach. However, in terms of VM, local authorities need educated on the benefits of using such an approach as currently, less than a third of local authorities have used VM and this is unlikely to be collective local authority approach.

What is reassuring is that almost all local authorities considered a Best Value Review as a project supporting the case for VM being used in a review. In addition to this, most local authorities agreed that quality tools assist in Best Value Reviews which again brings the Three Wheels Framework into play which also incorporates VM to promote a more structured approach to managing projects / reviews.

To conclude this stage of research, the three streams of research in value management, Best Value and projects have shown that VM can be successfully applied in local government. Action research will be conducted to finally substantiate this. The Three Wheels Framework includes a VM approach and tools and techniques already used in local authorities to achieve Best Value, and 'The Three-Stage Project Model' is a generic model where VM opportunities for a service have been highlighted to improve project practice within local authorities.

Other work in the doctoral research includes the use of the grounded theory methodology that will derive a theory from the issues which currently suggests that similar issues regardless of project type re-occur and therefore the same tools and techniques associated with VM may be applied. The questionnaire has confirmed the research work to date in terms of the 'Three Wheels of Best Value' and 'Three-Stage Project Model' and the action research study using the VM approach for a local government service project is the next stage which will, it is proposed, reinforce this.

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PFI FOR THE DELIVERY OF SOCIAL HOUSING PROJECTS

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Abstract: The procurement of Social housing is not limited to provision of shelter to those who cannot afford to acquire it at market rate but its role extends to other areas such as social autonomy, unemployment, crime and sustainability. Traditionally this role has been the responsibility of government and local authorities. During the last thirty years the government's policy is to transfer as much risk as possible to the private sector and the sector's structure has evolved to include major private sector participation. PFI is one of the ways in which private finance was introduced into the sector. PFI schemes adopted so far have always included a measure of regeneration, crime reduction and sometimes provision of employment to tenants. This paper examines PFI schemes used in the UK so far and assesses the conditions under which these schemes operate. By investigating the types of packages used, risk allocation processes and related management issues the paper explains the potential for delivery and success as well as provide a framework for effective PFI into future social housing provision.

Key words: Private Finance Initiative, Procurement, Project management, Risk, Social housing.

1. INTRODUCTION

The aim of this paper is to critically appraise the structure of PFI contracts and how they can best be utilised for the successful delivery of social housing projects. The paper forms part of an ongoing research into PFI in social housing. The research is at a preliminary exploratory stage, and will be developed into a major case study in a social housing project. However for the purpose of this paper, public and private sector issued project documentation, government guidance notes and various PFI publications have been used to investigate contracts and their structure. Several interviews with participants in the first operational social housing PFI project, the Grove Village in Manchester have also been used to give the perspective of stakeholders. Interviewees include: local authorities (Manchester, Leeds), members of the SPV, lending body, public advisors on PFI (4Ps).

2. BACKGROUND

Shelter is a basic human need with wider implications not only on individuals but on society overall. Poorer health and education have been linked to poor housing as well as reduced labour mobility which can hamper economic development. The overlap between housing and socio economic problems is almost total. Despite its high cost and management problems social housing has proved a necessary and most cost effective tool to target those groups that tend to be marginalized and a heavy cost to society. Governments invest a huge effort in social housing in an attempt to integrate their diverse societies, reduce urban conflict in a situation of growing polarisation and make the best use of their scarce resources of land and buildings (OECD, 1988). Social housing is housing that is not provided for profit and at rates below market, it is allocated to those whose income does not allow them to let a house independently and is usually regulated by the state (Power, 1993).

Investment in social housing was traditionally financed through a combination of public sector borrowing and government subsidies that kept rents at low affordable levels. Government's programmes are known to have produced unwieldy and inefficient housing structures often as a response to an arising need and not planned within a strategic context. Large bureaucracies have often slow progress that only succeeded in providing large scale developments that did not respond to customers needs and only created further stigmatisation (Power, 1993). Most dwellings in the sector were and remain to be provided by local councils. Privatisation seemed the only way of attracting additional investment and tackling management problems.

ODPM (Office of Deputy Prime Minister) as a central government body responsible for the housing sector, has set decent homes standard as a target to be met by all local authorities in delivering social housing services. The Decent Homes Standards are in line with the sustainable communities' initiative which clearly indicates that sustainable communities need decent homes. A home is said to be decent if (ODPM, 2001):

- meets the current statutory minimum standard;
- is in reasonable state of repair;
- has reasonably modern facilities and services; and
- provides a reasonable degree of thermal comfort

Surveys in 1997 have revealed a £19 billion backlog in renovation and improvement works in local authority housing and a total of 2.1 million homes, owned by councils and registered social landlords (RSLs) that were below the decent homes standard. With a need to provide up to 23000 units of social housing per annum an investment of 1.2-1.6 billion would be required (Barker, 2004). It was clear that the government could not finance this investment and significant legislation was issued to enable local authorities to seek and obtain private capital to finance their activities.
Local Authorities have several main options for introducing private finance into their activities (ODPM, 2005)

- Using mainstream housing funding;
- Large Scale Voluntary Transfers (LSVT);
- Arms Length Management Organisations (ALMO);
- Private Finance Initiative (PFI).

In 1998 local authorities were invited to submit detailed schemes that could be suitable for PFI for HRA. Eight of the participating authorities were selected as pathfinders to maximise lessons on how PFI could be made to work in different contexts for the provision of social housing. Authorities selected ranged from traditionally built estates, high rise towers and street properties to reflect a range of different applications suitable for regeneration, tenure diversification and ability to secure long term improvement in the stock. Only two of the submitted schemes are now operational with others in different bidding stages and a few completely abandoned (ODPM,2001, Housing Corporation, 2005).

A PFI contract is an agreement between the local authority and another party that undertakes to refurbish all properties within the scheme up to the Decent Homes Standard and maintain them at or above the standard for the duration of the contract term (up to thirty years). The party will receive an annual payment "PFI credits" based on performance throughout the contract term. This translates into paying tomorrow for services delivered today and although this is quite a controversial issue it does serve the governments purpose in reducing public sector borrowing which is another justification for using PFI procurement. There are two types of Housing PFI: Housing Revenue Account (HRA) PFI and non-HRA PFI. In HRA PFI the local authority owns the properties and the tenants remain tenants of the local authority with all their rights intact including the right to buy. Non HRA schemes are usually in the form of long-term service contracts with RSLs (Registered Social Landlords), involving new build or acquisition and refurbishment, and continuing management and maintenance. The stock will be in the ownership of the private sector operator, and tenants are tenants of the RSL although the authority retains nomination rights (Housing Corporation, 2005).

3. PFI AND VALUE FOR MONEY

In PFI projects value for money is the benefit to cost ratio indicating the project's economic efficiency. The Government defines value for money as: *"the optimum combination of whole-life cost and quality (or fitness for purpose) to meet the user requirements"* (HM-Treasury, 2003/2004, Allen, 2005).
Although there is no specific definition for Value for Money, it is thought to be associated with Economy, Efficiency and Effectiveness (*in public procurement where it can be shown that taxpayers' money has been spent economically, efficiently and effectively it is reasonable to conclude that value for money has been achieved*)(HM-Treasury, 2003). In PFI procurement, Value for Money is thought to be achieved through the adoption of private management practice and skills such as competition and economies of scale. Before selecting PFI as a procurement option, the procuring public authority should provide sufficient evidence that PFI procurement in that specific instance offers value for money. During the initial pre tender stage, the authority identifies business need, in a draft business case, that must clearly demonstrate the project lends itself to PFI. A clear operational need, scope for sufficient risk transfer and adequate market interest that promotes private sector competition during tender are required. At a later stage, after PFI has been identified as the most suitable option, another assessment needs to be made which is based on the full business case, received bids and final negotiations in a Public Sector Comparator assessment (PSC) (HM-Treasury, 2003, ODPM, 2001, Allen, 2005). PSC assessment is based on comparison between the Net Present Value of a PFI project and with a traditionally procured project. In the case of social housing, private finance is already used in the sector for the provision of affordable housing. Comparison in this case is between public sector use of PFI procurement and other private finance routes, LSVT and SHG. (4Ps, 2000). The focus is thus on the delivery of required outcomes and the degree of positive impact on the community.

Once PFI has been selected and approved as the procurement route the public authority needs to set its service requirements and the contract is tendered by companies in the private sector. Initially the private consortium's main concern is to produce the most competitive bid to win the tender. This translates into finding ways of delivering the

required level of service at the lowest cost. The SPV would need to ensure use of optimum solutions during construction and operation of the facility to reduce their cost while meeting performance requirements.
Value for money is implemented in the project through the ways in which the contract structure ensures e.g. that risks are mitigated or partnering and collaboration are promoted. The following paragraphs describe the principles of PFI procurement contracts and how they enable the achievement of value for money.

4. PRINCIPLES OF PFI PROCUREMENT

4.1 Risk Transfer

In any project or contract risk must be transferred to the party best able to manage it.
In PFI procurement the public sector needs to transfer sufficient risk to the private sector to make the project viable. Initially the client starts to transfer risks that it traditionally incurs to the SPV which has more control over those risks and VFM starts to increase. Thus in PFI contracts risk transfer should be optimised in order to maximise value for money. An example of this would be design and construction risks since they can only be managed by the private consortium.
Investors need to ensure that contractors are able to deliver efficiently and to the key performance indicators since any reduction in performance would mean unitary charge performance deductions which would seriously damage the profitability of the consortium and place equity at risk. In a typical consortium risks would be allocated as follows (HM-Treasury, 2004):

- The construction contractor, under a subcontract with the consortium company, take the design, construction and completion risk;
- The service provider, under a subcontract with the consortium company, takes the risk of timely and cost effective service provision;
- The house managers take the risk of dealing with tenants
- Insurers provide protection for risks of damage and business interruption; and
- The lenders and investors of the consortium company are left with a series of residual risks, such as credit risks on the subcontractors' performance.

Interviews with participants in social housing PFI projects revealed that projects are not considered particularly risky. Social housing projects however have risks that are unique and sensitive. Private consortia's main concern was dealing with social housing tenants. The nature of projects makes that an important issue since tenants, although not the client, have the ability to promote or disrupt project progress. It has to be noted that the sector is newly open to the market and thus many risks would be embedded deep within the sector structure and would only come up during construction or operation. Contracts have to be continuously redesigned and modified to work accordingly. In the Grove Village Project, it has been reported that issues such as boarding up or locking empty properties, issues related to drugs found on properties, or vacating resistant tenants to carry out repairs have been causes of dispute and disagreement between consortia and subcontractors where no one would take responsibility for them.

The Treasury Task Force (TTF 1999) definition of risk in a PFI project states that: *"risk is uncertainty as to the amount of benefits. It includes both potential gain and exposure to loss."*

This is particularly true for PFI projects in social housing that include an element of regeneration. For example the Grove Village project in Manchester included regeneration in the contract and it had about 30% of the properties for demolition and rebuild for commercial use. This achieves tenure mix which is a client requirement. It is also a demand risk for the SPV to fill those properties failure of which would incur penalties. However it is a good opportunity for a private development that could be a source of profit for the SPV.

4.2 Competition

Being based on output specification, the contract gives the SPV an opportunity to find novel ways to deliver a service at the required standard. In order to secure the contract at the bidding stage, the SPV needs to find ways of delivering those standards at minimum cost to the satisfaction of the client/local authority. In other social housing provision routes, such as LSVT, there is no element of competition for properties to be transferred to a Registered Social Landlord or housing association. Similarly in allocating Social Housing Grants to housing associations, the Housing Corporation does not require competition, it only requires that association meet a certain performance standard (4Ps, 2000). This lack of competition means that private sector is not encouraged to search for solutions that can reduce the cost to local authorities. In the first round of pathfinder PFI projects, local councils were not allowed to disclose their affordability to the SPV even at preferred bidder stage. This has put a lot of pressure on SPVs to minimise the total project cost (including whole life cost) as much as they could and to design efficient service delivery mechanisms. Thus competition encourages SPV to seek the maximum value for money solutions for the client. It has to be noted that private consortia invest large sums in the bidding process without any guarantee of winning bids. Local authorities also invested large sums and resources in the process. This has been sited as one of the main reasons parties are discouraged from bidding for PFI projects. The government through ODPM and the 4Ps are working on creating a set of standardised documents to make the bidding process shorter, less costly and more efficient.

4.3 Output Based Specifications:

In a PFI contract the client defines the service to procure in an Output Specification Document. The Output Specification is arguably the most important document in the procurement of a project through PFI. It is the basis through which the Authority and its Stakeholders define the services and outputs that the PFI Contractor needs to provide for the term of the Contract. The aim of the document is to describe what needs to be achieved rather than how it has to be achieved

A well-drafted Output Specification is fundamental to develop a robust PFI Contract and a successful delivery of long-term services. It is part of a process that is different from traditional procurement, as the emphasis is on affordable service outcomes and outputs. Output Specifications encourage a focus on strategic needs rather than the detail of current provision. (4Ps, 2004).

Output specification document describes the service performance output the clients want to provide to the end-users in sufficient detail without specifying the way in which those services are provided. It is then up to the SPV to design optimum ways of delivering the service at minimum cost.

Social housing projects have the added complexity of output based specifications that define regeneration and welfare issues such as reduced crime, increased social mix, improved demand etc. This gives the flexibility to come up with innovative solutions to welfare problems but it also helps the SPV to recognise embedded risks. It also brings out the importance of partnering in the need to include specialists such as housing managers and welfare officers as well as planners to work with the team from the start. In the Grove Village project the winning design provided solutions that exceeded what the local authority has envisaged.

4.4 Partnering

The public authority outlines its service requirements in the bid which goes out to tender and companies compete for the contract. To deliver the specified service private sector companies must build a consortium with different qualifications to meet the requirements usually involving construction contractors and facilities as well as housing management companies. The consortium needs to either include or subcontract to designers and maintenance contractors.

Again social housing projects can pose unique problems that only specialists can deal with. In the Grove Village project contractors had to deal on a first hand basis with tenants. They had to face situations ranging in difficulty from tenants refusing to cooperate to allow repair works to members of the consortia receiving death threats. It is also difficult to contractually set out a responsible party for such risks and therefore a strong sense of partnering is required to deal with such issues. As mentioned earlier in sector that is newly open to the market partnering is increasingly important in creating a knowledge base for all different participants to learn about the role of others and how different problems can be dealt with. This is particularly true at the design stage of any regeneration project where social welfare comes to the fore of the problem rather that general planning and design and hence expertise of different specialists is required.
Another problem faced by the Grove village SPV was dealing with a large number of subcontractors who were faced with difficulties in the projects that are new to them, often causing delays. The SPV reported situations of laying the blame, and lack of recognition of responsibility. Subcontractors were not partners in this project nor were they partners to the SPV. There is nothing in a PFI contract that requires or even encourages partnerships with contractors despite this being an issue raised by all those who were interviewed.

4.5 Contract Duration and Whole Life Cost

Whole life costing can be defined as the systematic analysis of all relevant costs and revenues associated with the acquisition and ownership of an asset (Robinson & Krosky, 2000). These costs would include initial construction costs and expected occupancy costs such as rent collection, maintenance and management. Whole life costing makes a building behave as an asset rather than a liability by including revenues it generates. This concept is particularly important in the case of PFI where project parties need to assess and price risks associated with the long-term operation and maintenance of a building where cost and performance need to be monitored. The whole life of a building in this case differs from the intended occupancy for the term of contract. In social housing PFI contracts provision of a building can be either through refurbishment of buildings to meet the Decent Homes Standards or through new build as in the case of Non-HRA PFI. Whole life costing involves the assessment of the most cost effective solutions such as disposal, new build or maintenance and renovation. Whole life costing includes the initial cost of the asset, its operation (energy), maintenance and salvage value. Its calculation is based on total capital cost, total revenues, inflation and tax. Social housing PFI contracts run typically for a duration of 30 years. This long duration encourages the SPV to make a large capital investment, knowing that it will be returned over time. The SPV would have an added incentive to invest in innovation and technology since improvements can be seen over time. The long duration also gives the SPV the chance to build on the skills and competence of the workforce and develop staff for other projects. The SPV would have to consider the performance of the asset over a long period which means they would have to make whole life cost considerations from the earliest stages to ensure adequate performance during the contract term. The SPV needs to create a balance between capital cost and maintenance cost that would achieve value for money.

The nature of housing in general and social housing in particular means that attention has to be given to whole life costing. The public sector has had a bad history of social housing provision particularly because of the short life of their stock and this is one of the main justifications of bringing in private sector expertise. Tenants of social housing usually take no pride in their homes, leading to neglect of properties. Providing good quality housing that tenants can take pride in, encourages more care of homes and neighbourhoods. Social housing should be designed to last for generations, and this highlights the importance of whole life of the assets.

4.6 Incentive based contract:

Incentives are management techniques that deliver the aspects that are of value to the promoter by eliminating or minimising wasteful activities that do not contribute towards aspects of value (Smith, 2000). Incentivisation in PFI contracts is based on risk transfer and payment mechanisms. By transferring risks to the SPV the client creates an incentive for the SPV to avoid risks through improved performance.

In PFI contracts, the SPV is paid for services provided which means that the SPV will only receive payment when the facility is designed, built and is fully operational. Thus the SPV have an incentive to complete the facility within time and budget to avoid additional cost of borrowing and to start earning revenue.

PFI contracts usually include penalty clauses to ensure service provision to the required level. This means that in case service provision does not meet output specifications, the SPV would not receive payments. An increased number of penalties can lead to contract termination. Payment mechanisms should be designed such that the cost of a penalty is greater than the savings of not meeting output specifications. This process is usually based on a set of performance indicators designed by the client to determine the required level of service.

The SPV in the Grove Village project for example are penalised on things such as grass in lawns reaching a certain height, number of times the telephone rings, on the tenant complaint line, before it is answered. In total the project has 298 performance indicators that must be met on a monthly, quarterly or annual basis. Although these indicators may seem restrictive, the SPV's comment was that these are the standards they work to anyway. Despite this being the case, it has taken a lot of effort and expense to draw out the legal documents involved.

The SPV monitors its own performance and the client audits SPV's monitoring. There is also a possibility for users/tenants to report service failures. Payments are made upon delivery which satisfies output specifications. The SPV faces penalties and reduced payment if delivery is below set standards and termination of contract is the last resort. Service provision should be set at a reasonable level by the authority which needs to recognise that 100% performance level may not always be necessary. In this case, the SPV would incur a set of negative points before suffering financially.

Unitary Charge should relate to the delivery of the overall input not only certain elements. Payment mechanisms are designed such that they should not contain a fixed element that can be received irrespective of performance. This ensures that Senior Lenders will not commit to contract unless they have confidence in the SPV's ability to perform.

Lenders in PFI contracts have a significant power since they need to make sure that their investment will be repaid. It therefore is in the interest of Private Lenders to ensure that incentives are designed to ensure delivery and thus payment.

4.7 Regeneration

Sustainable communities are places where people want to live and work, now and in the future. They meet the diverse needs of existing and future residents as they are sensitive to their environment. Sustainable communities also contribute to a high quality of life. They are safe and inclusive, well planned, built and run, and offer equality of opportunity and a good service for all (ODPM). The Deputy Prime Minister's Sustainable Communities Plan, published in February 2003, sets out an action programme for building successful, thriving and inclusive communities. The plan searches for a scope for PFI contribution in regeneration mostly due to risk allocation practice which is considered suitable for major capital assets.

The Decent Homes standards are part of the government's sustainable communities plan as explained above. By setting improved demand for social housing stock as a required output the private sector is given the opportunity and incentive not only of assessing the state of disrepair of houses but also improving whole areas. Grove village in Manchester was a highly undesirable area characterised by socially excluded tenants living within a community with a very high level of crime and drug abuse. In redesigning Grove to reduce crime, open up the community towards its neighbouring areas and trying to attract commercial tenants to increase SPVs profit the area was dramatically regenerated with a waiting list of up to 99 month. This has simultaneously improved housing conditions, reduced social exclusion, crime and drug dealing and enhanced image of the area. The value of properties in the area has also increased while they remain within the ownership of the local authority.

Often this is linked to the broader regeneration of an area which, in order to be successful, might be dependent on a range of social, economic and environmental improvements. These might include demolition of existing stock and re-provision with a mixture of tenures, estate remodelling and environmental works, the provision of re-establishment of shopping and retail facilities, health and leisure facilities. Not all of these will necessarily be delivered through the PFI contract itself although the project, in its widest sense, may well be delivered by the PFI contractor.

The Authority may carry out some initial master-planning or design works in order to help scope the project at the tender stage which can then be developed through the bidders' responses to the ITN.

Clearly, in due course, additional facets of the output specification may need to be developed in order to properly encapsulate these requirements to the extent that they are to be delivered under the terms of the PFI project agreement.

5. EFFECTIVE PFI CONTRACTS

The nature of PFI means that in trying to upgrade the stock to meet the Decent Homes Standards other benefits can be incurred most of which are related to improved efficiency in delivery and performance. There are a set of issues that need to be present for PFI contracts to work effectively:

5.1 Clear definition of Client’s needs:

PFI presents a challenge to the private sector to deliver facilities and services which will genuinely enhance housing standards. This challenge can only be met effectively if the client/authority are clear about their requirements, and communicate these in a way that allows the private sector to develop the optimal solution. This puts a large amount of responsibility on the Local Authority to produce adequate documentation to make their objectives and their expectations clear. Delivery of a PFI contract relies mainly on output specification documents that are produced by the council. It is imperative that these documents state clearly the requirements of the client such that private sector bidding consortia can produce a service that is suited to the project within the affordability range.

5.2 Creating a healthy market:

PFI Housing schemes are much more complex than other PFI projects as they will affect the lives of large numbers of tenants and leaseholders over a long period of time. To be successful the sector must be attractive to public sector (local authorities and central government) and private sector (housing associations, funders, and contractors). The central government has made it very clear that PFI is one of their preferred options for procuring public services and infrastructure under the right circumstances. The government is willing to support PFI procurement and this support can be seen in the provision of legislation, guidance and financial support. This leaves two major groups: the procuring local authorities with their tenants and private sector bodies (funders, contractors or housing managers). Procuring authorities need to be able to identify areas where PFI can be fully utilized to produce results bearing in mind that it might not be suitable for all their housing projects. According to the government the main driver for PFI procurement is achieving value for money mainly through the transfer of risk to the private sector. This aim may be slightly vague in the sense that it does not specifically state to who value for money has to be achieved: users, the taxpayers, the government itself or the society in general. Despite the fact that these sector groups are all interrelated achieving value for money for one does not necessarily achieve it for the others. Social housing in particular is a special case since users are not taxpayers but in fact are a non taxpayers group. In this instance understanding whether a project may in reality achieve VFM for taxpayers would be a complicated process of trying to understand the impact of improved social housing on different parts of the community through a series of cost benefit analyses.

The other part of the market is the private sector. Again the focus is on procuring public authorities to understand and take account of the profit making objectives of private sector consortia. This would mean that the public sector needs to provide opportunities for new developments that can encourage private sector to take adequate risks and produce the expected results. The length of pre contract processes and high bidding cost has been continuously identified as the shortcomings of the procurement route. This issue continues to discourage private sector potential bidders from PFI projects. For this reason, the government is trying to create standardised documents to make the process less onerous and less expensive.

5.3 Robust Contract Structure:

In the provision of major capital assets PFI's potential lies in its risk allocation and incentives structure that ensure delivery. The above described elements of a PFI contract cannot work in isolation but need to be interrelated and to operate simultaneously to deliver value for money. For example *because of their long life, assets could benefit from design, construction and costing made on a whole of life basis by private sector parties incentivised to ensure best value (Asenova et al., 2000).* This means that long term of contract requires whole life cost consideration to operate which in turn draws out the partnership approach that is required of the consortium. Incentives built into the contract are related to risk transfer and mitigation. Output Based Specifications are linked to the element of competition.

In creating a robust contract structure the clients' objectives need to be clearly understood by the bidding private sector consortia bearing in mind that these objectives should not be in conflict with the private sector's objectives of making profit. PFI has been quoted as the only realistic source of finance into the sector (ODPM, TTF, LA's, Housing associations). It involves key roles by private and public sector participants and the alignment of their objectives is key to its success. This in essence is the basis of PFI procurement and contract structures is the creation of opportunities for the private sector while delivering the objectives of the public sector.

It is apparent that there is a need for more investment into the social housing sector. As mentioned earlier there are a several options of attracting private sector investment open to local authorities. However these options continue to be heavily reliant on government policy particularly in the case of non-profit organisations and the nature of non paying customers (Whitehead, 1999). According to the 4Ps, the way in which other private investment routes in social housing are funded through loans means that the focus is always on maximising the value of the stock rather than on welfare community issues. Alternatively in PFI contracts lenders security relies on the performance of the PFI contractor, through specifications which should include welfare issues such as reduced crime and increased demand. The 4Ps also suggest that in retaining ownership of the housing stock local authorities are still responsible for the strategic management of their investment and in this way can create a better balance in the housing market in their community (4Ps, 2000).

The history of PFI is relatively short. The history of PFI in social housing is particularly short and only four projects of the first eight pathfinder projects have reached financial close. The social housing sector is characterised by its social nature and a tradition of not for profit operation. There is therefore a limited amount of research into the implementation of social housing PFI projects. There are significant gaps in knowledge on how the principles of PFI work in social housing projects. There is also a need to identify the aims of all parties to a contract and how those can be aligned together.

Although most participants interviewed acknowledged that projects have limited risk and great potential it is apparent that different stakeholders or sector players seem to be reluctant to get involved in social housing PFI projects. Investigation should be made to identify elements in PFI contracts that can either encourages or discourages involvement. Further research needs to investigate the real reasons behind this. Further research is also required to find correct ways of evaluating the performance of PFI projects. Evaluations done thus far have mostly focused the impact on one type of stakeholders and the need now is for analysis of the impact of different stakeholders on each other, on projects and on the sector as a whole. The social housing sector is new to PFI, and can therefore offer good opportunity of investigating performance against differing contractual solutions.

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A MODEL FOR ENHANCING ORGANIZATION PERFORMANCE THROUGH PROJECT SELECTION FOR SMALL CONSTRUCTION ENTERPRISES (SCES)

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Abstract: One of the most critical decisions that have to be made by construction companies/contractors is whether or not to bid for a new project when an invitation has been received. Decision making at the earliest stages of construction projects involves a process of gathering information from disparate noisy sources. Too often contractors then commit resources to a time consuming and expensive process that requires them to adjust and adapt their business processes in order to accomplish their projects perfectly. Smart contractors realise the importance of doing initial research and project evaluation before committing themselves to a construction project. This research aims to develop a model or framework that can be use as a decision aid for project evaluations at the initial project selection decision phase. It is expected that such an exploration would add detail at a sub-process level, to the construction industry's generic process model. It is further expected that such work would also reveal the need for a decision framework or aid that could be used in optimising judgments to enhance an enterprise's future projects and business performance. This paper reports on a study that aims to build up the case for this research and to explore its research methodology -in depth. The next phase of the work involves exploring- in more depth the influence of the early stage process of project evaluation on the small sized construction enterprises (SCEs) business decision making. The work contributes to the body of knowledge available on project evaluation processes and the research agenda related to enterprise project management in the construction industry.

Keywords: Project evaluation, process improvement, research methodology

1. INTRODUCTION

This paper reports on the early stages of an ongoing study that aims to build up the case for this research and to explore its research methodology -in depth. In this paper the researcher aims to illustrate the thinking that underpins the research methodology. To explore this aspect of the study it is necessary to conduct a brief review of the nature of the UK construction industry through key reviews and reports. Also, it is important to illustrate the aim and objectives of the research. The consideration of the research methodology includes information about the research philosophy, strategy, approach, method, and techniques.

2. BACKGROUND

Clients, industry and government are working together to improve the UK construction industry. The government's response in terms of reviewing the construction industry has resulted in publishing a number of significant reports, which aim to lead the industry's performance towards changing for the better. Key reviews of UK construction are; Constructing the Team Sir Michael Latham (1994), The Levene

Efficiency Scrutiny into Construction Procurement by Government (COEU, 1995), Rethinking Construction Sir John Egan (1998), Modernising Construction report by the National Audit Office (2001), Accelerating Change Sir John Egan (2002), Constructing Excellence Rogers and Lenard (2003), amongst others.

These reports and consequent work done by departments and industry bodies and other interested institution have identified a number of fundamental barriers which need to be overcome if construction performance is to be improved and become more cost effective. These reports are agreed on some issues that will contribute particularly in the area of continuous improvement for the industry. The main issues that have been identified by the reports include a lack of a culture of learning from previous projects or construction industry best practice, which is reinforced by a culture of blame, and little investment in research and development. Barriers related to the procurement and management of individual projects, the construction projects process, and the lack of client focus (NAO, 2001).

The UK construction industry has been under increasing pressure to improve its practices (Cooper et al, 2005). The direction to overcome the main problems were varied, hence the problems raised from many different areas. However, construction processes themselves have lacked focus on the differing parties within the process, while it seems to have valuable contribution to improve the industry (Latham 1994, Egan 1998). To counteract this, Latham said that clients' needs must be placed at the core of the process and that quality should be an overriding consideration (Latham, 1994). Also, Latham suggested using manufacturing as a reference point to the construction industry. The Egan Report recommended process modelling as a method of improvement, he said that the construction industry needed an efficient process in order to realise the optimum project (Egan, 1998).

Ten or so years ago, this idea of process focus would hardly to be accepted. People argued that every job was different. This argument was commonly used to distinguish construction from other industries. Although, some argued that what matters is the project; the project is about design - get the design right, the process is less important. In contrast, there are many practitioners and academics who believe that the construction industry has much to learn from manufacturing (Cooper et al, 2005). The response to this, is that the construction industry needs both. Of course good design is essential, of course the project is what matters, but at the same time the construction industry needs an efficient process in order to realise the project, and to accomplish the project to optimum effect. The project is constructed by a series of processes. As such each process is one task of the project, which may include several activities, it needs to be done successfully and then the whole project will move on to the next process or phase.

However, the clients are paying for the both (design and process) and what the client cares about is to achieve the targets through either the project design and/or project process.

3. THE RESEARCH PROBLEM

The call for productivity improvement and recommendations of the differing governmental reports to focus on construction process is the foundation of this research. However, until now, the industry has had few recognised methodologies or frameworks on which to base a process improvement initiative (Sarshar *et al*, 2000).

In addition, one of the most critical decisions that has to be made by construction companies/contractors is whether or not to bid for a new project when an invitation has been received (Wanous et al, 1998). Decision making at the earliest stages of construction projects involves a process of gathering information from disparate 'noisy' sources. Too often contractors then commit resources to a time consuming and expensive process that requires them to adjust and adapt their business processes in order to accomplish the execution of their projects perfectly. Smart contractors realise the importance of doing some initial research and project evaluations before committing themselves to a construction project. A great volume of literature exists that is concerned with bidding strategies and its importance to the construction company. The literature has been flooded with many bidding models. However, it has been asserted that most of these models continued in academic loops and did not penetrate into the practical world of industry practitioners (Wanous et al, 1998).

This research is considering the initial phase of the projects including its actual selection process. In particular, the research is based on the problem of business and projects failure in the construction industry. This research aims to develop a model in the practical world so as to provide a part of solution for the high notes of construction business failure. Business failure in the construction industry is caused by many reasons. The main problems found to be causing this failure included poor project selection and failure to evaluate projects profitability and the associated heavy operating expenses (PHCC, 1996). Hence careful project selection is the first step to the success of the construction company. As a result, it should not be carried out in a careless manner (Frame, 2002). Also, lack of managerial maturity in expanding operations was also a significant reason for construction business failure. It has been found that the qualities needed by managers to start a business are not necessarily the same qualities needed to manage growth of the business (PHCC, 1996).

The Office of Government Commerce (OGC, 2005) identified eight common causes of project failure, the causes that link to the considered issue is lack of clear links between the project and the organisation's key strategic priorities, including the agreed measures of success and evaluation of proposal's driven by initial price rather than long term value for money, especially securing delivery of business benefits.

When the researcher applied this idea of research to main related topic which is the company performance and project performance, it was found that the project selection process and the construction's project process are different from one project to another and from one contractor to another, in relation to the maturity level of the parties involved in the project. This has added another discussion to the research which is that it needs to recognise the construction enterprise maturity level. The nature of the research problem has been illustrated in figure 1.

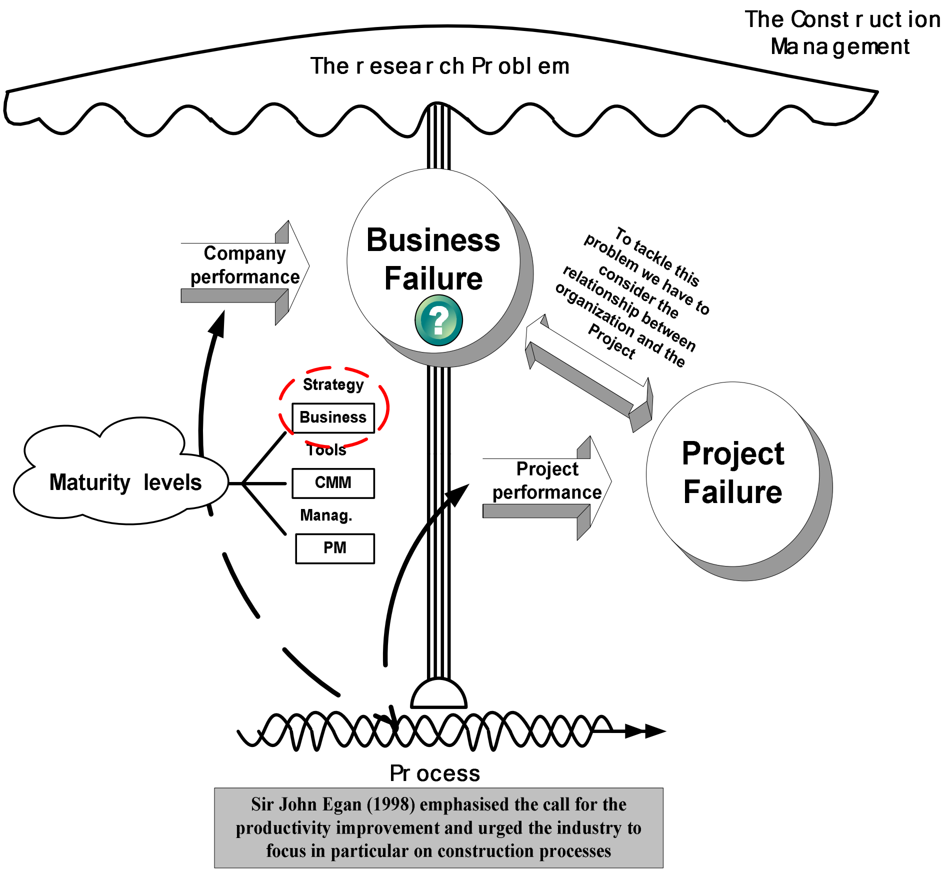

Figure 1: the research problem

4. THE RESEARCH QUESTIONS

Centre the arguments indicated above in the research problem part of this paper, it can be seen that the research will center on finding answers for the following research questions. Do SCEs have a model of project selection that evaluates the value of the projects before entering the project bidding stage? Does the model of project selection takes accounts of business management process, project development process, and project management process of the proposed project? Is the current models are business driven? Can the development of a model for project selection enhance business performance for SCEs?

5. OBJECTIVES

The aim of this research is to develop a model or framework that can be use as a decision aid for project evaluations at the initial project selection decision phase. The objectives to be achieved are as follows:

1. To study the influence of company business maturity level on the company performance.
2. To study the relationship between high PM capability level and high product quality, profitability, and stability.

3. To study the influence of business process and PM process upon the SCEs.

6. THE RESEARCH METHODOLOGY

This study follows the nested approach to determine the appropriate methodology to achieve the aim and objectives of the study (Kagioglou et al, 1998). The researcher has adopted this model because the research design is guided by the research method and the research method is guided by the research approach and the research approach is guided by the research strategy, and the research strategy is guided by the research philosophy.

The researcher believes that to decide on each element of this model it was necessary to consider the nature of the problem and the fundamental knowledge that is vital to be obtained. In addition how the researcher recognises knowledge is a fundamental issue that requires the researcher to establish the philosophical position for the work. Each element of this nested model is discussed in subsequent sections.

7. PHILOSOPHY

There is some disagreement on which research methodology is the most appropriate for use in construction management research. In fact, the issue of construction management research methodology is a highly debated one that has been detailed by Mukherjee, (2002). Indeed, it has been claimed that the different terminology and phrases used for the same things prove the existence of such a disagreement (Johnson and Christensen, 2004). The argument, which is still valid since the time of Aristotle, hinges on whether the researcher chooses a research method that is based on the approach to the problem or the identification of the problem demands the use of a consequent research approach (Kelly, 2004).

Research in construction management field is a new and young academic discipline in comparison to the other fields, such as architecture, medical studies and so on (Carter and Fortune, 2004). The construction management research field has been given great attention over recent years. The position of construction management research is closer to the approach adopted in the social sources, because it involves people as well as organization; the construction management researchers draw their research methodology from the both sides, from science and from the art (Carter and Fortune, 2004).

The construction management researchers draw from science an approach that is based on methods to do with quantitative study, measurement, hard edge data and facts. From the artistic side, (dealing with issues, ideas, and people) construction management researchers draw from the qualitative approach. Both approaches are overall strategies that reflect deeper under pinning philosophies (Carter and Fortune, 2004). The philosophies recognise knowledge from completely different ways. So the scientific, the mathematical, the hard edged approach in built environment research can be said to draw on what its called the positivist tradition (positivism). This approach seeks to make direct empirical links between cause and effect.

Research undertaken from this perspective can not make that link between cause and effect directly when it addresses people, issues, and ideas. The different strand of philosophy that supports such investigations is known as the qualitative approach or interpretivism (constructivism). Both approaches have a very strong tradition in western philosophy, and they reflect the opposite ends of the research continuum applicable to construction management research methodology. A middle way is also possible between the extremes of positivism and idealism or interpretivism. From this mid-position the construction management researcher can draw from the both traditions because the field is young and as yet construction management research has not got an established way of doing its research. Thus this methodological approach is called pragmatism (Seale, 1999).

The question posed for debate at the beginning of this section was whether the researcher makes the choice of a research method based on their approach to the problem or whether the problem itself stresses a particular research approach. This issue seems to depend on the researcher's philosophical perspective as it is fundamental in the choice of a research design.

The positivists' philosophy generally assumes that reality is objectively given and can be described by measurable properties which are independent of the observer (researcher) and his or her instruments (Kelly, 2004). Positivist studies generally attempt to test theory, in an attempt to increase the predictive understanding of phenomena (Seale, 1999). Those adopting a positivist stance, see reality as an inert amalgam of facts which can be released by the right methodology. They believe that there is one best methodology to do this and their aim is to get as close to it as possible (Loosemore, 1999).

Critical research assumes that social reality is historically constituted and that it is produced and reproduced by people. Although people can consciously act to change their social and economic circumstances, critical researchers recognise that their ability to do so is constrained by various forms of social, cultural and political domination (Sieber, 1998).

The interpretivist's philosophy says that the researcher is comfortable accepting that knowledge exists without it been written in black and white form and that one thing leads to another in a series of direct causal links. Accepting that means there is around the edges a grey area that people are interacting with and communicating within. Therefore research results must be filtered by their relevance within a particular social context (Kelly, 2004). The constructivists argue that the reality is not objective and exterior but is socially constructed and given meaning by people (Easterby Smith *et al*, 2002).

The researcher's philosophical perspective, for this research is out of pragmatism. In short, what works is what is useful and should be used, regardless of any philosophical assumptions, paradigmatic assumptions, or any other type of assumptions. (Johnson and Christensen, 2004). As a result of adopting this approach there may be some confusion over the research design used for a pragmatic study. The way to solve such problem is by asking; what is the knowledge that the researcher hopes to generate? Is it related to positivism or interpretivism? The researcher can then choose the appropriate approach that can mach the research requirements. How this philosophical standing of the researcher influences the selection of appropriate research approach is considered within the next section.

8. STRATEGY

The specific methods used in any type of research depend on the type of research being performed. The scope of the research process is to produce some new knowledge. This, in principle, can take three main forms: constructive research, empirical research, and exploratory research (AAR, 2005). Often researchers are using exploratory research for an inadequately defined problem area. However, this type of research might be interesting as it allows exploring a new knowledge. Exploratory research helps determine the best research design, data collection method and selection of subjects, and sometimes it even concludes that the problem does not exist! (AAR, 2005).

9. APPROACH

Research approaches can be classified in various ways; however one of the most common distinctions is between qualitative, quantitative, and mixed research approaches. Quantitative research approach was originally developed in the natural sciences to study natural phenomena. Quantitative research relies primarily on the collection of quantitative data (Straub et al, 2005).

The qualitative research approach was developed in the social sciences to enable researchers to study social and cultural phenomena. Qualitative data sources include observation and participant observation (fieldwork), interviews and questionnaires, documents and texts, and the researcher's impressions and reactions (Seale, 1999). Qualitative research relies on the collection of qualitative data (Seale, 1999). Although the results of qualitative research can give some indication as to the "why", "how" and "when" something occurs, it cannot tell us "how often" or "how many".

Mixed research which involves the mixing of quantitative and qualitative approaches or paradigm characteristics (Johnson and Christensen, 2004). The researcher has decided that the qualitative approach will be the general or overall approach for this research regarding to the nature of this research, and allows other approaches to get involved where necessary. The methods used to execute this approach to the research for this study are set out within the next section.

10. METHODS

There are number of research methods, each one of them has its own features. The main approaches are basic and applied research, evaluation research, orientational research, and action research. Basic research is research aimed to generate fundamental knowledge and theoretical understanding about basic human and other natural processes. (Miller, 1991). Applied research is focused on answering practical questions to provide relatively immediate solutions. Applied researchers seek to create knowledge that can be used to solve pressing social and organization problems (Miller, 1991). Basic and applied researches are generally conducted by researchers at universities. Orientational research is done for the purpose of advancing an ideological position. It is traditionally called critical theory (Johnson and Christensen, 2004).

Action research focuses on solving practitioner's local problems. Action research is a three-step spiral process of (1) planning which involves reconnaissance; (2) taking actions; and (3) fact-finding about the results of the action (SFCEL, 2005 cited Lewin, 1947). And a recent definition by Calhoun (1994) says that action research is a fancy way of saying let's study what's happening at our organisation and decide how to make it a better place (SFCEL, 2005 cited Calhoun, 1994).

Evaluation research involves determining the worth, merit, or qualities of an evaluation object. Evaluation research must evaluate the end product of a programme or process (Miller, 1991). Evaluation is traditionally classified according to its purpose: (Johnson and Christensen, 2004) Formative evaluation is used for the purpose of program improvement. Summative evaluation is used for the purpose of making summary judgments about a program and decisions to continue of discontinue the program. Generally speaking, evaluation research is done by program evaluators and is focused on specific programs or products. The researcher can use this approach for the purpose of process improvement on this regards. To achieve that, the researcher needs access and ability to work effectively with SCEs.

11.RESEARCH DESIGN

As set out above the aim and objectives of this research are largely related to theory building rather than theory testing. It involves the study of complex interactions between people, technological influences and construction processes in real life settings. The philosophy adopted allows the qualitative approach to be the general or overall approach for this research and allows other approaches to become involved where appropriate. So the research will be more influenced by the interpretivist thinking rather than the thinking usually associated with positivism.

Yet, the aim and objectives of this research are based on the exploration of the problems that influence the business failure for the construction company. Exploratory research will help to explore, understand, and identify the precise problems involved and point to their resolution. Hence this research involves study the influence of company business maturity level on the company performance and then using it to enhance the company performance through the process of project selection, it is vital to study and evaluate the existing processes and to start the improvement process from it. Then the model needs to be evaluated through the SCEs managers.

In practice, the accumulation of evidence for or against any particular theory involves planned research designs for the collection of empirical data. Access to sources of data in a PhD thesis has been identified as a constant problem; the researcher should consider that problem while deciding on the research design. To over came this problem, the researcher will approach the technique of focus group. There are many definitions of a focus group in the literature, but features like organised discussion (Kitzinger 1994), collective activity (Powell et al 1996), social events (Goss & Leinbach 1996) and interaction (Kitzinger 1995) identify the contribution that focus groups make to social research. Powell et al (1996: 499) define a focus group as:

> "A group of individuals selected and assembled by researchers to discuss and comment on, from personal experience, the topic that is the subject of the research"

This research is planned to divide the research activities into four main phases. The first one concerns the achievement of the first objective of the research which is to study the influence of company business maturity level on the company performance. This will be achieved through a qualitative approach using the techniques of literature review plus interviews.

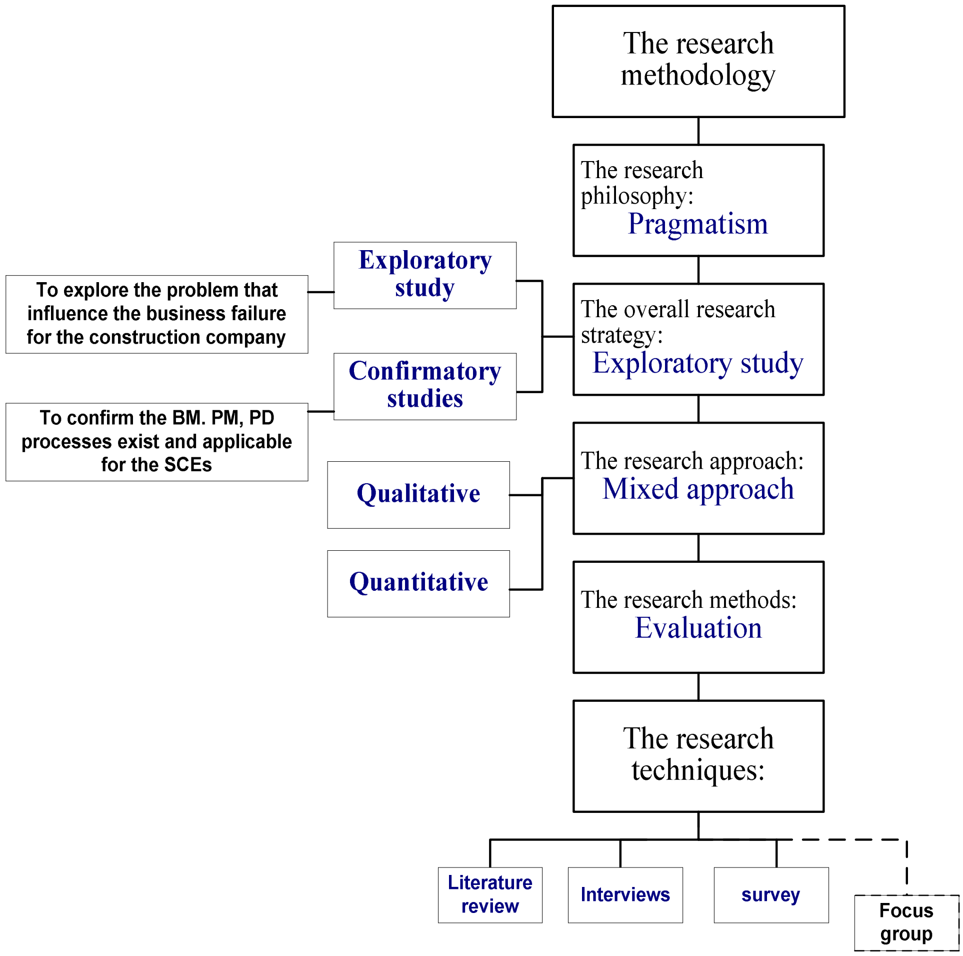

Figure 2: Summary of the research design

The second phase, aims to assess the relationship between high PM capability level and high product quality, profitability, and continued participation in the industry. Thirdly, to establish the critical business processes of SCEs and to study the influence of business process and PM process upon the SCEs by using a qualitative approach using the techniques of literature review plus interviews. The last phase which is to develop a decision framework for the process of careful project selection. This will be achieved through a literature review aims to collect data about the process of project selection, that exist in the construction management text books. Therefore, if will be necessary to conduct a number of interviews to compare the collected data with the process that exists in the practice. Finally, the data collected and the investigations results and analysis should assess the researcher to establish this framework and building up the model. At the end of the methodology section the follows figure (2) summarise the research design:

12. CONCLUSION

In conclusion the researcher considered that it would be worthwhile to investigate the extent to which some of the initiatives relating to process improvement are being taken up and used in the UK. To this end the researcher explored the concept of "process improvement". In particular, it is expected that such an exploration would add detail at a sub-process level, to the construction industry's generic process model. It is further suspected that such work would also reveal the need for a decision model or aid that could be used in optimising judgments on an enterprise's future projects and business.

The researcher also recognised that consideration of the research methodology needs to be undertaken in an in-depth manner. The researcher has illustrated the sequence thinking that aims to set out the research methodology for this particular research. This sequence thinking could be followed in other research in construction management. Access to field data in construction management research related to PhD thesis has been identified as a constant problem, and the researcher should recognise this and not set out a strategy that is going to prove difficult to achieve knows that going to have difficulties with.

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THE DESIGN AND DEVELOPMENT OF A DYNAMIC INTEGRATED SEARCH FACILITY FOR THE ENHANCEMENT OF EXISTING WEB PAGES

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Abstract: Information and communication systems for storing and sharing data, information, and knowledge on a large scale are undergoing rapid change, driven mainly by the success of the World Wide Web and its search engines. Soon a vast array of material will become available online, including vital materials now found only in paper documents such as technical manuals and research articles. Uploading these documents with today's existing web pages is often a time-consuming and frustrating process. This paper provides a real-case project example on how to design and implement an integrated search facility for the benefit of a research community. A thorough review of the current facilities provided on the International Council for Research and Innovation in Building and Construction (CIB) web page was undertaken. This was conducted to identify improvements which may benefit both the CIB and its members. This led to the submission of a proposal by the Joint CIB Student Chapter of the School of the Built and Natural Environment, Glasgow Caledonian University and the Department of Civil Engineering, University of Strathclyde, Scotland, which incorporated the development of an integrated search facility for the CIB, and eventually led to success in the annual Gyula Sebestyén Award in 2004. This paper highlights the process with regards to the design and development of the project. Also, for authorised users, there is a facility to upload files. This resulted in the reduction of the time it takes to search for information in the CIB web page as well as uploading files, alleviating the administrative burden for the CIB.

Keywords: CIB, Search facility, Student Chapter.

1. INTRODUCTION

The explosion of World Wide Web since the 1990's, the internet and intranet has become increasingly important for data, information and knowledge source for researchers and practitioners. There are now several billion documents on the World Wide Web, which are used by more than 300 million users globally and millions more are on corporate intranets. The continued rapid growth in information volume makes it increasingly difficult to find, organise, access and maintain the information required by users (Davies et al., 2003). Important data, information and knowledge is often scattered across internet and intranet resources. Users spend a substantial amount of their time browsing and reading to find out how documents are related to one another and where each falls into the overall structure of the problem domain. It is especially difficult for inexperienced users to discover informative pages, since they do not have a background or domain knowledge about the status of web systems. Therefore, many kinds of web search engines have been developed in order to support the processes of web information retrieval. Statistics shows that search engines are the most popular method used by web surfers to retrieve information. Forty six percent (46%) of people discover new websites via search engines. And Google has a well deserved reputation as the top choice. As crawler based service, it provides comprehensive coverage of the web along with great relevancy. However, there is often an excessive amount of information when a search is conducted, these can easily puzzle the user as to which one is the exact information you want (Zhang et al., 2003). If developers find a way to organise the information in a processed and manageable manner, i.e. explicit knowledge, tacit knowledge and further information links, it would be much more convenient for the users to get concrete information and knowledge and improve their competency.

Internet and Intranets have an important role to play in the more effective exploitation of both explicit and tacit knowledge in the construction industry. With regards to explicit knowledge, internet and intranet technology provides a ubiquitous interface to an organisation's information and knowledge at relatively low cost using open standards. Moving information from paper to the internet and intranet can also have benefits in terms of speed of update and hence accuracy. The issue then becomes how to get the right data, information and knowledge to the right people at the right time for effective action. With tacit knowledge, one can use internet and intranet based tools to connect people with similar interests or concerns, thus encouraging dialogue and opening up the possibility of the exchange of tacit knowledge (Davies et al., 2003).

This is usually in the form of project collaboration systems such as extranets which are restricted to project users within an intranet. For most organisations, there is the capacity to search for limited information within existing web pages. Many organisations also have knowledge management systems that capture information and knowledge that is disseminated to designated users. These systems are useful but the downside with most of these initiatives is the maintenance of the system and the problem associated with ownership. For any database, information needs to be uploaded and kept up to date. This is often a laborious and time consuming job. By allowing selected users to upload information via the internet, the process becomes more interactive and designated users take ownership of the information uploaded (Mattison, 1999).

An extensive desktop search suggests that in the construction industry, there are number of websites that have search facilities. Examples include the website of the Royal Institute of British Architects (http://www.riba.org/go/RIBA/Home.html), the IT Construction Forum (http://www.itconstructionforum.org.uk/) and Constructing Excellence in the Built Environment (http://www.constructingexcellence.org.uk/). In these websites, the uploading of files is not part of its functionality, with information having to be submitted to the person in charge. On the other hand, some websites like Pulling Together (http://www.pullingtogether.co.uk/) have provisions for updating but lack a search facility. The system developed for the CIB incorporates both these features i.e. the upload of files and ability to search the contents as soon as it has been uploaded.

2. AIM AND OBJECTIVES

The aim of this project is to enhance existing search facilities of the CIB web page that will be of benefit for members of the growing CIB Student Chapter community, and the wider CIB community. Objectives of the search engine project is aimed at "re-engineering" the vast amount of information found within the CIB by making it more accessible for both the growing Student Chapters and also the wider CIB community. A critical appraisal of the current search facility of the CIB website has identified that the wealth of accumulated information and knowledge is under-utilised and it is felt that searching for information is difficult in the present format.

The intention is to develop a search facility which allows for easier access to the existing information and knowledge developed in recent years and also allows for future events to be made available to more members. The search facility would generate a "template" for those organising CIB-related conferences and workshops to use. CIB intend for designated users (with password) to add future publication information through the use of templates to ease their administrative burden. CIB will provide the template and the intention is for the new information to be added into the data base so that it may be searched. This would make it possible for the organisers of these events to utilise the proposed template to upload conference proceedings and workshop materials in a 'standard' and user-friendly manner.

This search facility will provide a vital gateway for the Web-based collaboration system proposed by the 2003 winning proposal submitted jointly by the CIB Endorsed Student Chapter of the Department of Building and Real Estate, The Hong Kong Polytechnic University in collaboration with the CIB Student Chapter at the Department of Construction Management, Tsinghua University. It will allow the system's search facility to be improved by using a simple link that can be added easily to the existing web page.

In this paper, we highlight the process with regards to the design and development of an integrated search engine, from its conception and through its development. A comprehensive search facility is developed which consisted of both basic and advanced search. Also, for authorised users, there is a facility to upload files.

3. LITERATURE ON SEARCH ENGINES

The term ''search engine,'' as used by the average citizen of the World Wide Web, encompasses a wide variety of services which provide access to Internet resources. In the field of information retrieval research, a distinction is made between the interface and the engine—the former is the means by which the user interacts with the latter. The concept of a search engine includes the interface, the retrieval and presentation mechanism and the database. In common with library catalogue, users of Internet search engines are concerned with results. They rarely understand or even consider the mechanisms, and even more rarely make full use of the capabilities provided by sophisticated search tools. Introna and Nissenbaum (2000) conducted a study of search engine use by Internet-naive adults (whether computer- literate or otherwise). The results certainly backs this up. Subjects misunderstood what the Internet is, what types of resources it contains, why searches might require several iterations, what types of keywords might be fruitful, and even lacked sufficient basic world knowledge to be able to recognise ''answers.''

It also seems that most casual users use one or two words to drive a search. Despite this, many search services now provide an array of search tools approaching those available in the realm of commercial online searching (except for the enhancements provided by indexing languages and authority control) .

Boolean search (in some cases with nested parentheses); specification of terms which must or must not be present; truncation (terminal and internal) or conversely, inhibition of automatic stemming (Excite is one of the few engines to search character strings, allowing for initial truncation); exact phrase match; proximity searching (which can be as sophisticated as hat found in commercial online searching); fielded search (based on markup tags identifying title ext, meta text, heading text, link, and so on); specification as to case sensitivity; restriction by date, domain, language, or file type (based on file name extension).

Although experience with search engines sometimes makes this hard to believe, search results are usually ranked by relevance, with options for sorting the top of the list instead by URL (useful for spotting pages from the same site) or by date. Being proprietary, the means by which ranking is accomplished are rarely described in any great detail. At the very least, query term frequency in the document is taken into account, and calculations may involve normalization for document length.

Most search engines present results 10 or so at a time, in a default format showing title and some text, and accompanied by a cheery message along the lines of ''1–10 of 69,010.'' Both the number of hits per page and the format can usually be changed. Format displays (variations on short, medium, and long) can include any of the following:

Users searching the Internet face the problem of how to explore the many documents being retrieved or how to compare the documents found by different search engines. Search results tend to be presented as a ranked list, which has the advantage that users know where to start their search for relevant documents. However, only a small subset of documents is visible in a single screen. Most users only look at the first screen of search results. Individual search engines only index 20% of the Internet and therefore return different documents for the same query. Meta search engines address this limitation by combining the results by different engines. The automatic and effective fusion of different search engine results can be difficult. Research has shown that documents found by multiple retrieval methods are more likely to be relevant.

4. SOFTWARE DESIGN AND DEVELOPMENT

The requirement of the software was identified as part of a successful proposal for the 2004 CIB *Gyula Sebestyén Award*. The creation of an enhanced "search facility" which aims to enhance existing search capabilities of the CIB web page that will be of benefit for members of the growing CIB Student Chapter community, and the wider CIB community.

The proposal for the search facility is aimed at "re-engineering" the vast amount of information found within the CIB by making it more accessible for both the growing Student Chapters and also the wider CIB community. A critical appraisal of the current search facility of the CIB website has identified that the wealth of accumulated information and knowledge is under-utilised and it is felt that searching for information is difficult in the present format.

The intention is to develop a search facility which allows for easier access to the existing information and knowledge developed in recent years and also allows for future events to be made available to more members. The search facility would generate a “template” for those organising CIB-related conferences and workshops to use. This would make it possible for the organisers of these events to utilise the proposed template to upload conference proceedings and workshop materials in a ‘standard’ and user-friendly manner.

4.1 Design and development of a search engine

To produce quality products, understanding of requirements for a software system is a major concern. Requirements engineering is a common terminology used to specify various requirements-related activities. Requirements engineering comprises four specific processes (Raghaven et al., 1994):

Requirements elicitation: The process through which customers, buyers, or users of a software system discover, reveal, articulate, and understand their requirements. Statistics shows that incorrect, incomplete, or misunderstood requirements are the most common causes of poor quality, cost overruns, and late delivery of software systems in particular, and complex systems in general. A member of the project team spent two days at the client organisation’s headquarters (CIB) in the Netherlands, in order that their requirements were fully understood. This stage of the project was essential for the familiarisation and clarification of the existing set-up and ascertaining the client’s expectations.

Requirements analysis - The process of reasoning about the requirements that have been elicited; it involves activities such as examining requirements for conflicts or inconsistencies, combining related requirements, and identifying missing requirements.

Requirements specification - The process of recording the requirements in one or more forms, including natural language and formal, symbolic, or graphical representations; also, the product that is the document produced by that process. A project team was established early on to create a working document which established our aims, whilst identifying the existing capabilities and limitations. The document also provided an improved understanding of our roles and responsibilities. A preliminary design document was produced; which made explicit the remit of the project, the requirements from the client and also an outline project program.

Requirement validations - The process of confirming with the customer or user of the system that the specific requirements are valid, correct and complete. To develop high quality complex systems, the requirements elicitation process is an essential activity in the overall system development task. The preliminary design document was sent to CIB for their approval.

4.2 Identification of user groups

The search facility is an add-on and developed independently from the main system. The two main functions of the output were *Publication Search* and *Uploading New Publication*. These elements were designed as such that it may be inserted anywhere within the existing host website allowing it to be integrated more effectively. The system was developed for three identified groups of users: general; designated; and administrator. Each group has different privileges as will be discussed below.

General users - publication search: When the user clicks on the Publication Search link, he/she will be directed to a Basic Search facility, as is common with many search engines, with Google being the most popular. The user will be able to enter one or more keywords and perform a basic search and this will be available to all user groups. The core minimum functionality of any search engine is the ability to find documents based on keywords provided by the user. The developed search engine starts with a "search parameters" page. From this page, the user is able to input keywords that identify to the search engine what information to look for. The system then figures out which document are the most applicable to the keywords entered, and returns a listing of those documents that are the most likely to meet the requirements of the user. The user is then able to select the document or documents that seem pertinent, and view them for confirmation.

Figure 1: Screen shot of advanced search

There is also an option for advanced search by selecting the *Advanced Search* link. When the user clicks on this link (Figure 1) the information will be displayed. In a simple keyword search, user asking the system to review all of the available documents in the universe would mean that it would have to search through a lot of documents that could not possibly contain anything of interest. To avoid forcing the system to do unnecessary work, and to speed up the searches, most search engines include search context-limiting parameters. Users specify which populations of files they want the system to search through, allowing it to skip files that are outside of the parameters. The advanced search facility allows the user to select more specific fields in order to fine tune the search, in addition to the keyword(s) which must be inserted, these are: Working Commission/Task Group; Publication Type; Date Range; Article Type and

Language. As the Web is increasingly used in non-English speaking regions, providing search support for multinational organisations in these regions becomes important.

Designated users - uploading new publications: This function is for use of designated users only, i.e. Working Commission and Task Group Coordinators, as well as the administrator. Only authorised users can add new publications, hence a user ID and Password is required; this is prompted once the *Upload New Publication* link is selected in the Home Page. Once selected, the designated user will need to insert his user ID and password. Once this is done, the authorised user will be able to upload new publications and also search publications. When the *Upload New Publication* link (Figure 2) is selected, users will be able to input information and the data will be automatically inserted into the File maker database once the *Upload* button is selected. This will greatly reduce the administrative burden for CIB.

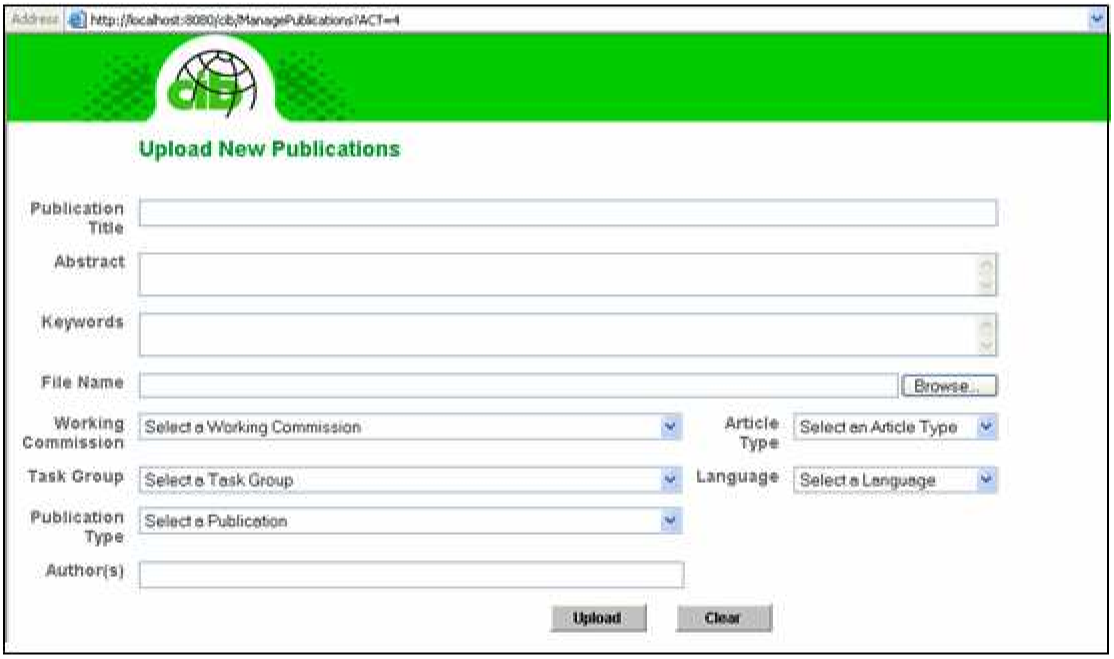

Figure 2: Screen shot of upload new publications

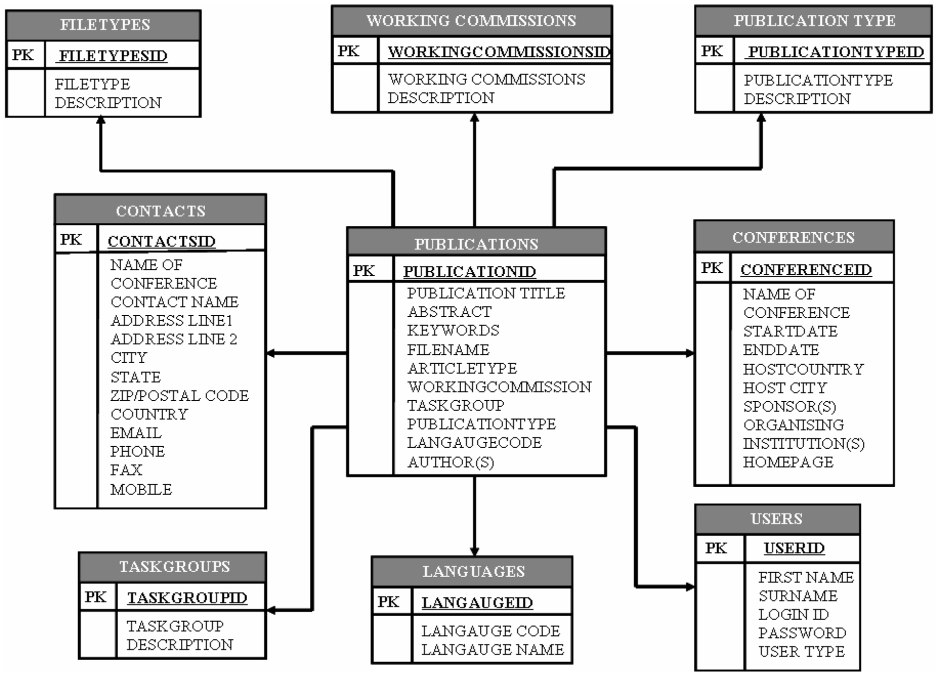

Figure 3: Database architecture

Administrator – maintenance: The role of the administrator, as is the case with most systems is to make changes by adding and removing items on the system which is visible to the users. These amendments could be conducted by selecting any one of the databases from the database architecture which forms the foundation of the search facility (Figure 3). Table 1 below provides a summary of the technical specification used during the development, deployment and testing stages.

Table 1: Technical specification of project

Development	Pentium III machines with minimum 256 MB Ram or equivalent
Deployment	Pentium IV, 2.4GHz machines with minimum 1024 MB RAM 300 MB Free Hard Disk Space for the application and the database Jakarta Tomcat 4.1.18 or equivalent as web server Java Development Kit 1.4.2 or above JSP – For the presentation layer Basic IDE for Java JMeter – For load testing FileMaker Pro 6.0 or above
Testing	The testing methodology adopted involved the following: a. Unit testing by the developer / peer b. Integration testing by the testing team and the project manager c. System testing by the testing team d. Load testing by *JMeter* e. Multi user testing by the testing team

5. CHALLENGES OF THE DEVELOPMENT STAGE

The initial capture of the client's requirements was essential in the development of the project. The development team created a requirements capture document which was used by a team member during two days spent at the client organization.

Once the requirements of the client and the setup of the existing infrastructure were established, numerous technical issues had to be addressed. The fact that we were limited by the existing IT infrastructure posed several challenges. Firstly, the operating system used was different to what the development team were used to. Secondly, the data was stored in a database which utilised specialised software. In addition, perhaps due to a conflict of interest, the external IT consultant employed by the client was slow with regards to the provision of information and general co-operation of the project.

6. BENEFITS OF THE DYNAMIC INTEGRATED SEARCH FACILITY

Search facility systems are becoming more common in the construction industry, especially amongst the larger organisations. For any database, information needs to be uploaded and kept up to date. This is often a laborious and time consuming job. The developed dynamic integrated search facility allows authorised users with the ability to upload files.

The search engine can increase user efficiency by either returning higher-quality document lists (e.g., through better index coverage and ranking algorithms) or by providing information that allows the user to evaluate the results more quickly. The developed search engine provides the document's URL, title and size, as well as a few sentences that summarises the document, although the user must evaluate the document's relevance by reading the text summary.

With increasing academic and research contents available online, the Web has become the largest information repository ever for most scientific domains. However, it has become increasingly difficult to search for high-quality domain-specific information. The developed search engine caters to a specific community with shared focused interests; it can take advantage of such integration; for example types of file and languages. Because if variety of interest, the function of the search engine has to encompass numerous criteria. This resulted in the reduction of the time it takes to search for information in the CIB web page as well as uploading files, alleviating the administrative burden for the CIB. Hence in the developed search facility both simple and advanced search options are provided.

7. CONCLUSION

This paper provides a real-case project example on how to design and implement an integrated search facility for the benefit of a research community. A thorough review of the current facilities provided on the International Council for Research and Innovation in Building and Construction (CIB) web page was undertaken. This was conducted to identify improvements which may benefit both the CIB and its members. This paper also highlights the process with regards to the design and development of the project. Also, for authorised users, there is a facility to upload files.

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THE ADOPTION OF THE REPERTORY GRID TECHNIQUE IN CAPTURING KNOWLEDGE FOR REFURBISHMENT IN THE CONSTRUCTION INDUSTRY

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Abstract: Refurbishments projects are generally considered to be of higher risk, more complex and in need of greater coordination than new build projects. In refurbishment work, there are many tasks where decisions are shaped not only by external factors but also by experience. In such situations, one is likely to find that experts rely on relatively unstructured methods in arriving at a decision. For the reason that there are proportionately more risks in refurbishment and renovation projects than in new-build, because of the associated degree of uncertainty and complexity, knowledge plays an important part in bringing the project to successful completion. Based on an on-going doctorate study which aims to develop an appropriate methodology to match the project requirements with the knowledge of project team members in refurbishment projects, this paper explores the applicability of a repertory grid technique in capturing knowledge for refurbishment in the construction industry. The need for knowledge in refurbishment projects is highlighted and a review of the available knowledge acquisition techniques pertaining to the research is made.

Keywords: Knowledge management, refurbishment projects, repertory grid technique

1 INTRODUCTION

The satisfaction of the client has long been acknowledged as a much needed issue to be addressed and the importance of including 'client satisfaction' in the measurement of project success factors was also emphasised by Pinto and Slevin (1988). In order to achieve client satisfaction two objectives have to be met, first, the translation of client needs into a design, which specifies technical characteristics, functional performance criteria and quality standards; and secondly, the completion of the project within a specified time and in the most cost effective manner (Bowen, et al, 1999). The briefing process, where the client's desire for a built product is documented into a clear 'brief' has been identified as an avenue to improve client's satisfaction. In the development of a project brief, a wide variety of skills are drawn upon including those of architects, planners and engineers who can envisage the options for the final product (Winch, Usmani, and Edkins, 1998).

Knowledge as quoted by Martensson (2000) is something that resides in people's mind and is one of the most important resources to an organisation (Nonaka and Takeuchi, 1995). Othman et al (2005) has indicated that project team members are the originators of brief development, with their knowledge or the lack of it; they can be a value source or a risk source to the project. This view is echoed by Hatten and Lalani (1997) who suggest that by selecting an appropriate consultant team the chance of delivering a project on time and within budget might increase. Cooley (1994) concurred that good consultants should bring genuine and lasting value to the organisation they serve. The requirements of the client are difficult to interpret by the project team and to reduce client's requirements to a textual form is clearly impractical. For refurbishment projects where the clients are very dependent on the knowledge and skills of the project team (Smith, Love and Jackson, 1999), it is all the more important that the project team are able to understand and interpret client's requirements and rely on their knowledge and experience to meet client's requirements.

Through our literature review, we discovered that the use of the term knowledge capture very often appears in literatures on knowledge management whilst knowledge acquisition is often used in knowledge engineering. Based on Newman's (1996) definition of the role of a manager and an engineer, we construe that knowledge management is concerned with the knowledge needs of the enterprise and it is concerned with the understanding of what knowledge is needed to make what decision and enable what actions. Knowledge engineering, on the other hand, would be the research of technologies needed to meet the enterprise's knowledge management needs. In the context of this paper, knowledge acquisition shall also mean knowledge capture and both terms shall be used interchangeably.

Based on an on-going doctorate study which aims to develop an appropriate methodology to match the project requirements with the knowledge of project team members in refurbishment projects, this paper explores the applicability of a repertory grid technique in capturing knowledge for refurbishment in the construction industry. The need for knowledge in refurbishment projects is highlighted and a review of the available knowledge acquisition techniques pertaining to the research is made.

2 THE NEED FOR KNOWLEDGE IN REFURBISHMENT PROJECTS

In refurbishment work, there are many tasks where decisions are shaped not only by external factors but also by the experience based capabilities and future workload of the firm's personnel and it general policy. In such situations, one is likely to find that experts rely on relatively unstructured methods in arriving at a decision (Okoroh, M.I., & Torrance, V.B., 1999). The Technology Foresight Report (OST, 1995) emphasized the importance of the acquisition of appropriate skills, knowledge and competencies through appropriate education and training. Lansley (1990) has suggested that the construction industry now requires greater 'knowledge workers' than in the past.

Knowledge is the ideas, wisdom and facts mangers acquire through experience, theory and practice; the acquisition of which gives them an ability to understand. Knowledge can be potential or manifested in performance. Management skills and knowledge should complement one another (Egbu, 1999).
In refurbishment, with the increase in contract labour, together with a corresponding increase in fragmented specialised work and the difficulties associated with labour on site, the skills of leadership and communication become even more necessary. Also, with an increasing need for speed of response to address the issues arising from variations to the works, the skills of communication becomes vitally important.

Koehn and Tower (1982) are of the view that refurbishment work demands greater supervision than new build work.

Willenbrock et al (1987) are of the view that the nature of refurbishment work, coupled with a long working week and overtime work by construction personnel, leads to low morale and low productivity of refurbishment work. Thus, the skill/knowledge of motivating others is needed.

Demolition work can involve the disposal of hazardous substances such as asbestos and lead. Statistics from the Health and Safety Executive (HSE, 1998) show that the repair and maintenance sector, including refurbishment, accounts for about 43% of the total number of construction fatal accidents in the UK. The need to understand and be able to control substances hazardous to health, such as asbestos and lead, especially by the site management team, is of the utmost importance. Egbu (1996) argued that appropriate management strategies need to be developed to cope with the safety risks and hazards especially for works carried out with tenants in occupation.

Refurbishment work is characterised by high risk, uncertainty and high numbers of variation orders to the works. Working under such situations, and at the same time attempting to achieve the stipulated time for project completion, managers would have to make impromptu and sound decisions. The skill of decision making therefore is of great importance at all levels of management. In an environment of uncertainty, increased variation to the works and costs likely to escalate at short notice and controlling the financial requirements of refurbishment processes is considered to be important, thus the skills and knowledge associated with forecasting and planning is very important.

Because refurbishment often involves working in confined site, the knowledge of site organisation is important. In addition, there is a need to understand the nature and qualities of the materials used originally so as to match them exactly or look for a material which blends in and harmonise with the existing environment (Aldous, 1978)

The nature of refurbishment work with a high level of uncertainty in the works, lends itself to project time over-run. The skills and knowledge associated with managing time therefore are necessary. The relatively high degree of importance attached to managing time is supported by Jothiraj and Fellows' (1986), who observed that time performance, was the major factor in determining clients' overall satisfaction with commercial refurbishment projects.

The ability to cope with unexpected, changes, conflicts and crisis is needed in refurbishment work. The skill/knowledge associated with the analysis of project risk/uncertainty is also of high importance. The high degree of importance attached to project risks/uncertainty by all levels of management reflects the high levels of risk and uncertainty associated with refurbishment works (Chapman, 1980; Quah, 1988; Teo, 1990). Refurbishment work therefore demands requisite skill/knowledge associated with being able to assess and analyse risks/uncertainty in construction work.

In summary, the most important management skills/knowledge for refurbishment are: leadership, communication (oral/written), motivation of others, health and safety, decision making and forecasting and planning.

3 CONCEPTUAL FRAMEWORK

In this section, the key issues identified in the literature review are summarised and synthesised for the identification of major research questions to be explored in the research study. Research questions identified in this research are:

1. Is there a formal and systematic way employed by project teams or clients in matching client's needs and expectations with the requisite knowledge of the project team in refurbishment projects?
2. Do the types and complexities of refurbishment projects have an impact on the types and sources of knowledge that the project team draws upon to address specific refurbishment tasks in order to meet client's needs and expectations?
3. Do the types and complexities of refurbishment projects affect the choice of knowledge capture tools and techniques employed by the project team to meet the needs and expectations of the client?

The developed framework shown in Figure 1 below is based on three of the five knowledge creation processes, namely knowledge sharing, knowledge generation and knowledge integration proposed by Fong (2003) in his modified model of Nonaka and Takeuchi's knowledge creation model (Nonaka and Takeuchi, 1995). The modified model takes into consideration social construction and communication within multidisciplinary project teams which Nonaka and Takeuchi do not look into in their knowledge creation model. Given that the construction project team in the construction industry is made up of multidisciplinary members, the modified model is deemed suitable and adopted in this research.

Project team members of differing knowledge domains share their uniquely distinct information and knowledge when the design issues and problems influence the project under each discipline domain. Knowledge is shared amongst the project team using each of their experience and perspectives. At the requirements elicitation and analysis stage for refurbishment projects, knowledge gap exists when the project team members posses insufficient knowledge to reconcile client's requirements with the constraints in refurbishment projects. To meet the client's requirements, the knowledge required had to be identified. With the identification of the required knowledge, the project team shall proceed to the next process of knowledge generation. Knowledge is generated through acquisition and creation (Marr, 2003), thus knowledge from various sources is acquired or created to fill the knowledge gap.

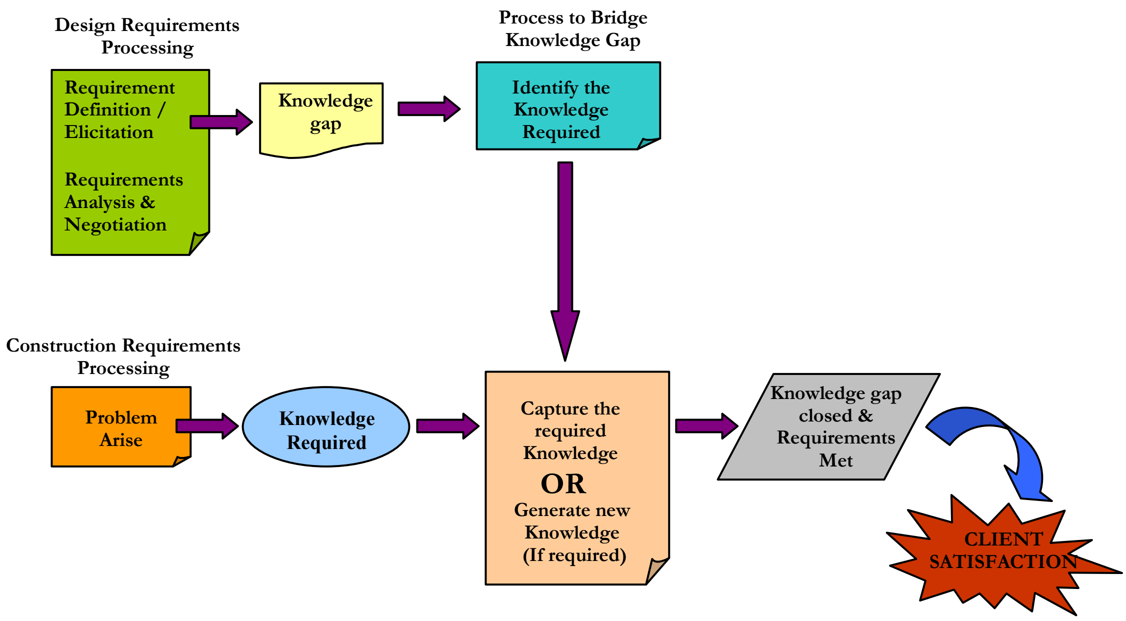

Figure 1: Conceptual Framework for Matching Knowledge of Project Team with the Project Requirements for Refurbishment Projects

With respect to refurbishment projects at the construction stage, the required knowledge is identified when a problem arise. The knowledge sharing and generation processes are repetitive until sufficient knowledge is found to meet the client's requirements. Once the knowledge gap is filled, knowledge integration happens when all knowledge from the project team members are combined. Clients' requirements are met and this brings about client satisfaction. In order for knowledge to be elicited at the knowledge generation process, knowledge capture techniques need to be used and in this paper various knowledge capture techniques shall be examined.

4 TOOLS & TECHNIQUES FOR KNOWLEDGE CAPTURE

Boose (1990) has differentiated knowledge acquisition tools and techniques under manual and computer-based and under computer-based this is further classified into interactive and automated. Little methodology is practised beyond unstructured interviewing and automated methods are, for the most part, still in the research stage (Boose, 1990). Coupled with the fact that the recognition of the benefits of IT is slow in the construction industry, therefore only manual knowledge acquisition techniques shall be discussed in this paper. The most commonly used human-centred techniques for knowledge acquisition (in descending order of frequency of use as stated by Edwards (2003) are: interviews, protocol analysis, repertory grid analysis, case study observation and introspection. Another method for knowledge acquisition as proposed by Gregory (1992) is the Soft System Methodology.

Interviews are a process where a knowledge engineer either informally or formally debriefs an expert. Interviews are the most frequently used way of acquiring concepts and terminology as used by the expert, and is more efficient than observation methods. Sixteen different types of interview have been identified by Neale (1988) but the more common types of interviews are structured, unstructured or semi-structured interviews. Structured interview is where the knowledge engineer asks at each interview the same questions in the same order and manner. This type of interview is useful when there is some particular knowledge that must be collected and when the problem characteristics and answers are predictable. Unstructured or semi-structured interview is similar to structured interviews where a set of questions are posed to the expert by the knowledge engineer, however, the order of the questions or the way they are posed differs from one interview to another. Such kind of interview gives flexibility to the knowledge engineer to adopt whenever required the vocabulary to the questioned expert and record the answers even if these answers can be derived from the answers to different questions.

Protocol Analysis involves inspecting verbal records of experts describing their own thought processes as they solve a typical problem. The verbal record usually in the form of tap record is transcribed in every detail into a ‘protocol’ and then analysed for valid associations from which corresponding production rules are derived.

Repertory Grid Analysis (Kelly, 1955) is also referred to as Kelly grids or personal construct theory. It is a way of representing the expert’s perception of a problem in a matrix of constructs and elements. The elements are the domain concepts (or other entities/objects) whose relationship is to be investigated.

Case study observation is used for acquiring essential tacit knowledge which cannot be articulated. It is an acquisition process where an observer determines useful information by observing an expert complete a typical task.

Introspection is used in knowledge engineering as the technique of last resort (Edwards, 2003). In introspection, the knowledge engineer interrupts the human expert during the performed task with questions such as ‘tell me what you are thinking now’ or ‘how would I do that myself?’ This method could be seen as offering the benefit that the expert is for the most part in charge of the session while the knowledge engineer can immediately ask for clarification. On the other hand, however, the interruptions by the knowledge engineer tend to ‘spoil the flow’ of the consultation.

It has been acknowledged that it is problematic to evaluate knowledge acquisition tools and methodologies (Cao and Compton, (2005); Menzies & Hamelen, (1999); Shadbolt and O’hara, (1999)). Thus in this paper, the authors shall not attempt to do so but instead look at the application the repertory grid technique as a knowledge acquisition method in this study.

5 REPERTORY GRID AND ITS APPLICATION IN THIS RESEARCH

Three routes for knowledge elicitation are identified by Okoroh and Torrance (1999). The psychological route, which involves some kind of interaction between the knowledge engineer and the domain expert; the machine induction route, which the computer induces rules from examples automatically and the route in which the domain engineer plays the role of the domain expert. The route in which the domain engineer plays the role of the domain expert is not adopted for two main reasons (Hart, 1986):

the expert normally will not have sufficient knowledge about programming and knowledge based systems techniques and the experts will find it difficult to describe their knowledge fully. As each refurbishment projects are unique and cannot be completely encapsulated the machine route is not used. Hence only the psychological route is considered in this research. Some of the knowledge acquisition techniques have been discussed in the earlier section. The repertory grid technique is chosen as it offers an extremely flexible methodology for obtaining the mental maps of the project team members. Access to such map is of vital help in any research which involves people and decision making and in this research, it is deemed appropriate.

The main purpose of the Repertory Grid knowledge elicitation exercise was to establish which of the given knowledge types can be obtained from the knowledge sources in order to meet client's project requirements in refurbishment projects.

There are a varieties of grid in use today which include grids using ranking, grids using rating, bipolar implications grids, resistance-to-change grids, dependency grids to name a few. Dependency grids, sometimes known more generally as Situation-Resource grids shall be used in this research. In this grid form, the subject relates situations (constructs) with people (resources/elements). The situations are those which are essentially situations which any of us might encounter and the people are those upon whom we may call for help or on whom we may lean on.

Given the need for strength of authority on the client side and the breath of expertise from the project team in a refurbishment project, knowledge elicitation shall be from several experts ranging from the client to the contractor with experiences in hotel, hospitals, office and retail refurbishment.

Repertory grids can enable an interview to be carried out to some detail and reduce observer bias, but this depends very much on how the grids are administered e.g. the provision of constructs by the interviewer will not eliminate observer bias and if the constructs are not familiar to the interviewee, the distinctions made will be reduced (Oppenheim and Stenson, 2003). The issue of supplied versus elicited constructs has been a basic concern for the use of personal constructs in repertory grid. Adams-Webber (1998) has found that elicited constructs are significantly more accurate then supplied constructs; Fansella (2003) however argued that accuracy also depends on the context in which the grid is being used. From a purely Kellyian perspective, the technique would seem to demand that the constructs be elicited; in this research however, the constructs are supplied because the research demands aggregated data and data cannot be aggregated without commonality.

Rating level from the range of one to five is considered to be appropriate in this research because more or fewer categories appear to be either too many or too few for user friendliness and accuracy for evaluation. Also, these five ratings can mesh readily with the levels of importance attached to each construct. Further, in Bell et al. (2002) testing of mean interclass correlations, supplied constructs and elements with ratings from one to five indicates no significant difference and since in this research both constructs and elements are supplied, a rating level of one to five is adopted.

6 CONCLUSION

Given the complex nature of refurbishment projects, knowledge is a valuable source of commodity which not only assists the project team to bring the project to a successful completion but also bring satisfaction to the client. The need for knowledge in refurbishment projects has been highlighted in this paper. The most commonly used human-centred techniques for knowledge acquisition are also reviewed.

Based on the modes of knowledge creation, where knowledge can be externalised, socialised, internalised and combined, the repertory grids technique is chosen for this research. This technique shows in a very compact way what an expert knows and can be used by an expert to think about what is important, create new insights by providing opportunities for reflection and provide a checklist of things to look for in a specific context in terms of creating knowledge through externalisation. In terms of creating knowledge through combination, repertory grids allow the manipulation of externalised knowledge in a variety of ways to think, reflecting and invite the questioning of assumptions.

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PRODUCTION MANAGEMENT IN CONSTRUCTION REQUIREMENTS AND METHODS

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Abstract: Trying to identify why Production Management in construction so often fails, the aim of this paper is to explore the most common reasons why this happens. To link the findings with practice this paper is based on an observatory case study made in a UK construction company. After that, the Production Management requirements are presented as well as the mostly used conventional methods in construction. Among them are the CPM, Line-of-Balance, Critical Chain, and the Last Planner System. The discussion compares them with the production management requirements previously presented. Finally, conclusions are made about Production Management in construction needs and future research expectations.

Keywords: Methods, Production Management, Requirements.

1. INTRODUCTION

Production Management methods can be responsible for many failings in construction projects (Kenley, 2004). Apart from a few cases of new methods developed, the construction industry has been used to planning and controls not complete satisfactory tools and techniques. The majority of these methods are based on bygone principles or they were adapted from the manufacturing industry to be suitable to construction. As a consequence they are not able to cover all the Production Management needs in construction. From this background the goal of this paper is define the requirements of Production Management as well as to evaluate the major methods that have been used in practice.

2. A CASE STUDY IN AN UK CONSTRUCTION INDUSTRY

The authors have been involved in a partnership to conduct a case study with a UK construction company during the first semester of this year. The project covered a refurbishment of an old mill and its transformation into a residential block as well as facilities for car parking spaces and accessibility. The academic objective of this case study was to sharpen the author's PhD research problem and identify construction industry needs. The data collection was made by direct observation where the company Production Management System could be analysed and its application in practice.

The company production system is explained in three guidance booklets to provide standard forms for information flow and consequently data for decision-making at all hierarchical levels of the company. These guidance booklets have good details regarding the way that managers should control the production and also what they have to report to their supervisor.

In practice what could be noticed is that the bureaucracy between the several managerial levels made the company inflexible. As a result of this inflexibility we can pinpoint the length of time for decision-making and the amount of waste regarding human effort and time in the construction processes.

Waste identified in the task analyses includes:

- Waiting time,
- Inadequate equipment,
- Over-manning,
- Rework,
- Unnecessary transport,
- No industrialization of process (pre-fabricated),
- Inadequate materials management,
- Discontinuous task execution.

The majority of these types of wastes is not unique and can be found as common problems around the world in the construction industry. Among the reasons for these wastes, common issues as well as situation specific issues could be observed:

- A push type of production control, conventionally used in construction, has overall in itself been found to lead to unpredictability and loss of productivity – indications of this could be perceived also in this case study,
- Split responsibility for planning,
- Complexity,
- Sub-contracted workforce hinders a continuous improvement programme,
- No commitment by all stakeholders in the scheduling phase,
- Buying department was not linked by any one of the plans,
- IT missing.

Thus, even in a company where, at first sight, production management seems to be orderly structured and implemented, the performance of production management is poor. From this background, it is pertinent to challenge the ends and means of production management.

3. PRODUCTION MANAGEMENT REQUIREMENTS

The objective of the requirements in Production Management is to supply the decision maker with information about agreed levels of utilization of materials, machines, and labour. Furthermore, it is achieved by controlling: quality, speed, dependability, flexibility, and cost (Henrich & Koskela, 2005).

Virtually all managers want on-time delivery, minimal work in process, short customer lead time, and maximum utilization of resources. Unfortunately, these goals are in conflict. It is much easier to finish jobs on time if resource utilization is low. Customer lead times can be made essentially zero if an enormous inventory is maintained. And so on. The goal of production scheduling is to strike a profitable balance among these conflicting objectives (Hopp & Spearman, 2001).

Koskela and Ballard (2003) summarized the requirements of the Production System in construction as follow:

A. A production system in construction should be designed to realize at least the following requirements: delivering the product, minimizing waste and maximizing value (lean construction).
B. All managerial functions: design, operation and improvement, must contribute to the realization of these requirements.
C. The generic peculiarities of construction, as well as the situation wise characteristics, must be taken into account in the realization of these requirements.
D. All parts and aspects of the production system must be integrated: synergies must be utilized, and contradicting issues must be balanced.

Further we will use these requirements to base a comparison among the production management methods in construction.

4. PRODUCTION MANAGEMENT METHODS

There are different kinds and varieties of production management methods; the most common of which are introduced and analyzed in the following sections.

Critical Path Method – CPM

The Critical Path Method (CPM) basically developed as an extension of the Gantt/Bar chart, to determine mathematically, the sequence of activities that would need to be followed to allow the project to finish in the minimum time possible. First developed by DuPont and Remington Rand (UNIVAC) around 1957 (Kelley & Walker, 1959), CPM networks not only included activity dependencies, but also provided each activity with a unique numerical identifier and an estimate of the activity's duration. Apart from determining which sequence of activities was 'critical' for the timely completion of a project, it was also possible to calculate the amount of 'float' that could be used before a delay to the start of a 'non-critical' activity impacted on the overall programme – considered to be very important on large and complicated projects. A variation of the CPM approach is the Programme Evaluation and Review Technique (PERT), which tries to allow for activity duration uncertainty, by using best, worst and most likely duration assessments to calculate each activity's approximate duration.

Whilst the majority of CPM networks are displayed in the Activity on Arrow (AoA) format, it is also possible to use the Activity on Node (AoN) or Precedence format to display a programme. However, the AoA method is often preferred due to the way the length of an activity is generally related to it duration on a project time scale.
Major benefits of using the CPM approach include providing a disciplined method for planning construction, showing the logic and construction methodology being used, showing the interdependencies between both critical and non critical activities and assessing the impact that various resource options might have on the project (Kelley & Walker, 1959; Jaafari, 1984).

Over the years, as CPM became more popular as a method of Project Management, the software that was developed to analyse the data has became more and more sophisticated, allowing for full project monitoring, activity splitting, resource levelling, cost control and variety of other functions to be included.

The Line-of-Balance – LOB

The Line-of-Balance (LOB) was originally derived from the manufacturing industry and was developed by the U.S. Navy Department in 1942 for the programming and controlling of repetitive or one-off projects. It was later developed by Nation Building Agency (in UK) for repetitive housing projects, where a resource-oriented scheduling tool – that considered resources as the starting point – was considered to be more appropriate and realistic than one that was more activity-dominated. This method was later adapted to planning and project control (Lumsden, 1968), where resource productivity is considered to be of particular importance.

Line-of-Balance proposes that activities should be planned within their production rhythms, in other words, the number of units that a crew can produce in a determined time unit. These rhythms are shown in a graph 'time x units' and it can represent the real production of units. The LOB helps the foreman of a production line, at anytime; to observe the progress of each activity by its ability to maintain a set rate of productivity. In many phases of its application many decisions have to be taken by the foreman such as: level of detachment in activities planning, crew size, production expected and achieved, production rhythm and learning, that result in the number of crew simultaneously on the site, their position/location; the direction of production and technologies available or able to be used (Mendes, 1999).

A common characteristic of Line-of-Balance techniques is the typical unit network. LOB is a variation of linear scheduling methods that allows the balancing of operations such that each activity is seen as being continuously performed, even though the work is carried out in various locations. The major benefit of the LOB methodology is that it provides production rate and duration information in the form of an easily interpreted graphics format (Figure 2, Arditi *et al.*, 2002).

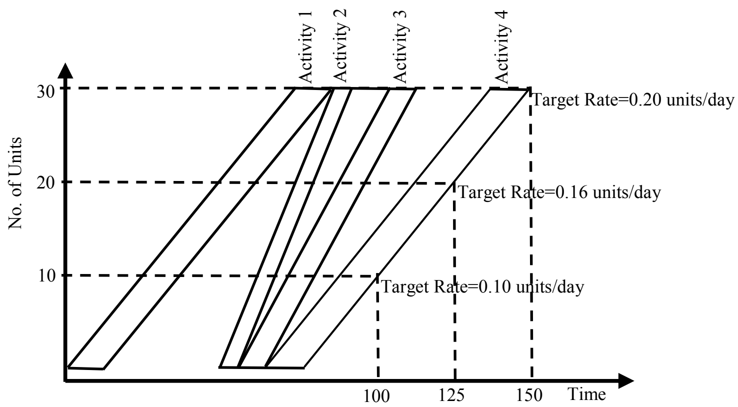

Figure 2. Line-of-Balance and production rate (Figure 1 in Arditi et al. 2002)

Critical Chain

The basic idea underlying Critical Chain Project Management (CCPM) derives from the theory of constraints (TOC), developed by Goldratt (1997). TOC asserts that goal achievement for any system is limited by a constraint.

Goldratt (1997) took this simple idea into the world of production with five focusing steps for system improvement:

a. *Identify* the constraint;
b. *Exploit* the constraint (do whatever is necessary to ensure the constraint works at full capacity);
c. *Subordinate* everything else to the constraint (eliminate interferences with exploiting the constraint to achieve system throughput);
d. *Elevate* the constraint (get more of the constraint);
e. Do not let *inertia* keep you from doing the cycle again.

In production planning terms the system's constraint is the bottleneck. Goldratt (1997) argues that the main reason for project overrun is because of the misuse of the safety time created within the estimated times for each activity. The tendency is overestimate the times to give a reasonable degree of certainty of completion. The approach of TOC is to relocate the safety times in strategic positions. Time estimates may be reduced, but safety buffers of time at the end of the project are added. This will have the effect of reducing the length of the critical path.

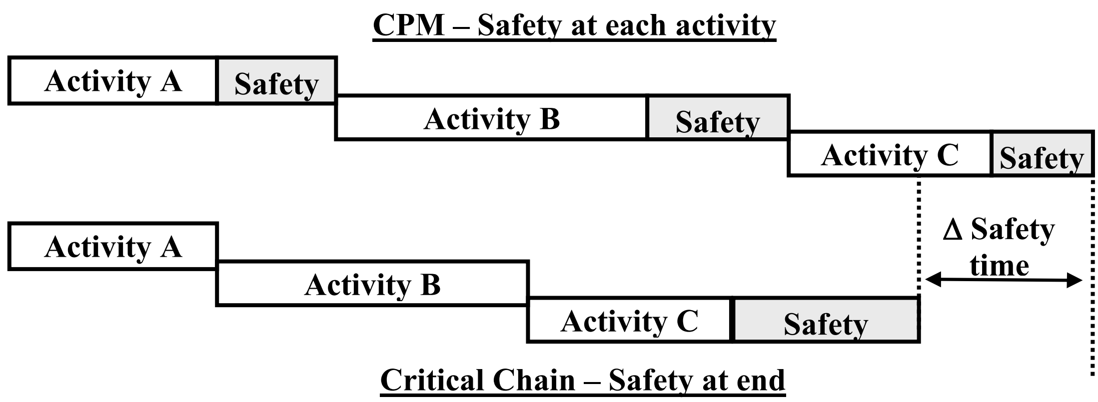

Figure 3. Comparison between CPM and Critical Chain regarding safety time

The first requirement is to ensure that preparations are made to start activities when they are passed over. One aspect of this is the creation of a resource buffer for activities on the critical path. The time of completion of ongoing activities is estimated, and the appropriate resources required for the subsequent activities are told to be available. The aim is that people know that when the time comes they must drop everything and work on the critical path. They are encouraged to start immediately, work only on the critical task and finish promptly. It is clear that is necessary to prevent multi-tasking is a crucially important aspect of project management that needs to be controlled (Rand, 2000).

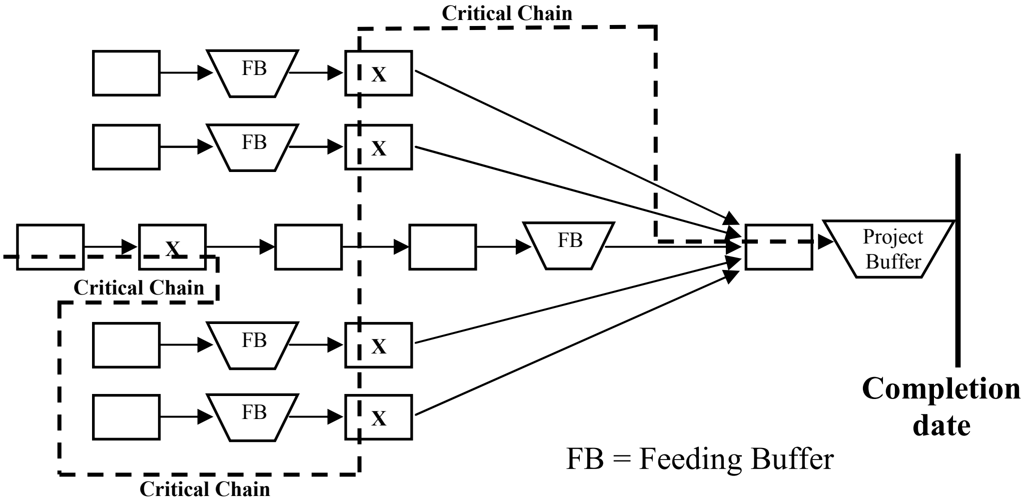

Figure 4. An example of critical chain (Goldratt, 1997)

The critical chain is defined as the longest chain of dependent steps: in other words, the constraint. To determine this, it is necessary to take into account any dependencies that might exist between activities because they require the same resource. If that is the case, they must be carried out sequentially rather than in parallel. This can be analyzed in the diagram shown in *Fig. 4*.

Last Planner System - LPS

The Last Planner System (LPS) was originally developed by Ballard and Howell in 1992. It is designed to increase reliability of planning as a mechanism to improve project performance.
Last Planner adds a production control component to the traditional project management system. Last Planner can be understood as a mechanism for transforming what SHOULD be done into what CAN be done, thus forming an inventory of ready work, from which Weekly Work Plans can be formed. Including assignments on Weekly Work Plans is a commitment by the Last Planners (foremen, squad bosses) to what they actually WILL do (Ballard, 2000).

The phase scheduling technique is used to develop a more detailed work plan that specifies the handoffs between the specialists involved in that phase. These handoffs then become goals to be achieved through Production Control. In other words, it is tried to achieve each handoff between specialists specified in the most highly detailed project schedule. They also recommend using pull techniques and team planning to develop schedules for each phase of work, from design through turnover. The phase schedules thus produced are based on targets and milestones from the APP and provide a basis for lookahead planning. The look-ahead has as its objectives to identify and eliminate constraints to achieve the milestones of the project, in a horizon that can be variable from four to eight weeks.

'Team planning involves representatives of all organizations that do work within the phase. Typically, team members write on sheets of paper brief descriptions of work they must perform in order to release work to others or work that must be completed by others to release work to them. They tape or stick those sheets on a wall in their expected sequence of performance. The first step of formalizing the planning and the phase schedule is to develop a logic network by moving and adjusting the sheets. The next step is to determine durations and see if there is any time left between the calculated start date and the possible start date' (Ballard & Howell, 2003).

The purpose of phase scheduling is to produce a plan for completing a phase of work that maximizes value generation and one that everyone involved understands and supports; to produce a plan from which schedule activities are drawn into the lookahead process to be exploded into operational detail and made ready for assignment in weekly work plans.

The weekly work planning process is built around promises. The agreed programme defines when tasks should be done and acts as a request to the supplier to do that task. The last planners only promise once they have clarified the conditions of satisfaction and if they are clear that the task can be done.

The LPS assumes that planning means selecting from what 'should' be done to complete a project and deciding for a given time frame what 'will' be done. Recognize that because of resource constraints, not all 'can' be done, and accordingly, if a subset of what 'should' be done 'can' be done, and a subset of what 'can' be done 'will' be done, then there is a high likelihood for what has been planned (will) be successfully completed ('did') (Ballard 2000).

5. PRODUCTION MANAGEMENT REQUIREMENTS VS. TOOLS

To analyse the methods of Production Management in construction we took as the base the requirements of the production system presented previously in section 3 (Koskela & Ballard, 2003). The Table 1 shows the findings of this analysis.

All methods of Production Management have their contribution, but as can be observed in Table 1 there is not one single method that completely satisfies all the requirements of the Production System. Each method has a weakness. For example, CPM does not identify the flow of resources through locations and it also uses a push-driven scheduling. On the other hand, LOB cares about location but this technique was designed to model simple repetitive production processes and, therefore, does not transplant readily into a complex and unpredictable construction environment. The Critical Chain method is recent, but it is still an evolution of the CPM, so it fails almost on the same points that CPM does. The most recent method presented was the Last Planner System. The LPS has two major focuses: short term planning and development of the social system on site. It has been applied with success in some construction companies, but it also has some gaps that still need to be improved. Some methods are also supported by software, but they are still not a total framework.

Table 1. Comparison between Production Management Requirements and Methods

REQUIREMENTS		CPM	LOB	Critical Chain	Last Planner
A	**Delivering the product**	**OK**	**OK**	**OK**	**OK**
	Minimizing waste	**NO** It is not involved with the process, just with scheduling.	**POORLY** Produce a task flow for even and continuous utilization of resources (workforce, equipments, materials, etc.)	**POORLY** Paying attention to the constraints avoids the waste of waiting time.	**PARTIALLY** Reduces making-do[1]; working backwards from a target completion date eliminates work that has customarily been done but doesn't add value.
	Maximizing value	**IMPLICIT**	**IMPLICIT**	**IMPLICIT**	**PARTIALLY** By reducing making-do kinds of waste, quality is increased
B	**Design of Production Management System**	**OK** Very useful to draft the first tasks sequence.	**OK** Flow concept.	**OK** Identify the tasks sequence and their constraints.	**PARTIALLY** Does not cover all project phases.
	Operation	**POORLY** It is difficult to keep it up to date. Software is needed.	**PARTIALLY** It is difficult to keep it up to date. Software is needed.	**POORLY** It is difficult to keep it up to date.	**OK** Because it works directly with the lowest level of production.
	Improvement	**NO**	**NO**	**NO**	**OK** There is a learning process involved.
C	**Peculiarities of Construction**	**OK** Can be used with any kind of project.	**PARTIALLY** Some authors argue that it is just useful for repetitive projects.	**PARTIALLY** Useful just for complex projects.	**PARTIALLY** In projects driven by equipment capacity, it is not very useful.
D	**Integration with all aspects of the Production System**	**NO** It is not linked with resources supply and people.	**NO** It is not linked with resources supply and people.	**NO** It is not linked with resources supply and people.	**PARTIALLY** It involves people synergy, but not resources.

6. CONCLUSIONS

The authors tried to demonstrate that there is a lot to be done on this area of Production Management. What is missing is a specific theory for construction. With a developed and tested theory, it would be much easier to develop a Production Management method that satisfies all the construction requirements. Furthermore, best practices would contribute to this development. As part of the first author's PhD programme,

[1] Making-do - Tasks are started without all their standard inputs (materials, machinery, tools, personnel, external conditions, instructions, etc.) (Koskela, 2004).

further research will be done in this field trying to develop such comprehensive production control concepts and principles, on which a usable method could be based.

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THE INVOLVEMENT OF BUILDERS' MERCHANTS IN THE DEVELOPMENT OF IMPROVED CONSTRUCTION LOGISTICS

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Abstract: Supply chain management (SCM) has been heavily emphasised in research for a number of years within the construction industry. Essentially this interest can be traced to the publication of the Egan report in 1998. By comparison, logistics is a developing field within the industry. This represents a huge paradox for research. Firstly, construction is uniquely suited for benefiting from an improved capability within logistics, since the majority of its components and raw materials are both high volume and low value. This means that transportation is a disproportionately high element of the cost of construction (or manufacturing) than in other industries. Secondly, the effective functioning of a logistics system is a prerequisite to an effective SCM process (Bowersox and Closs, 1996). However, currently there is a very limited understanding of the logistics function within the construction industry as a whole. This must of necessity compromise the ability of the industry to have effective SCM processes. Indeed at the 'lower' end of the construction supply chain, particularly around local builders' merchants (BM), this understanding is practically non-existent.
This paper aims to show the development of a new research project that seeks to identify, quantify and improve the effectiveness of the logistics systems around builders' merchants. The paper demonstrates the most effective methods of conducting the study and identifies the critical parameters and variables for measurement. These variables will lead to the generation of a model in order to develop a simulation of a generic construction logistics system.

Keywords: Builders' Merchants, Building Materials, Logistics, Transportation.

1. INTRODUCTION

In recent years, construction has sought to learn from industries outside its normal terms of reference. In particular manufacturing has been seen as the source of many 'best practice' principles leading to enhanced performance. Lean production and Just-in-time (JIT) delivery systems are extensively cited as being of potential use in construction (Egan, 1998; Fairclough, 2002). Such systems are manipulated in order to accommodate the special nature of construction projects and characteristics of construction industry. Additionally seminal industry reports like those of Egan and Latham (Egan, 1998; Latham, 1994) highlighted the need for collaboration, trust and open agendas among the contributors of construction's industry performance. A holistic approach is starting to be seen as necessary in order to address all the longstanding problems of the industry, and overcome its fragmented nature. Overall, Supply Chain Management (SCM) represents in an axiomatic way this more holistic thinking. The adoption of SCM links each element of the operation and supply processes, cutting across organizational boundaries by creating a unified value chain (Tan et al., 2002). This view of the industry implies that it is necessary to examine all links of the value chain in order to best generate improved performance. In effect this has forced research and thinking away from a contractor-centric view, to a more holistic view of the problems in construction.

In order to develop a more holistic view of the construction supply (or value) chain, it is necessary to expand the scope of current research. At present, in spite of the need for SCM to address the totality of the supply chain, there still tends to be a contractor emphasis in current research. Primarily, it is contended, because research is generally easier when the subject for study is large and easily identified – i.e. contractors. This does not however fulfill the implicit requirements of SCM research. The aim of the research outlined in this paper is to redress the current imbalance in SCM research within the construction industry. The paper begins by developing an appreciation of the fundamental role of logistics within SCM and the size of the market for builders' merchant's (BM) products. The paper goes on to identify the critical role of BMs in the construction supply chain. Having identified transportation as a critical aspect of the supply role of BMs, key parameters governing BM performance in the construction logistics system are identified. The paper concludes by proposing a methodology for the sampling and modeling of current BM performance within construction logistics systems as a means of optimizing BM performance and reducing costs within the construction value chain.

2. BREAKING DOWN THE CHAIN

The effective function of a logistics system is a prerequisite to an effective SCM process (Bowersox and Closs, 1996; Cooke, 2001). Therefore it can be said that enhanced understanding of the logistics process could significantly contribute to improved construction industry performance. However, currently there is a very limited understanding of the logistics function within the construction industry as a whole. Even in publications where logistics are examined, they are considered on a project basis and/or from a contractors' point of view. The role of the contractor is undoubtedly important in the construction supply chain. The contractor can normally be seen as either the 'end' – final destination – of a supply chain. More correctly the contractor should be seen as the centre – or 'hub' – of a network of supply chains. Because of the pre-eminent position of the contractor, most SCM research focuses on the view from the contractor standpoint. For example the work of Bertelsen and Nielsen (1997) and Wegelius - Lehtonen (2001). Notwithstanding this emphasis, the performance of the set of linkages in the chain(s) is acknowledged to be of utmost importance (Tan et al., 2002). The literature reveals little mention of construction supply chain behaviour outside of the contractor (Agapiou et al., 1998a; Wegelius - Lehtonen and Pahkala, 1998; Dainty et al., 2001), or indeed the other links that form this much debated 'unified value chain'(Normann and Ramirez, 2000). The issues of collaboration, trust and networking seem to be left for consideration only under generic SCM theories outside the built environment. Since 1995 Hameri and Paatela have recognised that there is no longer sustainable policy to consider solely one's own interests, the true competitive advantage stems from the efficiency in networking (Hameri and Paatela, 1995; Vrijhoef et al., 2001).

Studies attempting to introduce SCM principles in construction have been undertaken by various authors initially founded upon SCM's contribution to the manufacturing industry. Recently construction focused approaches have been developed and published including works of Wegelius - Lehtonen and Pahkala (1998), Vrijhoef and Koskela (2000) and Briscoe et al. (2001). Logistics application in construction is still thought to be in its infancy but studies from Wegelius - Lehtonen (2001), Shakantu et al. (2003)

and Shakantu (2005), have introduced and developed logistics thinking in construction. These studies share one common goal, the optimization of materials and information flow from their point of origin to their point of use. Their results have been extended to include logistics' contribution to:

1. Cost savings (Agapiou et al., 1998b; Shakantu et al., 2003),
2. Increased productivity (Bertelsen, 1995; Wegelius - Lehtonen, 2001),
3. Lean thinking (Salagnac and Yacine, 1999),
4. Sustainability (Shakantu, 2005).

The role of BMs has been acknowledged as of a great importance for the operation of construction business (Bertelsen, 1995; Agapiou et al., 1998a; Nicholas et al., 1999; 2000). However, current literature does not demonstrate significant evidence of research into the function of SCM using logistics channels as a unit of analysis. Furthermore, BMs and their critical role in the flow of materials in construction supply chains have barely been addressed (Agapiou et al., 1998a). In order to understand the importance of BMs in efficient construction logistics, it is necessary to further examine the BM market.

3. THE BUILDERS' MERCHANTS MARKET

A review of the UK's construction industry structure is the initial step in assessing BM's role in construction. Also, considering the economic performance of the BM market will allow for measuring its contribution to total construction output. Contractors form the majority of construction firms. BMs are ranked in second place in terms of both the number of firms existing and total number of employees. Table 1 (Construction News Plus, 2005) demonstrates the physical and financial size of BMs in the UK construction industry relative to other firms (2003 figures).

Table 1: Proportion of types of firms in the UK's construction industry

Type of firms	Number of firms	Employees	Contribution to construction's output
Contractors	192,404	1,665,000	52%
Builders' Merchants	81,997	591,000	15%
Professional Services	57,636	308,000	16%
Products Producers	20,863	382,000	15%
Quarrying Firms	2,248	23,900	2%

Source: Construction News Plus (2005)

Demand for building materials is directly linked to fluctuations in the level of activity in the construction sector. Thus, in common with the remainder of the industry, reduced or increased activity levels will have a directly proportional coupled effect in BMs. The market's worth in the 5 years' period ending at 2003 increased by 18%. This year by year increase is explicitly described in Table 2.

Table 2: Builder's merchants market worth for the period 1999 - 2003

The Builders' Merchant market by value 1999 - 2003					
Year	**1999**	**2000**	**2001**	**2002**	**2003**
Value (£bn)	8.57	8.98	9.3	9.5	10.1
% change year on year	4.5%	4.8%	3.6%	2.2%	6.3%
Source: Key Note Ltd (2004) and AMA Research (2003)					

Structurally, the market can be characterised as highly consolidated. Three major companies - Wolseley, Jewson (owned by St Gobain) and Travis Perkins - dominate the market. Their total market share is estimated to be around 50% (Grafton Group plc, 2004) and is continuously increasing. Indicatively, Wolseley and Travis Perkins have added 636 new branches to their branch network, including those obtained through acquisitions, over the last three years (2002 to 2004). The principal activities of these companies are the distribution of building, plumbing and timber materials. According to Key Note Ltd (2004) and AMA Research (2003) reports, factors that will affect the market during the forthcoming years, are thought to be:

- Further consolidation within the market,
- Competition with DIY stores,
- Domination of electronic trade.

However, it is not only the size or the financial performance of the market that indicate that BMs represent an essential link in the supply chain of building materials. Indeed, there are some special issues associated with the unique characteristics of construction that allocate merchants a key role in the production process of any construction operation. These issues, analysed from a financial perspective, are associated with the trade conditions within the industry and the physical nature of construction materials.

4. CONSTRUCTION INDUSTRY STRUCTURE

A review of the available literature would appear to demonstrate three major issues that determine the interdependency between the BM market and the wider construction industry. These issues are so closely linked with construction common practices and physical nature that they should be considered as facts. These 'facts' in turn allow for stable syllogisms about the significance of BM involvement in construction logistics.

1. *Construction is highly competitive with low profit margins and large risks.*
   Because of these prevailing conditions, the nature of the supplier / contractor relationship is primarily determined by contractual conditions. In particular, it is noted, by the credit facilities for payments provided by the BMs. Agapiou et al. (1998a) and Nicholas et al. (2000) have underlined the fact that one of the major functions of a merchant is to act as a channel for credit to the construction industry. Such credit is a vital source of working capital for most contractors. It is interesting that research undertaken by Nicholas et al. (1999) identified that over 60% of suppliers have 70% or more of their turnover, accounted for by credit sales. Detailed results can be found in Table 3. For this reason, not surprisingly the

construction materials suppliers have earned the reputation of being the Builders' Bankers (Lowe, 1997; Agapiou et al., 1998a; Nicholas et al., 2000).

Table 3: Suppliers: credit to turnover ratio

Proportion of credit sales to turnover	Percentage of materials suppliers	Cumulative percentage of materials suppliers
90.1 – 100	5.8	5.8
80.1 – 90	32.1	38.5
70.1 – 80	23.1	61.6

Source: Nicholas et al. (1999)

2. *Materials indirect costs affect in a great extent final construction costs.*
   Materials constitute a large proportion of the total cost of construction. Regarding the type of the project they usually account for between 40% (Agapiou et al., 1998a) and 50% (Bertelsen and Nielsen, 1997). Materials prices are not manageable since they are affected both by trade deals between merchants and contractors and by factors external to construction (political, social, etc.).

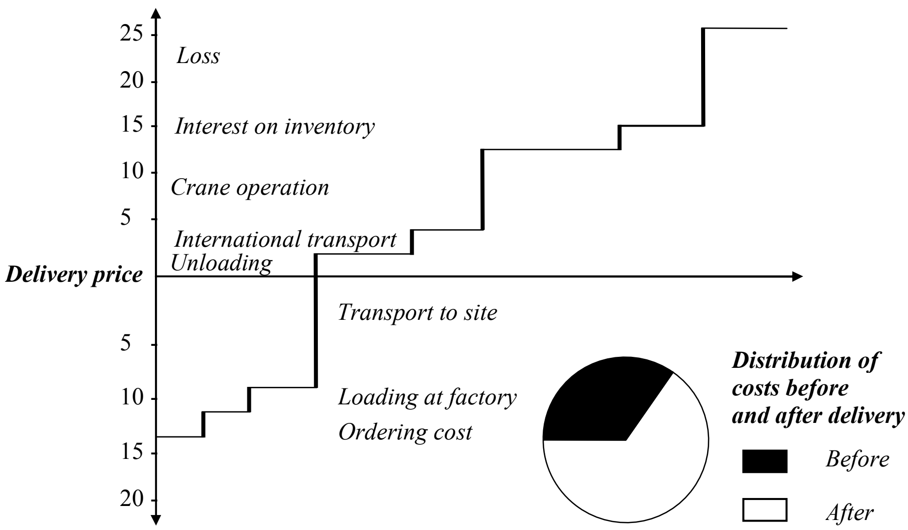

Figure 1: The cost staircase - Mineral wool for insulation (Soderman, 1985)

However, indirect costs associated with the materials could be minimised. An analysis conducted by Soderman (1985), for a number of building materials, calculates the "cost staircase", which is illustrated in Figure 1. This illustrates the increase of the material price from the moment that the order was placed until that the material was used. Apparently, one can observe a remarkable increase because of the loss on site and the cost of the transportation function (the role of transportation in logistics is discussed later in this paper). Also, it is estimated that around 40% of these indirect costs arise before the delivery on site, when the product is still handled by the supplier. If BMs managed to minimise these costs, the material price would consequently reduce. This would lead to a significant reduction of the cost of the building project.

3. *Uncertainty of demand in construction projects imposes a need for maintaining high level inventories.*

> BMs play a key role in the construction industry as an intermediary between the manufacturer and the contractor. Because of their physical position, BM facilities represent a natural storage and consolidation point for construction supply chains. The important role of interstitial storage and movement of materials within supply chains has been frequently remarked upon and is well into the mainstream of logistical understanding (Bowersox et al., 2002). By retaining high level safety stocks, because of the fluctuating demand, BMs have to bear the cost of carrying these inventories. The annual inventory carrying cost is estimated to be around 20% of the average inventory value (Bowersox and Closs, 1996). Actually, it is not only the direct cost of it, but especially the cost of the capital invested in it. If these inventories were carried by contractors, already subject to cash flow problems (a record of 10% annually of the total number of construction companies to have gone insolvent over the last 15 years (DTI, 2004)), the consequences would be catastrophic to the industry.

Thus it would appear manifest that BMs in construction have a pivotal role in the continued performance of the industry. As a means of offsetting risk and providing additional credit, BMs are an essential element in the supply chain. Also, indirect costs associated with construction materials are particularly important in the overall performance of the industry. BMs and their activities are a primary component of the indirect materials costs. The role of storage within the construction supply chain is massively important, and yet widely unresearched. Storage per se becomes critical in order to achieve the ‘stockless’ or ‘just in time’ construction site. Materials should be delivered as late as possible, but without causing any delays to the construction process. Thus, the problem of storage is transferred to the suppliers who consequently bear the inventory carrying costs. Once again the BM has a critical function to play in the storage and issue of materials to site in order to facilitate construction. Similarly BMs must never impede construction progress through a ‘stockout’ of materials at the point of need.

Given the nature of the demands on the BMs listed above, it can be seen that the logistical role of BMs is the common theme through their activities. Thus it becomes necessary to begin to analyse the logistical context of the BM role in the construction industry. In terms of the study currently being undertaken by the lead author, the conceptual framework for the analysis will be based on the node-and-link perspective. According to Coyle et al. (2003) the complexity of a logistics system often relates directly to the various time and distance relationships between the nodes of the system. Time and distance are essential parameters of transportation. Consequently, transportation links that a company utilizes in order to gap the distance among different nodes in the logistics system are deterministic. Apparently the role of transportation becomes more crucial for construction especially when considering that “construction is fundamentally an assembly operation utilizing materials that are generally low value and high volume, moving at irregular times to geographically mobile points of distribution” (Shakantu et al., 2003).

5. CONSTRUCTION MATERIALS LOGISTICS

While figures compiled by Diamond and Spence (1989) indicate that transport costs account for 2.6% of motor vehicle part production, 7.7% for pharmaceuticals and 12%

of wholesale distribution, as a percentage of operating costs, it is highlighted that in sectors like construction the figures can be significantly higher (SACTRA, 1999). Indeed, transport accounts for 10-20% of construction costs according to BRE's report "Construction site transport: The next big thing". Furthermore, in the same report, it is indicated that BAA has estimated that its workforce spend 10-40% of their time dealing with ordering and transporting materials (BRE, 2003). The need for materials storage on site, their high volume and special natural characteristics together with the uncertain place of their use and the temporary location of the construction site contribute to the determinative role of transportation for construction logistics systems. Considering the increasing proportion of overheads represented by transportation within the construction process, it would seem apparent that construction logistics management optimization is likely to be "the next big thing".

Additionally, according to Johnson and Wood (1993) the importance of transportation for the successful operation of any logistics system is based upon the fact that transportation mode defines in a great extent the:

- packaging requirements;
- inventory levels;
- materials handling equipment;
- customer's service level requirements.

Therefore, the analysis of the relation between transportation basic aspects and logistics core concepts will potentially ameliorate the design of a construction logistics system. In order this relation to be analysed the parameters associated with vehicle movements from BMs warehouses to construction sites have to be identified and measured.

6. CRITICAL PARAMETERS

It is a major concern in this research to avoid analysing construction logistics solely from the contractor's point of view. In a construction contract various work packages are nominated to sub-contractors. In this case, the sub-contractors trade with a limited number and type of suppliers. The situation becomes more complex when all the suppliers have to be managed on a project level. In this case a logistics strategy, which involves mainly the planning of materials deliveries, becomes necessary. Actually, this emanates from the need for better use of the limited storage area available at the construction site. Additionally, one can say that issues of variability in demand come to an end as soon as the building is designed. Although variation in the design due to requirements evolution in the construction phase are very common in the industry.

On the contrary, when supply chain is viewed from a BM standpoint the demand is very difficult to be predicted. This, in sequence causes a series of logistical problems that concern mostly the supplier rather than the contractor. Ballard and Cuckow (2000) have identified the main difference when supply chain is viewed from a supplier standpoint (see Figure 2).

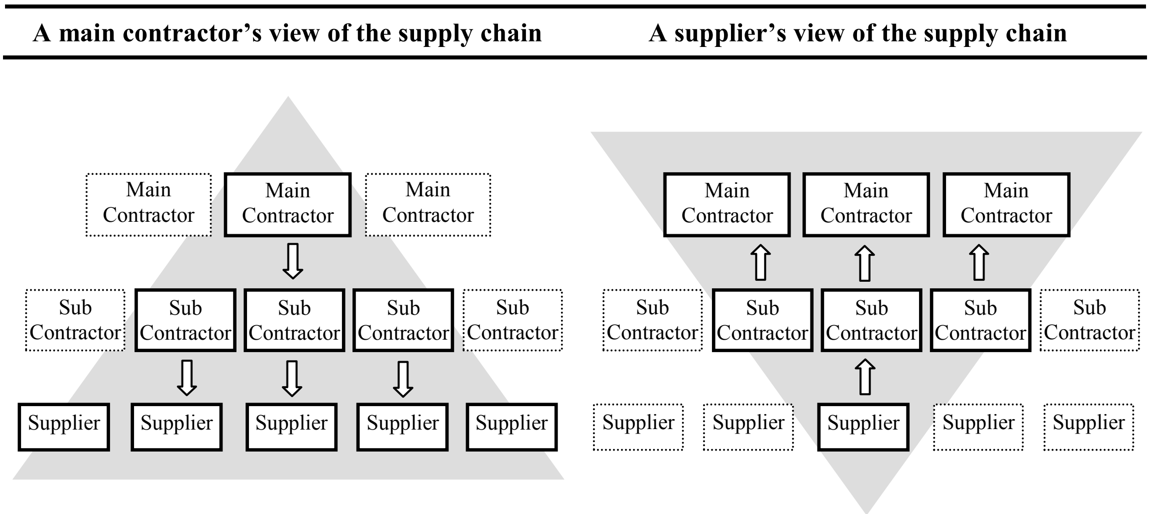

Figure 2: A main contractor's and a supplier's view of the supply chain (Ballard and Cuckow, 2000)

From this point of view in the supply chain fluctuation in demand is most likely to occur. There are many sub-contractor customers at any time, just as there are many building contracts. The role of the BM is to follow the schedule of different sub-contractors regarding material deliveries. Simultaneously, the BM should ensure that the uncertainty of demand is accommodated by the adopted logistics strategy at the lowest cost. In logistics terms this means that BMs seek to maintain high level of customer satisfaction while reducing inventory levels and increasing resources' utilisation.

Therefore, the critical parameters for measurement will be divided in two groups. The first group contains the parameters associated with the logistical operation of the BM warehouse. The second one includes those linked to the transportation of the materials and their demand. Figure 3, is split in two parts in order to demonstrate the two different groups of variables.

Figure 3 represents the delivery mechanism of different materials from the moment an order is received to the moment the materials are delivered. The flow is designed deliberately consisting of Work Centers and Storage Bins in order to introduce the use of the SIMUL8 software package in the design of the model. In the simulation model, Work Centers (WC) should be considered to act as dynamic decision objects which determine the required time for the completion of a task. Additionally, they can change certain aspects of a work item in order to direct it through different channels inside the model. Storage Bins (SB), are passive objects whose main purpose is to hold work items that are waiting to be processed by a work center. They could be used simply as queues or as inventories of different types of products (Hauge and Paige, 2001).

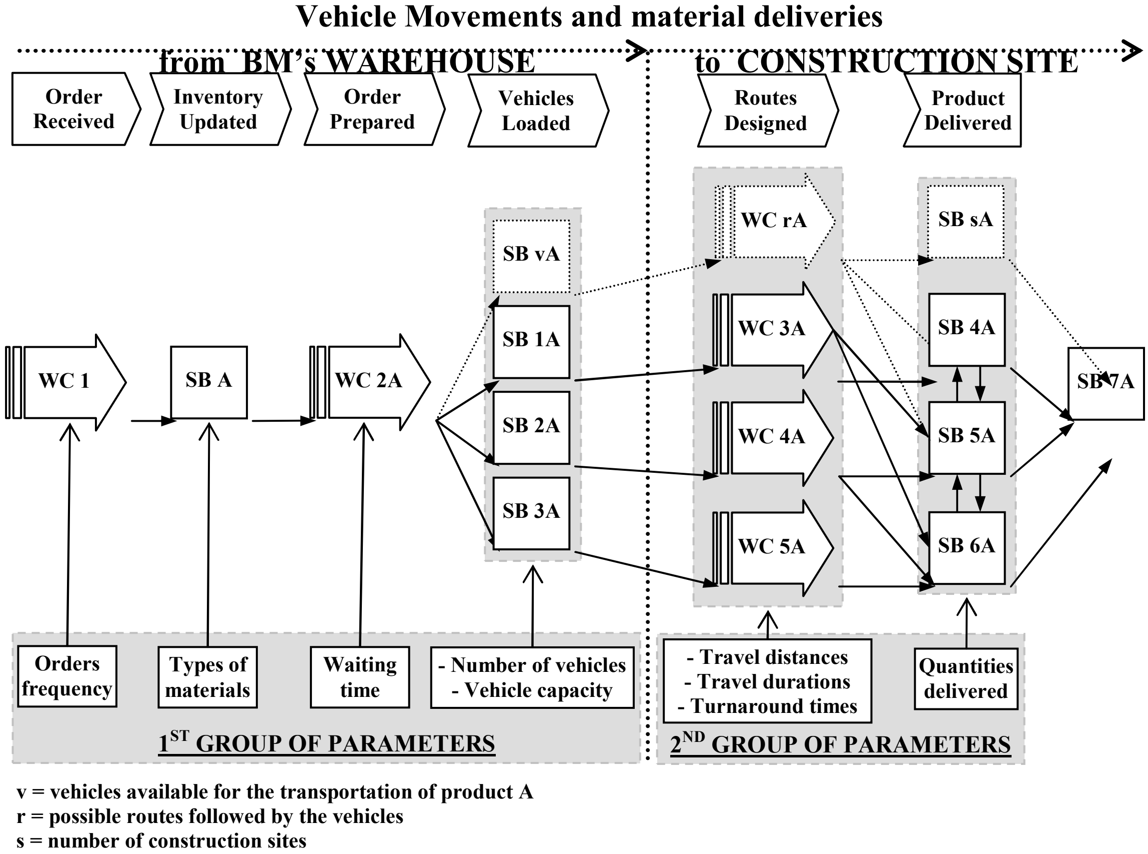

Figure 3: Parameters associated with the logistics of a single product deliveries.

The left part of figure 3 represents the operation of the BM warehouse. An order, which includes a number of different products and quantities, is received by WC 1. This information is distributed to the relevant inventories (SB A for product A, SB B for product B, etc). WC 2A removes the required quantity of the inventory and places it to available vehicles that serve the warehouse. These vehicles, which are of different type, tonnage and cubic capacity, are illustrated as SB 1A, SB 2A and SB 3A.

The right part of the figure illustrates the vehicles movements and the delivery of the product at different construction sites. WC 3A, WC 4A and WC 5A represent the transportation of the product through different routes. Additionally, they contain information about the location of the site and the time vehicles spend there (i.e. turnaround time). Finally, SB 4A, SB 5A and SB 6A are used to depict construction sites where a certain quantity of the product is delivered. The total quantity of product A delivered will be indicated at SB 7A.

The above discussion facilitates the identification of the critical variables that drive the model. These parameters for measurement are demonstrated in Table 4 and are the input data for the model that simulates the logistics systems within construction industry.

Table 4. Critical parameters for measurement

1st Group of Parameters	2nd Group of Parameters
• Frequency of orders • Type of materials & product families • Number of vehicles serving the warehouse • Vehicle tonnage and cubic capacity • Waiting periods at merchant's warehouse	• Travel distances (between the nodes of the system) • Travel durations (for every link of the system) • Turnaround times at construction sites • Quantities transported

This simulation model will provide a comprehensive analysis of the construction logistics and an assessment tool for alternative logistics strategies. By the use of special simulation software (Simul8), the distribution strategy of building materials will be examined in terms of cost-effectiveness and responsiveness. Additionally, the fluctuations in demand due to changing customer requirements and sufficient supply lead times will be more accurately assessed.

The two distinct groups of parameters identified will provide results and information pertaining to:

1st Group of Information	**2nd Group of Information**
Inventory levels	Lead times
Safety stocks	Fleet utilisation

The provision of reliable information for these major issues in terms of any logistics system will fulfill the aim of understanding and improving the functions of logistics in the UK's construction industry.

7. METHODOLOGY

The theoretical framework of the research includes both logistics and transportation management issues bound together with modeling techniques. These together will help unraveling the numerous and complex interactions that exist in the construction supply chain. The nature of the problem under analysis is multifaceted, dealing with inventory levels, safety stocks, lead times and fleet utilization. Together these elements will allow the researcher to develop a logistical model governing the function of the BM in construction. Although the role of the BM is generic, the depth and context of the data that needs to be recovered, makes the task impossible with a wider sampling approach. Thus it is intended to initially conduct a study that allows a 'working' model of the process to be developed which can in future be evolved and enhanced to give it wider applicability. Probability based or random sampling strategies are not appropriate in the circumstances of this study. In order to generate useful information as to the nature and role of the BM in the logistics process in construction, a purposive sampling approach needs to be adopted (Marshall and Rossman, 1999). Longer term, the research is expected to lead to further efforts to expand the use of the model created. This in turn will require further purposive sampling to 'fill in the blanks' left in the preliminary study.

The envisaged research is that of a field study, used to address the uncertainty of demand in building materials and the measurement of the numerous variables affecting materials' deliveries. Objective observation of a limited number of case study examples will preferably result in the creation of a stable and comprehensive basis of the logistic processes in construction. However, there is an acknowledgement that there will be a need to interpret certain data and extrapolate other data into a more widely appropriate model. This in turn militates towards adopting a triangulation approach to the research effort (Easterby-Smith et al., 2002).

8. THE CASE FOR USING SIMULATION

The final stage of the research is the generation of a model and the test of alternative scenarios, i.e. different logistics strategies, in order improvement actions to be evaluated. Models can be divided in two main categories (Shapiro, 2001; Bansal, 2002):

- Descriptive models and;
- Optimization models

The first type of models are used in order to describe a system that is to provide a better understanding of the systems function, while the second enables managers for making better decisions. The selection of a particular type of model should not be an obstacle for this research in providing both an understanding of logistics processes in the built environment and an optimum logistics strategy through the test of alternative logistics techniques. Indeed, a descriptive model can be extended to an optimization model through sensitivity analysis (Shapiro, 2001; Greasley, 2004; Kleijnen, 2005), which is perfectly accommodated by a simulation model.

The complexity of the construction's supply chain, not in terms of structure but in terms of uncertain interactions between participants requires the generation of a detailed model which will allow the application of different logistics techniques. This is possible by developing a simulation model (Bansal, 2002; Biswas and Narahari, 2004). Then, by incorporating sensitivity analysis the system's reactions to alternative scenarios (model input data) will be investigated and optimum decisions will be made. Additionally, according to Kleijnen (2005) by simulating the supply chain an insight into the causes and effects of the supply chain performance is given. This is the fundamental aim of this research: Understanding causes and effects of the supply chain performance in the built environment so as a better understanding of construction logistics to be established and areas of improvement to be identified.

9. CONCLUSION

An examination of the supply chain from a supplier point of view can provide a comprehensive analysis of the logistics in the UK's construction industry. BMs are positioned in the heart of the flow of building materials from the point of production (manufacturer) to the point of consumption (construction site). From this position a better view on the roots of materials delivery problems is given. Besides, it is common sense that for the majority of the builders there is not a particular strategy upon logistics. Therefore a more judicious analysis, outside of the "noisy" construction site environment, takes place.

This paper has established some of the issues associated with the need to increase understanding of the function performed by BMs within the construction logistics system. The most appropriate approach of addressing this need was discussed and the related parameters were identified. The use of simulation will allow the application of alternative logistics techniques in a risk free environment providing both an understanding of the construction logistics system and a platform for testing improvement actions.

Whilst new production theories and practices emerge, the objective will remain the maximization of the return on investment made in every industrial project. Any development that contributes to cost savings leads to the fulfillment of the above objective. This is the main reason why logistics have been widely used in all kind of industries. The additional advantage of their application in construction is that logistics will not only accomplish cost reducing but also make a step forward by applying logic in the uncertainty of materials and information flow, against the risky nature of the industry.

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THE EFFICACY OF USING APPROPRIATE TECHNIQUES AND TECHNOLOGIES FOR KNOWLEDGE CAPTURE IN SMALL AND MEDIUM ENTERPRISES IN ARCHITECTURE, ENGINEERING AND CONSTRUCTION

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Abstract: Knowledge capture techniques and technologies are important for any knowledge management strategy. Organisations that have implemented knowledge management (KM) strategies seem to have realised that if techniques and technologies are not carefully selected, the likelihood of success is very limited. This requires careful selection of techniques and technologies based on the organisations' needs and the functions that these can perform. There seems to be very few empirical and construction related studies on knowledge capture geared towards small and medium enterprises (< 250 employees). This paper investigates the efficacy of current techniques (informal and/or paper based) and technologies for capturing knowledge (including knowledge of individuals) within organisations in small and medium enterprises (SMEs). The paper is based on an-ongoing PhD research study which adopts, inter alia, a grounded theory approach as a systematic means of investigating knowledge capture in SMEs. Forty one architects, engineers and contractors from the UK were interviewed as part of the study. The paper documents and discusses the main challenges which SMEs face with regard to the capture of employees' knowledge through the use of current and existing techniques and technologies. Attempts were also made to establish which techniques and technologies the participants felt would be helpful to capture knowledge for the future (next five years). The paper concludes that capturing knowledge in SMEs is not easy. It is an integrated and complex social process, which has culture, people, technology, communication, leadership and organisational structures at its core. Similarly, face to face discussion is the most effective technique to capture tacit knowledge and project database is the most effective technology to capture explicit knowledge. It is suggested that a qualitative research has been adopted in this research study is necessary to uncover many of the complex and intricate issues associated with knowledge capture in SMEs.

Keywords: grounded theory, knowledge capture, knowledge capture techniques and technologies, small and medium enterprises.

1. INTRODUCTION

The UK construction industry has changed significantly over the last 50 years, placing considerable pressure on its organisations to respond to their business environment (Holt *et al*., 2000). Demands for industry-wide improvement led to a series of government commissioned reports examining the industry's structure, culture and operation (Latham, 1994 and Egan, 1998). The important role of improving people-management practices within the construction industry has also been recognised by reports such as the Rethinking Construction report on respect for people (Rethinking Construction, 2003). Knowledge management (KM) can also promote innovation and business entrepreneurship, help manage change, and emancipate and empower employees (Nonaka and Takeuchi, 1995). This view is supported by the UK Government in its White Paper focusing on KM (Department of Trade and Industry, 2000). It is argued that the main drivers behind the increased interest in KM amongst organisations operating in the UK construction industry are the Government's prerequisite to achieve industry-wide improvements and the desire of individual organisations to seek competitive advantage. The industry has begun to recognise that knowledge is an asset, just like the physical assets of an organisation (Wiig, 2000).

The question regarding the nature of knowledge is extremely challenging. Although philosophers have been discussing the issue for several hundred years, the search for a formal definition continues (Emery, 1999). The definitions appearing in the literature range from studying knowledge from a broader perspective to more sophisticated definitions. For the purpose of this research, knowledge is viewed as a complex concept which consists of information and skills acquired through experience; truth and belief, perspective and judgements, expectations and methodologies. Knowledge exists in individuals, groups and in organisations, in various forms. Knowledge can be tacit and explicit (Nonaka, 1994). Tacit knowledge is personal, context-specific, subjective and experience-based knowledge and therefore, hard to formalise. Explicit knowledge, on the other hand, is formalised, coded in a natural language (French, English, etc.) or artificial language (Unified Markup Language, mathematics, etc.) which could be transmitted. It is objective and rational knowledge that can be expressed in words, sentences, numbers or formulas. It includes theoretical approaches, problem solving, manuals and knowledge base.

Polanyi (1962) and Ryle (1949) suggest that the distinction between tacit and explicit knowledge is critical to understanding how people deal with the world in a purposive manner. Sheehan *et al* (2005) argued that an appropriate balance of 'explicit' versus 'tacit' approaches depends on each organisation's strategy and the particular case in point. An organisation is bound to require elements of both approaches and must integrate the two effectively. Hence, the focus of the study presented in this paper, is to consider both tacit and explicit knowledge. The operational definition for knowledge capture adopted in this research is defined as a process, through which knowledge is recognised from its source, examined and in accordance with the organisation's strategy. Appropriate techniques and technologies are implemented to retain the knowledge, which is filtered, banked, disseminated and updated. The process is iterative (Hari *et al*, 2004).

A thorough review of literature identified the following KM tools: storytelling, knowledge maps, ontologies, organisational memory information system, expertise directory, e-learning and performance tracking system, virtual collaborations, content management, specialised web-oriented search, categorisation tools, data mining system and information repositories (e.g. documents, databases, electronic document management system to name a few. Egbu and Botterill (2002) have conducted an empirical study on construction, manufacturing, aerospace and the utilities oganisations in the UK to investigate the information technologies for KM. Egbu *et al* (2003) in one of their interim report for "Knowledge Management for Sustainable Construction Competitiveness" project cited that a survey of 170 UK construction organisations carried out by Loughborough University by Carrillo *et al* (2002) showed that Communities of Practice (CoPs) is the most widely used technique for knowledge management particularly in large organisations. Large construction organisations with a range of specialist skills tend to have the need and resources to set up communities of practice and to benefit significantly from them. Other techniques that are used include brainstorming, job observation and rotation systems, research collaboration, conferences and seminars. However, there is a lack of empirical study in small and medium enterprises (SMEs < 250 employees) in architecture, engineering and construction (AEC) organisations in UK.

Levy (2003); Frey (2002); McAdam and Reid, (2001) and Sparrow (2001); have considered KM in SMEs in other sectors such as the business sector, manufacturing and hospitality. Capture and re-use of project knowledge in construction a research is in progress (CAPRIKON, 2003). Another research investigated the use of audio diary to capture knowledge events in a project environment in SMEs in construction industry (Boyd *et al* 2004). Few papers based on this research are discussed in Egbu *et al* (2005), Hari *et al* (2004, 2003) to mention a few. However, there seems to be paucity of empirical evidence for knowledge capture tools (techniques and technologies) in SMEs in the AEC industry from an organisational perspective.

This paper investigates the efficacy of current techniques (informal and/or paper based) and technologies for capturing knowledge (including knowledge of individuals) within organisations in SMEs. The paper is based on an-ongoing PhD research study which adopts, inter alia, a grounded theory approach as a systematic means of investigating knowledge capture in SMEs. The paper documents and discusses the main challenges which SMEs face with regard to the capture of employees' knowledge through the use of current and existing techniques and technologies. Attempts were also made to establish the future (next five years) techniques and technologies the participants felt would be helpful to capture knowledge.

2. RESEARCH METHODOLOGY

In this study, qualitative research approach which includes grounded theory has been adopted to uncover many of the complex and intricate issues associated with knowledge capture in SMEs. Glaser and Strauss, (1967) first described the method of grounded theory in 1967 as a means of enabling the 'systematic discovery of theory from the data of social research'. Since then two different approaches have emerged; the Straussian and the Glaserian. It should also be noted that a number of other adaptations have developed as identified by Heath and Cowley (2004). Backman and Kyngas (1999) suggest that the researcher should follow one particular author i.e. Glaser or Strauss and then develop their own method using one of these as a foundation for analysing data. If the researcher was to apply a combination of applications of grounded theory from different texts this would undoubtedly result in confusion and the resulting findings would be lacking in substance. Hence this study chooses the Strauss and Corbin methodology for analysis of data.

In terms of obtaining a suitable sample size in grounded theory, the grounded theorist does not decide on the size of the sample population before the study begins. Sample size is deemed to be satisfactory only when the key concepts that have been identified from the collected data have reached saturation point, in other words, when no new data emerges. However, Morse (2000) cited in Robson (2002) suggests that to reach saturation point, the sample size depends on several factors: the scope of the study, the nature of the topic, quality of the data, study design and research technique. Semi structured interviews were used as research technique for this study. Morse (1994) produced a 'rule of thumb' for grounded theory studies recommending approximately thirty to fifty interviews. This research included 41 interviews.

Organisations that participated in the study employed more than 10 people but less than 250 employees. Database for the study was collected from the Small Business Gateway (2003) for the construction industry. The period of study was from 5th April – 27th August 2004, Scotland, UK. The sample consisted of seven small and eight medium enterprises (Table 1). Attempts were made to have a sample across the architecture; engineering and construction organisations.

Table 1: Organisation distribution in the construction industry that participated in the study

Organisations	**Architects**	**Engineers**	**Contractors**	**Total**
Small	2	3	2	7
Medium	2	3	3	8
Total	**4**	**6**	**5**	**15**

Twelve (12) interviews from small and 29 interviews from medium enterprises were interviewed (Table 2). This difference clear indicates the characteristics of small firms, where the owner/partner/manager assumes that he/she knows about the organisations and there could not be any important information that the others might contribute to the research.

Table 2: Distribution of the job role

Hierarchy / **Organisations**	**Partners**	**Managers**	**Engineers**	**Total**
Small	5	4	3	12
Medium	7	11	11	29
Total	**12**	**15**	**14**	**41**

Interviews with personnel across organisational hierarchy allowed some insights at organisational, group and individual levels. Interview in this research spanned between 45 minutes to one hour. Interviews were recorded through a digital dictaphone and later transcribed.

Grounded theory is a repetitive process; the analyst is required to return constantly to data sources, to check aspects of the emerging interpretation and to gather new data where appropriate. Indeed, Smith (1997) refers to grounded theory as a process of constant comparative analysis. The main features of the area of interest are mapped through repeated comparison of the data. In-depth detail regarding grounded theory approach adopted for this research is not presented in this paper, due to space constraints. For more details refer Egbu *et al* (2005).

3. TECHNIQUES AND TECHNOLOGIES FOR KNOWLEDGE CAPTURE WITHIN SMES IN AEC: AN EMPIRICAL FINDING

Ruggles (1997) and Tiwana (2000) state that knowledge management tools are technologies, broadly defined, which enhance and enable knowledge generation, codification and transfer. As with any tools, they are designed to ease the burden of work and to allow resources to be applied efficiently to the tasks for which they are most suited. It is important to note that not all knowledge management tools are computer-based, as paper and pen can certainly be utilised to generate, codify and transfer knowledge. This research adopts Al-Ghassani *et al* (2002) who refers to KM tools as KM techniques (non-information technology (IT) tools) and KM technology (IT tools) (Table 3).

Table 3: KM tools: A comparison between the techniques and technologies (Source: Al-Ghassani, 2002)

KM tools	
KM Techniques (non-IT)	**KM Technologies (IT)**
• More focus on tacit knowledge • Requires strategies for learning • More involvement of people • Affordable to most organisations Examples: - Brainstorming - Face to face interaction - Training	• More focus on Explicit knowledge • Requires IT infrastructure • Require IT skills • Expensive to acquire and maintain Examples - Internet/Intranets/Extranets - Knowledge bases - Data and text mining

Knowledge Capture Techniques (Non-IT)

Interviewees discussed various techniques that they use in their job role and in their organisation to capture knowledge (see Figure 1). The first technique that emerged is face to face discussion that occurs at various levels (partner, manager and engineer) which was suggested by 41 interviewees. At partner level they have close contact with client i.e. understanding client priority, informal feedback from client and word of mouth marketing. Partners review financial aspects about the projects. Through this it is evident to the partners / owner-managers which project is delayed and which project is on time. Henceforth, partner's / owner-manager have knowledge about the projects and well as the clients. At managers level they have meetings with the project teams which included allocating jobs, checking on projects, discussing issues and complaints which engineers have on projects.

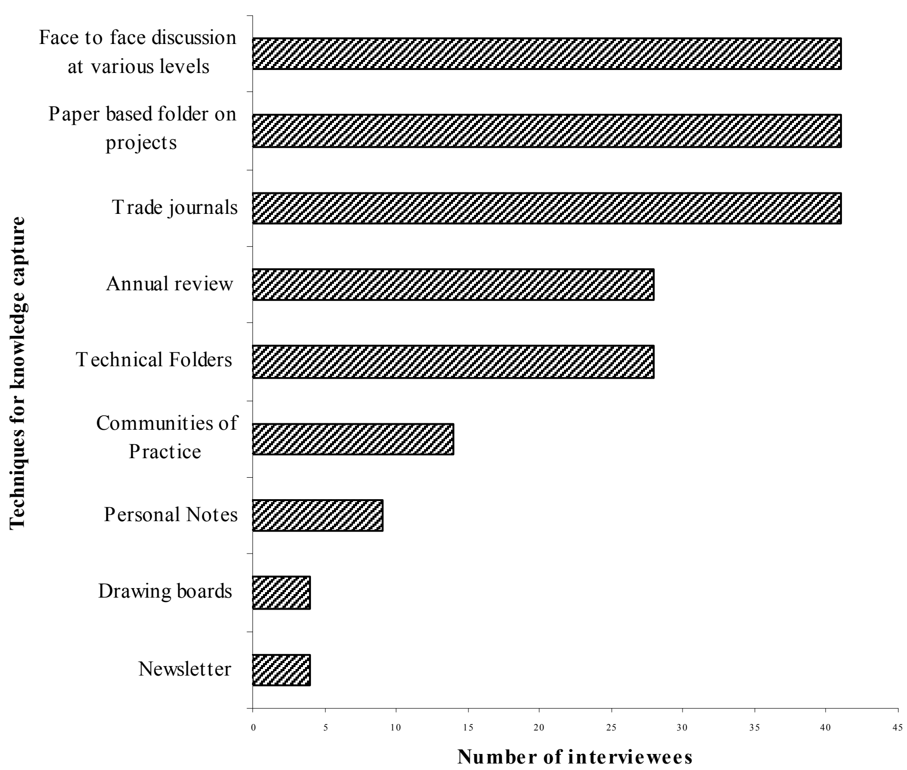

Figure 1: Techniques for knowledge capture in AEC organsiations

Project reviews are held at various stages with experts within the organisations at tender stage, contract stage, design stage and at times crucial stages in construction phase. The knowledge created and captured during this process is in tacit form. There are no documentations of the lessons learnt or best practice at this stage. The experts in two medium organisations have made a document on frequently asked questions. This is an indication of how tacit knowledge been converted to explicit form. In the engineers level informal discussion is by asking their colleagues in the corridor or just shouting the questions if anybody as come across a particular technical aspect or discussing with their immediate line manager. Exit interviews were conducted when an employee leaves the job. Shadowing, send of party and informal discussions were the categories that emerged for exit interviews. Eleven interviewees said that they have shadowing for one week. Send-of- party was revealed by three interviewees where story telling was the main focus. All the interviewees said that the exit interviews were mostly face-to-face discussions with their partners/owners- mangers. It is evident that there is no formal capture of knowledge during exit interviews. However, it could be argued that techniques such as shadowing and story telling help to retain some tacit knowledge.

The second knowledge capture technique that emerged from the 41 interviews was paper based folder on projects. This folder contains summary sheet of the project at the start of the folder which includes client details and the contact list of the organisations involved in the project for example list of quantity surveyors, structural engineers, contractors and other services. Summary sheet is followed by project process sheets which contains three phases namely pre construction phase, construction phase and post construction phase. The pre construction phase contains building warrant, planning permission, designs, meeting minutes about working drawings, tender documents and appointment of the contractor/engineers/services. Construction phase documents contains site meetings with the project team, time sheets (time needed to complete a particular task) and site instructions. The time sheets are revisited if and only if the project is delayed or if the project is financially over run by partners / owner-managers. It was noted that the best or worst practices identified during the project execution were not formally captured and not widely disseminated in the organisation. During the post construction phase depending on the size of the project and depending on the clients, post project review was prepared. Formal procedures of project handover were evident in three interviews. While others followed informal procedures which involved discussion with clients regarding their satisfaction with respect to quality, time and cost to name a few. It was evident that most of the knowledge gained during projects remained tacit in nature with those employees involved in the project.

Other techniques that emerged were trade journals (41 interviewees) followed by annual review which was revealed by 28 interviewees. It was mainly to review the training requirements of the employees. Technical folder was suggested by 28 interviewees. This folder contained technical guideline documents, templates for checklists at various stage in the project and templates for letter and faxes. Communities of Practice which included: technical group, project feedback procedure group and marketing group were evident in 14 interviewees. Followed by personal notes (9 interviewees), drawing boards (3 interviewees) and newsletters (3 interviewees) as knowledge capture techniques in SMEs in the AEC organisations.

When the interviewees had discussed about the techniques, they were then questioned about the efficacy of the techniques that the interviewees had stated. From the interviews it emerged that the most efficient technique in an SME in AEC organisation are: Face to face discussion (21 interviewees) which included financial review and project reviews; Paper based project folders (13 interviewees); personal notes (5 interviewees) and documentation of frequently asked questions developed by experts (2 interviewees).

Face-to-face discussion helps in increasing the organisation's memory, developing trust and encouraging effective learning. Lang (2001) considers it to provide strong social ties and tacit shared understandings that give rise to collective sense making. This can also lead to an emergent consensus as to what is valid knowledge and to the serendipitous creation of new knowledge and therefore new value. It is interesting to note that in Egbu and Botterill (2002) study face-to-face discussion was ranked as being one of the most effective techniques for KM, supporting the notion that social interaction is a pre-requisite for successful KM (Davenport and Prusak, 1998). This view has been supported by Ingo Hoffmann (2000) who suggests that transfer of information and knowledge occurs primarily through verbal communication (experiential knowledge, rules-of-thumb, tips and tricks).

The interviewees were asked to volunteer information on the techniques they were likely to use for knowledge capture in the future (next 5years). Twenty one interviewees expressed the need for formal procedures to see why a particular task went well or wrong. Use of technology as an enabler to capture, store and share knowledge was suggested by 21 interviewees. Thirteen interviewees suggested that they would like to have seminars by experienced staff on right and wrong things by devoting time and resources.

KM Technologies (IT Tools)

Information Technology supports the collection, storage, processing and communication of information by electronic means (Armstrong 2001). Construction organisations have been slow to acknowledge the benefits of IT in managing knowledge (Egbu *et al.*, 2001), suggesting that the role of IT for KM in these organisations, needs to be addressed. During the semi – structured interviews the interviewees discussed various technologies that they use in their job role and in their organisation to capture knowledge (see Figure2).

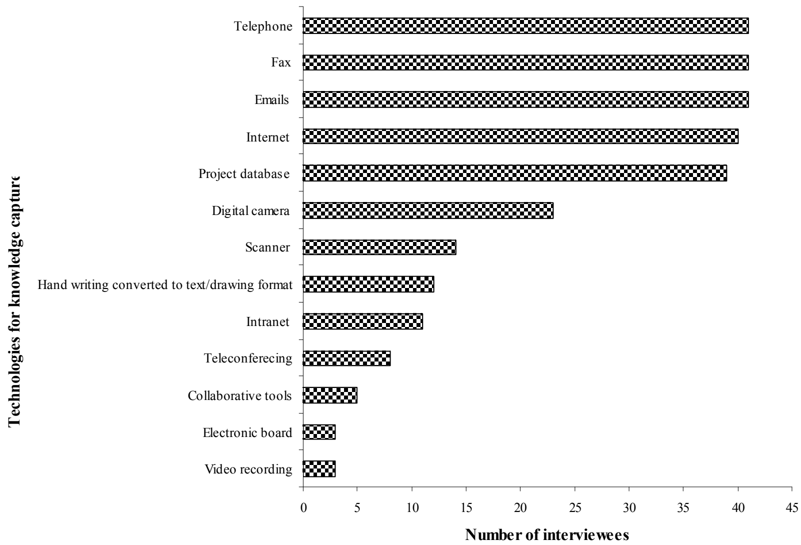

Figure 2: Technologies for knowledge capture in AEC organsiations

The first technology that emerged is telephones (41 interviewees) followed by fax (41 interviewees), emails (41 interviewees), internet (40 interviewees), project database (39 interviewees), digital camera (23 interviewees), scanners to convert the drawings into electronic format (14 interviewees), technology to convert hand written material into text or drawing format (12 interviewees), Intranet (11 interviewees), teleconferencing (8 interviewees), collaborative tools (5 interviewees), electronic board (3 interviewees) and video recording (3 interviewees). When interviewees had discussed about various technologies, they were then probed into the efficacy of the mentioned technologies for knowledge capture. Interviewees suggested that the most efficient technologies in an SME in AEC organisation are: telephones (16 interviewees) followed by project database (15 interviewees), emails (6 interviewees), intranet (2 interviewees), electronic board (1 interviewees) and collaborative tool (1 interviewees).

Collison and Parcell (2001) suggest that in an ideal world, people would all share knowledge in a face-to-face discussion and never need to capture knowledge. The only difficulty is none of the person is omnipresent (cannot be everywhere at once). In this study it was revealed that the owner/partner/managers were available to be contacted by their staff members at any given point of time through telephone.

An empirical study by Department of the Environment, Transport and the Regions, (DETR, 1999) reveals that almost all construction professionals are computer users, particularly in word processing, spreadsheets and CAD, with high rates of emails and internet access. However, some felt working with drawings on the screen was difficult. The DETR study reveals that for many users the technology is not yet used to its full potential and capacity. This was evident in this study as 39 interviewees had electronic project databases but it was only 15 interviewees who said project databases are an effective explicit knowledge capture technology. These project databases contained the aspects of projects as discussed earlier in this paper under knowledge capture techniques for paper based folder on projects.

The interviewees were asked to volunteer information on the technologies they are likely to use for knowledge capture in the future (next 5years). They suggested: wireless gadgets that could facilitate in capturing knowledge (20 interviewees) namely laptops with wireless network connection; Software like AutoCAD that could enable 3 D drawings (2 interviewees); provide internet access to clients for enquiries (2 interviewees); develop intranet to inform employees about: the projects, new recruitments, events scheduled to take place and discussion groups was suggested by 2 interviewees followed by extranets that enables to work on a single building model and also clients could have access to it (1 interviewees). The other interviewees suggested that they did not know as technology as been changing at a rapid rate.

4. CHALLENGES FOR KNOWLEDGE CAPTURE TECHNIQUES AND TECHNOLOGIES

There are many barriers associated with KM in construction industry such as the need for new organisational culture, the requirement for changing the attitude of employees, the significance of the time required, the importance of sufficient budget, and the identification of the most appropriate KM tools for the business (Al-Ghassani *et al*., 2002). As organisations proceed in implementing their KM strategies, they realise that if KM tools are not carefully selected, the likelihood of success is very limited. Knowledge management tools (techniques and technologies) are important for any KM strategy. In fact, they consume one third of the time, effort and cost required to develop and use a KM system (Davenport and Prusak 1998). This requires careful selection of these tools based on the organisations' needs and the functions that these tools can perform. When interviewees were asked about the present challenges for knowledge capture techniques, it was revealed that lack of communication with colleagues (16 interviewees); time constraint (10 interviewees); lack of commitment from the staff (5 interviewees); lack of motivation (5 interviewees); people's negative attitude to capturing their knowledge (4 interviewees); unable to use existing knowledge (4 interviewees); lack of structure to keep explicit knowledge updated (3 interviewees); cultural issues (3 interviewees); lots of bureaucracy (2 interviewees) and budget constraint (2 interviewees). Future issues for knowledge capture techniques highlighted by the 21 interviewee were to ensure: information flow between and across required teams in the organisation and structure in place so that progress can be captured, reviewed and managed.

When interviewees were asked about the present challenges for knowledge capture technologies, it was revealed that legal issues (3 interviewees), speed of change in computer industry (2 interviewees), communication issues (3 interviewees), advice from experts (5 interviewees), need for training (18 interviewees), people attitude to adopt technology (6 interviewees), need for in-house IT knowledge (10 interviewees), security issues (3 interviewees), culture issues (9 interviewees), utilisation of the existing IT (10 interviewees), finance issue (9 interviewees), IT selection (6 interviewees), lack of time (2 interviewees) and upgrading issues of technology (3 interviewees). Future issues for knowledge capture technologies highlighted by the interviewee were more training needed with regards to software packages (20 interviewees) such as computer aided design and file management. Followed by effective utilisation of present technology resources (9 interviewees), for example at present buyer's and planning department do co-ordinate by word of mouth and through regular meetings; in the future it could be put on the IT system. The last issue emerged was upgrading the IT systems which emerged in 6 interviewees.

It is interesting to note that the present challenges for knowledge capture techniques and technologies emerged from this study can be summarised as lack of: culture, communication, structure, time and finance. People attitude to adopt technology and their attitude to capturing knowledge is a challenge as well. The results of this study are in line with Liebowitz (1999); Skyrme (2000) and Heisig (2001) who have identified few critical success factors/key challenges for knowledge management.

5. CONCLUSION

Knowledge capture helps to improve performance and increase productivity within organisations by: avoiding work duplication; preventing the repetition of mistakes; aiding problem solving; supporting decision-making; retaining tacit knowledge; facilitating staff training; managing and improving work practices and processes; generating competitive advantage so as to lead market (due to increased chances of innovation) and improving business performance. Knowledge capture techniques and technologies are important for any knowledge management strategy. Organisations that have implemented knowledge management strategies seem to have realised that if techniques and technologies are not carefully selected, the likelihood of success is very limited. This requires careful selection of techniques and technologies based on the organisations' needs and the functions that these can perform.

The paper concludes that capturing knowledge in SMEs is not easy. It is an integrated and complex social process, which has culture, people, technology, communication, leadership and organisational structures at its core. Similarly, face to face discussion is the most effective technique to capture tacit knowledge and project database is the most effective technology to capture explicit knowledge. It is suggested that a qualitative research has been adopted in this research study is necessary to uncover many of the complex and intricate issues associated with knowledge capture in SMEs.

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SELECTION OF ELECTRICAL ACCESSORIES: A "COST MODELLING" APPROACH

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Abstract: Electrical installations contribute to 6% -10% of the total cost of a typical house. Therefore, the selection of the most appropriate electrical accessories is very important from the client's point of view. But lack of information about the products and prices makes these decisions very difficult for clients to make. Development of a product-cost model for the selection of electrical accessories could be seen as one of the solutions for this problem. Thus the authors have developed a product-cost model for the selection of electrical accessories for housing constructions in Sri Lanka.

A market survey and a series of interviews were conducted in order to collect cost and product data pertaining to electrical accessories used in Sri Lankan domestic electrical installations. All the accessories identified were classified into five main categories based on their functionality. In the data analysis, three main cost categories were identified. On the other hand, three different designs were selected to represent the collection of accessories in a typical domestic electrical installation. Finally, a simple decision support system was developed as the front end for the developed product-cost model.

Keywords: Cost Modelling, Decision Support System, Electrical Accessories.

1. BACKGROUND

Electricity was a luxury for houses in the past, but it is a necessity for each and every house, irrespective of the scale or the category of the household. Within the Sri Lankan construction industry, the installation cost of an electrical system in a building has a significant contribution to its cost. Sri Lankan housing construction is not an exception within this context.

Unlike other items of a house, the individual house builders (clients who employ direct labour to build their own houses) are naturally reluctant to identify their requirements on purchasing electrical accessories. According to Lawrence (1993) the electricity supply is one of the essential elements of the home that seems to strike fear into the hearts of individual house builders everywhere. This fear and unawareness may lead to undue costs in domestic electrical installations. Hence, it has become apparent that the client should be made knowledgeable about the domestic electrical accessories in order to optimise the domestic electrical installation costs. The key barrier to this is the low confidence of individual house builders and lack of proper reference points regarding the cost, quality and the functionality of electrical accessories in the market. The complexity of the technology and safety concerns keep the electrician, rather than the client, in the commanding position within this process, which makes the individual house builders feel uncomfortable in decision-making.

To solve this problem, a huge boost in confidence of the client's decision making is necessary. Accordingly, there should be a solid base for comparison of information and facts. A cost model may provide an acceptable solution within this scenario. As identified by Beeston (1987), "A cost model's task is to estimate the cost of a whole design or of an element of it, or to calculate the cost of effect of a design change." Authors have used this approach to solve the above problem and adopted the following methodology to build a product-cost model with the aim of addressing the above mentioned problem.

2. RESEARCH METHODOLOGY

Having identified the need for a cost model for the selection of electrical accessories, information about the existing electrical accessories in the market was collected, by means of interviews with suppliers and manufacturers. For this purpose, marketing managers of 3 major electrical accessory manufacturing companies (Sri Lankan branches) were interviewed. Further references were subsequently made to collect technical specifications of these accessories based on published sources. Further 4 unstructured interviews with industry professionals were conducted to find information and views about quality standards of electrical accessories in use. Further, all the collected information were categorised according to the basic functions of the accessories. Thirdly, accessories were evaluated in terms of costs and qualities and were ranked accordingly under relevant categories. Cost model was subsequently developed based on the collected information. Finally, a computer-based simple Decision Support System was developed, as the front end of this cost model, using an object oriented programming language: Visual Basic. Further, a website was also created in order to publish information pertaining to electrical accessories.

Prior to the process of building the cost model, a literature survey was conducted to identify the nature of building cost models and the methods in use.

3. WHAT IS COST MODELLING?

As the name implies, Cost Modelling is a technique which is used to model the cost of a system. More comprehensive definition has been given by Ferry and Brandon (1999) by stating; "Cost Modelling may be defined as the symbolic representation of a system, expressing the contents of that system in terms of factors which influence its cost" (Ferry and Brandon, 1999). By looking at the practical aspects of the Cost Modelling, Smith (1989) has stated that, with the development of Cost Modelling systems, the quantity surveyor is not only be able to represent the total cost profile of a project but also to interact with the model; to indulge in 'what if' simulations as the design progresses to ensure the minimal gap between the client's requirement and the completed scheme. The cost models which are used for 'what if' simulations are often known as parametric cost models. Parametric cost models are made up of one or more algorithms or cost estimating relationships (CERs) that translate technical and/or programmatic data (parameters) about a product or asset into cost results (The Association for the Advancement of the Cost Engineering, 2004) Further, Ferry and Brandon (1999) has identified several features that should be contained in a good cost model:

- Provide cost information quicker
- Provide more information
- Provide more reliable cost information
- Provide information at an early stage in the design process
- Provide information in a more understandable manner

Cost Models can further be used as a tool in the decision making process. Ferry & Brandon (1999) have represented the role of models in the decision making process as follows. (See Figure 1)

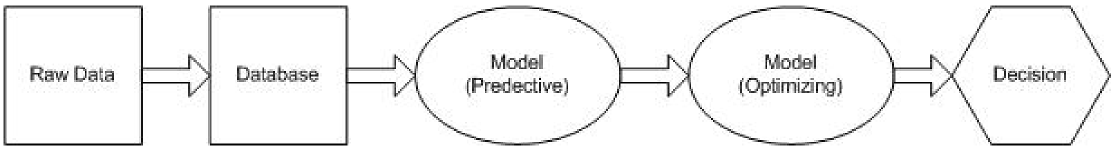

Figure 1-Role of models in the decision making process - (Ferry & Brandon, 1999)

Building a cost model involves a systematic approach. Common methodologies for cost model building are described below.

3.1 Methods of building cost models

Ashworth (1989) being one of the leading researchers in the field of cost modelling has mentioned two major categories of forecasting costs.

- Deductive method - Use statistical analysis of previous performance data as the basis for cost modelling. Usually uses the regression analysis as the tool for measuring the association between data.
- Inductive method - A method of predicting the cost by using detail cost breakdowns.
- Further he highlights four major methods of building cost models.
- Empirical methods - These types of models are based upon observations, experience, and intuition. In this method it is usually assumed that there is a fixed relationship between the design variables and cost, and which have been derived from observation and experiment. (Ferry & Brandon, 1991)
- Algorithmic methods - Algorithms include a number of step by step procedures for determining the optimum values of variables in model building (Ashworth, 1989). Regression analysis is one of the techniques used in building algorithmic cost models. Since there is always a rationale behind model building, these models can create a confidence in the user's mind. Unlike in the empirical method, this particular method often consists of tedious calculations which require a high degree of mathematical and statistical knowledge.
- Simulation method - A simulation model seeks to duplicate the behaviour of the system under investigation by studying the interaction among its components. For a cost model to be successful as a creative design tool, rather than being a passive monitor of cost, a mathematical modelling technique is required to simulate a large number of possible solutions and provide a comparative evaluation of these so that the best solution can be indicated (Brown, 1987).

This necessity of a simulation method for building a cost model can be fulfilled by using the Monte Carlo technique. Ashworth (1989) has identified this method as very useful in dealing with complex problems. As disadvantages, the inherent drawbacks of statistical analysis can be highlighted.

- Heuristic method - These models are based on 'rule of thumb' procedures. In Contrast with the algorithmic method, those procedures are not based on statistical analysis. This approach has the advantage of being less complex in mathematical terms. But, since these types of models have inbuilt behavioural characteristics of the modeller, the reliability of the model is doubtful.

Since this cost model is aiming at a knowledge transferring activity (transfer of sufficient decision making knowledge of the expert to the end user) the development is influenced by empirical and heuristic methods.

4. DEVELOPMENT OF THE COST MODEL

Typically there are several common factors considered by most individual house builders when selecting appropriate electrical accessories. Some of those were identified during the unstructured interviews conducted by the authors with experts in the industry, and with some individual house builders. They are: the cost, aesthetic appearance, safety and durability, and quality assurance – (manufactured country, brand name, recommendations of experts, standards, etc.)

However, the priority of the list of these features varies with the situation and the characteristics of the person with the need. In the selection process of the electrical accessories for a domestic electrical installation, for the ease of reference, all the accessories can be grouped into five main categories (Lawrence, 1993).

Accessories in power circuits

- Accessories in lighting circuits
- Protective devices
- Accessories in other circuits
- Cables and other sundry items

Each of these categories comprise of several key accessories, as listed within the table 1 below:

Table 1-Electrical Accessories in main groups - Lawrence, (1993)

Group	Accessories
Accessories in power circuits	Socket outlets, Shaver Sockets, Cooker Controllers
Accessories in lighting circuits	Switches, Light Dimmers, Lamp Holders, Ceiling Roses, Light fittings
Protective Devices	Miniature Circuit Breakers, Residual Current Circuit Breakers, Earth Terminals
Accessories in other circuits	Telephone Sockets, Television Antenna Sockets, Bell Switches, Electrical Bell Units, Ceiling Fans
Cables and other sundry items	Wiring Cables, Conduits, Conduit Accessories, Enclosures, Cable Trunks, Junction Boxes, Sunk Boxes, Wiring Clips

Due to the diversification of availability of different types of accessories, a systematic approach should be adopted in the process of building the model. Several procedures can be adapted to this effect and the authors followed the following three steps in building this particular cost model:

- Identification of the Cost Variables
- Collection and analysis of cost and product data
- Representation of analysed data in the model in a way that it reflects the cost variables of the system, while catering to the need of ease of use of the model and ability of simulating various combinations

4.1 Identification of Cost Variables

Identification of cost variables is one of the most important tasks in developing a cost model. The whole success is dependant upon the ability of the modeller to identify the correct and all the cost variables in the system. In developing this particular model, two basic streams were identified as major cost variable streams:

Types of accessories to be incorporated to the electrical installation – Unlike in most of other elements of a house, the electrical installation has variety of optional accessories which significantly influence the cost of the installation. The decision to incorporate or omit those optional accessories in the installation will have a definite cost impact; and

Cost Category of electrical accessories – It is one of the salient features of the electrical accessories market that the prices of accessories available have a huge range of variation even if the accessory gives the same functionality. Hence, the household's choice of the cost category of the accessory is the other crucial factor which influences the cost of the installation.

During unstructured interviews held by the authors, the interviewees' perception towards the cost variables in this regard is questioned and the above stated outcomes are based on those interviews.

4.2 Collection and analysis of the cost and product data

Cost data required to build this cost model was collected through a market survey. Three categories of sources were identified for data collection purposes. Those are: leading manufacturers and distributors of electrical accessories in Sri Lanka, retailers of electrical accessories located within the Colombo city limits and the suburbs and electricians who provide labour for domestic electrical installations. Data collection is based on obtaining price lists and product catalogues from leading electrical manufacturers, importers and distributors operating within the country, price lists obtained from retailers and data obtained from domestic electricians regarding the labour charges. Prices for all the electrical accessories were collected from several places subjected to a maximum of five places per accessory.

During the price analysis, mean of all the prices pertaining to a single accessory is calculated and taken as the price for that particular accessory. When prices were not available for a particular cost category of an accessory, price of the "Standard" cost category of the same is substituted. Usage of accessories in these respective designs is unique to the design and can be tabulated as table 2 below. In this, the 'usage' describes a final circuit. Necessary accessories, cables and sundry items are included in a final circuit (please refer table 2 below)

4.3 Data Modelling

Prior deciding on methodology of analysis and modelling, ideas and views were taken from the experts in the industry. Five unstructured interviews were held with marketing managers and other officials in leading electrical accessories manufacturing, importing and distributing companies in Sri Lanka. Accordingly, two major approaches were followed as the basis for modelling the collected data:

Table 2-Number of final circuits and accessories in respective designs

Category of accessories	Usage	Basic	Moderate	Complex
Power Circuits	5A Socket outlets	5 Nos.	8 Nos.	13 Nos.
	13A Socket outlets	-	6 Nos.	10 Nos.
	15A Socket Outlets	1 No.	1 No.	2 Nos.
	Shaver Sockets	-	-	2 Nos.
	Cooker Controllers	-	-	1 No.
Lighting Circuits	Pendent lamp with switch	8 Nos.	4 Nos.	4 Nos.
	Wall Bracket lamp with switch	2 Nos.	6 Nos.	10 Nos.
	Ceiling Lamp with switch	-	2 Nos.	2 Nos.
	Wall Bracket Lamp with 2 way switch	-	-	1 No.
	Pendent lamp with chandeliers with Dimmer	-	1 No.	2 Nos.
Protective Devices	Consumer Unit (Distribution Board)	1 No.	1 No.	1 No.
	Earth Electrode	1 No.	1 No.	1 No.
Other Circuits	Telephone Sockets	-	2 Nos.	8 Nos.
	Television Sockets	-	-	3 Nos.
	Door Bell	1 No.	1 No.	1 No.
	Gate Bell	-	-	1 No.
	Ceiling fans	1 No.	6 Nos.	8 Nos.

1. Selection of three main designs of electrical installations to represent the various combinations of usages of electrical accessories in housing electrical installations, namely,

- Basic - Represents most important and primary accessory requirement in the basic capacity
- Moderate – Represents a typical domestic electrical installation within the Sri Lankan context, where all the important and basic accessories are included and some of the optional accessories are also included

- Complex – Represents a fairly comprehensive domestic electrical installation in Sri Lankan standards

2. Categorisation of cost of accessories in three main ways to represent the cost implication of the selection of each cost category. Those categories are named as,
   - Economical
   - Standard
   - Luxury

Each cost category represents the cost of accessories in different amounts. Those can be represented in a tabulated format as below (Table 3). Costs of final circuits mentioned in the 'Economical', 'Standard', and 'Luxury' column are calculated with respect to final circuits mentioned in the 'Usage' column by applying the costs of accessories in their respective cost categories.

Table 3-Composite rates for final circuits

Category of accessories	Usage	Economical (Rs)	Standard (Rs)	Luxury (Rs)
Power Circuits	5A Socket outlets	725.00	827.00	1,016.00
	13A Socket outlets	999.00	999.00	1,171.00
	15A Socket Outlets	967.00	1,060.00	1,249.00
	Shaver Sockets	2,969.00	2,969.00	4,568.00
	Cooker Controllers	1,194.00	2,094.00	3,344.00
Lighting Circuits	Pendent lamp with switch	540.00	563.00	591.00
	Wall Bracket lamp with switch	804.00	987.00	3,615.00
	Ceiling Lamp with switch	804.00	1,118.00	3,055.00
	Wall Bracket Lamp with 2 way switch	842.00	1,016.00	3,783.00
	Pendent lamp with chandeliers with Dimmer	2,451.00	4,623.00	25,630.00
Protective Devices	Distribution Board	3,216.00	7,710.00	10,036.00
	Earth Electrode	706.00	706.00	706.00
Other Circuits	Telephone Sockets	781.00	944.00	1,211.00
	Television Sockets	846.00	1,015.00	1,156.00
	Door Bell	869.00	1,101.00	2,071.00
	Gate Bell	1,331.00	1,513.00	2,313.00
	Ceiling fans	3,108.00	3,108.00	6,041.00

Tables 2 and 3 above provide the basis for a simulation of the cost variation with the change of either the product category (economical, standard and luxury) or the design category (basic, moderate or complex). The following graph shows the result of the simulation when both the parameters are changed with respect to each other.

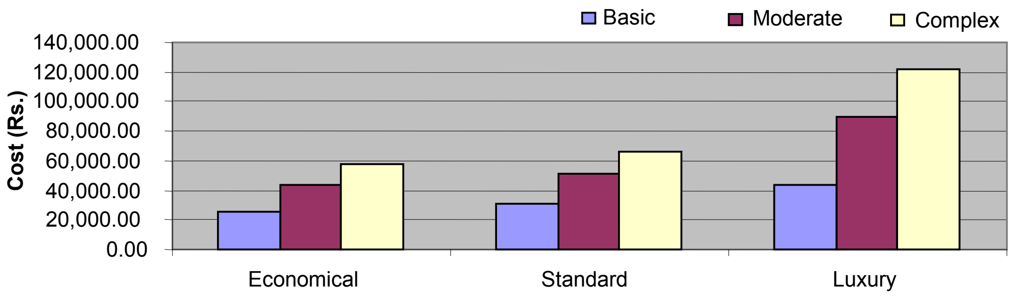

Figure 2-Comparison of cost differences with the change of both the design and the Cost category

From the graph it is visible that the difference between the economical and standard cost categories is marginal where as the luxury cost category shows a noticeable deviation. This fact is further discussed within the conclusions.

5. USER INTERACTION AND THE FUNCTIOANLITY OF THE COST MODEL

When using this Cost Model, the user interaction and the functionality can be represented as shown in the Figure 3.

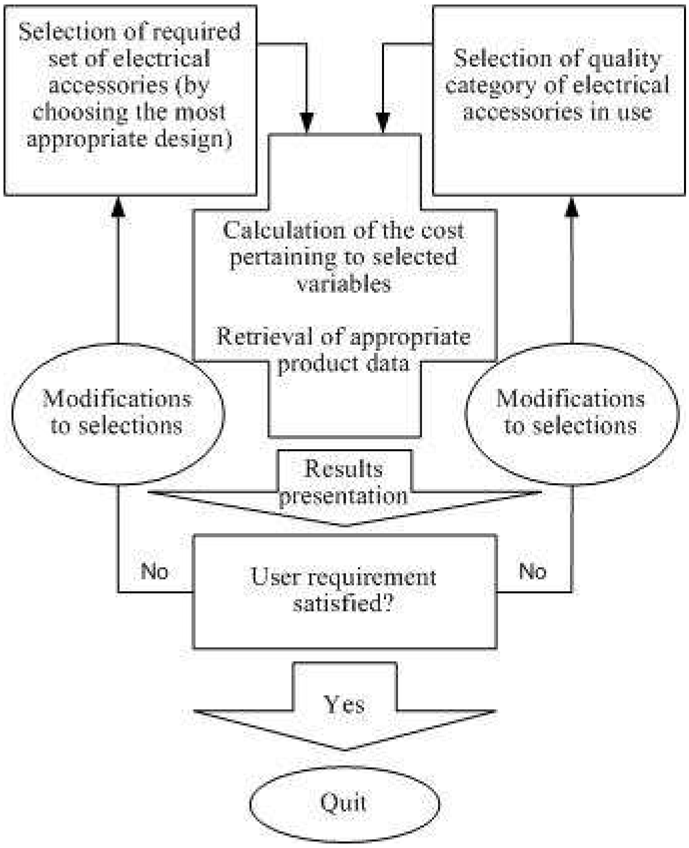

Figure 3-User interaction and the functionality of the cost model

As the dissemination method of this Cost Model, authors developed a computer based simple Decision Support System. The functionality of the Decision Support System can be illustrated as follows:

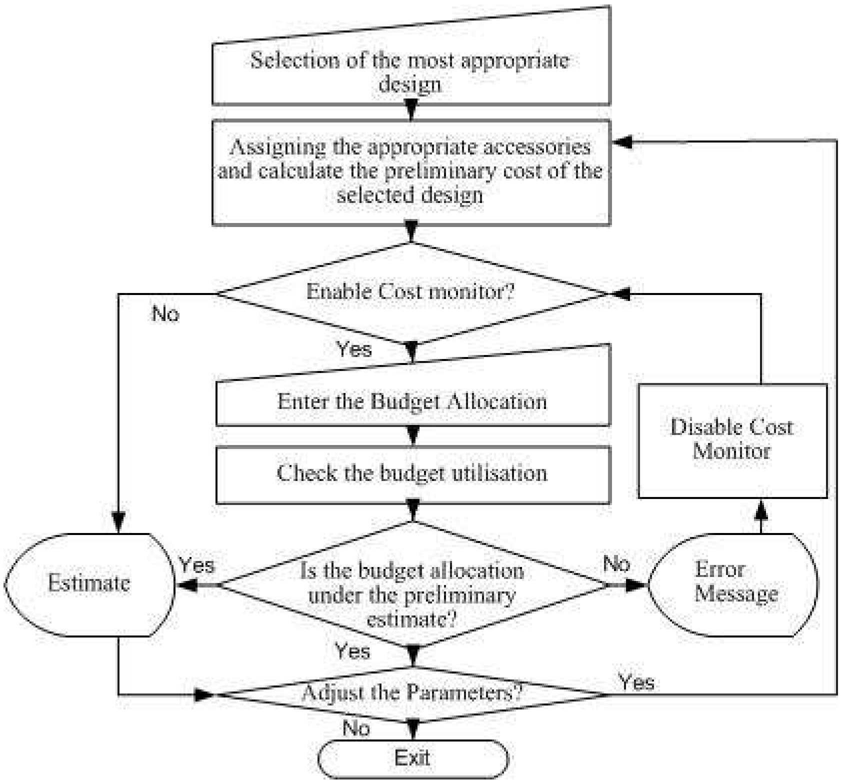

Figure 4-The DSS Functionality

Some of the special facilities that could be arranged in this mode of dissemination of the Cost Model are:

- By selecting the most appropriate in-built design to match with the real situation, the system will instantly calculate and determine the needed accessories for the installation and its cost.
- By providing the option of enabling and disabling the 'cost monitor' facility, the system allows the user to restrict or neglect the selection of accessories according to its cost.
- By providing instance error messages regarding the insufficient fund allocation in the budget, the user will be able to have an instant idea about the minimum fund requirements pertaining to particular type of installation.
- By providing instant on-screen cost breakdown facility, the system allows the user to determine its own cost components.
- With the graphical cost monitor the user is able to graphically see the allocated percentage of budget to the installation at a given situation.
- The On-line web based product and cost information system allows the user to find relevant technical information and costs of accessories used for the installation.
- Single Price Database allows developers and users to easily update the prices when necessary.

As a method of improving the availability of technical information with respect to Electrical Accessories, a website was developed by the Authors. This gives some added benefits to the user:

- Availability of the information world wide at any given time
- Flexibility to update and insert timely information, like new innovations in the industry

6. CONCLUSION

Within the Sri Lankan context, lack of confidence, lack of knowledge and safety concerns are the major barriers between the selection of proper domestic electrical accessories and the end user. In this research, Cost Modelling is used as a solution for this problem. The developed cost model is used as a simulation tool to understand the patterns of the Sri Lankan domestic electrical accessories price variations.

It is clear from the data analysis that the cost difference in any design, when using electrical accessories in "Economical" and "Standard" cost categories is marginal comparatively to that of "Standard" and "Luxury". In fact, the percentage cost increase between the "Economical" and "Standard" cost categories is 23% in the Basic Design, where as the cost increase between the "Standard" and "Luxury" cost categories is 41%. The situation become more clearer when considering the Moderate & Complex Designs, where the percentage cost increases between the "Economical" and "Standard" cost categories are 15% and 14 % respectively, and the cost increase between the "Standard" and "Luxury" cost categories are 75% and 84% respectively.

From the composition of categories of electrical accessories in different designs and different Cost Categories, it can be seen that with the change of Basic Design to Complex Design and Cost Categories from "Economical" to "Luxury", the 'Protective Devices' category contribution has dropped from 15% to 5%. Hence, the increased cost was less influenced by Protective Devices. This may be very useful to encourage house holders to consider use of high quality protective devices even in low cost electrical installations, as it may ensure one key aspects of electrical installations, the safety.

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ACHIEVING HIGHER CAPABILITY MATURITY IN CONSTRUCTION PROCESS IMPROVEMENT

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Abstract: Process improvement has been identified as one of the potential mechanisms to achieve the desired performance improvements within the UK construction industry. In addition, it has further been recognised the importance of learning construction process improvement lessons from other industry examples. Software industry has exemplified a successful implementation of a process improvement strategy, based on the Capability Maturity Model (CMM) which evaluate the capabilities and maturities of organisations in concern to establish the next level of process improvements needed. This model consists of five maturity levels where level 1 being the least matured and level 5 being the most matured. After considering the close similarities between the software industry and the construction industry, the principles of software CMM were attempted to be applied within the construction industry, under the research project "Structured Process Improvement in Construction Enterprises (SPICE)". Within this research the Key Process Areas (KPAs) of level 1, 2 and 3 of software CMM were evaluated and customised to the UK construction industry, after taking its unique characteristics into consideration. This leaves the software CMM level 4 and 5 KPAs unevaluated and un-customised, leaving the maximum potential of SPICE un-revealed. This paper aims at addressing this gap by reviewing the literature on construction process improvement and the software CMM to evaluate the applicability of software CMM higher capability maturity level KPAs within the UK construction context.

Keywords: Construction Process Improvement, Software CMM, SPICE, Higher Capability Maturity Level KPAs.

1. BACKGROUND

It is generally admitted that there is a need for performance improvements within the UK construction industry as it is unpredictable and under-achieving (Koskela et al, 2003, Santos and Powell, 2001; Egan, 1998; Love and Li, 1998; Latham, 1994). Further studies about this need revealed that the fragmentation and confrontational relationships are the major inhibits for performance improvement initiatives (Love and Li, 1998; Egan, 1998; Latham, 1994). Fragmentation and confrontational relationships are sharpened due to the traditional functional view of construction projects, where the tasks are assigned to individuals based on their functions with minimum attention given to the integration issues (Fairclough, 2002; Holt et al, 2000).

Having identified this nature, Egan (1998) highlighted that "focusing on the customer" and "integrating the process and the team around the product" as two of the key drivers to achieve the desired change within the UK construction industry. This emphasises the need within the UK construction industry of deviating from its functionally oriented project structures towards a customer focused, process oriented project delivery mechanisms. It appears that the above recommendations from Egan are based on the view that the process improvement is the way forward to improve the performance of the UK construction industry (Sarshar et al, 2000a).

Even though the performance improvements have been achieved through process improvement initiatives within the manufacturing and services sectors, the direct applicability of this strategy within construction is debated (see: Santos and Powell, 2001; Love and Li, 1998; Egan, 1998). It is argued that the principles of process improvement of the industries like manufacturing and services are not readily applicable within the construction context, due to the "unique" nature of the product. Further, the complex supply chain arrangements and project based product delivery systems have also been identified as inhibits for process improvement initiatives. Contrary to this view, Egan (1998) argues that the construction is a set of repetitive processes when viewing from the organisational point of view. He further emphasises that the project based nature should not be a barrier for process improvement initiatives within the construction industry. Reinforcing this argument, despite its project based nature, the software industry exemplifies the successful implementations of process improvements (see: Sarshar et al, 2000a). This suggests that there are similarities between the construction industry and other industries which have success stories in process improvement where the construction industry can learn lessons from.

However, the above argument does not suggest that the innovations and improvement initiatives within other industries can readily be applicable within a construction environment. As Lillrank (1995) have pointed out, the core idea of an innovation in one industry should be abstracted and then recreated in a form, which it fits in local conditions. The problem then becomes how to recreate process improvement initiatives and innovations of other industries within the UK construction environment.

2. CONSTRUCTION PROCESS IMPROVEMENT STRATEGIES: CURRENT RESEARCH STATUS

Until recently, the construction industry has had few recognised methodologies or frameworks on which to base a process improvement initiative (Sarshar et al., 2000a). This is particularly apparent when considering the availability of such frameworks or methodologies to look at the organisational maturity and capability aspects within construction process improvement initiatives. Unlike in a linier production situation, the project based nature of construction demands complex relationships between various parties. These complexities are influential factors when determining the organisational capabilities which are visible in varying degrees. Moreover, this hinders the capabilities of organisations to assess their standards and prioritise their process improvements appropriately. Further, absence of clear guidance at the macro level hinders the repeatability and benchmarking capabilities of individual performance improvements (if any) at industry level (Sarshar et al, 2000a). Thus it is important to establish a structured, common approach to construction process assessment and improvement based on the current capabilities of the organisation. One such approach which was a success within the software industry is "The Software Capability Maturity Model (CMM)". The Software Capability Maturity Model was developed for the US department of Defence (DoD) who is a major software purchaser (Sarshar et al 1998). The use of CMM includes the evaluation of software manufacturing organisations prior to award them contracts. CMM is based on a five levelled structure. Within this organisations are ranged from level 1 to level 5 based on their maturity. Within this framework, s been defined as "a well defined evolutionary plateau towards achieving mature processes. Each maturity level provides a layer in the foundation for continuous process improvement" (Paulk et al, 1993). Level 1 organisations are the least matured organisations where as level 5 organisations are the most matured organisations. In order to achieve a specified maturity level, organisations must satisfy all the key processes defined within the immediate below maturity level. The organisations are tested against "key enablers" to determine weather they have satisfied each key process. Through this framework, organisations are guided to adopt stepwise process improvements. This framework ensures that the organisation in question is ready for the next level of process improvement. This, intern initialise a process improvement culture within the organisation and guides the procedures and the people towards improvements, using the available and potential tools.

Sarshar et al (1998) have attempted to apply the principles of this model within the construction industry. The next section provides a background description about this research project and its current status.

3. THE SPICE MODEL

The similarities between a software development projects and construction projects have laid the foundation for the SPICE to consider CMM as its base. Adopting the five level architecture of the CMM, the SPICE framework has also organised the process improvements of a construction organisation into five evolutionary steps. Each step is known as a maturity level. Within this paper maturity levels up to the third maturity level are identified as lower maturity level and 4th and 5th maturity levels are considered as higher maturity levels. The five maturity levels of SPICE can be illustrated as follows.

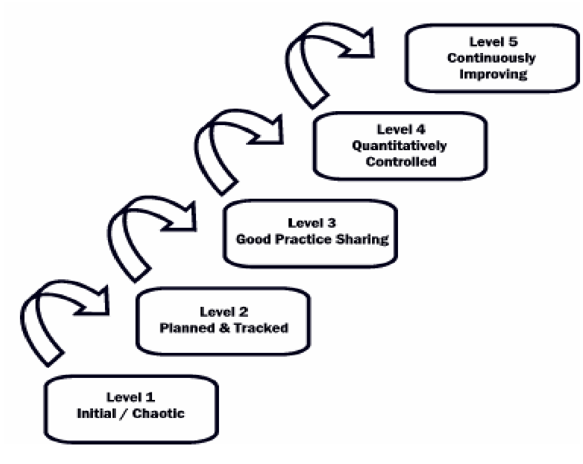

Figure 1 – SPICE maturity levels (source: Sarshar et al, 1998)

Each maturity level has several "Key Process Areas". In order to achieve a level of maturity, the organisation should successfully perform all key processes related to that maturity level. This ability of performing key processes of that particular organisation is evaluated against five key process enablers. Those are,

- Commitment
- Ability

- Evaluation
- Verification
- Activities

It is also said within the SPICE framework that one organisation cannot skip maturity levels while progressing. As an example, to achieve third level maturity, organisations have to go through the second maturity level and cannot advance directly from first maturity level to third maturity level. In addition to the SPICE framework, the SPICE project has produced a mechanism of testing the position of an organisation within the SPICE framework. The mechanism is basically a questionnaire and a series of interviews, through which an organisation can evaluate their position against requirements of key processes and key process enablers within a given maturity level.
The initial SPICE project was aiming at improving processes at individual construction projects. In addition, it concentrated on the development of level 2 characteristics and key processes. Level 1 organisations have been identified as organisations which use ad-hoc processes during their day to day activities. And generally these organisations are surviving or performing due to the ability of some individual characters within the organisation. And generally these organisations are trying to survive today, rather than planning for the future.

Within the SPICE framework the level 2 has been identified as planned and tracked. At this level there is a degree of project predictability. A level 2 organisation has established policies and procedures for managing the major project-based processes (Sarshar et al, 2000b).

After publishing the first iteration in 2000, due to the increased interest of industrialists, the second phase of SPICE was commissioned in 2002 focusing on process improvement across the construction organisation. During this phase the third level parameters and key processes were evaluated. Level 3 is identified as “Well Defined”. Within this level practices are well defined and institutionalised. Knowledge capturing and sharing mechanisms are established within these organisations to institutionalise the good practices and processes. After this institutionalisation, a high level of predictability can be expected towards future projects of an organisation.

Up to date research status of the SPICE project shows clear gaps in identification of the characteristics of higher maturity levels. As the Sarshar et al (2000b) have explicitly mentioned, so far the SPICE research has had little focus on level 4 and 5 issues. Since level 4 and 5 of the CMM are specifically aiming at continuous process improvements, the exploration of the dynamics of these levels is essential within the construction context, to achieve the desired performance improvements.

4. HIGHER CAPABILITY MATURITY LEVEL DYNAMICS

While lower maturity levels of CMM establish the required capability and the background of the organisation, the higher maturity levels are responsible for dramatic and sustainable process improvements. Within the SPICE, the dynamics of higher maturity levels were not explored thoroughly, leaving its full potential unexplored. This part of the paper investigates this gap from a comparative basis. The CMM level 4 and Key Process Areas will be analysed thoroughly, comparing the distinctive characteristics of both the software and construction industries. Furthermore, this analysis will be extended to discuss the applicability of these CMM 4^{th} maturity level dynamics within the construction environment. In addition, the 5^{th} maturity level dynamics will also be evaluated briefly visualising its potential applicability within construction.

4.1 Level 4 Characteristics of CMM

CMM level 4 is classified as the "The Managed Level". The most significant quality improvements begin at this level (Humphrey, 1989). The characteristics of this level (and level 5) are relatively an unknown within the software industry as there are too few examples of software organisations to draw general conclusions about the characteristics (Paulk et al, 1993; Dymond, 1995). As and example, as of March 1999, of the 807 organizations active in the SEI's assessment database, only 35 were at levels 4 and 5 (Paulk, 1999). However, the characteristics of these levels have been defined by the analogy of other industries and the few examples in the software industry. Many characteristics of levels 4 and 5 are based on the concept of statistical process control (Paulk et al, 1993). From a project management and organisational perspective, the focus of level 4 is on establishing quantitative process management processes, while from engineering processes perspective, it is on establishing Software Quality Management processes (Paulk et al, 1995; Paulk et al, 1993).

The KPAs of the level 4 are probably the most misunderstood requirements in the entire CMM structure, because the directions about how to move from Level 3 to Level 4 are very fuzzy (Raynus, 1999). There are two KPAs at CMM level 4, which are based on above mentioned focuses. One has to do with process quality, that is, process performance (Quantitative Process Management – QPM) and the other, Software Quality Management, with product quality (Dymond, 1995).

Quantitative Process Management (QPM)

The purpose of QPM is to control the process performance of the software project quantitatively. Software process performance represents the actual results achieved from following a software process (Paulk et al, 1995). QPM involves establishing goals for the performance of project's defined software process, taking and analysing measurement of the process performance and making adjustments to maintain process performance within acceptable limits (Paulk et al, 1995).

Once the process performance is within the acceptable limits, the settings are established as a baseline and used to control process performance quantitatively. Further, within this KPA, special causes of variations in process performance will be identified and removed (Dymond, 1995). Collection of process performance data across all the projects of the organisation will be used to characterise the process capability of the organisation's standard software process. This process capability data in turn will be used by the software projects to establish and revise their process performance goals (Paulk et al, 1995).

Software Quality Management (SQM)

The second KPA of the CMM level 4 is SQM. The purpose of SQM is to develop a quantitative understanding of the quality of the project's software products and achieve specific quality goals (Paulk et al, 1995). This KPA involves defining quality goals for software products, establishing plans to achieve these goals, monitoring and adjusting the software plans and products to satisfy the needs and desires of the affected stakeholders.

The determination of quality goals is based on the plan developed for the project software quality. This plan takes its quality requirement input from customers, organisational and project quality plans and organisational capabilities. The quality requirements become numeric quality goals when data values describing those quality features are produced from the measurement plan (Dymond, 1995). After establishing the quantitative quality goals, the actual quality is measured against the goal at the start of each life cycle stage and corrective measures will be taken as and when necessary.

4.2 Applicability of CMM 4th level KPAs within construction

Within the construction context, the principles of the above KPAs can be interpreted from a different view point. Taking QPM into consideration as a KPA in within the construction context, it is important to establish the definition of "construction process performance" in relation to the "software process performance". Since "performance" is a relative measure, firstly it is important to establish an objective basis within which the "construction process performance" can be defined. Since the major objectives of a construction project are based on the time, cost and quality aspects, scaling it down to the process level, the objectives of a construction process can also be identified within a time, cost and quality framework. In effect this means that the performance of the construction processes can be measured monitored in terms of time, cost and quality. The major emphasis is on the ability to take quantitative measurements of these parameters to establish "goals" for the processes based on which the performance of the processes can be evaluated for improvements. Within the UK construction context, it is visible that some of these practices are in place within some construction organisations. Often these practices are embedded within work studies or performed as a part of initiatives such as Key Performance Indicators (KPI). Even though these initiatives may have had some impact upon the performance improvement of the organisation, it is questionable whether these statistics are used for its maximum potential. Without a optimisation plan these statistics may just lead the organisation towards a sub-optimisation. However, it is not the intention of this study to investigate and propose suitable methodologies for measuring and monitoring the performance of the processes in place, rather it is intended to identify whether the organisation;

- has the commitment to quantitatively measure the performance of processes as described above
- has the ability to perform quantitative measurements of its processes
- have activities in place to perform the quantitative measurements
- evaluate the activities in place to measure the performance of processes (internal evaluation)
- Verifies the activities to measure the performance of the processes are in compliance with standard practices (external verification).

The above five items are the key process enablers against which each of the KPAs has to be tested.

When mapping the "Software Quality Management" KPA to construction, the main emphasis has to be given to the quality of the final product. This effectively reflects on the performance of the "core processes" or "technical level processes" as well as other related parameters such as programmer's skill within the software industry and workmanship and material quality within the construction industry. While the software industry uses quantitative measures such as number of bugs per thousand lines of code to quantify the quality of its final product, construction industry practices various material testing techniques and industry standards for material quality determination to ensure the quality of its final product. Due to the reason that the software quality does not heavily depend upon external factors such as material quality or the soil bearing pressure, it is sensible to assume a strong relationship between the software quality and the software processes in place. This is further justifiable since the measures such as number of bugs for thousand lines of code have a higher chance to get a high figure if the programmers work under stress within ad-hoc fire fighting situations in contrast to the existence of a working environment where proper processes in place to ensure minimal stress to the programmer.

Within this context, construction has a strong requirement to monitor the quality of its final products as it will be determined by a combination of various factors. These factors include quality of workmanship, construction processes in place, external factors such as ground and weather conditions, supply chain arrangements, etc. In order to enable continuous improvements within an organisation, it is important to monitor the impact of these parameters to the quality of the final product. This establishes justification for the need a different KPA within construction to quantitatively monitor and manage the quality of the construction product. Further, it is required to emphasis here that it is not the intention of this study to identify "how" the quality of the construction product is measured within construction organisations, but to identify the level of the construction quality measurement within the five key process enablers described above.

After establishing the "Quantitative Control", the next aspect of the organisation is to move towards an "Optimisation" where the monitored processes are continuously improved. This is the main objective of the CMM level 5.

4.3 CMM Level 5 Characteristics

CMM level 5 is classified as "Optimising". The focus of this level is on the continuous process improvement. The software process is changed to improve quality, and the zone of quality control moves to establish a new baseline for performance with reduced chronic waste (Paulk et al, 1993). Lessons learnt during these improvements will be applied in future projects. At this point, common causes of variations are addressed which in tern will result in reduced chronic waste and new baselines for improved performances. This feedback loop completes the cycle of continuous process improvement. CMM Level 5 consists of three KPAs which lead the organisation towards the ultimate goal of continuous process improvement. Those KPAs are;

- Defect Prevention (DP)
- Technology Change Management (TCM)

- Process Change Management (PCM)

The purpose of the DP is to identify the common causes of defects and prevent them from recurring (Paulk et al, 1995), while the purpose of TCM is to identify new technologies (i.e. tools, methods and processes) and transition them to organisation in an orderly manner (Paulk et al, 1995). It involves identifying, selecting and evaluating new technologies and incorporating effective technologies into the organisation. PCM is aiming at continuously improving the software processes used in the organisation with the intention of improving software quality (Paulk et al 1995). It involves defining process improvement goals and systematically identifying, evaluating and implementing improvements to the organisation's standard software process and project's defined software process on a continuous basis.

4.4 Applicability of CMM 5th level KPAs within construction

When viewing the above KPAs from the construction perspective, it is important to take the construction specific characteristics into consideration. The place of Defect Prevention KPA in software CMM is justifiable as a 5th level capability maturity level dynamic as lesser number of defects (bugs) found in a software product directly contribute to the software quality positively, as this is the major measurement of software quality. Further the quantitative measurement and control of the software quality has considered as a key process area within the 4th maturity level enabling the organisation to concentrate on preventing measures once the organisation reaches the 5th maturity level. In contrast, the construction "defects" does not covers the full aspects of construction product quality as explained under the 4th maturity level dynamics. Rather "defects" in construction projects are treated separately and treated under the arrangements such as "defect liability period" and "maintenance period". However, if a construction organisation to practice defect prevention measures at the 5th maturity level, it has to establish quantitative defect measurements and control preferably within the 4th maturity level. This triggers a necessity to revisit the 4th maturity level dynamics with the flexibility of modifications. The same applies when considering the Technology Change Management. Technology Change in software is relatively straight forward due to the fact that software uses relatively less number of different technologies within different sections of the product. As an example, in software a technology change would mean migrating from one programming language to another. In this case the change effect is organisation wide. But the construction utilises different technologies within different sections of the product. As an example, a new technological innovation in fabrication of steel structures might influence the processes involve for the erecting of the steel structure but might not have significant effects on processes to erect other elements like services or finishes. And due to these diversifications it is difficult to adopt an organisation wide technology change management as a single key process area within the 5th level of the construction capability maturity. The final KPA considered within the software CMM is the process change management, which is the core to achieve continuous process improvements. The principle of this KPA is generic and the same principles can be used within the construction industry. Since the 4th level capabilities ensure the availability of the quantitative data within the organisation to reflect the opportunities for improvement, this KPA can be used to establish new stretch goals for the processes in place which can stimulate innovative processes. Thus this can be used as the starting point for the "revolutionary process improvements" within the organisation with out straining the organisational resources.

5. CONCLUSION

By considering the similarities between the two industries, some construction process improvement initiatives have adopted the principles of software industry's Capability Maturity Model. However to date, the higher maturity level characteristics of the software CMM has not been analysed thoroughly to evaluate its applicability within the UK construction environment. Thus, this paper analysed these characteristics within the comparative setting between the software industry characteristics and the construction industry characteristics to build a initial model on how the CMM higher capability maturity level characteristics fit within a construction environment.

6. WAY FORWARD

As this is a part of an ongoing PhD, it is intended to validate this initial understanding about the higher capability maturity dynamics through a case study approach. This paper presents a partially the initial understanding of how the construction higher capability maturity dynamics can be. Further, this initial understanding is intended to go through several refinement cycles to ensure that it captures the actual industry characteristics and requirements. It is an objective of this PhD research to build a comprehensive framework ultimately, to guide construction organisations on the steps of achieving higher capability maturity levels as a mean of improving the organisational processes continuously. On the other hand, this research further looks at the role of the information technology as an enabler to achieve higher capability maturity dynamics within the UK construction organisations. It is therefore intended to build a process – IT co-maturation model to guide construction organisations to use information technology strategically for their process improvement initiatives.

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THE VALIDATION OF PHARMACEUTICAL FACILITIES

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Abstract: The work reported is part of an ongoing PhD study prompted by the particular difficulties encountered when two very different quality cultures interact - in this case Pharmaceutical industry clients and Construction industry providers. The main academic grounding of the research is in Systems Theory and empirical data is being collecting using a multiple case study approach. Research data was collected from a number of pharmaceutical facility construction case studies and was used to test and inform a best practice model of facility validation. The qualitative methods of participant and direct observation were used as the main information gathering tools. The paper reports on the regulatory expectations that influence the construction of projects of this type and the impact on the best practice model of validation.

Keywords: Quality, Commissioning, Validation, Attitudes.

1. INTRODUCTION

Projects for the construction of pharmaceutical facilities differ from many construction projects because of the complex manufacturing processes housed within the facility and the critical nature of products that are manufactured. Tedesco & Titus (1995) suggest that the costs of items such as finishes, services installations, support systems, utilities and other hardware are far more significant than for non-pharmaceutical manufacturing facilities of equivalent size. Due to the nature of pharmaceutical products, it is critical that the facility housing the production process complies with current regulatory requirements and performs its function perfectly from the very start of production, and even before. In order to demonstrate that facility compliance has been achieved, there is a stringent validation process, and failure of the facility to satisfy the relevant regulatory body will result in non-compliance, rendering the facility useless until it is remedied.

2. AIM OF THE RESEARCH

The reported research forms the early part of a PhD study. The aim of the study is to investigate the way that validation activities are currently accommodated within the process of constructing pharmaceutical facilities; to compare this with what *should* be done to arrive at a model of best practice. In order to achieve this aim, the following objectives have been set:

- define what constitutes validation of a pharmaceutical facility;
- analyse the cultural views of the client and contactor in terms of project success criteria, project quality and regulatory compliance;

- examine the implementation process and identify and explain those factors that influence the success of the validation activity;
- assess what validation service provider models are commonly used and determine by the use of a research case study, the implications of the adopted approach;
- establish what validation process stages typically occur and analyse the research data to establish if there is any deviation in content and timing from the third order validation cybernetic model.

3. PROBLEM STATEMENT

Despite the fact that facility validation is such a crucial element of pharmaceutical projects, it is still generally treated by the building team as an after-thought, an unpleasant duty to be performed at the end of commissioning, rather than something that is central to the construction process. There is evidence of a 'clash of cultures' (Odum, 1992) that underlies the aspirations of building providers (designers and constructors) and those who have commissioned its use (the client).

As a result, non-compliance, expensive re-work and project delay is common, and this leads to late plant start-up, delayed production, client dissatisfaction and, in some cases, litigation. However, these problems have received little or no research attention from those concerned with construction industry processes. Wheeler (1994) underlines the significance of project termination by noting that how we complete and handover our buildings is as important as how we design and construct them.

The validation process is based on providing documented proof, through testing, that the installed facility and systems, that are critical to the manufacturing process, consistently operate as specified. Testing procedures and strategies adopted in the industry seem to be based on past experience and company procedure and not on theoretical concepts.

4. VALIDATION OF A PHARMACEUTICAL FACILITY

To determine the key reasons why pharmaceutical facilities are validated and to determine what regulatory constraints are put on the construction industry a literature review was undertaken. The literature on facility validation is almost exclusively produced by the healthcare technology industry, which includes pharmaceutical, biological and medical device manufacturing sectors.

Various authors have recognized the effects of these regulations. De Valle (1995) suggests that factors such as plant geographical location and product market location have to be well understood to effectively manage the design, construction and validation of a pharmaceutical facility. Allan (2004) also found that the regulations have made validation costly and time-consuming. In order to understand why these effects occur in the UK and USA, regulations have been analyzed, and the following sections report this analysis.

5. UK AND EUROPEAN REGULATIONS

The Medicines and Healthcare products Regulatory Agency (MHRA) is the UK regulatory agency responsible for ensuring that healthcare products and medical equipment meet the required standards. The Agency is an executive arm of the Department of Health. In April 2003 the MHRA replaced the Medicines Control Agency (MCA) and the Medical Devices Agency (MDA).

The MHRA is the Competent Authority for medical devices and pharmaceuticals Licensing Authority. The main activities of the agency are to enforce the requirements ensuring compliance to standards of pharmaceutical manufacture.

In 1991 there was a harmonization of manufacturing authorizations and Good Manufacturing Practice (GMP) within the European Community and pharmaceutical inspections are now regulated by European Commission Directives. There are two main European Commission Directives that give the principles and guidelines of Good Manufacturing Practice (GMP). Directive 91/356/EEC gives information for medical products for human use and Directive 91/412/EEC gives information for veterinary medicine products.

Article 8 of the Rules and Guidance for Pharmaceutical Manufacturers and Distributors (MCA, 2002) states that 'Premises and manufacturing equipment shall be located, designed, constructed and maintained to suit the intended operations'

It goes on to say 'Layout, design and operation must aim to minimize the risk of errors and permit effective cleaning and maintenance in order to avoid contamination, cross contamination and, in general any adverse effect on the quality of the product' and 'Premises and equipment intended to be used for manufacturing operations which are critical for the quality of the products shall be subjected to appropriate qualification'.

Qualification, or as it is also widely termed *validation* is 'the action of proving, in accordance with the principles of GMP, that any procedure, process, equipment, material, activity or system actually leads to the expected results' (MCA, 2002). The directives define those areas of specific importance as:-
1. Avoidance of material or product contamination.
2. Premises maintenance operations that do not present a hazard to the product quality.
3. Appropriate lighting, temperature, humidity and ventilation.
4. Premises design to afford maximum protection against insects or other animals.
5. Prevention of entry of unauthorized people.

The focus of this research is primarily concerned with items 1, 2 and 3 of the directives, as these are the areas that the construction industry has most influence and control over.

The level of guidance that is given by the different regulatory authorities is general in nature and leaves the responsibility to the pharmaceutical manufacturer to provide documented evidence that the manufacturing facility is compliant with GMP. *Quality* therefore must be designed into the facilities and associated systems that will be used to produce the finished pharmaceutical product (Odum, 1997). The success of building in quality into a facility and hence the final drug product is dependant on the understanding of GMPs and the validation program.

6. SUMMARY OF GMP REQUIREMENTS

The study thus far has identified the main regulatory agencies, their expectations and their influence on the construction of pharmaceutical facilities. Building on the definitions of the validation activity, the goal is therefore to provide documented proof that:

1. The premises, the facilities, the equipment and the processes have been *designed* in accordance with the requirements of current Good Manufacturing Practice (GMP). This represents the activity called Design Qualification (DQ).
2. The facilities and equipment have been constructed and *installed* in compliance with their design specifications. This represents the activity called Installation Qualification (IQ).
3. The facility and the equipment *operate* in accordance with their design specifications. This represents the activity called Operational Qualification (OQ).
4. The facility and equipment operate within their design specification to repeatedly and reliably *produce* a finished product of the required quality. This represents the activity called Process Qualification (PQ).

It is essential that the construction and client teams operate in an integrated manner, sharing their specialist knowledge, with the common goal of regulatory compliance.

7. MODEL DEVELOPMENT

Together with the understanding and interpretation of the main regulatory requirements, there are a number of other success related factors that will have an effect on the project outcome. The success factors at this stage are partly developed independent hypothetical propositions that may or may not be directly influential. Yin (1994) argues that each proposition directs focus on an area to be examined and each specific proposition may assist in enclosing the study within reasonable boundaries. The success factors are not exhaustive and by the process of interpretivist methods (Bryman, 1988) may lead to the generation of others. This then leads to the following model of Pharmaceutical Facility Validation (See Figure 1).

The validation process model can be viewed as an open system. The system of the type described by Yolles (1999) comprises of input, process and output. Roper (1994) describes open systems as having no mechanism for comparison of the output and input and are termed *black box* system. The introduction of a feedback loop, sensor and comparator allows direct comparison of output with input. This comparison will result in the observation of deviation and is known as a *white box* system.

In the same way the validation process can be considered in similar terms where the desired system output is GMP compliance, the input is the validation test stimuli and the process is the implementation model. The introduction of a feedback loop, sensor and comparator give the ability to provide cybernetic control. The term cybernetic comes from the ancient Greek word Kubernesis which means ‘steering’ or ‘governing’.

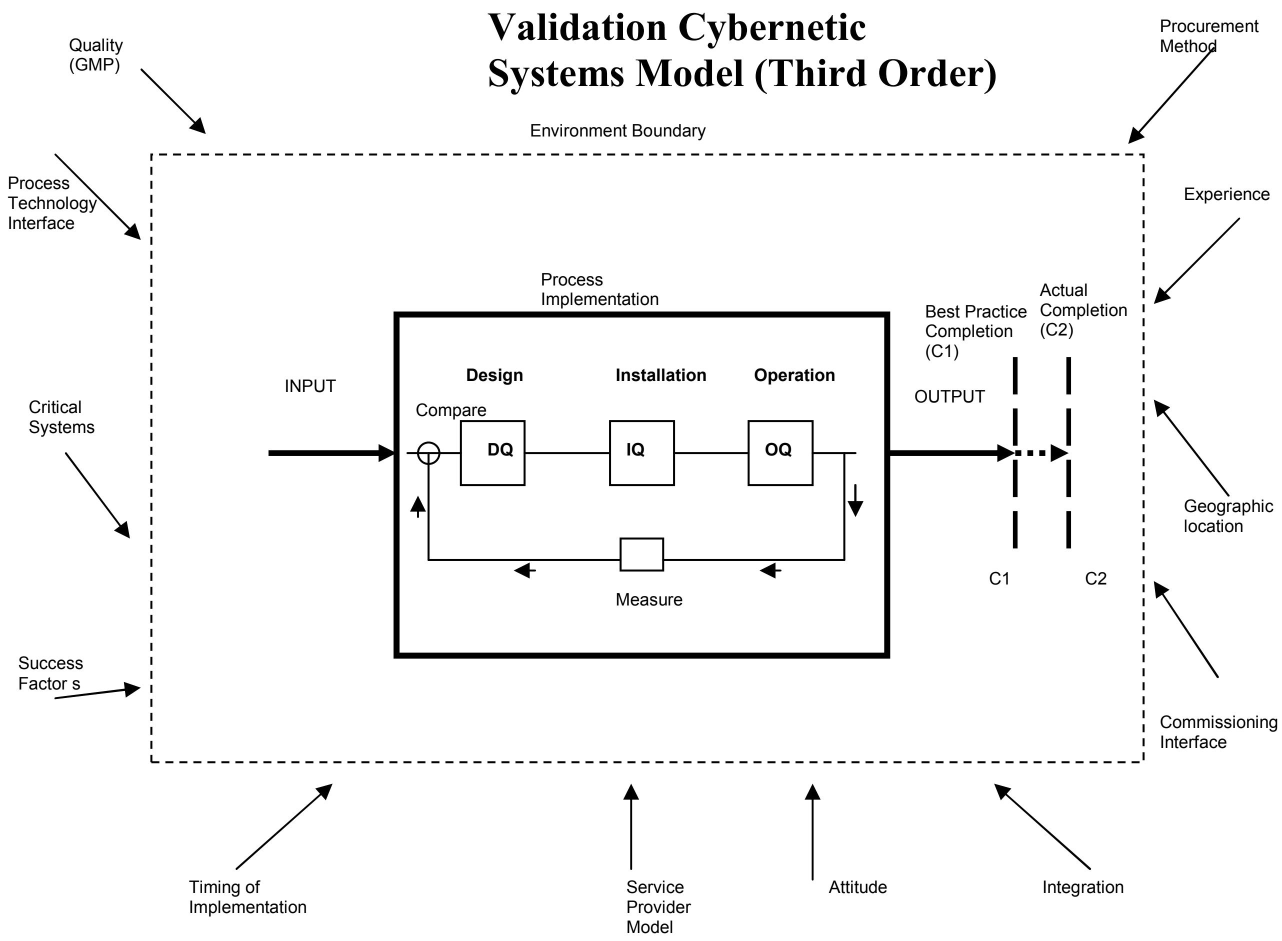

Figure 1: Validation Cybernetic System Model (Third Order)

To provide sufficient validation system testing coverage, black box or functional system analysis alone would not be a suitable system model. The combination of structural or white box techniques and functional analysis would provide a more suitable model.

It is recognized that the utilization of *sufficient* validation test procedures and testing concepts will be fundamental in achieving project success. Therefore, other industries that have similar characteristics as the pharmaceutical industry (i.e. technically complex processes, with the requirement for system testing to provide assurance of project quality) have been additionally investigated in the research. The main aim is to determine if there are any highly developed testing and implementation solutions currently being used that could be applicable to the provision of pharmaceutical buildings. The open system view of validation, as part of the construction process, also leads to the system being open to the local environment at the system boundary. Success factors, as identified in figure 1, will be acting at this boundary. The negative feedback is based on circular causal chain mechanisms monitoring and feeding back information on deviations from the goal.

The model represents a sequential set of activities that are time series dependant. Each activity can only commence once the previous one is completed. Best practice project completion point is represented by C1, and C2 represents the actual completion of the project in the termination phase. The deviation between C1 and C2 can be seen as the measurement of the absence of in-built quality and time delay. Allan (2004) has examined downstream problems of this type. He has found that cost can escalate and schedules can extend due to the failure of construction organization to integrate and to produce quality documentation. It is proposed that the reason for deviation from best practice is related to those factors acting at the system boundary.

8. RESEARCH STRATEGY

Participant Observation

Two main research strategies identified by Glaser and Strauss (1967) are verification and generation. Verification positivist (Easterby -Smith et al, 1991) or logico-deductive strategies relate to proposition or hypothesis testing. These are most commonly associated with empirical data that is quantitative.

Generation or interpretivist methods of research allow theory to emerge from the data; and there is a tendency for such data to be of a qualitative nature (Bryman, 1988). The nature of the study problem has *shaped* the research strategy. The limited amount of existing theory published on the subject pointed to the need to employ an almost exclusively qualitative empirical study. According to Jorgensen (1989), use of participant observation is particularly applicable to research problems where little is known about the problem being studied and the phenomenon is somehow obscured from the views of the outsider. In essence, human studies require a unique methodology that allows the observer to be placed in the everyday setting of the observed. Therefore a case study was undertaken with the researcher adopting the research methodology of participant observation.

8.1 Case Study and Questionnaire

The two main data collection methods employed in the research have been:-
1. Site based participant observation, as a member of a validation team within a pharmaceutical manufacturing company's quality assurance department.
2. An industry questionnaire.

The case study project was the construction of a pharmaceutical pilot plant which comprised of a tablet compression suite, tablet coating suite and packaging hall. The data collection methods used were interviews with the construction project manager and validation manager, collection of observation notes in the form of a case study diary, memos, reports, validation protocols, letters, and informal interviews. Once the research data was collected it was then analyzed. This was done by breaking the data into segments that were of a controllable size, that allow the identification of patterns, sequences, classes, types or processes. The analysis process then consisted of assembling the data in such a way that permitted comprehension or meaning to be derived from the data.
By piecing together the research findings in this way and making sense of them, the process of theory building or theorizing takes place. Jorgensen, (1997) describes theorizing as 'an arrangement of facts in the form of an explanation or interpretation'.

To supplement the fieldwork an industry questionnaire was sent to construction and pharmaceutical practitioners. The survey was used specifically as a sampling tool to gauge the attitudes and views of both study groups. This mixed mode research was used to help provide what Yin (1994) terms *converging lines of enquiry.*

9. RESULTS

9.1 Case Study Findings

The findings below are a summary of a number of generalizations that came from the site-based research:

- Experience - The main contractor demonstrated a limited knowledge of the pharmaceutical industry. This lack of understanding stemmed from limited experience of this project type and no formal education within the subject area. It became evident that there are wide cultural differences between pharmaceutical manufacture and construction working practices.
- Service Provider Model – The validation specialist employed by the pharmaceutical client was not sufficiently experienced in construction/engineering disciplines to create suitable validation test protocols. The *specialist's* background was related to process engineering and not facility construction.
- Validation Process – The client failed to appoint the validation specialist until after construction had commenced. This resulted in problems associated with the sequencing of validation tasks.
- Risk – The main contractor viewed the validation works as specialist and therefore an area of high financial risk. This view was based partly on previous experience of providing validation assistance as an un-charged extra.
- The commissioning activity became the project phase for carrying out nearly all of the validation works. The commissioning and validation teams did not work as an integrated team and expensive re-witnessing tests were required.
- Regulatory expectations – Those involved appeared to be unclear of levels to be achieved. The team member who had the greatest experience in this area was the client validation manager. Unfortunately, the validation manager was not part of the *core* project group.
- Communications – Project progress meetings were too time consuming and were attended by too many different disciplines. As a result it became difficult for the main contractor to progress the project while waiting for specific issues and problems to be addressed.
- Some Good Manufacturing Practice issues were not included in the initial project design and they were not discovered until after project completion. The main reason for this was that a design review exercise was not carried out.

The main problems associated with timing and implementation that have informed the third order cybernetic systems model have been identified as:-

1. Incomplete and unsuitable User Requirement Specification (URS).

2. Inadequate resultant Functional Specification (FS).
3. Absence of a Validation Master Plan (VMP).
4. Missing validation process stages.
5. Non-sequential validation process.
6. Validation process occurring post-construction.
7. Change control – inability to accommodate project change and prevention of GMP non-compliance.

10. CONCLUSIONS

The criteria by which the success of any construction project is assessed are normally time, cost and quality. Time and cost are readily measurable, but the meaning of quality can be more elusive, and this is at the root of the problem of successful validation of pharmaceutical buildings. During the research, it has become clear that construction project managers probably tend to understand quality as a measure of workmanship, while pharmaceutical project managers view it in terms of assurance and regulatory compliance. This difference in understanding and the importance of the construction project managers input into the validation activity has been overlooked or at best underestimated.

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THE UTILISATION OF CROSS-FUNCTIONAL INTER-ORGANISATIONAL TEAM THEORY IN PARTNERING TEAMS

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ABSTRACT: Partnering agreements are increasing in contemporary business and writers have argued the importance of teamwork within them (Clay, MacNaughton & Farnan Jr., 2004). However, mistrust and lack of inter-organisational cooperation seem to be major barriers preventing successful partnering performance (Larson & Drexler, 1997; Egan, 1998; Cheung et al, 2003); indicating that the dynamics within the partnering teams are retrogressive and impact on their effectiveness. Historically, there seem to be limited amount of research into how these teams are developed and sustained. This study has therefore endeavoured to investigate the utilisation of cross-functional inter-organisational team theory in partnering teams by conducting a survey covering a wide range of industrial sectors and different partnering teams. The results suggests that theory is not being utilised and that traditional adversarial influences prevents partnering teams, and hence also the partnering agreements, from maximising and realising their potential. This can further be seen as a reflection of traditional attempts to exploit a post-industrial philosophy that is based on ways of working which traditional organisations are arguably not designed for nor can successfully produce without changing.

Keywords – Cultural Change, Innovation, Organisational Structures, Partnering, Teamwork

1. INTRODUCTION

1.1 Post-Industrial Marketplace Conditions

It was not until the 1970's that the, till then, superior business models, which prevailed the industrial scene with unwavering and routine operations, saw flaws in their systems when experiencing problems in meeting the changing demands of fragmenting markets and shifting patterns of customer demand (Brown et al., 2000; Turner, 2003). As a result, innovation became the new imperative for organisations (Harvey, 1989; Thamrain, 1996).

Despite being an area that has been subject to a vast amount of attention in academia, organisations continue to have difficulties innovating effectively (Dougherty, 1996). The problem seems to be much less one of implementation and more likely to be with the organisations themselves and their ability to be receptive to innovation.

This debatably questions the current validity of traditional organisational structures and some authors even suggest that the days of functional and hierarchical organisational configurations are nearly gone (Roberts & Grabowski, 1996). To replace them are networks of systems, people and teams (Monge & Eisenberg, 1987; Belbin, 2004). The importance of restructuring organisations to facilitate effective teamwork then arguably becomes significant and a pre-requisite to be able to excel as an organisation within and beyond the post-industrial marketplace.

1.2 Partnering and Teamwork

Partnering in the UK has seemingly been highly influenced by the Latham Report (1994), which identified adversarial relationships, focus lowest cost and fragmentation in construction procurement as major barriers to improving quality and productivity, and later by the Egan Report (1998) which indicated a shift to a more project-focused, collaborative working environment and sharing best practice and world class performance (Turner & Simister, 2000). The growing interest in the area from scholars and practitioners has led to several definitions and interpretations being proposed (Duysters & Hagedoorn, 1995) and has perhaps brought about an unsettled terminology. Being referred to as a confused concept (Cox & Townsend, 1998), McGeorge and Palmer (1997, p188) put forward that partnering *'means many things to many people'*.

Although there are variations in the different definitions available, there seem to be an attribute which the lion's share of researchers attaches utter importance to, i.e. the importance of creating trust-based relationships between organisations through innovative and effective teamwork in the supply chain. This then becomes an expression for a shift in the attitudes towards client and supplier relationships and moving the procurement emphasis away from lowest cost to best value and placing the customer at the centre of attention (Turner, 1995; Rowlinson, 1997; Egan, 1998), arguably matching the imperatives of the post-industrial marketplace.

Studies have shown, however, that mistrust and lack of inter-organisational cooperation are major barriers to successful partnering performance (Larson & Drexler, 1997; Cheung et al, 2003), indicating that the dynamics within the partnering teams are retrogressive and impacting on their effectiveness. This should indeed be alarming as writers and researchers (Elmuti, 1996; Manz & Stewart, 1997; Burnes & Dale, 1998; De Leede & Stoker, 1999; Belbin, 2004) have reported an increase in the use of teams in industry and in addition consider teams as key drivers in future inter- and intra-organisational relationships. If teams are not being recognised for their value and are seen as being ineffective in partnering agreements it becomes hard to understand how trust will be established altogether, something which subsequently may affect the realisation of the proposed benefits that might otherwise be derived from the partnering philosophy.

1.3 Aim and Objectives

Newer research (Bayliss et al.2004) argues that partnering success stories have so far been mostly descriptive, and when it comes to research into partnering teams and their structure, behaviour and effectiveness the selection is arguably strictly limited to a few samples. Building on the background given above and the apparent gap in the existing literature, the researcher has attempted to meet the following aim:

To investigate the utilisation of cross-functional inter-organisational team theory in partnering teams and the potential impact this may have on their effectiveness

This has been conducted by pursuing the following four objectives:

- To evaluate writer's views on and practitioners approaches to developing and sustaining partnering teams

- To consider the impact of leadership and empowerment on partnering teams
- To assess how decision making and selection of improvement initiatives impact on the effectiveness of partnering teams
- To examine the influence of organisational culture on partnering team performance

1.4 Definition – Partnering Team

To be able to achieve the above and to enable benchmarking of prospective findings it seems necessary to establish what is meant by the term partnering team and their purpose, characteristics and function. As mentioned previously, the partnering literature is relatively unsettled and has seemingly limited empirical basis in the subject area. The researcher has therefore experienced difficulties in finding, evaluating and contrasting supporting academic material which would have endorsed any proposed description. Arguably this makes the labelling difficult. The researcher has therefore been obliged to put forward a working definition based on the aspects in the existing partnering and other corresponding literature and research which different writers have emphasised as important to the partnering process. Because of this, a partnering team may thus be defined as:

An effective and innovative inter-organisational cross-functional team responsible for maintaining a trust-worthy team culture and long-term commitment between the partners. This implies effective communication, management and control of all project work within the partnering agreement, evaluation of processes and instigation of improvement initiatives to secure that the potential of the supply chain is exploited and the proposed benefits of partnering can be achieved in a successful manner.

2. LITERATURE REVIEW

To be able to effectively utilise teams in partnering agreements it is seemingly important that organisations have a certain understanding and appreciation of how these are created and sustained, as well as the role they play in improving partnering performance. By creating a theoretical framework it may be possible to test this with practitioners and arguably contribute towards drawing a realistic picture of how partnering teams are being developed and sustained in industry.

By using Sundstrom et al.'s (1990) two criteria for measuring team effectiveness, i.e. performance and viability, it has been possible to link the characteristics of effective cross-functional inter-organisational teams and their contribution to best partnering practice.

Although Sundstrom et al. (ibid) emphasises internal dynamics in assessing team effectiveness, some may argue that an essential element in building effective partnering teams is having organisational support (Hackman, 1990). This should probably be implicit, but the effectiveness of the team can seemingly be negatively affected by the lack of the right type of organisational commitment.
Parker (1994) identified barriers to successful cross-functional teams, among these were bewilderment about team authority, complexity of the leadership role, uncertainty about team goals and objectives, upsetting inter-personal dynamics and unwieldy team size to name a few. This can debatably be linked to Tuckman and Jensen's (1977)

model of group development (see below) and used to locate where partnering teams are in their life cycle.

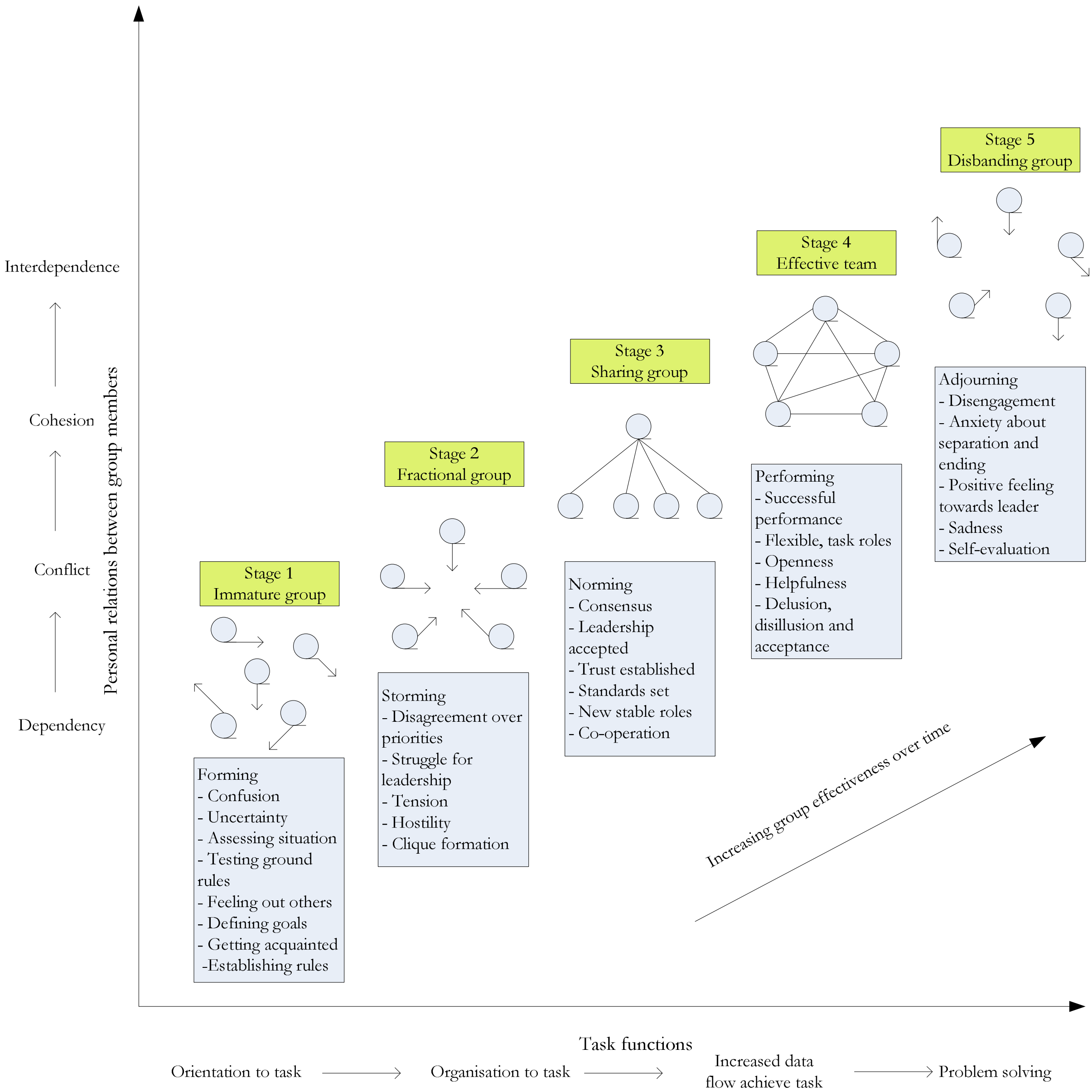

Figure 2.1 Tuckman & Jensen (1977) Group development. Adopted from Huczynski and Buchanan, 2001, p298)

Team stability in terms of keeping the same members for the length of the coalition is suggested by some authors (Adobor, 2004) to affect inter-organisational team performance. He proclaims that there is an optimum level of how long this period should be before the team may become retrogressive. This though, as he partially recognises, may be difficult to obtain in practice as partnering agreements often run for a long period of time, often three to five years and even longer (Burnes & Dale, 1998), and turnover of staff during these periods is seemingly inevitable. However, he continues to claim that members should stay together for a sensible length of time for cohesion to build as he points to research arguing that some organisations tend to neglect this and often make unscheduled and premature changes to a team (Harrigan, 1988; Pucik, 1988).

Team size is seemingly also an important factor since it is argued to be the best differentiator between a group and a team (Mullins, 2002) (see Tuckman & Jensen's model above). This is likely to affect the effectiveness of the teams as the number of interactions between members increases as team size increases and above a certain size a balanced pattern of interactions is hard to achieve, leading to subgroups within the team being formed [(i).] Managing such teams is difficult since it becomes harder to maintain the focus of all subgroups to the overall objective. With a smaller team, however, it logically becomes easier to uphold the overall aim of the team (Wickham, 1999).

Another noticeable and noteworthy difference between groups and teams can be seen in writers view on leadership within them. There seem to be a common understanding between scholars (Katzenbach & Smith, 1993; Belbin, 2000) that groups are subject to a strong a clear leader, while teams have shared or rotating leadership roles. Compared to an internal organisational team with arguably a superior culture prevailing, the partnering team environment is a much more fragile gathering consisting of diverse cultures as well as the fear of mistrust within them as described above. With one of the main characteristics of and milestones in partnering agreements being a collaborative atmosphere (Turner & Simister, 2000), it may follow that that effective partnering teams would not benefit from being influenced by a strong dominant leader. In practice, though, the setting seems in many cases not to be a question of who has formally been given the leadership role in the partnering teams, but who has seemingly the most power within them (Lamming, 1996). Research has shown that powerful clients often drive partnering arrangements with an iron fist to get what they want from their suppliers (Dobson, 2003), explicitly suggesting one-way exploitation of the other parties without considering their wants and/or wishes in any fashion. It may therefore be argued that this setting in reality illustrates the opposite of what the partnering philosophy stands for, i.e. trust-worthy developing inter-organisational collaboration for mutual benefits.

A significant factor emerging from the Hawthorne studies was that less supervision reduced stress and increased productivity (Huczynski & Buchanan, 2001). The level of empowerment is an issue also argued to affect the effectiveness of cross-functional inter-organisational teams (Elmuti, 1997). With reference to the partnering environment, Hellard (1995) suggests that empowerment is an essential feature within it and that team members should be encouraged to be venturesome and innovative. Ross (1998) supports this by arguing that it is necessary for teams to have 'the freedom to develop improvement initiatives without the typical noise of management politics and the worthless exercise of management authoritarianism', clearly leaving the impression that a team being monitored by their management will be restrained.

Having structured processes for decision-making and selection of improvement initiatives, such as SMART value management by Green (1992), are also areas which are considered to be of importance to the effectiveness of partnering teams. This is because they promote teamwork, but also because it may help to ensure that the partnering philosophy is communicated and adhered to. Selecting the wrong improvement initiative may have catastrophic consequences for the organisation(s) carrying out the work, and may realistically put the whole partnering agreement at risk. The importance of having a trained facilitator in this process is seemingly vital. This is to ensure that the techniques and methods are followed and equally important appreciated by the team members to be able to land on the most valuable and suitable improvement initiative for all parties in the team. It is arguable that it is in this process that cross-functional inter-organisational team theory comes into play to create a flourishingly creative, innovative and effective partnering environment.

Another issue surfacing from the literature that may affect the effectiveness of the partnering teams is the impact organisational culture may impinge on its dynamics. In fact, the presence of cultural differences has been identified in research as a main weakness in partnering agreements leading to fragmentation of the partnering team (Sarshar & Amartunga, 2004). This has lead to writers suggesting that organisational culture has become one of the greatest challenges in the project environment (Turner, 2003), and indeed in the partnering environment (Sommerville, 1997; Cox & Townsend, 1998). The reason for organisational culture having such an impact on partnering teams is because team members are bringing different values and ways of working to the team which may lead to a cultural clash between them. As certain writers (Cox & Townsend, 1998) have indicated, team members often believe that other cultures within the team are the reason for bringing the partnering agreement to a halt and not the culture within the partnering team as a whole. Partnering teams need to overcome these cultural barriers, meaning that team members have to fully commit to the culture of the team long term, i.e. leaving the culture of parent organisations behind (Schultzel & Unruh, 1996).

3. RESEARCH METHODOLOGY

The research project lends itself to the positivistic philosophy in the way that it has taken extensive use of the existing literature to build a theoretical framework and to find the gap which has become the main focus of the study (Remenyi et al, 1998). This has in turn been used to investigate the utilisation of cross-functional inter-organisational team theory in partnering teams.

The scope of this particular research project has prevented the researcher from studying partnering teams over time through observation and triangulation, debatably sought-after options to increase the validity of the findings and with regards to generalisation.

The researcher took advantage of a deductive approach to collect the primary data by distributing a questionnaire. The method can be described as a fast and time efficient way to gather data from a large sample, but which also hold the characteristics of '*eliciting reliable responses...with the aim of finding out what a selected group of participants do, think or feel'* (Hussey & Hussey, 1997, p161).

In order to get substantial and applicable feedback on the issues portrayed in the literature review, it was decided to contact several organisations from different sectors. By obtaining data from a range of sectors it would be possible to avoid regularities which presumably occur in homogeneous settings. The type of information needed from practitioners indicated that the preferred samples would be organisations utilising partnering agreements as well as, probably even more important, professionals with extensive knowledge of and involvement with them. Selecting a sample has indeed been recognised by writers as being a fundamental element of a positivistic study (Hussey & Hussey, 1997). The problem is however that it is difficult to determine the propagation of partnering, mainly because of its unsettled terminology and the fact that it arguably means 'many things to many people' (McGeorge & Palmer, 1997, p1988). With assistance from the Centre for Project Management at Leeds Metropolitan University, 33 appropriate research objects were identified.

The questionnaire was pilot tested with regards to its suitability and validity to meet the research aim and objectives, i.e. to secure that the standard was satisfactory before distribution. This process was carried out by referring to checklists prepared by Hussey and Hussey (1997), Bell (1999) and Saunders, Lewis and Thornhill (2000).

With regards to research ethics, the researcher strongly emphasised the interviewees' anonymity in the covering letter and assured that all information perceived by the informants as sensitive would remain confidential.

A process for the analysis was also proposed and focused mainly on how the coding of the questionnaire lays the foundation for the data matrix and the subsequent analysis. A working outline of how the findings would be treated in the analytical component of the study was also developed.The research project has from its beginning been influenced by explicit limitations. The following will therefore try to briefly emphasise some of these and comment on their immediate effects.

- The scope of this study was limited and had a direct effect on the breadth and depth of the research area.
- There are limitations by using a single research strategy instead of combining approaches (e.g. questionnaires and interviews). This would have enabled triangulation and increased the reliability and validity of the findings and the subsequent conclusions.
- The issue of generalisation is only commented on with respect to practitioners in the geographical research area and the limited sample size, mainly because of the unique setting the research was conducted in. A wider scope of the results is not applicable, unless similar results are found in comparable research.

4. PRIMARY RESEARCH FINDINGS AND ANALYSIS

This section will present the most salient findings emerging from the primary data collection method and analyse these in conjunction with issues identified in the secondary research to demonstrate their relationship with the aim and objectives of the study.

4.1 Overview of Primary Sources

As previously mentioned, 33 research objects were identified and of them 20 agreed to participate and returned the questionnaire, giving a response rate of 67%; a relatively high figure according to the experience of certain writers (Saunders, Lewis & Thornhill, 2000).

The organisations represented in this study were based in the private (55%) and public (45%) domain with the number of employees reaching over 600 in most cases, independent of nature. The type of operation carried out was mainly service related (95%) and in seven different industrial sectors with the majority within construction

(35%). The number of organisations within one partnering agreement varied significantly ranging from 2 to 24, but there was a tendency to have fewer than 6 partners (40%).

The nature of the agreements was further collected, and 15 of the 20 respondents reported that their partnering agreement was inter-organisational within the UK. The researcher also wanted to determine the proposed length of the contracts as well as at what point they were currently at since this may have an impact on the dynamics of the partnering teams The partnering agreements represented in this study were mainly between 1-3 (45%) and 4-5 years (35%).

4.2 What does the Term 'Partnering' mean to Practitioners?

Writers have argued that partnering *'means many things to many people'* (McGeorge & Palmer, 1997, p188). The findings, though, revealed that there were noteworthy similarities in the way the practitioners articulated their understanding of the term. Emphasis on and wording such as collaboration, equal contribution and working together, as well as common goals, agreement of joint project objectives in addition to trust, openness and sharing were prevailing. The fact that the majority of the practitioners strongly pointed to teamwork as being central to the philosophy, firstly discounts the above argument. Secondly, it may be suggested that cross-functional inter-organisational team building and sustainability should be one of the driving forces within partnering agreements if they were to exercise their theoretical 'best practice' understanding in practice.

4.3 Partnering Teams & Cross-Functional Inter-Organisational Team Theory

Organisational support has been considered to be an important element in building effective teams (Hackman, 1990). Given that the majority of the practitioners felt they had organisational backing it may be concluded that this aspect of theory has been utilised by the sampled population. This may as a result reduce the likelihood of unclear goals and objectives surfacing which have been identified in the literature as retrogressive factors in progressing into effective teams. Therefore, it may be suggested that this effort will affect the effectiveness of the partnering teams in this study positively[(ii).]

Although the better part of the practitioners signalled that they had agreed upon mutual goals and objectives, their clarity was considered to be moderate. This may question the level of organisational support as described above, but it may also be that other team theory factors, such as a process for decision making or team size, which combined, may inhibit the generation of goals and objectives, have yet not been fully satisfied. The researcher therefore concludes that this aspect of theory has not been successfully utilised by the organisations, and may as certain writers (Shea, 1986; Parker, 1994) have suggested, leave their teams in bewilderment about their purpose and hence also affect their effectiveness.

As writers (Mullins, 2002) have argued that the best differentiator between a group and a team is its size, it followed that the researcher saw it as necessary to investigate this aspect with the practitioners. Although acknowledged authors such as Belbin (2000) have propagated that a team should consist of no more than 4-6 members, the majority of the sample had eight or more people within their partnering teams. In fact, no more than four of the teams (20% of the sample) had six or fewer members within them. This may affect their effectiveness as the number of interactions between the members grows in parallel with the team size and the influence of culture, personality, position and social, academic as well as professional background becomes stronger and may affect the dynamics within them. This may also as a consequence complicate and inhibit the partnering team environment with regards to decision-making and innovativeness. Based on this differentiator between a group and a team alone, it may be concluded that the majority of the partnering teams in this study are not teams, but working groups, i.e. the organisations have not taken advantage of this facet of theory which subsequently may impinge on the effectiveness of their partnering teams.

It is seemingly accepted in the literature that teams need sufficient time to develop into cohesive units (Hayes, 1997; Huczynski & Buchanan, 1999). This indicates that team stability in terms of keeping the same members within a team becomes an important aspect to consider, as it will affect their performance (Adobor, 2004). The primary research, however, revealed that all but one, of the surveyed partnering teams did not consider their team size to be fixed. This indicates that the organisations are making changes to their teams which might be considered as premature and impulsive, an argument descending from Harrigan's (1988) and Pucik's (1988) research. This evidently means that their teams are not given the chance to become cohesive and consistent entities. By not keeping the sizes of the teams relatively stable, it rationally follows that the numbers of people who feel a sense of ownership to the teams will also grow, indirectly making the team sizes even larger than reported above. This may fortify the potential problems described in the previous paragraph. For these reasons, it may be concluded that the organisations in this study have not successfully utilised this part of theory and as a consequence may affect the effectiveness of their partnering teams.

The aspect of power and leadership has attracted a lot of attention in partnering since there has been a tendency for strong clients to use their power over other members within the arrangements to realise their own objectives (Dobson, 2003), arguably creating a traditional adversarial environment. This inclination seems to continue in the partnering teams studied in this research project. The results suggest that the client is the dominating entity within the teams. This may be illustrated by the fact that in the eleven teams where the client sat as chairperson, eight of them did not have any guidelines which secured the interest of all parties in the team. This indicates that the members within the teams (including the client) are not aware of/haven't thought about such a remedy or that the client drives the teams with an iron fist exploiting the other partners by ignoring their interests. Interestingly, none of the partnering teams had taken advantage of a neutral facilitator which could have contributed to secure the integrity within the teams and in the building of trust between the team members. The characteristics within the partnering teams has led the researcher to suggest that the sampled population in this research project have not utilised the aspects of shared leadership which has been argued to be a fundamental feature of effective teams (Katzenbach & Smith, 1993; Belbin, 2000).

Empowerment has been described in the partnering literature as being an imperative, facilitating greater creativity and productivity (Hellard, 1995). The results from the primary research suggest that the lion's share of the partnering team members felt a moderate or high level of empowerment. The analysis, however, suggests that the partnering organisations are only partially utilising this aspect of theory. The levels of control the parent organisations are imposing on the partnering teams are seemingly greater than first anticipated, due to the fact that their team members do not feel they can be venturesome and take risks. This is an important element to the effectiveness of a partnering team as their task is to come up with innovative ways of working, in other words thinking and doing things differently from others, i.e. taking risks. When reflecting on the possible reasons for not fulfilling this aspect of theory entirely, it may be argued that the lack of empowerment is a consequence of a series of factors. The seemingly moderate clarity and understanding of goals and objectives within the teams indicates that the parent organisations are not completely clear about what they want from the partnering agreements. This arguably, maybe unconsciously, leads them to exercise a certain level of control over the partnering teams due to the fear of them, if empowered, heading off in a direction which the parent organisations do not consider as a beneficial (which might be possible as they have no obvious directions), i.e. they are controlling and not empowering their teams because the blurred goals of the teams give rise to a fear of not going in the right strategic direction. This consequently indicates an immaturity among the parent organisations with regards to partnering as they are not providing strategic directives nor allowing their partnering teams to realise their maximum potential. It may also be that the personal rewards from working in the teams, such as motivation and social satisfaction, will be affected by this type of control, issues suggested to be important to human needs (Maslow, 1943). The researcher therefore suggests that empowerment has not been successfully utilised in the partnering teams, which may as a result impede on their effectiveness.

Given that empowerment is being emphasised in the literature as essential in partnering agreements, the need for guidelines for decision making and formal processes for selecting improvement initiatives seem necessary to lessen the likelihood of powerful members being overly influential as well as securing that the right decisions are made and improvement initiatives taken. The fact that the majority of the respondents did not have any guidelines in place when it came to decision-making indicates that this process is either difficult or very simple in the partnering teams. Difficult, because the large team sizes complicates the environment with regards to interactions and diversity in opinions; simple due to power issues where the clients dominate and control the partnering teams leaving the other members without a choice but to follow their lead. The results also revealed that half of the organisations did not take advantage of a formal process for selecting improvement initiatives. This might be seen as disquieting, especially since the literature suggests it makes the decision making process explicit and rational which in turn increases the chances of implementing a successful and valuable improvement initiative (Green, 1992). Yet again, this may be a result of immaturity and/or internal power, but the significance of such a remedy can arguably be illustrated in the fact that seven of the organisations which used a process for this had all delivered improvement initiatives, while seven that did not had delivered none. It therefore seems reasonable to suggest that these facets of theory have not been fully utilised, and hence may impact on the effectiveness of the partnering teams in this study.

Certain writers (Sommerville, 1997; Cox & Townsend, 1998) have argued that cultural barriers are the principal threat to partnering. This was somewhat confirmed by the practitioners as the majority reported that it had caused major difficulties within the partnering teams. As a result, it seems rational to suggest that this will affect their ability to effectively carry out their work and that the organisations have not been able to generate a common partnering team culture. Although the above writers pinpoint a significant problem within partnering, it may be argued that this notion is too simplistic and is rather scratching the surface of a problem which has deeper roots and have received little attention so far in the partnering sphere, i.e. the organisations' inability to utilise and sustain cross-functional inter-organisational teams and their receptivity and maturity in the post-industrial marketplace. This can be explained by referring back to the introduction to the study where the post-industrial marketplace was characterised by the extensive use of teams in the delivery of organisational strategy. The level of maturity organisations show in utilising and working with teams as well as other organisations will arguably be reflected in their organisational cultures. This may subsequently influence their employees' and their ability and willingness to focus on the internal partnering team culture, and not on other organisations' values, beliefs and assumptions which seem to be the case today (Sommerville, 1997; Cox & Townsend, 1998). Consequently, it may be argued that the most prevailing barrier to partnering is not only cultural differences, but also the individual organisation's inability to respond to the changes and requirements that may be emerging in their environment.

5. CONCLUDING COMMENTS & RECOMMENDATIONS

This research project has investigated the utilisation of cross-functional inter-organisational team theory in partnering teams and the potential impact this may have on their effectiveness. However, when investigating how organisations in this study have utilised such factors a disquieting picture emerges.

5.1 Conclusions

In summary, it may be concluded that cross-functional inter-organisational team theory is not being fully utilised in the partnering teams in this study and that their effectiveness may be inhibited as a result of this. Based solely on the findings, it may also be suggested that they as a collection of units cannot be theoretically characterised as effective teams, but rather as fractional and partially sharing groups[iii] ; if using Tuckman & Jensen's (1977) terminology. In addition, their characteristics also question if they can be labelled as true partnering teams, especially if seen in comparison with the proposed definition of the term.

The results illustrate a significant variance in what both academics and practitioners emphasise when articulating their understanding of the partnering philosophy and what is evidently carried out in practice. The omission of the utilisation of team theory and therefore the maximising of the potential of the partnering teams might be seen as alarming and may question why the organisations are not utilising inter-organisational cross-functional team theory, i.e. what is preventing them from doing so? The response to this may be linked with the organisations fundamental views of doing business.

It might be argued that much of what have been illustrated in this paper is the result of classical[iv] organisations' endeavours to utilise a post-industrial philosophy which requires ingrained work methods the organisations are not primarily designed to bring about. This suggests that conventional work methods and structures are put into practice in an environment which they are not suited for, meaning that they will prevent the organisations from realising cross-functional inter-organisational team facets which may contribute to the exploitation of the full potential of their partnering teams and hence also their partnering agreements. The following tries to demonstrate this point.

- The issue of client power within the partnering teams exemplifies that traditional adversarial customs are prevailing and that members representing other tiers in the supply chains are not being recognised as adequate contributors to the teams.
- The relatively high level of control of the partnering teams prevents empowerment and illustrates a lack of trust in their employees.
- The team instability shown in the partnering teams may indicate that there is limited appreciation of the fragile partnering team environment and a belief that inter-organisational relationships can be treated impulsively without affecting their dynamics.
- The relatively high team sizes may well exist because of an ignorance of theory, but it may also be that there exists a majority issue where the belief is that plurality within the partnering team will provide benefits to the parent organization [v]; arguably an adversarial approach.

The above seemingly illustrates that traditional characteristics are apparent in the partnering teams in this study. On the basis of this and founded on the non-utilisation of factors which would improve cross-functional inter-organisational team performance, it might therefore be further concluded that there exists a certain level of partnering immaturity among the organisations. In addition and as a rational extension to the above, it may also be suggested that the organisations do not hold the imperative characteristics which typify successful participants in the post-industrial marketplace.

5.2 Recommendations

This section will principally argue that it is important for the organisations to successfully address the cross-functional inter-organisational team theory aspects studied in this project to amplify the chances of increasing the effectiveness of their partnering teams and consequently also their partnering agreements.

There was, however, one particular aspect not any of the practitioners had utilised in their partnering teams which academia (Poirer & Houser, 1993; Turner & Simister, 2000) sees as an essential element in cross-functional inter-organisational teams and thus it seems rational to emphasise in this section, that is the use of a neutral facilitator. Such a remedy may contribute to suppress some of the power issues revealed in this study and help to maintain the commitment, perspective, enthusiasm and integrity of the partnering teams. In addition, their expertise may also be beneficial in terms of managing the cultural differences which were reported to cause major difficulties within the teams, and hence may be instigating an internal partnering team culture.

Although the above might contribute to improve the dynamics within the partnering teams and align them better with the norms of the partnering philosophy short term, it may be suggested that they should also, perhaps more importantly, reflect on and evaluate in depth *why* they are not utilising team theory in their partnering teams to begin with. Reasons for this have already been briefly suggested in preceding paragraphs, but an investigation into this area within the different organisations will arguably give indications about what factors are preventing them from doing so. To unveil these issues and unlock their underlying complexity it might be favourable to take advantage of strategic learning techniques, such as cognitive mapping. This may contribute to identify several causes in which actions can be designed and subsequently used or assist in breaking the underlying barriers that arguably prevents them from utilising partnering in its true form. This will probably also affect their organisational culture which may consequently transfer to their employees' values, beliefs and assumptions about working in inter-organisational cross-functional teams(vi) .

5.4 End Notes

The results from this study have illustrated that organisations are not fully utilising cross-functional inter-organisational team theory in their partnering teams. This may be seen as surprising as the majority of the organisations taking part in the research, clearly emphasised teamwork when articulating their understanding of the partnering philosophy. By not making the most out of team theory facets which are considered in academia to be essential in team building and may affect the effectiveness of their partnering teams, it seems hard to understand how the potential of their partnering teams and hence also their partnering agreements can be maximised.

One of the most fundamental characteristics of partnering teams is their ability to find other ways of doing things; in other words being innovative which is an imperative under post-industrial market conditions. However, the results from the study suggests that this aspect may not be entirely fulfilled within the partnering teams as certain team theory factors such as organisational control and the influence of client power may affect the internal dynamics and the sought after synergy effects. This may indicate that traditional adversarial methods of working are current and acting as underlying embedded barriers to effective partnering teams as well as partnering performance. In other words, it may be argued that the results are a reflection of traditional attempts to exploit a post-industrial philosophy which is based on ways of working which the former is arguably not designed for nor can successfully produce without changing, i.e. partnering is beyond classicalism. As certain writers (Burnes & Dale, 1998, p71) put forward *'partnering is a way of doing business through teamwork'*, and this may only be achieved in its truest form if the organisations are designed for the post-industrial marketplace and are behaving in a way which naturally facilitates cross-functional inter-organisational teamwork.

Footnote:

i. Writers (Belbin, 2000; Mullins, 2002) propose that the ideal team size consists of four to six people.
ii. However, this behaviour will later be contested.
iii. The researcher recognises that such a statement is subject to strict limitations and has limited validity.
iv. Classical refers to organisations typified by their rigid, hierarchical structure where control and supervision are central elements. Much of this arguably relates back to the industrial age and up to the 1970's (Huczynski & Buchanan, 1999).
v. The researcher recognises that such a statement is subject to limitations, as the questionnaire does not provide significant in-depth knowledge into the specific organisations.

vi. The researcher stresses the importance of the prevailing limitations and the amount of care which should be taken in either using or interpreting the results with regards to their validity and generality.

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IMPACT OF SITE PLANS ON PRODUCTIVITY IN PUBLIC SECTOR BUILDING CONSTRUCTION PROJECTS IN SRI LANKA

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Abstract: Improved productivity in the construction industry can have an important role in improving national competitiveness and achieving a satisfactory growth rate in developing counties. The construction site plan is a focal factor that strongly influences construction productivity.

This research aims, to investigate how productivity could be improved in the Sri Lankan public sector building construction industry through effective and efficient site plans. The main objective of this research is to develop an empirically grounded framework for understanding the relationship between site plans and site productivity in the Sri Lankan construction industry.

This research contributes to a greater understanding of productivity, particularly in respect of site plan, in the Sri Lankan construction industry. It develops a coherent framework for analysis that may be applied to similar studies in other developing countries, particularly in the Asian sub-region. In addition to the empirical evidence generated, this study will be of benefit to Sri Lankan policy makers in respect of facilitating a more effective and efficient construction industry, contractors and clients.

Key words*:* Site Productivity, Site Plan, Construction Industry, Sri Lanka, Framework

1. INTRODUCTION

Many official reports have highlighted the difficulties associated with the construction industry. The Emerson Report (1992) and Abdul - Kadira and Price (1995) have suggested that one of the numerous difficulties is the alarmingly rapid decline in the growth of productivity. Kellogg *et al* (1981), noted that construction productivity has grown at the minuscule rate of less than 0.1% per year; and the situation has become worse since 1993. Ireland (1990) also states that current statistics show that productivity in construction has declined over the last decade relative to other industries. Given the impact of the construction industry on national GDP, this historical trend is of some concern. This research study is about construction site productivity special reference to site plan.

2. SRI LANKAN CONSTRUCTION INDUSTRY

The construction industry of Sri Lanka has a long history of which the country can be justly proud. Unfortunately, the achievements of the past are only evident in the ruins of cities, irrigation structures and other religious edifices. Notwithstanding these past achievements, Ganesan (1992) describes how many factors have combined to limit the capacity of the Sri Lankan construction industry to execute major projects. For instance, there has been a prolonged absence of a consistent policy framework that allows for the advanced planning of construction resources. The institutional capability of the Sri Lankan industry is seriously lacking in this respect. The weakness is evident especially with regard to private contractors and the traditional building materials industry. Furthermore, government economic planning has seldom examined in detail the implications of development plans for the construction sector.

Every major political change has introduced a new set of policies substantially different from the earlier ones. Furthermore, traditional economic thinking failed to recognise construction as a key sector in development. Ill-conceived state policies have too often been aimed at short-term gains, serving only to blur the long-term vision for the development of the national construction industry. However, the new economic strategies developed after 1977 consistently promoted the construction industry as a lead sector in the quest for development. The government's ambitious investment projects gave work to a large number of domestic contractors. This provided an unprecedented opportunity to upgrade the structure and technology of both large and small firms, and also to strengthen their capabilities.

In the early 1980s the Sri Lankan Government, with World Bank assistance, created the Construction Industry Training Project (CITP). The declared objective was to train personnel to 'minimum employable levels' to overcome the acute shortage of manpower which then prevailed in the construction industry. The World Bank credit loan also required the CITP to identify deficiencies that stood in the way of an efficient construction industry. Another important covenant in the first credit loan was the creation of a strong Association of construction contractors. The second World Bank loan in 1986 provided for a wider scope of activities which was deemed necessary for the development of the industry. The CITP was therefore converted to the Institute for Construction Training and Development (ICTAD) which was provided with a much broader mandate. Both CITP and ICTAD performed to a high degree of acceptance. The credibility of ICTAD is currently so high that it effectively serves as a 'think tank' to advise the government and implement state decisions on all matters related to the construction industry.

The government of Sri Lanka has declared the years from 1997 to 2006 as the National Productivity decade. It was identified that two major caused of low productivity are the lack of understanding of the concept of productivity and the inadequacy of knowledge of the many techniques available for improving organisational and personal productivity. Therefore the first five years of the productivity decade was allocated for creating awareness of the concepts and techniques of productivity which will serve as the foundation for a major productivity drive. The Ministry of Industrial Development is scheduled to implement the tasks of the productivity decade. The productivity concept in the construction industry is directly coupled with the quality and economy. Presently, training and awareness programmers are used for productivity improvements in the industry along with the publicity programs on positive thinking, towards the development process (Sri Lankan-Country report, 2004)

3. STATEMENT OF THE PROBLEM AND SIGNIFICANCE OF THE STUDY

The construction industry (CI) is one of the world's most important industries (Mawdesley *et al,* 1996). The crucial importance of the construction industry to a sustained development effort in a developing country cannot be overemphasised. Although construction is not an end in itself, it is the means for the achievement of the desired end, which is the development of new production capacity in the economy. However, in developing countries, productivity in construction has remained at a relatively low level compared to other major industries (Zakeri *et al*, 1996). Therefore the effect of productivity on a nation's economy is highly significant. Improved productivity in the construction industry can have an important role in promoting national competitiveness and a satisfactory growth rate. The importance of productivity to any society cannot be over emphasised because it is a valuable measure of how well resources are used in society. There are countless ways to define construction productivity (Olomolaiye *et al,* 1998; Pinder, 1984). Researchers have defined productivity differently. The lack of consensus among researchers makes it difficult to evaluate which definition is most appropriate for everyday management. This is considered necessary as a prelude to understanding the link between productivity and the construction site plan. Productivity at its simplest is a ratio that compares units of output with units of input, often against predetermined standards (Newstrom and Davis, 1997). There is still controversy surrounding the definitions and measurements of productivity.

The Sri Lanka State Engineering Corporation, Sri Lanka Building Department, Sri Lanka Port Authority and Sri Lanka Labour Department have experienced that most of their projects are affected by low productivity (Perera, 1999; Rajasiri, 1999). Most projects have also suffered from serious setbacks and even termination of contracts: productivity is believed to be low compared to other developing countries and to the Asian sub-continent in particular (Jayawardane, 1994). The construction site plan (SP) is one focal factor that strongly influences construction productivity (Demir, 1996; James and Lagro, 2001; Jayawardane, 1992; Olomolaiye, 1990). Ineffective SPs are responsible for increasing wastage of construction material, equipment manpower and time; there is also a relationship between SP, working environment, site interaction and labour and material productivity (James and Lagro, 2001; Jayawardane, 1992 and 1994). Therefore it can be argued that one of the key factors contributing to such low productivity in Sri Lanka is that of inefficient SP. In the ancient and colonial eras, the Sri Lankan CI was well established (Mahavamsa, 1950; Paranawithana, 1946), although there is no evidence of the methods they used to manage construction sites. On the other hand, in Sri Lanka Western management approaches have been employed in CI over the past few decades, without an assessment of the appropriateness of such approaches (Jayawardane, 1992). This has raised some crucial problems.

Objectives

i. To review the theoretical basis of existing concepts relating to construction site productivity.
ii. To ascertain, to what extent employers in the construction industry (CI) in Sri Lanka are aware of the supposed advantages of effective site plan (SP).

iii. To identify the perceived productivity benefits realised through the implementation of the above SP practices
iv. To ascertain if there are significant differences between site plans amongst developed countries and Sri Lanka.
v. To develop an empirically grounded framework for understanding the perceived relationship between site plan and site productivity of the Sri Lankan CI.

To achieve the above objectives the research propositions are as follows:

1) The employers in Sri Lanka are aware of the supposed advantages of efficient SP in CI
2) Construction SP in Sri Lanka is different to SP in developed countries
3) Effective and efficient SP in Sri Lankan CI would contribute to improve their productivity.

4. RESEARCH SAMPLE

The research will be carried out within the context of construction projects commissioned by the Sri Lankan public sector construction industry. The public sector in Sri Lanka is involved in a wide range of construction projects of different types and spread all over the country. Out of the several construction sites commissioned by the Sri Lankan public sector construction industry, 15 construction sites representing the general construction practice in Sri Lanka employing 60 site agents will be initially selected. Accordingly one project manager, one site engineer one architect and one foreman will be randomly selected from each of the 15 sites, totalling 60 site agents.

The 15 construction sites will be selected in the following manner:

Sri Lanka is divided into nine provinces. They are: Northern, Eastern, Southern, Western, Sabaragamuwa, Uva, Central, North Western and North Central provinces. Due to terrorist attacks and for security reasons, the researcher will not reach the Northern and Eastern provinces of the country. Therefore, from seven provinces, three construction sites from Western province and two construction sites from each remaining province (i.e. 12 construction sites from the remaining six provinces) will be selected utilising a purposeful selection caring based on the largest building projects in each province. Why large scale building projects?: starting with a large-scale building project will aid a comparative analysis of similar cases (Most of the factors which focus on this research (e.g. rest rooms) do not exist in small scale public sector building sites in Sri Lanka). Furthermore the provinces can be categorised as developed (i.e. Western, Southern and Central provinces) and remote (i.e. other provinces) (Rajasiri, 1999). Therefore in the ongoing research, the researcher intends to consider the following separately:

a. Overall
b. Intra region :(2a) Developed
    1. (2b) Remote
c. Inter region: Developed Vs Remote

Tsunami-affected areas will not be selected for this research because their construction projects are of a different style (involving non-government organisations rather than public sector organisations) and do not represent the true picture of Sri Lankan public sector construction projects. Most of these particular projects in tsunami-affected areas are very small scale maintenance projects and spread in only some coastal areas. The funding structure and the resources allocation of these projects are also independent and separate from the normal Sri Lankan building construction projects. Building projects which had already started before the tsunami disaster will be selected in this study. These had already-allocated resources and would not be affected by the tsunami reconstruction.

5. METHODOLOGY

Research data will be collected by means of a survey of site agents (e.g. site engineers) in Sri Lanka with particular emphasis on the public sector CI. Public sector is chosen as the focus of this research because most of the factors affecting construction productivity can be assumed to be constant within the public sector. This emanates from the fact that as direct labour organisations they employ their workforce on a long term basis and have standardised quality control procedures, training programmes, pay and work incentives and safety procedures across the country in comparison to the private sector. As such the researcher and respondents can more readily isolate the effect of SP on productivity given that it is more prone to variation due to topographic and project technical requirements. In addition the public Sector CI is the dominant sector of the industry in Sri Lanka undertaking most of the major building and infrastructure construction activity.

Data will be collected to investigate the characteristics of site plan factors (e.g. location of site office, stores, rest rooms etc), interpret the research objectives and to test the above propositions.

Pilot Study

Pilot Observations

Three different construction sites are selected for pilot observation. They are: a building construction project in Reading; Oxford; Basingstoke. The main purpose of these pilot observations is to test the pre-structured observation schedule and amend accordingly prior to the main observation sessions.

Pilot Interviews in UK

Krueger (1997 and 2000) advocates that the first and easiest strategy for testing questions is for researchers to try the questions on other researchers who are familiar with the programme or activity. It is best if the questions are not just read, but asked conversationally. The researcher will ask the question and the second researcher attempts to answer. With this exercise, several aspects can be tested simultaneously: the ease with which the questions can be asked and the nature of the answers.

Moreover, as the second step in the pilot interview sessions, the researcher will try the pre-structured interview guide on 12 selected construction site agents: one project manager, one site engineer, one architect and one foreman from each construction site. Those agents were selected from three different UK construction sites – the same sites where the pilot observation sessions will be conducted – and their comments on the following points noted. Do the questions seem awkward when asked orally? Do the words flow smoothly? Does it sound conversational? Is the emphasis placed on certain key words in the questions correct? Do the responses occur relatively quickly? Can questions be misinterpreted? Findings of this exercise also used when modifying the final interview guide (Fraenkel and Wallen, 1990; Robson, 1993). Furthermore this pilot study will help to add impact to conceptual and logical issues in the research.

Pilot Study in Sri Lanka

The interview guide will be administered during interview sessions to 60 respondents of the sample. It will be done thus: first, interviews will be held with 10 of the respondents, considering their attitudes and behaviour. The researcher's style and pattern of posing issues to the respondents will be slightly modified when holding interviews with the rest of the participants.

The Data-Gathering Techniques

Interviews (one-to-one)

Interview sessions will be the main research instrument in the study. 60 semi-structured interviews will be conducted and these will be fully tape recorded. This interview schedule will be pilot tested prior to the main research work. Most of the interviews will be conducted in Sinhala, which is the lingua franca of the Sri Lankan operatives.

Observation Sessions

15 observation sessions will be conducted in 15 construction sites within the public sector in Sri Lanka. A pre-structured observation schedule will be used for each observation session. This schedule will be also pilot tested. The findings of the observations will be triangulated with findings from the interview sessions.

Data Analysis

Qualitative data will be analysed by using special software packages for example: N6 (NUD*IST 6).

Data gathered from pilot study will be analysed prior to the analysis of the main survey data as a pilot data analysis. The results from the pilot data (except data from the pilot study in Sri Lanka) will be used both to design the field study and develop the conceptual framework.

6. CONTRIBUTION TO KNOWLEDGE

This research contributes to a greater understanding of productivity, particularly in respect of SP, in the Sri Lankan CI. It develops a coherent framework for analysis that may be applied to similar studies in other developing countries, particularly in the Asian sub-region. In addition to the empirical evidence generated, this study will be of benefit to Sri Lankan policy makers in respect of facilitating a more effective and efficient CI, contractors and clients. Most previous studies looked at productivity (Olomolaiye, 1988; Price, 1992; Smithers and Walker, 2000) by referring to factors such as employees' motivation. However, in Sri Lanka no one has conducted productivity studies with special reference to effective SP within the CI. This study will thus fill a gap and also develop new research ideas in the area of construction management.

7. SUMMARY

This paper reports ongoing research about Impact of Site Plans on Productivity in Public Sector Building Construction Projects in Sri Lanka. The currently popular productivity improvement techniques have been analysed and critiqued in terms of their underlying assumptions. Of particular note is the way in which such techniques are derived from the construction projects with effective and efficient site plan practices, rather than the traditional construction projects that tend to prevail in Sri Lanka.

The purpose of the research is to challenge the widely-held assumption that productivity improvement site plan practices remain meaningful when transferred to the context of a developing country like Sri Lanka. A methodology as been derived that is compatible with the interpretive paradigm. The research is based upon a mixed methodology which combines participant observation, semi-structured interviews, and documentary analysis.

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AXIALLY LOADED HELIFIX CONNECTORS IN TIMBER

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Abstract: This paper presents an experimental investigation on the withdrawal of a new connector type for use in structural timber. The structural performance of Helifix fasteners, which have been used as efficient wall ties and masonry repairs for a number of years, are investigated for use in a variety of timber connection systems. This paper details tests performed to investigate the withdrawal resistance and behaviour of Helifix fasteners in comparison to conventional nails. It also describes the effects of pilot hole diameter, timber density, depth of penetration and angle to the grain on the withdrawal resistance of the fasteners. The results show that Helifix fasteners achieve greater withdrawal resistance and exhibit a more ductile behaviour than common nails.

Keywords: Fasteners, semi-empirical model, timber connections, withdrawal resistance.

1. INTRODUCTION:

Timber structures are nowadays more popular than ever, due to the environmental and cost benefits of the use of timber in construction. Joints are the most critical components, as they govern the overall strength, of any timber structures (ASCE, 1996). As a result a considerable research has been carried out on connection behaviour, and different connectors have been developed in order to achieve stronger, stiffer, more reliable and durable joints.

Helifix connectors have been used since 1984 as efficient, economical, non-disruptive wall tie and masonry repairs (Keitley, 2003). Other uses include cladding, roof batten fixing, extending or securing a new leaf to an existing wall and crack stitching. Preliminary studies have shown that these connectors can provide a simple, highly efficient and reliable fixing system for use in structural timber as well as in masonry and concrete.

The objective of this study has been to develop an understanding of the withdrawal behaviour and performance of Helifix fasteners in timber. The research has aimed to determine the withdrawal resistance of these fasteners, to examine how they compare to conventional timber fasteners, to determine the factors influencing the withdrawal behaviour, and to develop numerical models for predicting the structural behaviour and performance of Helifix fasteners in direct withdrawal.

2. EXPERIMENTAL PROGRAM:

An experimental program was developed to investigate the performance of Helifix fasteners in direct withdrawal in timber and the factors influencing their behaviour. The testing was performed in accordance with BS EN 1382:1999 (BSI, 1999).

2.1 Test Set up

Four sizes of Helifix fasteners were tested: StarTie 10, StarTie 8, InSkew and TimTie with nominal shank diameters of 10mm, 8mm, 6mm and 4.50mm. Common 4.50mm diameter round wire nails and 3.00mm diameter helically threaded nails were also tested for comparison purposes.

The fasteners were tested perpendicular to the grain and in end grain. Following a series of preliminary tests perpendicular to the grain, it was found that the direction of the fibres, tangential or radial, did not influence the withdrawal strength and so was not taken into consideration. Pilot holes of 4.00mm, 3.50mm, 3.20mm, 3.00mm, 3.60mm and 2.40mm, for StarTie 10, StarTie 8, InSkew, TimTie, round wire nails, and threaded nails respectively were drilled vertically to have the fasteners at right angle to the samples. The timber samples were of class strength C24, with the following dimensions 200 × 80 × 45mm for tests perpendicular to the grain, and 200 × 45 × 100mm for tests in end grain. Due to the fact that Helifix fasteners do not have a head, and cannot be pulled directly by the travelling head of the machine, the fasteners were driven into two pieces of timber and were pulled apart (See Figure 1). This method also prevented the fastener to rotate and unscrew. The tests were performed at a loading rate of 2.0mm/min.

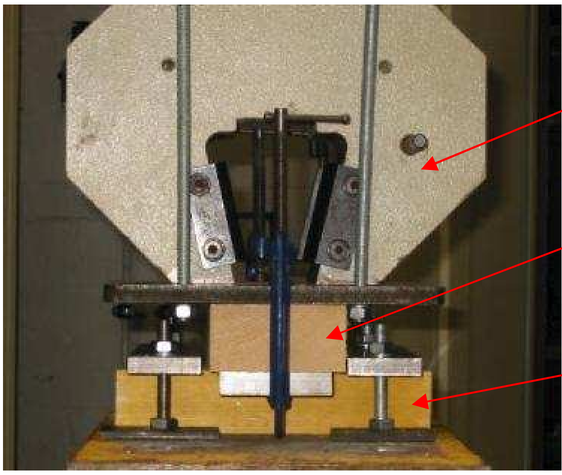

Figure 1: Withdrawal test set up for Helifix fasteners.

2.2 Further testing

The test details described above were used as the datum for further testing performed to investigate the factors influencing the withdrawal strength and behaviour of Helifix fasteners. The factors investigated were:
- Pilot hole diameter (See Table 1). Samples were first tested with no pilot holes, with a pilot hole of 2.00 mm, and then the dimensions of the pilot hole were chosen as function of the diameter of the fasteners: 0.8×core diameter, 0.8×effective diameter, 0.9-1.0×core diameter, and 0.8×average of core and overall diameters (for TimTie 0.8×overall diameter). The effective diameter was taken as defined in Eurocode 5 (CEN, 2003) for screws with no smooth shank, as 1.1×root thread diameter which is the core diameter. The maximum size of the pilot hole was taken as 0.8 times the average diameter, as it was assumed that from a certain size the withdrawal strength of Helifix fasteners will decrease as the diameter of the pilot hole increases. Preliminary tests

showed a decrease in the withdrawal strength values with pilot hole taken as 0.8×average diameter, compared to tests with pilot holes with smaller diameters. Using bigger drill bit sizes would mean that a smaller percentage of the fastener thread would be in contact, and inserted into the timber, resulting in low withdrawal values. A pilot hole smaller than 2mm was considered in order to have a wide range of drill size to describe as precisely as possible the relationship between the pilot hole diameter and the withdrawal strength. However, practically a 2mm drill is not viable due to its short length, and its slenderness, so it is assumed that smaller drill size will not be used with Helifix fasteners.

Table 1: Pilot holes for withdrawal tests perpendicular to the grain (in mm).

Pilot hole	StarTie 10	StarTie 8	InSkew	TimTie
0.00	0.00	0.00	0.00	0.00
2.00	2.00	2.00	2.00	2.00
$0.8 \times d_{core}$	3.40	3.00	2.70	2.40
$0.8 \times d_{ef.}$	3.80	3.20	3.00	2.70
d_{core}	4.00	3.50	3.20	3.00
$0.8 \times d_{av.}$	5.70	4.70	3.80	3.60

- Timber density. Three different classes of timber were considered: C16, C24 and a hardwood, Maple.
- Depth of penetration. Tests were performed on samples with the following thicknesses: 20mm, 30mm, and 60mm.
- Angle of penetration to the timber grain. Tests were performed with the fasteners inserted at 23°, 45° and 67° to the direction of the grain.

3. RESULTS AND DISCUSSION:

The withdrawal strength of a fastener is determined by the following equation given in BS EN 1382:1999 (BSI, 1999):

$$f = F_{\max} / d \cdot l_p \qquad \ldots(1)$$

With f = withdrawal strength (N/mm^2), F_{max} = Maximum withdrawal load (N), l_p = depth of penetration (mm), d = diameter of the fastener (mm).

3.1 Comparison to conventional nails

The results of the tests show that Helifix fasteners achieved greater maximum withdrawal load than the common nails, when inserted perpendicular to the grain and in end grain. Table 2 shows the maximum withdrawal loads attained with the fasteners and the corresponding withdrawal strengths calculated using Eq. (1). The results showed that Helifix had greater withdrawal strength than common round wire nails, however helically threaded nails achieved similar values. This can be explained by the fact that the nominal diameter of Helifix fastener was used in the equation, as BS EN 1382:1999 specifies to use the shank diameter of the profiled fasteners to determine their withdrawal strength. Table 2 also shows that end grain Helifix fasteners attained greater maximum withdrawal loads and withdrawal strength.

Table 2: Withdrawal tests results for Helifix and conventional nails.

Fastener type	Direction of the grain	Maximum withdrawal load, N	Withdrawal strength, N/mm^2
Round 4.5mm	perpendicular	782.45	3.90
Threaded 3.0mm	perpendicular	831.93	6.22
TimTie	perpendicular	1632.23	8.19
InSkew	perpendicular	1799.24	6.72
StarTie 8	perpendicular	2241.48	6.33
StarTie 10	perpendicular	3169.60	7.13
Threaded 3.0mm	parallel	482.18	2.78
TimTie	parallel	778.47	3.46
InSkew	parallel	1102.98	3.68
StarTie 8	parallel	1701.34	4.24
StarTie 10	parallel	2292.95	4.59

The mode of failure of Helifix fasteners tested perpendicular to the grain was a flattening of the helixes (See Figure 2). Pulling apart the two pieces of timber applied a torsion force on the fasteners, causing their unwinding.

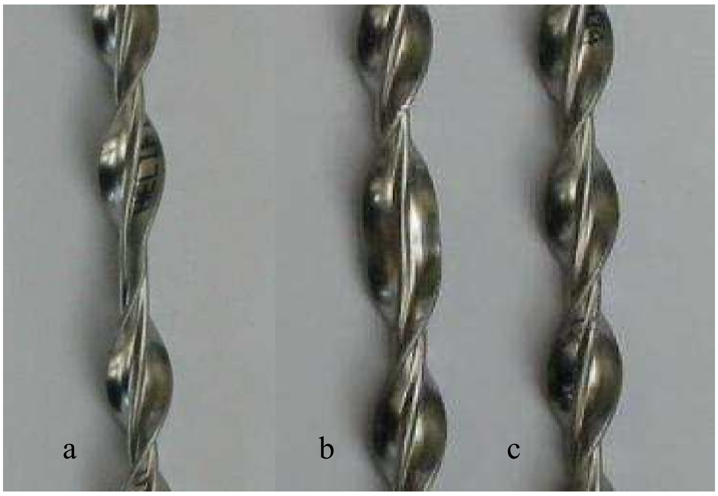

Figure 2: Fasteners: a) and b) after withdrawal tests perpendicular to the grain, c) fastener before test.

In end grain the fasteners were not unwinding but the timber fibres caught in the helixes were sheared off as the fasteners were pulled out of the samples (See Figure 3); indicating that the quality of the timber (density and microfibril structure) may be the major factor affecting the withdrawal of Helifix fasteners in end grain.

Nailed and Helifix fastened joints exhibited different load-displacement characteristics when subjected to withdrawal tests. For the nails there was an exponential increase in the load until failure occurs. However Helifix fasteners exhibited clearly different load-displacement characteristics, with a sharp increase in load until yielding of the fastener. This was followed by a much less steep but steady increase in load with respect to increase in deformation, which lead to unwinding of the Helifix threads until failure occurred. Helifix fasteners exhibited a more ductile behaviour than nails, the decrease of the load with respect to the increase of the deformation was slow and steady until most of the fastener had been pulled out of the timber.

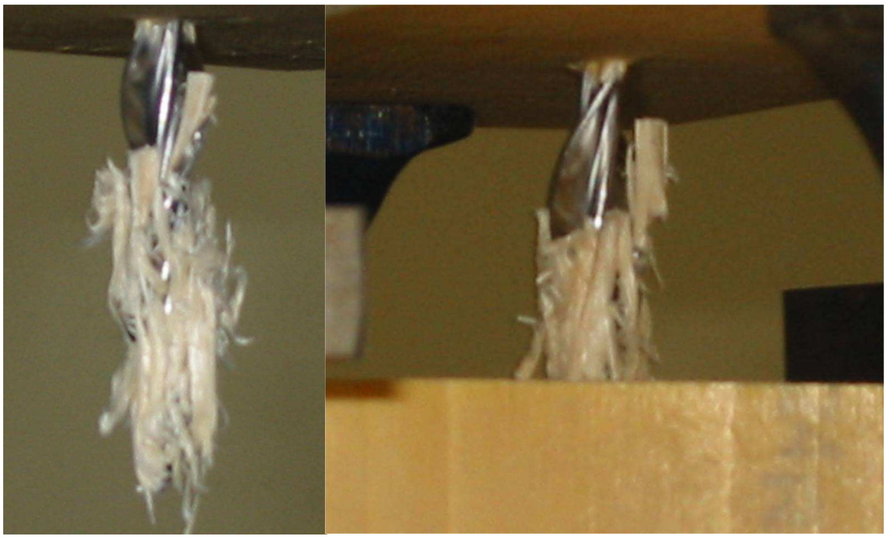

Figure 3: Withdrawal of the Fasteners in end grain.

Figure 4 shows the load-displacement curves for the nails and Helifix withdrawal tests for the first millimetre of displacement. For Helifix fasteners, the maximum loads were usually attained between 7mm and 14mm of displacement.

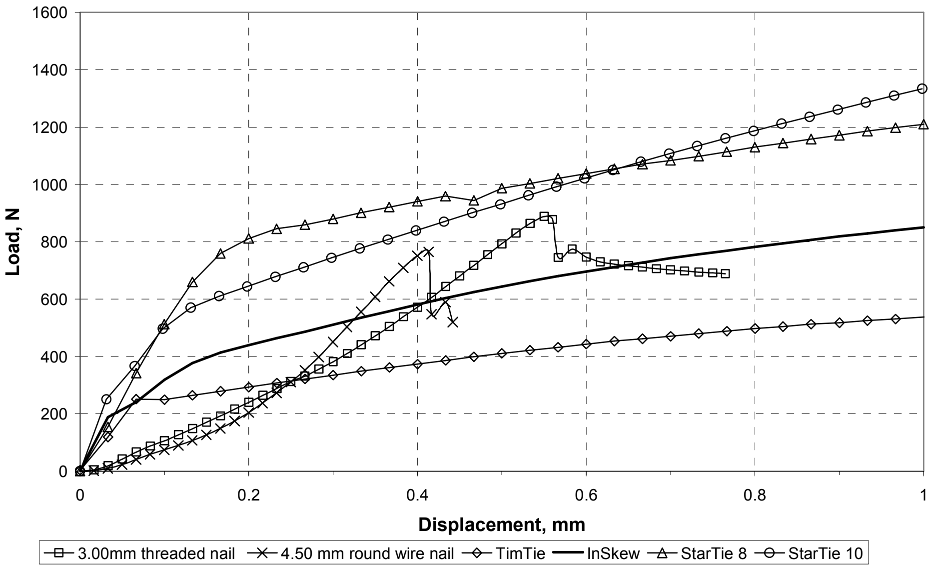

Figure 4: Withdrawal curves at 1.0mm displacement.

The results show that Helifix fasteners achieve higher withdrawal loads than conventional nails, however the withdrawal strength calculated do not reflect this. An equivalent diameter could be used for the fasteners, by calculating the diameters of round nails with similar cross section areas. The equivalent diameters calculated were: 4.55mm, 3.613mm, 3.099mm and 2.815mm for StarTie 10, StarTie 8, InSkew and TimTie respectively. Using the equivalent diameters result in higher withdrawal strength for Helifix fasteners, giving a better representation of the performances of the fasteners in withdrawal.

3.2 Factors influencing Helifix fasteners in withdrawal

Figure 5 shows the effect of the pilot hole diameter on the withdrawal strength. Pilot hole diameter to equivalent diameter ratios were used to get a better representation of the influence of the pilot holes for the four sizes of fasteners.

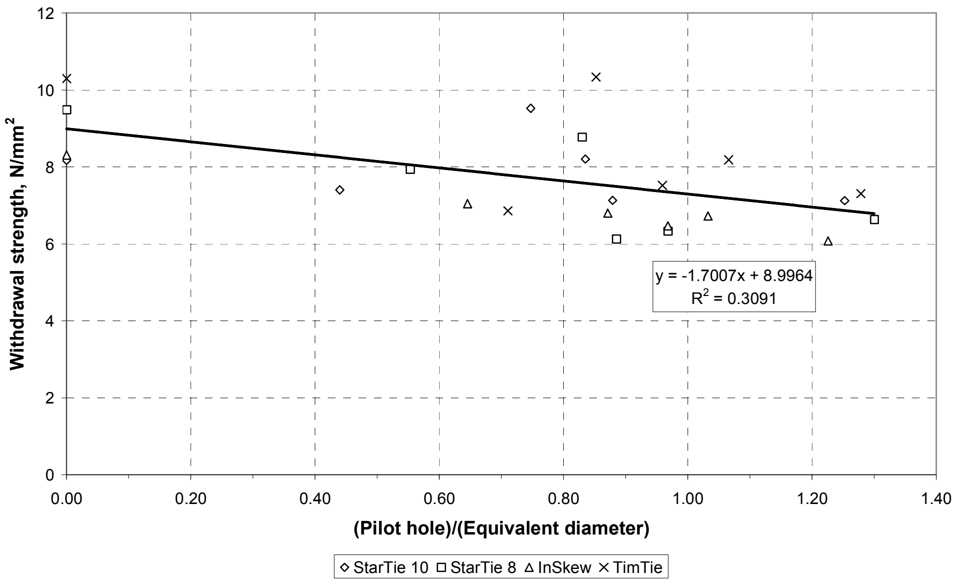

Figure 5: Effect of the pilot hole diameter on the withdrawal strength of Helifix

In general the trend of behaviour indicates that as the pilot hole diameter increases the withdrawal strength decreases. However it can be noticed that the maximum withdrawal strength values are not reached with the same dimension of pilot hole for the four fasteners (See Table 3). The maximum withdrawal strength values were reached with a pilot hole of 0.8 × the core diameter for the fasteners StarTie 10 and TimTie; while they were reached with no pilot hole for the fasteners StarTie 8 and InSkew. Previous research showed that the withdrawal strength of nails is increased when driven into timber with a pilot hole (Forest Product Laboratory, 1999), however for Helifix fasteners it seems that this is not the case. This may be explained by the fact that when the fasteners are driven in to the timber they turn and screw themselves without disturbing the timber fibres as much as nails or screws. However predrilling allows the fasteners to be inserted into the timber with more ease. So from these tests, it seems that inserting the fasteners into the timber with a pilot hole of 0.8 times the core diameter would be the best solution, resulting in achieving high withdrawal strength, and allowing the fasteners to be inserted into the timber quickly and easily.

Table 3: Effect of pilot hole on the withdrawal strength (N/mm^2)

Pilot hole	StarTie 10	StarTie 8	InSkew	TimTie
0.00	8.14	9.49	8.31	10.30
2.00	7.41	7.94	7.05	6.86
0.8 x d_{core}	9.53	8.77	6.80	10.34
0.8x $d_{ef.}$	8.21	6.13	6.47	7.52
d_{core}	7.13	6.33	6.72	8.19
0.8 x $d_{av.}$	7.12	6.63	6.08	7.31

Historically, (Rammer, 2004), numerical models to predict the maximum withdrawal load of the fasteners have related the withdrawal load (W), to the specific gravity (G), the fastener diameter (d) and the length of penetration (L) as:

$$W = adLG^b \qquad \ldots(2)$$

The mean densities of the timber tested to investigate the effect of density were 352.34 kg/m^3 for C16, 402.70 kg/m^3 for C24 and 574.45 kg/m^3 for Maple. Figure 6 shows the withdrawal strength achieved in different timbers. The figure shows that the withdrawal strength is increasing with the density of timber increasing. The relationship between the withdrawal strength of Helifix fasteners and the timber density can be described using the equation given above.

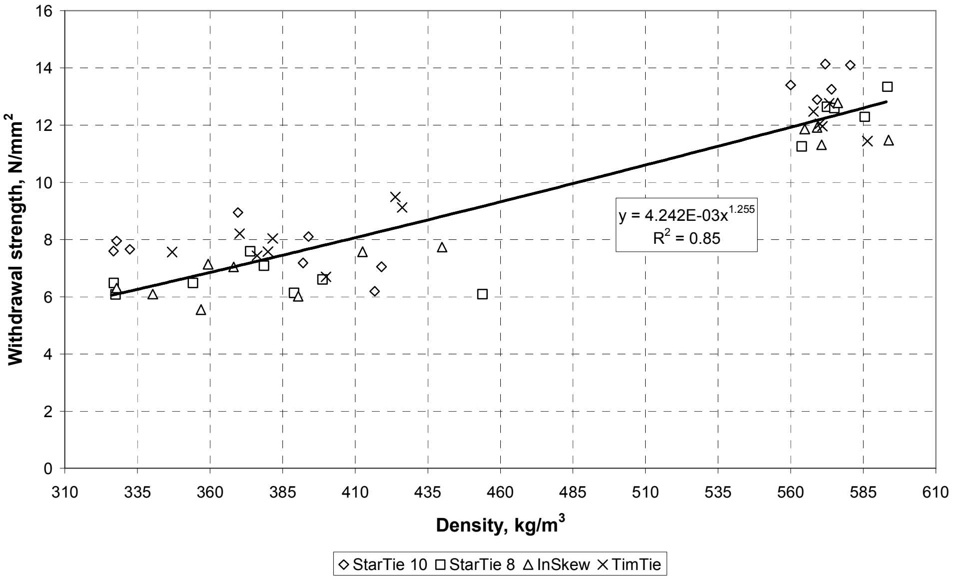

Figure 6: Effect of the timber density.

Equation 2 shows that the depth of penetration is proportional to the withdrawal resistance of fasteners. Helifix fasteners were tested in samples of 20mm, 30mm, 45mm and 60mm thick and the results show that the same relationship applies. Figure 7 shows that for the four different sizes of Helifix fasteners the withdrawal resistance is linear to the depth of penetration.

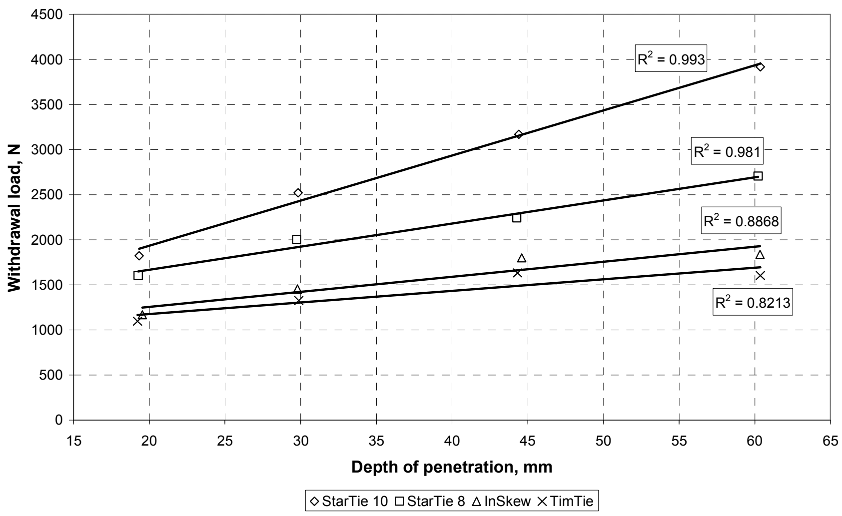

Figure 7: Effect of the depth of penetration of the withdrawal loads.

Tests on the influence of the angle of the grain on the withdrawal strength were performed on timber strength class C24. The results show that the maximum resistance is achieved with the fasteners inserted at right angle to the grain (See Figure 8). And minimum resistance was attained for fasteners inserted in end grain.

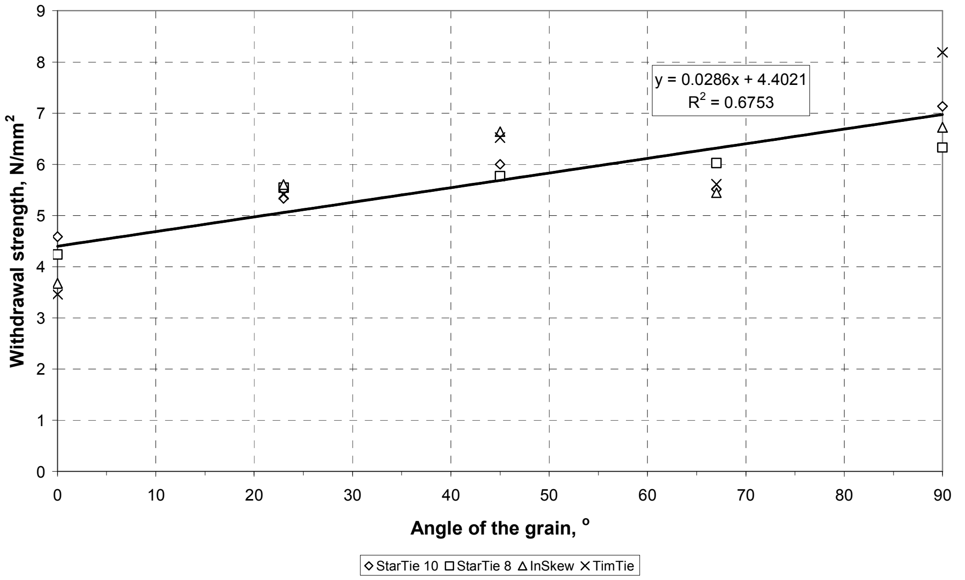

Figure 8: Effect of the angle of the grain.

As expected the pilot hole diameter, timber density, depth of penetration and angle of the grain influence greatly the withdrawal performances of Helifix fasteners. Numerical models used to predict the withdrawal resistance of nails were developed on the form of Eq.(2). However as the behaviour of Helifix fasteners differs greatly to that of conventional nails, numerical models to predict their behaviour and performances may be developed empirically, assuming the factors influencing the resistance do not interact.

4. CONCLUSIONS

4.1 Conclusions

The withdrawal tests performed on Helifix fasteners and conventional nails show that Helifix fasteners achieve greater withdrawal load than nails. The fasteners also exhibited different load displacement behaviour, Helifix fasteners showing a more ductile behaviour, and reaching the maximum loads at displacement of 7 to 14 millimetres.

However using the equation given in BS EN 1382:1999 the withdrawal strength achieved between threaded nails and Helifix fasteners were similar, as the nominal maximum diameters were used. The use of equivalent diameters based on the cross section area of the fasteners may be recommended, as they give a better representation of the performances compared to other nails.

Further testing showed that the timber density, the pilot hole diameter, the depth of penetration and the angle of insertion to the timber grain influenced the withdrawal performances of Helifix fasteners.

4.2 Future work

Withdrawal tests consisted in one part of a wider research on Helifix fasteners as connectors in structural timber systems.
Future work on the fasteners will include:

- Lateral shear tests to examine their behaviour, and performances in comparison to existing fasteners,
- Mechanical tests on the fasteners,
- The development of semi empirical models to predict the structural behaviour and performances of the fasteners in variety of timber connections systems
- The development of design procedures for use in a variety of timber structural systems,
- The development of new applications for Helifix fasteners.

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UK CONSTRUCTION SECTOR AND THE CITB 'EMPLOYMENT MODEL': A FRAMEWORK FOR COLLECTING AND DISSEMINATING DISAGGREGATED INFORMATION

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Abstract: Varying anecdotal sub-regional and regional construction specific information is largely accountable for the sectors perceived and persisting skills mismatch, 'deprived' retention for trainees, paucity of employment data, male dominated and an aged workforce. Regardless, the CITB 'employment model' and most one-off research reports (published data) seem to have placed little or no emphasis on the critical issue of gathering robust construction and building services information which a review of UK employment models reveal is fundamental to the future development of the sector – realising a sustainable community. A conceptual framework for collecting and disseminating disaggregated information is developed. Policy makers and industry stakeholders should depend on holistic forecasts for effective decision making and planning. The costs / benefits of developing a new 'Model' is fundamental to the findings of an on-going research

Keywords: CITB, conceptual framework, construction sector, employment model.

1. INTRODUCTION

It is no surprise that the UK's construction and building services sector which is persistently regarded as one of the strongest in the world (DTI, 2004; Ejohwomu et al., 2005a) still attracts reports of the detrimental effects of a construction skills crisis on the image, performance and future development of the sector (Dainty et al., 2005). Today the sector is currently characterized as having a skills mismatch, 40% – 60% retention for trainees, a high level of fragmentation, paucity of employment data, male dominated and an aged workforce (Latham, 1994; Love and Tucker, 1996; Churchill 1997; Ejohwomu et al., 2005b; Olomolaiye et al., 2005). These characteristics can be traced to changes in national curriculum; the perception of the industry; the apparent excitement for new disciplines as a reason for a shortage of trainees entering the sector, forecasting and modelling techniques should be realistic (Clarke, 2005).

However, fundamental to this papers argument is the obvious absence of a construction and building services specific framework for collecting; disseminating; quantifying and disaggregating sub regional and regional information (Olomolaiye et. al., 2005). This may explain why most accessible sources of data present varying and anecdotal construction and building services forecasts (see CITB, 2003 p47). Acknowledging that the development and efficiency of a 'good model' arguably rests on the reliability of its data source. However, many recent research publications still purport a paucity of empirical research and a lack of comparable data into the sectors precise 'status', including its highly complex labour market (Pietroforte and Gregori, 2003; Dainty et al., 2005; Ejohwomu et al., 2005b). Indeed some of these earlier reports have already identified and predicted today's skills crisis phenomenon yet it's still being perceived as persistent (Dainty et al., 2004). Given that there is sufficient evidence from literature confirming the complexities and peculiarities associated with the construction and building services sector; this report seeks to question the rationale for the absence of a construction specific forecasting model. (Hillebrandt, 1995; Harvey and Ashworth, 1997; Koskela, 2000; Koskela, 2003; Hillebrandt, 2003).

The remainder of the report is structured as follows: section 2 emphasizes the varying intents behind data collection by different organisations in the UK; section 3 discusses the conflict in forecasts amongst five different organisations; section 4 defines a good forecasting model as a prerequisite for discussing the structure of the CITB's employment model; section 5 presents of a new conceptual framework for the collection and disaggregation of information and section 6 discusses the focus of the report as a basis for signposting gaps in CITB's 'employment' model.

2. THE DIFFERENT SOURCES OF DATA IN UK

There are many ways of gathering and obtaining regional and local labour market information employed by various organisations in the UK. Common amongst these is a 'one-off' survey research – this is largely used in refuting and/or establishing trend perceptions. A summary of the main approaches used now and a summary of sub regional survey of Black Country training providers follows:

The Labour Force Survey (LFS): The Labour Force Survey (LFS), which is the largest regular household survey in the UK (ONS, 2005) implores labour market concepts and definitions agreed by the International Labour Organisation (ILO) – an agency of the United Nations. Overall this survey aims at collecting information by interviewing households on issues relating to migrants' personal circumstances and their labour market activity.

Labour Force Survey Annual Local Area Database (LADB): The Labour Force Survey Annual Local Area Database (LADB) is developed using data from four consecutive quarters of the LFS. Its overall purpose is geared towards making available more accurate data for Unitary Authority / local authority districts (UA / LADS) only (ONS, 2005).

Local Labour Force Survey (LLFS): The Local Labour Force Survey (LLFS), which commenced in March 2000, is designed to produce a more robust data for Learning Partnerships (LPs). The overall aim of this survey however tends towards augmenting the quarterly LFS so that a minimum sample size is achieved in each Local Education Authority (AES) in England.

Annual Business Inquiry: This Annual Business Inquiry (ABI) survey, which was introduced in April 2001, replaced the Annual Employment Survey (AES). However, like the others already mentioned the ABI is not specifically tailored towards the collection of construction and building services data.

Micro Economic Data: Micro economic data are a set of data collected largely for simulating micro economic trends and analysis. Overall, micro economic data seem to offer several important advantages for the study of investment and employment behaviour regardless of its limitations (Bond and Reenen, 2003). Some of these advantages include:

- Allowing the elimination of the input of aggregation over firms when estimating a particular model;
- Identifying parameters of interest through cross-sectional variation in explanatory variables;
- Availability of microeconomic data allows researchers to investigate heterogeneity in behaviour between different types of firms;
- To test some of the simplified assumptions that is made in specifying traditional factors of demand.

Construction Skill Supply Trend in the Black Country: In pursuant of comprehensive information on sub regional skill supply trend a structural survey of significant issues with four of the five F.E. Colleges in the sub region; and a convenience survey of Black Country training providers is detailed (see table 1) – the framework for collecting this data is specific for evaluating skill supply.

Table 1: FE enrolment in Construction main trade areas for 2002 / 3 academic year

TRADE AREA	NO ENROLLED	% OF ALL ENROLMENT
Trowel trades and plastering	789	14
Wood trades, carpentry and joinery	579	10.4
Heating and ventilation, industrial pipe work and plant maintenance	985	17.7
Mechanical services and plumbing & gas fitting	1716	30.8
OCN WM	398	7.1
Multi-skilling	135	2.4
Painting and decorating	198	3.6
Others including general top-ups	775	14
Total	5575	100

From table 1, it seems that current supply pattern is mostly dependent on gut feelings, the media and varying quality of data. Hence, enrolment figures tend to increase during periods of high demand. The current media-led interest in plumbing within the sector is a poignant example. Because 'new entrant' trainees lack adequate information on supply and labour market trends, they may likely be unemployed on completion of their respective programmes, with the exclusion of those who are already in employment. It is unbelievable that this non-factual skill supply base has been allowed to exist for such a long time. This continually reinforces the generally held view that a career in construction is unstable; but it can be as stable as any other with better information. Regardless, the focus of the underpinning argument developed in this paper (absence of a construction specific framework for collecting and disseminating data) is largely aimed at identifying the ambiguity in the CITB's employment model as a basis for developing a sufficiently holistic employment framework for UK's construction and building services industry. Wherein the key expectation of the emerging model will be the disseminating of disaggregated information through harnessing of microeconomic data.

3. CONFLICTING FORECASTS

The UK's construction and building services sector is currently associated with a plethora of qualifications, variable quality of training, recruitment and retention difficulties (Olomolaiye et al., 2005); varying definitions of the skills crisis phenomenon and variation in sub regional, regional and national forecasts which in no doubt further compounds the skills crisis problem. The construction and building services sector produces voluminous quantitative data that are created during the control phase of projects and relates to cost, schedule and administrative information (Songer et al., 2004). Most forecasting models are currently not able to manage or incorporate recent storage and processing advances required for the modelling of project control databased on existing project control systems. Table 2 (adopted from Skills Foresight Report (CITB, 2003 p.47) presents a summary of forecast made by five major organisations, namely:

- Cambridge Econometrics (CE)
- Experian Business Strategies/Construction Forecasting and Research (EBS/CFR)
- Construction Products Association (CPA)
- Hewes & Association (H&A)
- Construction Industry Training Board (CITB)

Due to poor correlation in the information presented amongst the five different organisations, the data in table 2 raises many questions on the future directions / expectations of UK's construction and building services sector. However, there is a degree of consensus amongst all five organisations on the source of growth which is the perceived plan by government to increase future spending in the sector. The majority of these discrepancies arguably stems from the absence of a generic framework for optimising information gathering and modelling. In the 'one-off' survey, the emerging discrepancy is blamed arguably on the absence of a sub-regional framework for quantifying skill supply patterns to enhance training providers and funding agencies' understanding, there is a clear paucity of basic skill supply data. This is not peculiar to the Black Country alone but other regions of the UK.

Table 2: Construction Output in Prices, Great Britain: 1997 – 2007

Actual	Percentage (%)			
1998	1.6			
1999	1.5			
2000	1.5			
2001	3.5			
2002	8			
Forecast	**CE Summer 2003 %**	**CPA Summer 2003 %**	**H&A Apr 2003 %**	**CITB Employment Model 2003 Forecast for WM %**
2003	3.6 (2.6)	1.9 (4)	1	- 2.1
2004	1.8	1.0 (0.6)	-1	7.4
2005	2.1	1.1 (1.3)	3.2	2.0
2006	1.3	N/A	N/A	2.9
2007	0.7	N/A	N/A	2.1

Source: Actual: Department of Trade and Industry - Figures in brackets refer to Winter 2002/03 forecasts, which were used to forecast construction employment.

3.1 The CITB and its Data Sources

The CITB is a major source of national, regional and sub regional construction specific information and is the most widely cited source of information in the UK (Dainty et al., 2004). However, its employment model surprisingly relies on other sources (LFS and DTI output data) for modelling information (CITB, 2003 p.44). Although the CITBs construction output is based on measures established by the DTI. The CITB's new model (supply side) which was developed by Meen, (2002) takes advantage of the better data available to it on net retirement flows offered by the LFS. Consequently, the CITB model has been designed to take advantage of the data potentially available from the LFS (Ive, 2004).

4. A GOOD FORECASTING MODEL

Whilst the essence of a 'good' model cannot be overemphasized (Ejohwomu et al, 2005b), Ive, (2004) has defined a good model as one, which in turn produces testable forecasts. In putting forward his agreement Ive, (2004) established the distinct differences / attributes which coexisted between 'flow models' and 'stock models'. Ive, (2004) also emphasized why a disaggregated model is normally more testable as well as being more relevant than an aggregated model. Thus a good forecasting model should be testable because it should provide a crucial foundation and framework for any planning exercise.

4.1. The CITB Employment Model

The CITB employment model presently adopts a top-down design approach (Construction Skills Foresight report, 2003). The model is largely dependent on DTI and LFS data sources. An analysis of the basic methodology starts at the national level with total construction employment and is subsequently broken down by occupation and region. Construction output, price of capital and wage rate are the key variables used in explaining construction employment. For details see the Construction Skills Foresight, (2003 p44-45). However, there seems to be more failures than successes in attempts made by the CITB to develop a sufficiently holistic employment model (CITB, 1968 and 1988; Briscoe and Wilson, 1993). There is evidence to suggest continued persistence (Meen, 2002 and Ive, 2004 p44) by CITB to develop a sufficiently holistic employment model, which might effectively accommodate the complexities and technological changes associated with the sector today if it is sufficiently holistic. Given that the primary objective of the CITB is to achieve a fully skilled and professional UK construction industry by working safely, adding value and delivering sustainable development (CITB, 2004). Presently the CITB employment model generates forecasts, which are partly disseminated through construction regional and national skills foresight reports e.g. constructional regional skills foresight reports for the West Midlands see the Construction Skills Foresight, (2004). However, if these annually disseminated reports provided the basis for which training providers, constructors and construction and building services stakeholders including the local authorities and government at large make plans and projection then there should be need to exercise great caution as to the future direction of UK construction and building services sector. Wherein the degree of caution to be exercised would depend on how much reliance has been placed on the model.

5. A NEW CONCEPTUAL FRAMEWORK

Figure 1 presents a conceptual framework tailored to accommodate the complexities of UK's construction and building services sector which will in turn compliment sub regional, regional and national disaggregation of construction specific information. It is evident from literature that the sector lacks a framework for collecting and harnessing information from both supply and demand sides of the sector (Olomolaiye et al., 2005). However, because this framework emphasizes the usefulness of construction specific information sources, data collected should remain structured for easy disaggregation and specification. Songer, (2004) presents details of the applicability of multidimensional visualization of project control data. Figure 1a adopted from Olomolaiye et al., (2005) is an indication of how disaggregated information (sub regional and regional) would fit into the conceptual framework for the collection and modelling of construction specific information. Olomolaiye et al., (2005) provides details of a Black Country construction data management model. The disaggregation and construction specification zone (sieve) will be used in optimising the necessary level of detail required which will enable the data set to be stored in the repository. The data repository will house different types of structured data while the construction specific model would rely on the construction specific data source for useful predictions and forecasts. The inclusion of a repository in the conceptual framework (figure 1) is primarily to bridge some of the identified gaps in the CITB employment model as the current model seems to rely solely on secondary data sources. That is, the CITB's data sources are not tailored to capture construction specific information which should be bespoke. It would be misleading for planners to fully rely on information generated by the CITB employment model.

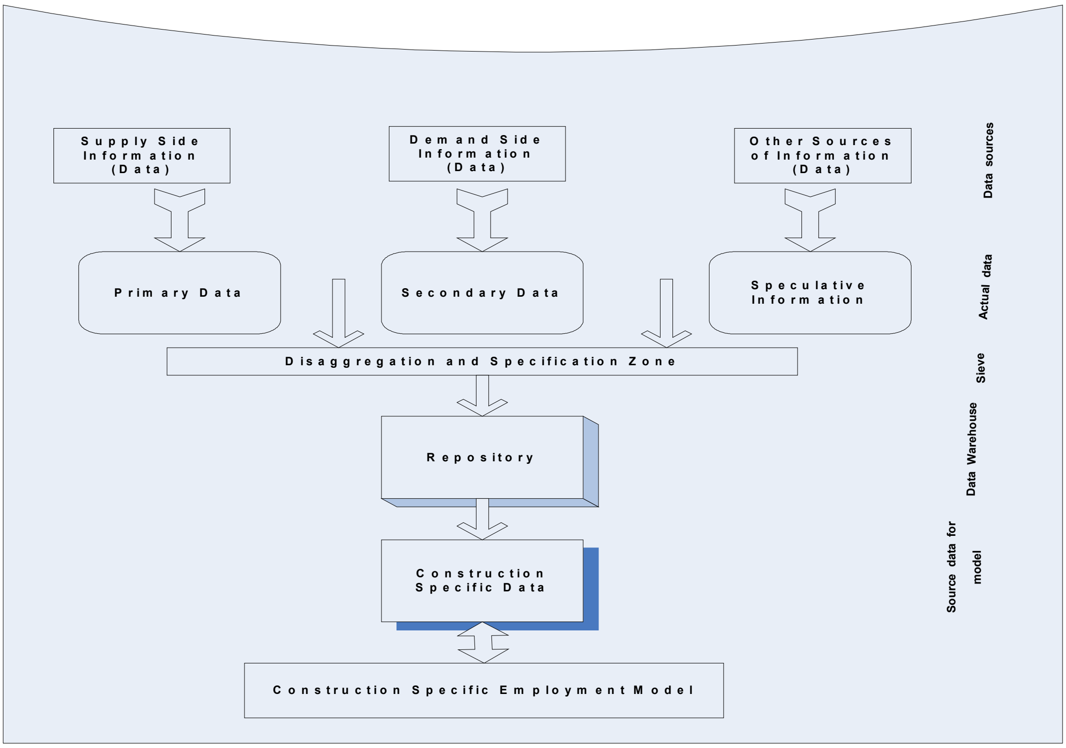

Figure 1: A conceptual framework for the collection of construction specific information

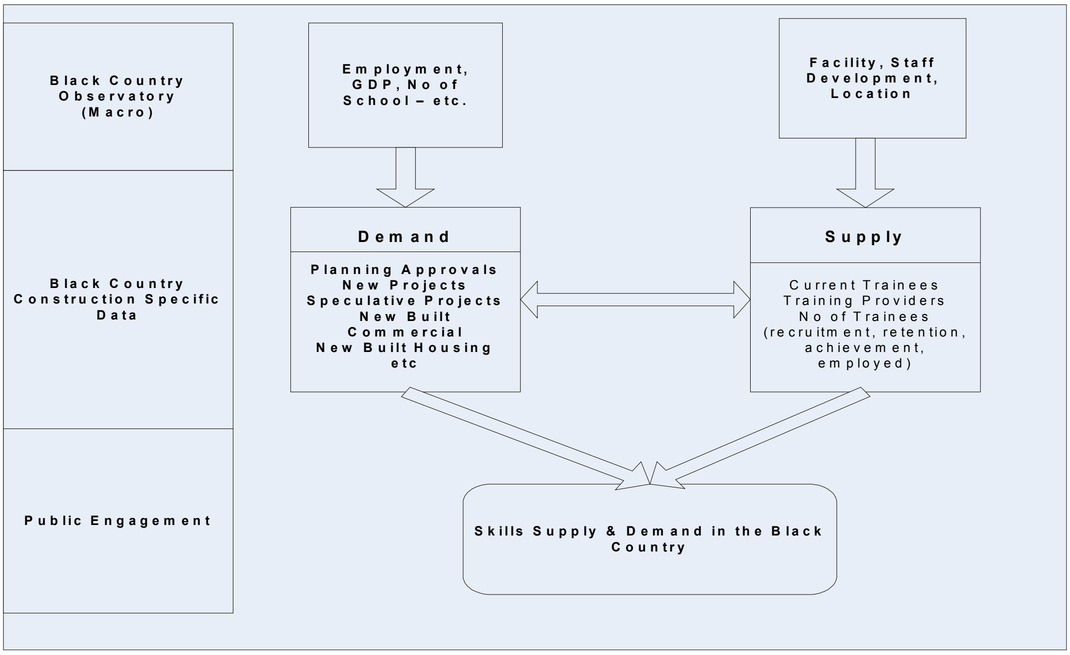

Figure 1a: Schematic view of a models meta data showing the development of a construction specific database from macroeconomic information

5.1 Constraints

Factors including functional fragmentation, self-protective pressures, and adversarial attitudes have been argued to work against the multidisciplinary teamwork needed for collaborative realization of the proposed conceptual framework (Anumba et al., 1995;

Love and Irani, 2001; Kumaraswamy and Dulaimi, 2001; Titus et al., 2004). Hopefully, the signposting of the unlimited merits associated with the attainment of a sustainable construction and building services sector might serve as a driving force for tackling these barriers.

6. DISCUSSION

Whilst the underpinning focus of this discussion hovers on evidence from literature review, 'one off' quantitative research, use of information gathered during workshops / conferences and semi structured interviews with authoritative reviewers of forecasting models in the UK is included. The role of information in the construction and building services sector cannot be over emphasized. Consequently, nobody should deny that proper gathering and management of information brings total value (Titus et al., 2004). However, it is worth noting that information gathered for any specific purpose will lose most of its value if it is not harnessed for the purpose for which it was collected. Hence, in section 2; this paper argues there is meaningful correlation between the 'purpose of data collection' and 'quality of the data collected'.

The Organisation of Economic Cooperation and Development (OECD) for example which is best known for its publications and its statistics is relied upon to produce internationally agreed instruments, decisions and recommendations to promote roles of economic and social issue in areas where multilateral agreement is necessary for individual countries to make progress in a globalised economy (OECD, 2005). Consequently, the OECD continues to seek macro economic data to help achieve its set aims and objectives. Wherein any fundamental change to its present aims and objectives will interfere with its information gathering and dissemination procedures. This might partly explain why most of UK's information tends to be aggregated. By accepting this papers fundamental argument of the unlimited benefits associated with the disaggregation of information the construction and building services sector should seek a framework for disaggregating the already aggregated information as a redress for developing a new employment model as the current construction specific model is largely dependent in anecdotal information. Nickells' (1978 and 1986) discussion of aggregated biases in the context of dynamic investment and labour demand equations argued that aggregation can distort the underlying dynamic relationship thus motivating the use of micro data to study adjustment processes for both capital and labour.

The merits of adequately imbibing the culture and concept of sustainability in the UK's construction and building services sector (Egan, 2004) are indeed limitless. The question needing immediate redress should however hinge on how prepared and willing is the sector in relation to accepting adequate information management and innovation as means of achieving a sustainable construction and building services sector? This and the cost / benefit of developing a new 'employment' model for the construction sector is fundamental to the findings of an on-going research.

6.1 Gaps in the Current Employment Model

Some of the identified gaps in the CITB model are acknowledged below. Most of these gaps have been adopted from literature. For fuller details see Meen, (2002) and Ive, (2004).

- No consideration for gross recruitment and gross availability;
- Treats skilled labour supply and demand exclusively in terms of qualified works rather than being nested within a broader model of total demand for and supply of skilled labour;
- Over looks the different sources and degrees of skill acquisition and skill decay;
- Divides non-trainee recruits to the industry in just two categories (skilled and unskilled);
- Lacks a well designed construction-employer-based surveying of employer assessments of non-trainee recruits;
- Does not distinguish between young and old workers;
- Is powered by data from mainly LFS and ONS which are not sufficiently robust to produce construction specific forecasts and prediction.

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DYNAMIC RESPONSE OF TIMBER FLOORS

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ABSTRACT: Developments in composite timber construction have been widely used for forming relatively large-span floors. This has also resulted in undue floor vibrations, causing inconvenience to the occupants and requiring the vibrational response of the structure to be considered in more detail during the design process. The problems associated with vibration of floors are not adequately addressed in the current British Standards. The UK National Annex to Eurocode 5 considers the fundamental natural frequency of the floor, the deflection under a unit point load and the unit impulse velocity response. These design criteria have been analysed in this paper and parameters influencing the vibrational behaviour of the flooring system have been investigated by performing parametric studies on floors built with solid timber joists and engineered I-joists. Regarding fundamental natural frequency and deflection, the results show that the floor span and beam height are the critical parameters and the floors built with I-joists have a poorer vibrational performance.

Key words: Dynamic response, engineered joists, serviceability, timber floor.

1. INTRODUCTION

Structures tend to vibrate when excited. Since the invention of new light timber beam elements (such as I-Joists or parallel-chord trusses) for constructing larger floors, and offering more space for residence, floor vibrations in particular increasingly cause more inconvenience to the occupants. For decades, investigations have been made to evaluate vibrational performance of buildings or structural components and control its effects through appropriate modification of the structural system. The current available design criteria cannot satisfactorily provide adequate solutions in many cases.

The Eurocodes are generally sub-divided into two main categories, the ultimate limit states (ULS) and the serviceability limit states (SLS). The former are associated with the stability and load capacity of structures. The latter have been established to avoid impairment of the buildings, which can lead to excessive deflections or vibrations of the structure, even though non-compliance of the SLS may not cause collapse of the structure.

The vibration of timber floors is regulated by the SLS requirements in Eurocode 5 (EC5) "Design of timber structures". The vibrational performance of the floor is controlled by assuring the fundamental natural frequency to be greater than 8 Hz, and limiting the deflection under unit point load and the unit impulse velocity response. These three requirements are influenced, to different degrees, by several parameters. Investigation is needed to analyse the relevant formulas by performing parametric studies and to identify which parameters contribute more to vibrational performance of floors than the others. This helps to identify what parts of a flooring system need to be modified to eventually improve the dynamic response.

2. ANALYSIS OF THE EC5 VIBRATIONAL CRITERIA

The variation in parameters that significantly influence the vibrational criteria, i.e. fundamental natural frequency, deflection under unit point load and unit impulse velocity response, are identified and investigated for the floors built with solid timber joists and engineered I-joists. This study aims to provide information on the difference in vibrational performance between the solid timber joists and I-joists, and on the parameters which influence their response, which can be eventually utilised for the design of timber flooring systems.

The parametric analysis (although at its early stage) is focused on the most commonly used flooring systems in the UK, namely the floors with solid timber joists and engineered I-joists. Geometrical properties are the main difference between solid timber and I-joists. Each parameter in an appropriate formula is gradually increased, while the remaining parameters are kept constant. This procedure is repeated for all the parameters. Three floor dimensions are adopted here by increasing the original dimensions of 3 × 4 m by 15% and 30%, respectively. The floors which are simply supported and one-way spanned have been initially designed according to the appropriate Eurocodes [EC0, EC1-1-1, EC5-1-1, EN 12369-1, EN 338] whereas only the initial width of the solid timber beam has been adjusted for easy comparison with I-beams. All the floors are assumed to be built with solid timber joists or I-joists of 45 × 195 mm, spaced at 400 mm, and 19 mm particleboard for decking. The dead load or the mass per unit area is assumed to be 51 kg/m^2 or 0.5 kN/m^2.

2.1 Fundamental Natural Frequency

A higher frequency is basically considered to be positive compared to a lower frequency [Trada Technology]. The fundamental natural frequency is calculated as follows [EC5-1-1]:

$$f_1 = \frac{\pi}{2L^2}\sqrt{\frac{EI_\ell}{m}} \quad [\mathrm{Hz}] \tag{1}$$

where

EI_ℓ	= Equivalent bending stiffness of the floor about the major axis y-y and $EI_\ell = E_{0,\mathrm{mean}}\, I_y / s$ [Nm^2/m];
$E_{0,\mathrm{mean}}$	= Mean characteristic elastic modulus, parallel to the grain [N/m^2];
I_y	= Second moment of area about the major axis y-y and $I_y = bh^3/12$ [m^4];
L	= Floor span [m];
b, h, s	= Breadth, depth and spacing of timber joists [m];
m	= Mass per unit area [kg/m^2].

Including all parameters into Eq. (1) yields:

$$f_1 = \frac{\pi}{4\sqrt{3}\,L^2}\sqrt{\frac{E_{0,\mathrm{mean}}\, b\, h^3}{m\, s}} \quad [\mathrm{Hz}] \tag{2}$$

Figure 1 shows the fundamental natural frequency f_1 monotonically increasing with the increase in h and b but decreasing with the increase in s for the floors built with both solid joists and I-joists. Larger slopes of f_1-h curves indicate that increasing h is more effective than increasing b. The present parametric study also shows a better performance of the floors built with solid timber joists than with I-joists for the same height, width or spacing of the joists. It can also be seen that in all six figures, the floors with longer spans will significantly decrease the frequency f_1, even below the design limit of 8 Hz. The floor width B has been considered and increased in all the calculations but is irrelevant to the frequency.

In general, a small percentage change in the floor span L affects the frequency f_1 more than any other parameters. The height of the joist has the second highest impact. To increase the frequency, the floor span, the mass or the joist spacing need to be decreased, or the modulus of elasticity, the beam width or the height need to be increased.

2.2 Deflection Under Unit Point Load

The deflection under unit point load is calculated as follows [NA to EC5-1-1]:

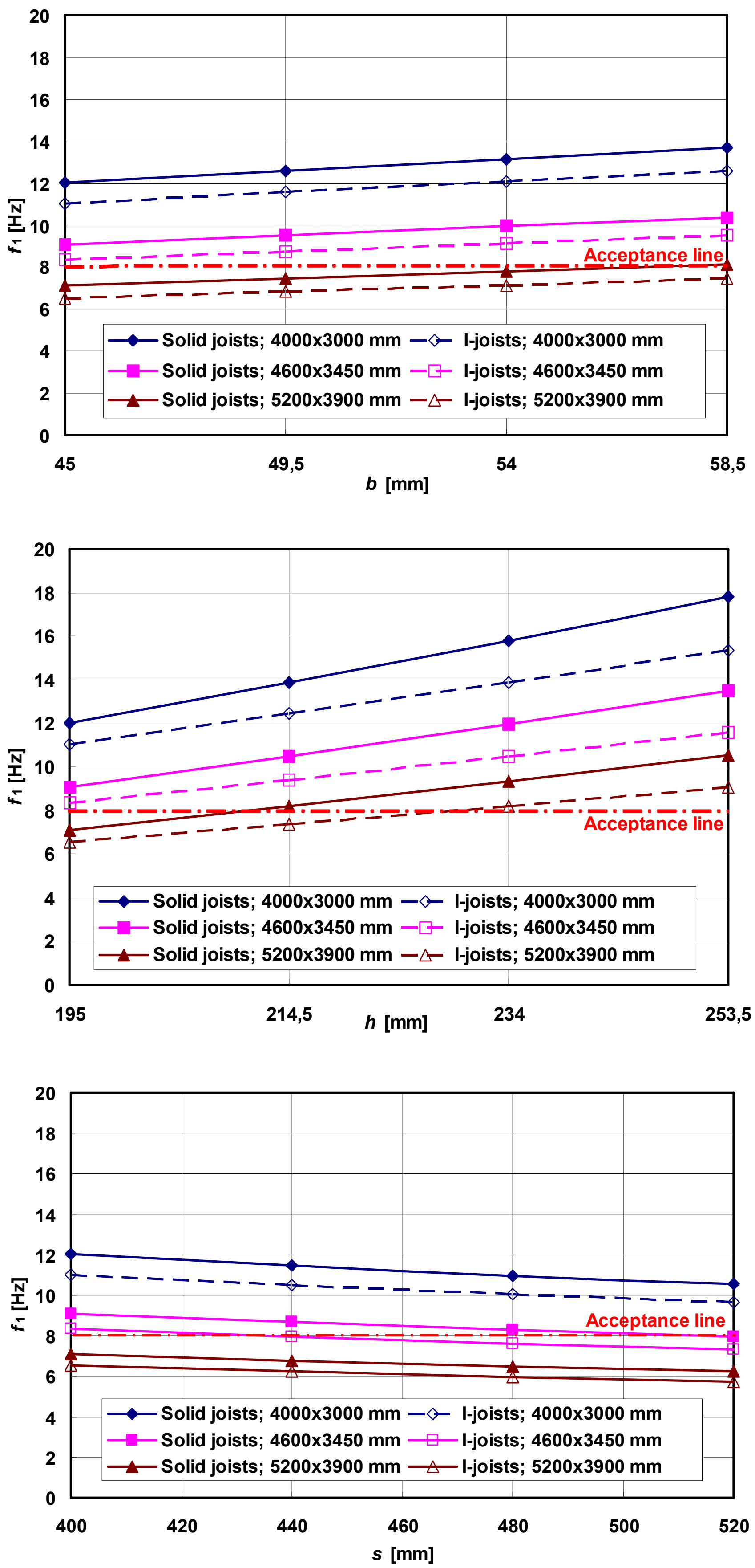
$$a = \frac{k_{\text{dist}} 1000 L_{\text{eq}}^{3} k_{\text{shear}}}{48 k_{\text{comp}} EI_{\text{joist}}} \quad \text{[mm/kN]} \tag{3}$$

where

k_{dist}	= Factor to account for proportion of point load distributed to adjacent joists by floor decking and $k_{\text{dist}} = \max\{[0.42 - 0.09 \ln(14EI_b / s^4)], 0.35\}$;
EI_b	= Equivalent plate bending stiffness of the floor about the axis x-x parallel to the beam and $EI_b = E_{0,\text{mean,deck}}\, t^3/12$ [Nmm²/m];
$E_{0,\text{mean,deck}}$	= Mean characteristic elastic modulus of the chosen decking [N/mm²];
T	= Thickness of the floor decking [mm];
L_{eq}	= Equivalent floor span, see EC5, [mm];
k_{shear}	= Amplification factor to account for shear deflections, see EC5;
k_{comp}	= Factor to account for composite action between the joists and floor decking, see EC5;
EI_{joist}	= Equivalent plate bending stiffness of the floor about the major axis y-y and $EI_{\text{joist}} = E_{0,\text{mean}}\, I_y$ [Nmm²].

Eq. (3) can also be re-written and expanded as far as possible to include more parameters by noticing that k_{dist} is often larger than 0.35:

$$a = \underbrace{\left[0.42 - 0.09 \ln\left(\frac{7E_{0,mean,deck}t^3}{6s^4}\right)\right]}_{k_{dist}} \frac{250 L_{eq}^{3} k_{shear}}{k_{comp} E_{0,mean} b h^3} \quad \text{[mm/kN]} \tag{4}$$



a) Relationship between f_1 and b

b) Relationship between f_1 and h

c) Relationship between f_1 and s

Figure 1: Fundamental natural frequency for solid timber joists and I-joists with varied *L*, *B*, *b*, *h* and *s*

The results of the parametric study show a better performance of the floors built with solid timber beams compared to the floors built with I-joists; as shown in Figure 2. An increase in the beam width or in particular the beam height will cause a decrease in deflection. An increase in the spacing or especially in the floor size, however, will lead to a higher deflection. A decreased deflection can also be expected by increasing the (equivalent) modulus of elasticity of the beams, or the modulus of elasticity and the thickness of the floor decking. In actual fact, an increase in the thickness of the decking will generally decrease the modulus of elasticity of the decking and this has been considered in this study (due to the use of particleboards) [EN 12369-1]. The most influential parameters on the deflection are, however, the equivalent span of the floor and the height of the beam. The impact of $E_{0,\text{mean}}$ and b is the same if both are changed by an equal percentage but is much less pronounced than that of h and L_{eq}.

The deflection has to be smaller than its design value, which is not investigated further in this study since it has a fixed value of 1.75 mm for $L \leq 4.5$ m and is only dependent on the equivalent floor span in the other cases (§7.3.3 in EC5).

2.3 Unit Impulse Velocity Response

The unit impulse velocity response of the floor, v, should not be larger than its design limit v_d. The response v for a floor with overall dimensions of $L \times B$, simply supported along all four edges is calculated as (see §7.3.3 in EC5):

$$v = \frac{4(0.4 + 0.6\,n_{40})}{m\,L\,B + 200} \quad [\text{m/(Ns}^2)] \tag{5}$$

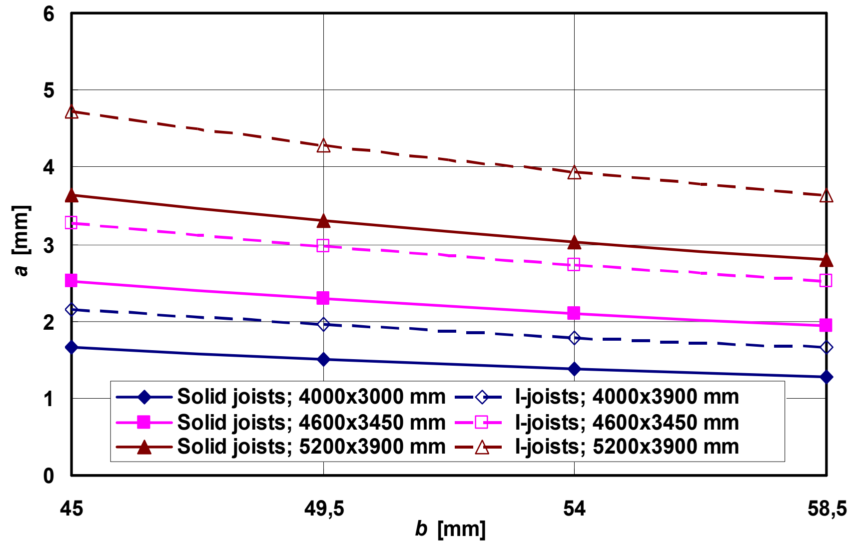
where:

n_{40} = Number of first-order modes with natural frequencies up to 40 Hz and

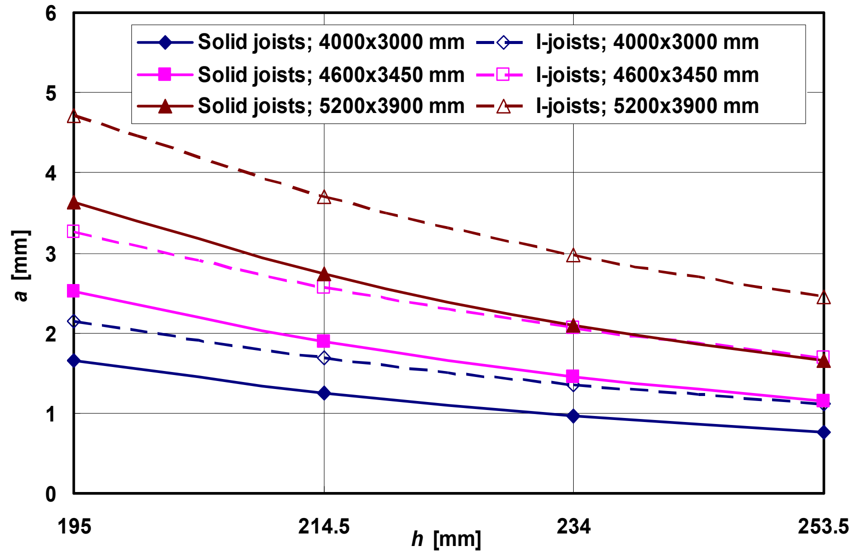
$$n_{40} = \left\{\left[\left(\frac{40}{f_1}\right)^2 - 1\right]\left(\frac{B}{L}\right)^4 \frac{(EI)_\ell}{(EI)_\text{b}}\right\}^{0.25} = \left[\left(\frac{76800 L^4 ms}{\pi^2 E_{0,\text{mean}} bh^3} - 1\right)\frac{E_{0,\text{mean}} bh^3}{E_{0,\text{mean,deck}} t^3}\right]^{0.25}\left(\frac{B}{L}\right) \tag{6}$$

Figure 3 shows the relationships of the velocity response of the floor with some most influential parameters, including the thickness of the floor decking and the floor mass.

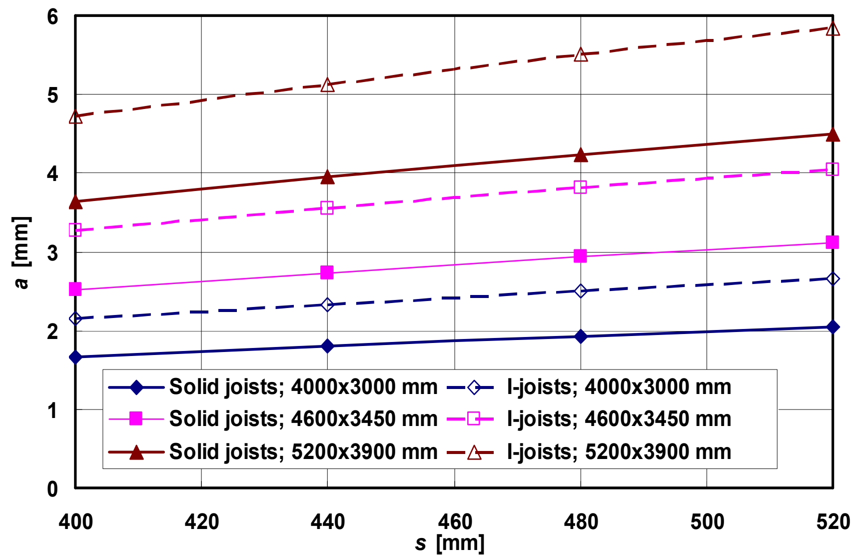
Increasing the beam height only slightly decreases the velocity response. An increase in the deck thickness is generally accompanied with a lower value of the modulus of elasticity, and again this has been considered in the calculations. In this example, the I-joists perform just slightly better than the solid timber beams.



a) Relationship between *a* and *b*

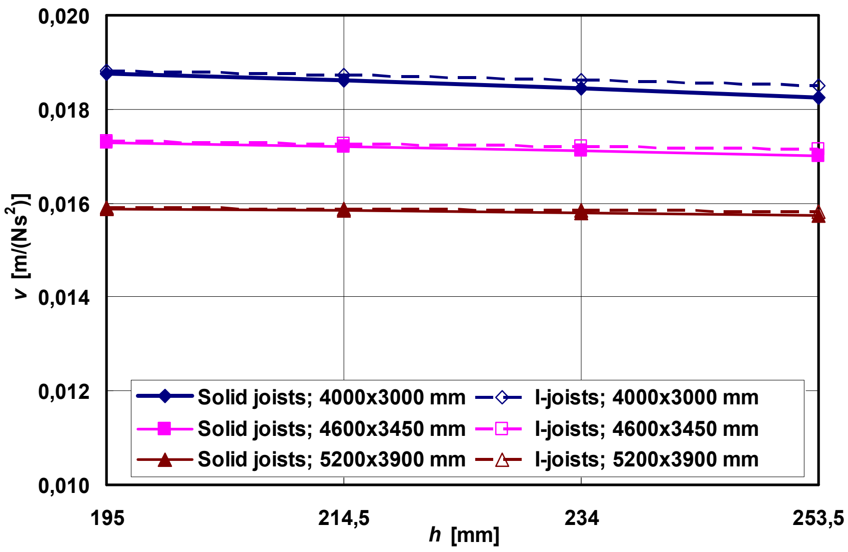


b) Relationship between *a* and *h*

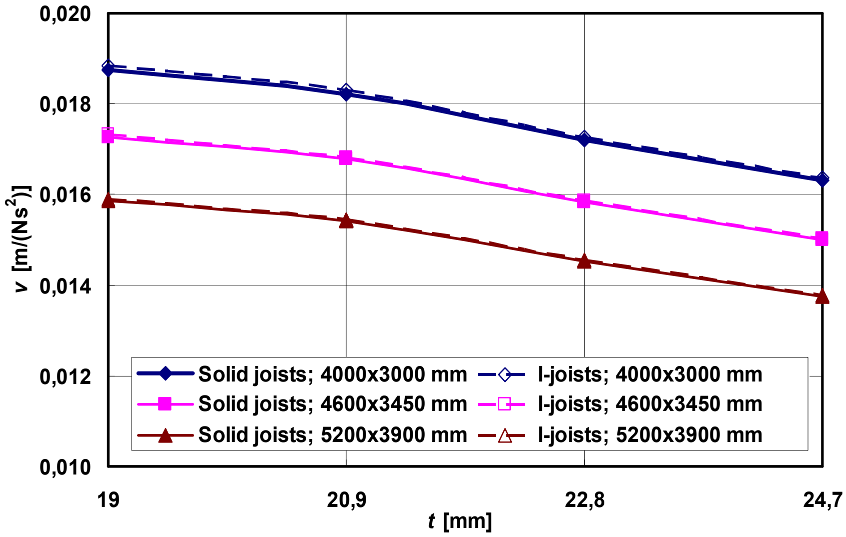


c) Relationship between *a* and *s*

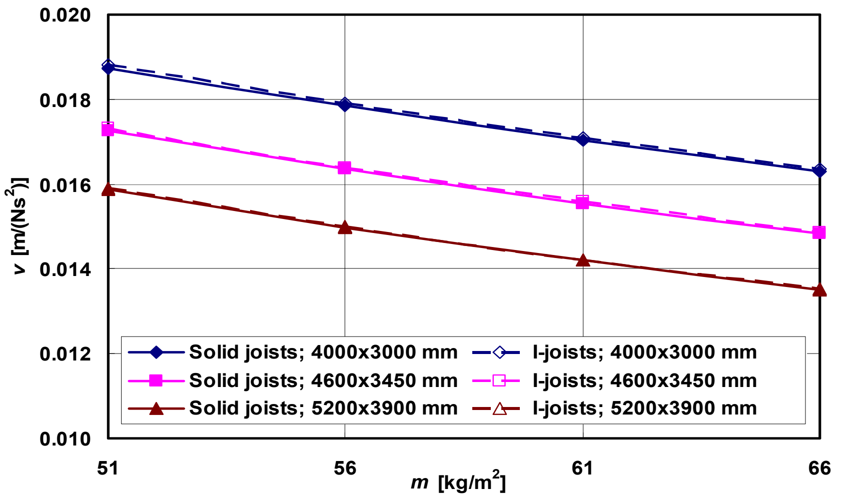
Figure 2: Unit point load deflection for solid timber joists and I-joists with varied *L*, *B*, *b*, *h* and *s*



a) Relationship between *v* and *h*



b) Relationship between *v* and *t*



c) Relationship between *v* and *m*

Figure 3: Unit impulse velocity response for solid timber joists and I-joists with varied *L*, *B*, *h*, *t* and *m*

2.4 Design Value of Unit Impulse Velocity Response

The design value of unit impulse velocity response v_d is calculated as [EC 5-1-1]:

$$v_d = b_{\mathrm{f}}^{(f_1\zeta - 1)} \qquad (7)$$

where:
b_f = Parameter for calculating v_d, see §7.3.3 in EC5;
ζ = Modal damping ratio, which is taken as 0.01 (or 1 %).

The procedure used for this parametric study has also been applied to the equation for the design limit but provides uncertain results. Therefore, it is necessary to extend the investigated range concerning parameter adjustments. Figure 4 shows a plot of the velocity response and its design value versus the beam height. In this case the beam height was set to 150 mm and gradually increased to 390 mm, up by 160%.

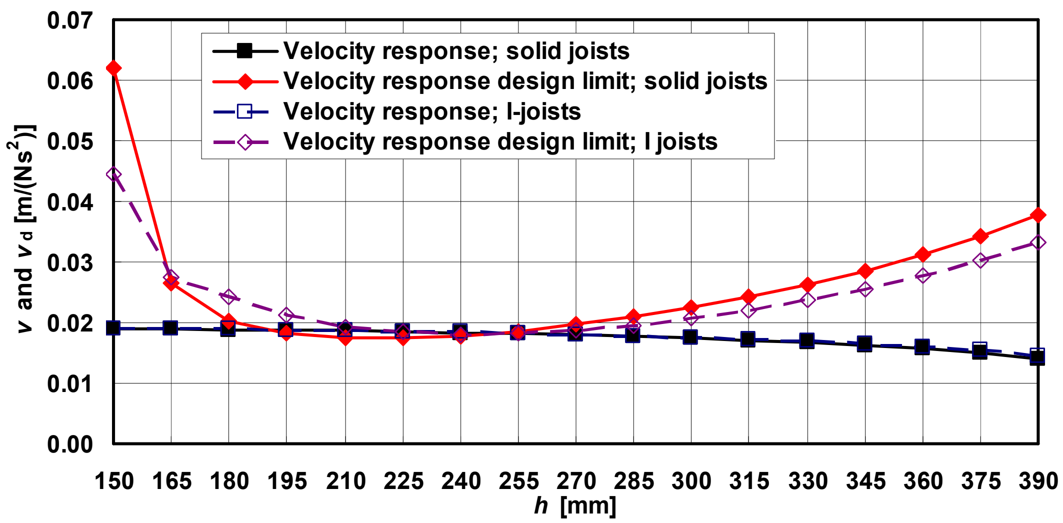


Figure 4: Unit impulse velocity response and the design limit for solid timber joists and I-joists with
varied *h*

It can be seen that the design limit, v_d, first sharply decreases until it reaches the minimum of 0.0174 mm/(Ns^2) corresponding to the height of 225 mm for the solid timber joists, and of 0.0181 mm/(Ns^2) corresponding to the height of 240 mm for the I-joists. Thereafter, the curve gradually increases. Since the velocity response only slightly decreases, there is a reject zone where the velocity response is higher than its design limit and the design requirement is not satisfied. This parametric study also reveals that the variation of v_d is uncertain with other parameters, e.g. the beam width.

3. DISCUSSION OF RESULTS

The effects of increasing the geometrical properties or the dead load on the fundamental natural frequency, the deflection under unit point load, the unit impulse velocity response and the design limit of unit impulse velocity response are shown in Table 1. The table is also valid for the effects of decreasing the geometrical properties or the dead load. Varying $E_{0,\mathrm{mean}}$, b, h or s will affect f_1, a and v in a similar way. A decrease of the floor span is favourable for f_1 and a, but unfavourable for v. An increase of $E_{0,mean,deck}$ or t will be favourable for a and v but unfavourable for f_1. Even though an increase in the mass per unit area is unfavourable for the frequency and irrelevant to the deflection, it is advantageous for the velocity response. The width of the floor only influences v.

Table 1: Variation of f_1, a, v and v_d with increasing individual parameters

Parameter \ Criteria	f_1	a	v	v_d
$E_{0,mean}$	+	+	+	±
$E_{0,mean,deck}$	/	+	+	- or /
B	+	+	+	±
H	+	+	+	±
T	/	+	+	- or /
S	-	-	-	±
L	-	-	+	±
M	-	/	+	-
B	/	/	-	/

Note: "+" = positive effect, "-" = negative effect, "±" = uncertain, "/ " = no effect.

The effects on the design value of the velocity response can be exactly contrary to those on f_1, a and v with regard to parametric changes. The increase of the beam height, for example, favourably affects the fundamental natural frequency and the deflection under unit point load but significantly lowers the design value for the unit impulse velocity response. Although the unit impulse velocity response is decreased, the requirement concerning the velocity response may not be fulfilled because of a higher decrease rate of the design limit (Figure 4). Hence, clear, distinct conclusions regarding the velocity response design limit cannot be drawn.

Comparison of the floors built with solid timber beams with those built with I-joists indicates that using solid timber beams is advantageous for the fundamental natural frequency and the deflection under unit point load since the vibrational performance of the floor corresponding to these two criteria is more satisfactory with the design limit criteria. As for the velocity response, there is little difference between the two types of construction. In practice, I-joists still stand great advantages for building large span floors.

4. CONCLUSIONS

The study to date has shown that it is difficult to make a general recommendation about a parameter change which can improve vibrational performance of a timber flooring system. This is due to the fact that no parameter change can have a definite positive or negative effect on all the serviceability criteria simultaneously. In particular, the design limit for the unit impulse velocity response is complex for evaluating whether a parameter change will be beneficial or not. Increasing the moduli of elasticity, the beam height and width, or the deck thickness will always positively affect the frequency, deflection and velocity. Increasing the spacing in general is unfavourable. Changes of the span length and the height of the beam have the largest impact on the frequency and deflection. The highest influence on the velocity is provided by adjusting the deck thickness, the mass and again the floor span. A change in the beam height only has a nominal effect on the velocity response.

The design values are important to fulfil the serviceability requirements and thus should be considered. The difficulty lies in that the design value of the velocity response, v_d, can be affected even more than v even though v is influenced in the same way as f_1 and a in several cases with regard to individual parameter changes. This may cause serviceability criteria not to be completely fulfilled.

This study also indicates that simple predictions may still not be possible for assessing the improvement of the serviceability behaviour of timber flooring systems, and more comprehensive and understandable formulations for the design limit of the unit impulse velocity response are needed. Extensive experimental investigations are required as well.

At present experimental investigations are being carried out at Napier on the vibrational behaviour of a series of timber floors prefabricated with engineered I-joists according to the existing design rules of EC5 and construction practices for the ultimate and serviceability limit states. Adjustments are made to the tested floors to enhance their vibrational performance, including adding blockings between joists, altering nail spacing and joist spacing, varying dead load, etc. Parameters to be measured include natural frequencies, damping ratios, mode shapes, deflections, velocity responses, accelerations, etc. Theoretical predictions and numerical simulations using FEM software will be compared with the measured data, so as to provide valuable guidance for existing construction practices of timber floors and to further make useful recommendations to the design codes with respect to serviceability design criteria.

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SHOT FIRED DOWEL FLITCH BEAMS

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Abstract: Flitch beams are a form of sandwich construction using steel and timber elements. They are used in the construction of domestic dwellings when relatively high loads and long spans predominate but available depth of section is restricted in some way. Traditional flitch beams use a bolted connection to hold the elements together, which is a time consuming method of fabrication requiring the pre-drilling of holes in the steel and timber elements. It also presents problems in design detailing. Bolt slippage and fabrication tolerances result in disproportionate stress transfer due to uneven strain affecting the stiffness and strength properties of the beam.

This paper details the findings from a series of laboratory tests and parametric studies on flitch beams constructed from either Kerto S Laminated Veneer Lumber (LVL) or C24 grade timber using a shot-fired dowel connection. The tests showed that during the elastic range proportional stress transfer took place. However, at higher load levels there is uneven stress transfer due to localised buckling of the steel in the top chord and a weakening of the timber elements of the beam due to splitting at the nailing points.

Keywords: composite beams, strength and stiffness, timber structures, connections.

1. INTRODUCTION

As far back as 1859 the advantages of Flitch Beams were being explored (Desai, 2003). Flitch beams consist of one or more pieces of flat steel plate sandwiched between two or more solid rectangular timbers which are bolted together at intervals along the length resulting in the creation of a steel-timber composite beam. The composite beam combines the benefits of timber construction (ease of working, readily available resource, simple connection of ancillary components) with the strength and stiffness of structural steelwork (Bainbridge, 2001) resulting in a timber composite option where relatively long spans and heavy loads predominate.

2. TRADITIONAL FLITCH BEAM FABRICATION

One of the disadvantages of traditional flitch beams is the bolted connection; which requires the pre-drilling of holes through the steel and timber elements and the subsequent bolting together of the beam. Not only is this method of fabrication time consuming but it also has implications on the design and detailing of the beam.

It is reported that laterally loaded timber joints constructed from bolts experience an initial slip as a result of the bolthole clearance whereby load transfer across the joint is only achieved once the bolt is brought into bearing contact with the wood (Davis, 2000). There is also a 'bedding in' stage where the initial load results in localised crushing of the cut wood surface.

Full composite action of a flitch beam is as a result of full stress transfer due to even strain of the beam elements. However, even strain may not take place in traditional flitch beams as there will be an initial slip δ on load application due to bolthole clearance (see Figure 1).

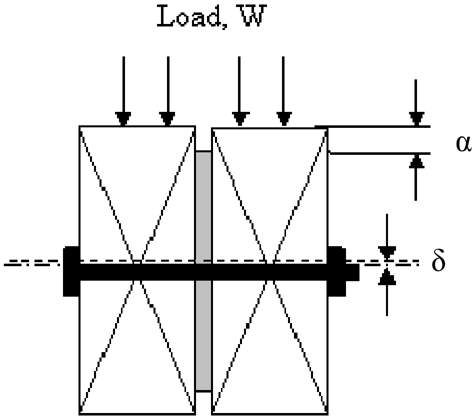

Figure 1: Traditional flitch connection

The initial slip will be determined by the bolthole clearance and quality of fabrication. Fabrication tolerances, such as misalignment of the boltholes, lack of straightness of the boltholes, variation in the bolthole diameter and the initial position of the bolts in the holes can further increase the variability in load distribution between fasteners (Blass, 1995)

To allow for fabrication tolerances, the steel plate element of the flitch beam will, in normal circumstance, not be the same height as the timber element but a distance α (normally of at least 10mm) will be allowed between the elements. This tolerance ensures that the steel does not stand proud of the timber elements which could occur due to poor fabrication or shrinkage of the timber, causing a problem when erected. However, a greater depth of steel would be desirable as it would improve the strength and stiffness properties of the beam.

For the design of composite beams designers often adopt the transform-section method. In traditional flitch beam fabrication, slippage, due to bolthole clearance and fabrication tolerances, may result in an uneven stress distribution due to disproportionate strain and consequentially a reduction in safe working load. Slippage can also add to the initial deflection at the on-set of loading. In most circumstances flitch beams are used for carrying loads over relatively long spans and as a result serviceability is often the limiting design criteria. A proposed improved connection method is the use of shot fired dowels which do not require the pre-drilling of holes and therefore reduce fabrication time and alleviate fabrication tolerances.

3. TESTING PROGRAM

For mass fabrication of shot fired dowel flitch beams it is important to optimise the number of fixings used so that production costs are kept to a minimum. Accordingly the laboratory testing programme examined the following options with regard to the use of shot fired dowels, beam elements and dowel patterns:

1. C24 grade timber or Kerto S LVL only.
2. C24 grade timber or Kerto S LVL and steel plate sandwich configuration clamped together with finger tightened screw clamps.
3. C24 grade timber or Kerto S LVL and steel plate sandwich configuration connected with shot fired dowels of varying patterns and densities.

Several test specimens were constructed each consisting of one length of 3mm thick grade 43 flat steel plate and two lengths of C24 grade timbers or Kerto S LVL. Each test specimen was a sandwich configuration comprising the three flitch elements with the steel plate being sandwiched between the two timber elements. An ITW Spit P200 gun was used to shot fire 3.6mm diameter 60mm long dowels through one timber element and the steel element, penetrating the second timber element to a depth of approximately 12mm or more depending on embedment depth in the first timber. This was done on alternate sides of the beam for the specified nailing requirement. Alternating the side of application ensures full fixity of both timber elements and means that dowels could be spaced in accordance with EC5 (BSI, 2004) guidance.

Testing of the flitch beams was carried-out over two effective spans of 1.8 metres (C24 grade timber and Kerto S LVL) and 2.1 metres (C24 grade timber only) and although these are relatively short spans the depth of section was scaled appropriately to be representative of longer spans. Testing beams with no nails was to demonstrate the method of stress transfer, whether it was via the connection or simply through load sharing as a result of the beam elements being the same height.

Initial designs to EC5 (BSI, 2004) stipulated that a minimum number of 5 nails would be sufficient to carry the maximum design shear force to be exerted on the test beams. The beams were to be loaded in excess of the maximum design loads, to ultimate failure, so nailing patterns were specified as follows, (see also Figure 2):

- No dowels, elements clamped together with finger tightened screw clamps.
- 5 dowels per side
- 8 dowels per side
- 13 dowels on one side and 14 on the other
- 18 dowels per side

4. TESTING METHOD AND RESULTS

The stiffness tests were performed in accordance with EN 408:1995. A minimum of three beams of each fixing method were tested with displacement measurements taken at incremental loading until failure occurred. The average test results of each dowel pattern were then plotted and in the case of C24 grade timber adjusted to account for variations in density (Figure 3).

From the average trend line the EI value for each beam of varying dowel pattern was calculated. The EI value was calculated over the elastic part of the curve at approximately 40% of the ultimate loads.

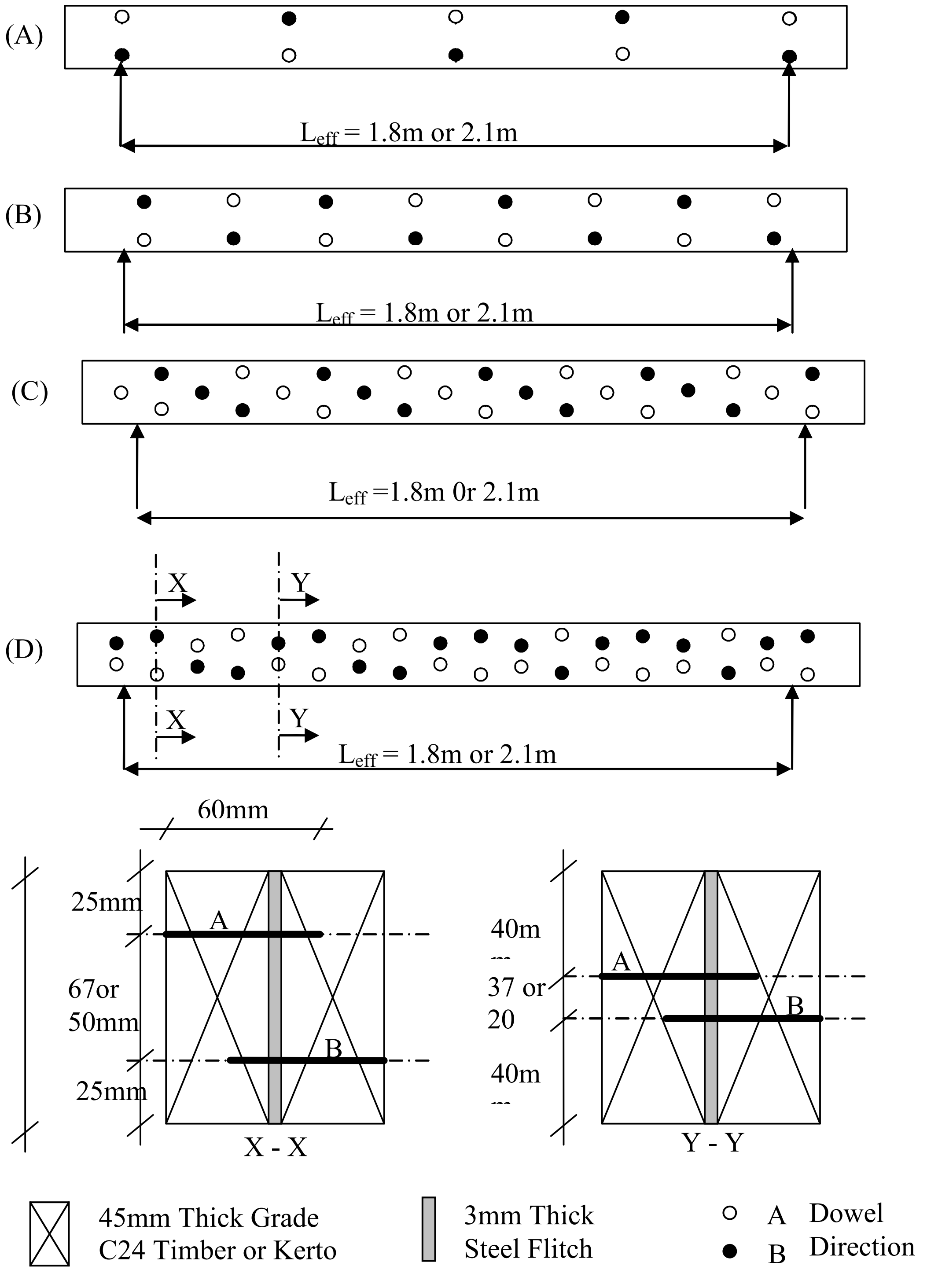

Figure 2: (A) 5 dowels per side; (B) 8 dowels per side; (C) 13 dowels on one side & 14 on the other and (D) 18 dowels per side

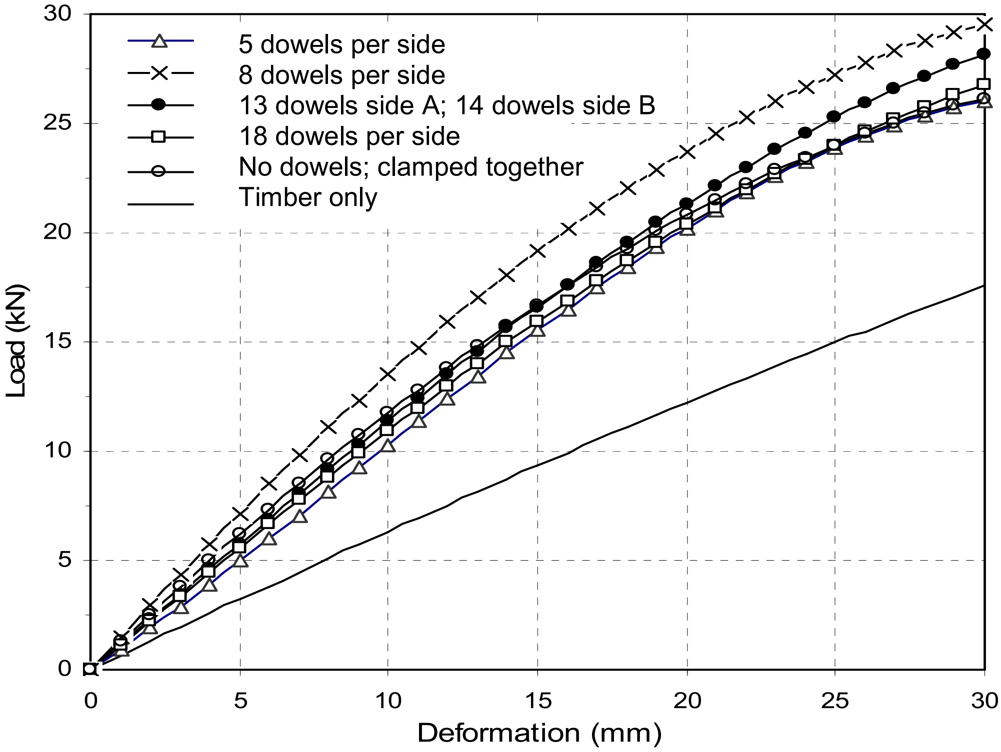

Figure 3: Grade C24 beams over 2.1m effective span load against deflection plots adjusted for density

Figure 4 shows the consistency in stiffness of flitch beams constructed using C24 timbers tested over a 1.8m span. This consistency was also demonstrated in the beams constructed from C24 tested over 2.1m and in beams constructed using Kerto S LVL tested over 1.8m. Deviations in the results can be credited to variations in timber material properties. What the results show is that the nailing pattern has little or no effect on the stiffness of the beam.

The recorded loads at failure were used to determine the bending strength of each flitch beam in accordance with EN 408:1995. The average bending moment carrying capacity for each beam type, segregated in accordance with the employed fixing method, was then calculated using the characteristic strength to allow for sample deviation. Figure 5 shows the variations in bending strength of the flitch beam types constructed using Kerto S LVL.

A consistency in results of the Kerto S LVL and C24 flitch beams was demonstrated taking into due consideration the variability in material properties. What the test results served to demonstrate was that no particular dowel pattern enhanced the bending moment carrying capacity, in fact it was noted during the testing programme that dowels can in some instances serve to weaken the timber elements of the beam by introducing points of weakness through splitting of the timber.

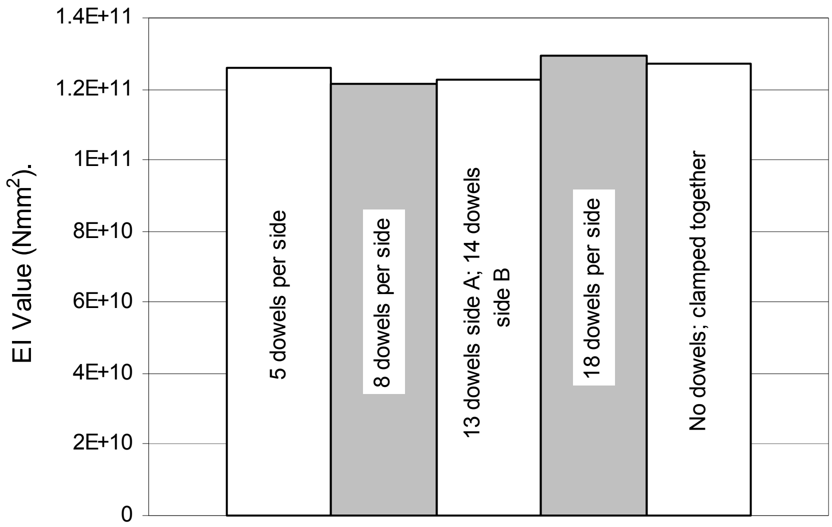

Figure 4: EI Value variations of C24 flitch beam over 1.8m effective span

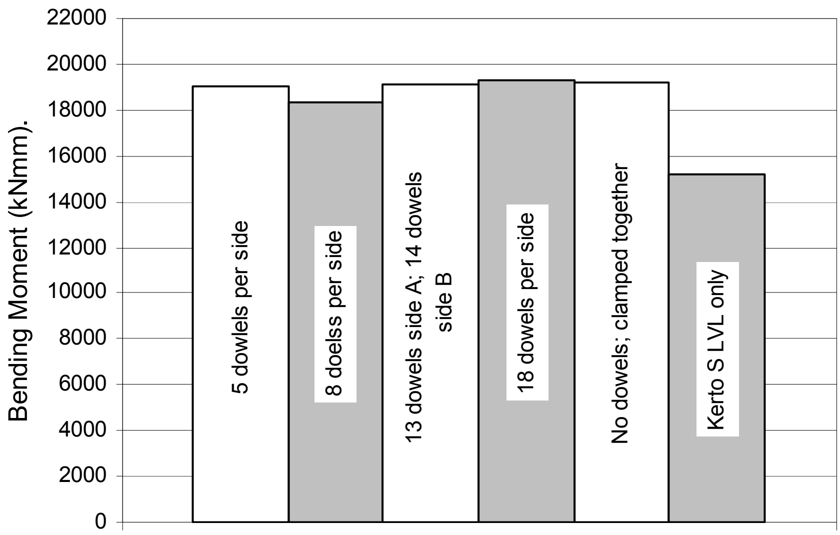

Figure 5: Bending moment capacity variations of Kerto S LVL flitch beam over 1.8m effective span

4. ANALYSIS & COMPARISON OF RESULTS

As expected the test results have confirmed that the stiffness and flexural strength of flitch beams, with the steel plate and timber being of the same depth and length, are relatively the same regardless of the dowel pattern. This is due to the fact that the elements of the flitch beams tested are forming a load sharing system whereby stress transfer occurs as a result of even strain.

Table1 shows the correlation in results between test out-put EI, for a particular fixing method and element configuration, and calculated EI values. Average test set specimen dimensions have been used to determine EI on each occasion.

Table 1: EI value comparison

Set	Test EI Values		Calculated EI Values		Mean Percentage Difference	Characteristic Percentage Difference
	Mean	Characteristic	Mean Properties	5th %'ile Properties		
	Nmm^2	Nmm^2	Nmm^2	Nmm^2		
Set 1	1.25E+11	1.07E+11	1.28E+11	1.03E+11	-2%	4%
Set 2	1.88E+11	1.60E+11	2.04E+11	1.64E+11	-9%	-2%
Set 3	1.33E+11	1.14E+11	1.53E+11	1.41E+11	-15%	-24%

Note:

- A negative percentage difference is as a result of the test results being less than the calculated result.

Set Reference:
Set 1 – C24 Flitch Beam Over 1.8m Effective Span (Dowel Only)
Set 2 – C24 Flitch Beam Over 2.1m Effective Span (Dowel Only)
Set 3 – LVL Flitch Beam Over 1.8m Effective Span (Dowel Only)

From the test results two columns of information are presented: the mean test values and the characteristic test values. To give a true comparison the mean test values have been compared with the EI values calculated using mean material properties and the characteristic test values have been compared with EI values calculated using 5^{th} percentile material properties.

Although a relatively good correlation between test results and calculated results is demonstrated by flitch beams constructed of C24 grade timber, the material properties used in calculations are in accordance with BS EN 338:2003 where the mean E value is $11000Nmm^{-2}$ this value is higher than the mean E value from the tested timber beams which was $9840Nmm^{-2}$. If the E value from the tested timber beams was used in the mean EI calculation for Set 2, then the percentage discrepancy would be of the order of +9% as opposed to -9%.

The correlation between calculated EI values and test EI values of flitch beams constructed using Kerto S LVL, are not as consistent as those of flitch beams constructed using C24 grade timbers and this is the converse as to what would be expected due to the higher degree of uniformity of Kerto S LVL. Although poorer correlation is demonstrated this is attributed to the fact that the Kerto S LVL E values used in calculating EI are from the manufacturers specification which states a mean E value of $13500Nmm^{-2}$ and 5^{th} percentile E value of $12000Nmm^{-2}$(Finnforest Building Systems, 2004), the mean E value from tests conducted on plain Kerto S LVL beams was $12350nmm^{-2}$.

If the mean test value of $12350Nmm^{-2}$ was used in the mean EI value calculation for Set 3, the percentage discrepancy in results would be of the order of +6% as opposed to -15%. It would be appropriate to compare the mean test EI results with the calculated EI results determined using mean property values when deciding upon the correlation because of the consistency of Kerto S LVL. It is, therefore, concluded that the correlation in results is good considering the variability of material.

It is also concluded that during elastic deformation of the flitch beam, full stress transfer is taking place as a result of load sharing through even strain because the elements of the beam are of the same height. With the above in mind a method of connection is still required to provide lateral restraint during service to prevent the slender steel element buckling out of plane and also to hold the beam elements together for ease of construction.

At high stress levels buckling of the steel plate results in uneven stress transfer which in turn results in a reduction of ultimate failure load. Table 2 contains the mean and the factored ultimate failure load of the tested beams for each fixing method. A factor is applied to allow for sample variation. Table 2 also contains the ultimate failure load calculated in accordance with EC5 (BSI, 2004).

The ratio of experimental load to calculated load shows that the ultimate failure load of the experimental beams constructed using shot-fired dowels are up to 16% lower. Experimental results will have a lower failure load mainly due to disproportionate stress transfer as a result of the steel buckling in the top chord due to compression. There may also be a further reduction of bending strength in flitch beams with a dowel fixing due to the intrusion of dowels cleaving apart the timber fibres creating points of weakness.

Table 2: Ultimate strength effectiveness of flitch beams

Set	Experimental		Calculated	Ratio of Experimental to Calculated
	Mean Ultimate	Characteristic Strength	Characteristic Strength	
	N	N	N	
Set 1	26071	19658	18590	1.06
Set 2	28696	24937	25350	0.98
Set 3	36451	31676	37720	0.84

Set Reference:
Set 1 – C24 Flitch Beam Over 1.8m Effective Span (Dowel Only)
Set 2 – C24 Flitch Beam Over 2.1m Effective Span (Dowel Only)
Set 3 – LVL Flitch Beam Over 1.8m Effective Span (Dowel Only)

5. CONCLUSIONS

Test results demonstrated that when the flitch beam elements are of the same height and length they act in load sharing even when they are not connected together. However, a method of connection is required so that the timber element can provide lateral restraint of the slender steel element to prolong the onset of buckling in the top chord and also to hold the beam elements together during construction.

The use of shot fired dowels provides an adequate connection for the elements of a flitch beam to act in a load sharing system. In design calculations, the designer should allow for a decrease in design strength to take account of the reduction in failure load arising from disproportionate stress transfer as a result of eventual lateral buckling of the steel and also from splitting of the timber due to the intrusion of the dowels. The number of dowels specified should be in accordance with the minimum shear requirement and spaced adequately to reduce splitting of the timber.

It can therefore be concluded that the use of shot fired dowels is a relatively quick and cost efficient method of fabrication and the structural properties of the beam are of a standard high enough to allow economic application.

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PARAMETRIC STUDY OF MULTI-WEBBED COMPOSITE TIMBER JOISTS

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Abstract: This research details structural performance of engineered multi-webbed composite timber joists of Double I, Box and Box I cross-sections in comparison with the commonly used I and solid timber joists. As part of a PhD research programme and the Proof of Concept (PoC) funded R&D work, the static and dynamic response of a series of composite timber beams were studied. This paper details results and findings of a parametric study, based on Eurocode 5 (EC5), carried out on a range of engineered composite timber beams. The beams varied form 150 to 500 mm in depth at 400 and 600 mm centres. Results of the study have shown that the serviceability, in general, is the controlling design criterion for typical UK timber flooring systems. Out of four different sub-criteria which are defined under serviceability conditions, deflection under unit point load is the governing criterion in most cases. Adopting the Option B of the UK National Annex results in a longer permissible span compared to the Option A.

Keywords: Composite timber beams, flooring system, serviceability, solid timber joist**.**

1. INTRODUCTION

Beams are primary structural members which are commonly used in flooring systems. In structural design to Eurocodes, two types of limit states are normally considered: ultimate limit states (ULS) and serviceability limit states (SLS). The ultimate limit states are associated with collapse and other similar forms of structural failure and concern the safety of people and the structure. These states include loss of equilibrium, failure due to rupture, fatigue or excessive deformation, instability, mechanism transformation and sudden system change for the structure or its parts. The serviceability limit states are associated with conditions of normal use and concern the functioning of the structure or structural members, comfort of people and appearance of the construction work. Most design codes provide safe design by setting up limits for both stress and deformation.

Along with the requirements for stresses, serviceability is a big concern for the design of a timber flooring system and requires considering both deformation and vibration. Vibration performance becomes significantly important in modern construction as lighter weight and longer spans are adopted for the flooring system. Walking and domestic machineries are normally the causes of vibration. BS 5268 only specifies the lesser of 14 mm and 0.3% of the span as the limit to control the deflection of the floor. Eurocode 5 (EC5) together with the UK National Annex requirements are more rigorous and limit both deflection and vibrational effects.

Based on EC5 and the UK National Annex, the structural performance of solid timber joists and multi-webbed engineered beams as members of a flooring system is studied in this paper. The permissible span as a unique parameter is investigated by varying geometric properties of the beams. This study has focused on one-way timber floors where beams are spanned in one direction and considered as simply supported, with a view to implement them in heavily loaded or longer spans.

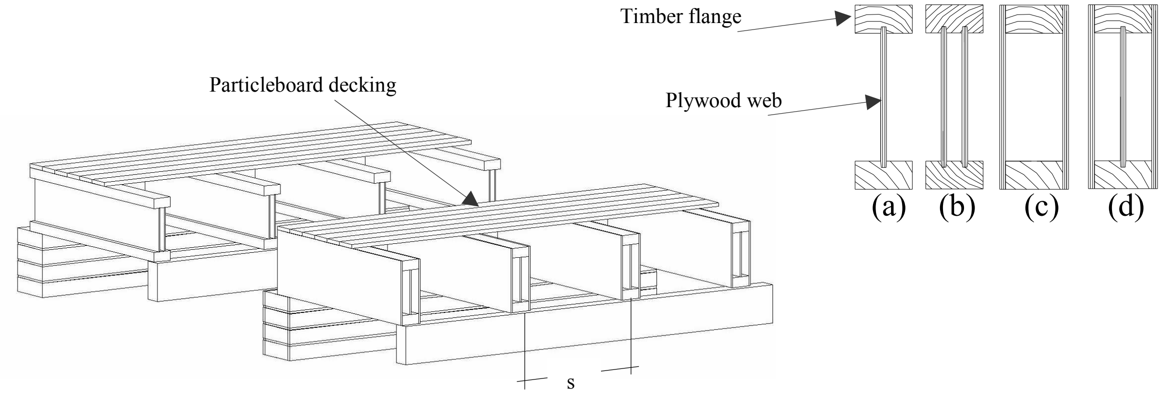


Figure1. Composite beams used in flooring systems
a: I-beam, b: Double I-beam, c: Box beam, d: Box I-beam

2. PARAMETRIC STUDY

2.1 Evaluating procedure

A series of parametric study is carried out on a timber floor system which is built from solid timber joists, I-beams, Double I-beams, Box beams and Box I-beams with particleboard decking. For each floor, the depth of joists is varied from 75 to 225 mm for solid timber joists and from 150 to 500 mm for engineered joists, with the spacing of 400 and 600 mm for both joists. Solid joists have a constant width of 50 mm while the engineered joists are made of timber flanges of 90mm wide, 45mm deep and 9 mm thick three-ply plywood as web.

Parametric study in this research is based on the requirements of EN 1995-1-1-2003 for solid timber joists and glued thin-webbed beams, together with the latest UK National Annex. Each profile covers two categories, namely ultimate limit states design (ULS) and serviceability limit states designs (SLS).

2.1.1 Ultimate limit states design (ULS)

Here, ten ULS criteria are adopted for I-beam, Double I-beam, Box beam and Box I-beam as:

1. Bending in compression and tension timber flanges ($B_{c/t,f}$)
2. Compression in timber flanges due to bending ($C_{b,f}$)
3. Tension in timber flanges due to bending ($T_{b,f}$)
4. Compression in plywood web due to bending ($C_{b,w}$)
5. Tension in plywood web due to bending ($T_{b,w}$)
6. Panel shear in plywood web (S_p)
7. Planar (rolling) shear in plywood web (S_p)
8. Lateral stability under bending (LS_b)
9. Compression perpendicular to the timber grain ($C_{\perp}$)

10. Compression parallel to the plywood grain ($C_{||}$).

Four ULS criteria are applied for solid timber joists as follows:

1. Bending in the timber joist (B)
2. Shear in the timber joist (S)
3. Compression perpendicular to the grain (bearing) ($C_{\perp}$)
4. Lateral stability of the timber joist subjected to bending (LS_b).

2.1.2 Serviceability limit state design

SLS includes two different categories, deflection and vibration. The limits for both deflection and vibrational parameters are based on the recommendations in EC5 and the corresponding UK National Annex.

For deflection, the net final deflection should satisfy the following equation as:

$$w_{\text{net,fin}} \leq L / 250 \qquad (1)$$

Where L is the floor span in mm.

For vibration, the UK National Annex proposes two Options, A and B, to assess the vibration in residential floors. Both options follow the similar procedures and the only difference lies in the suggested equations for calculating the following parameters:

- fundamental frequency, f_1
- deflection of floor under unit point load, a
- equivalent plate bending stiffness in the direction of span, EI_1.

This research considers both options for evaluating the vibration criteria.

For $f_1 > 8$ Hz, two conditions have to be satisfied. First, the deflection of timber floor under unit point load of 1 kN, a, should satisfy the following equation:

$$a = w / F \leq a_d \quad \text{mm/kN} \qquad (2)$$

where

w is the maximum instantaneous vertical deflection caused by a vertical concentrated static force F (1 kN) at any point on the floor, in mm

a_d is the design limit of the deflection under unit point load, in mm/kN.

For unit impulse velocity response v, the following equation should be satisfied:

$$v \leq v_d = b_f^{(f_1\xi - 1)} \quad \text{m/Ns}^2 \qquad (3)$$

where

v_d is the design limit of the unit impulse velocity response in m/Ns^2

b_f is a parameter for assessing v_d

ζ is the modal damping ratio and here $\varsigma = 0.01$.

As a result permissible span under SLS criteria is investigated within two categories (Deflection and vibration) which include 7 conditions as following:

Deflection 1. Static deflection (Δ)

Vibration

- **Option A**
  2. Natural frequency (f_1)
  3. Deflection of the timber floor under unit point load (a)
  4. Unit impulse velocity response (v)
- **Option B**
  5. Natural frequency (f_1')
  6. Deflection of the timber floor under unit point load (a')
  7. Unit impulse velocity response (v')

2.2 Permanent load (dead load) and imposed load

Dead or permanent load (G), excluding the joist, is assumed as 0.50 kN/m^2 for intermediate floor with 60 minute fire resistance (Eurocode design aid I, 1994). Imposed or live load (Q) is considered for normal construction which should not exceed 1.5 kN/m^2 (BRE Building Elements, 2003).

2.3 Assumptions

The following assumptions are made for this parametric study:

1. No allowances are included in the calculations for partition load;
2. Lateral displacement of compressive flange is effectively restrained by the floor deck and torsional rotation is prevented at the supports so the lateral buckling factor $k_{\mathrm{crit}} = 1$ (BS EN 1995-1-1)
3. Bearing length is kept as 100 mm for all cases;
4. Weight of the joist for each profile is added to the permanent load.

2.4 Characteristic values

The characteristic values of the material properties used in this study for solid timber and engineered products are based on the published codes of practice listed below.

Solid timber joists

The characteristic values of the material properties for C16 solid timber are taken form BS EN 338:2003.

Component of engineered joists

The characteristic values of C16 timber flanges, F11 plywood webs and P5 particleboards for decking are obtained form BS EN 338:2003, NZS 3603:1993 and EN 12369-1:2001, respectively.

3. RESULTS AND DISCUSSION

3.1 Results

Sample permissible span values for Box I-beams and solid timber joists with 400 mm spacing are listed in Tables 1 and 2 while the spans for all the profiles studied are presented in Figs. 2 and 3. In Table 1 and Fig. 2, the permissible spans for engineered joists under ULS criteria correspond to conditions 1 to 10, while those under SLS criteria to conditions 11 to 17. Similarly, Table 2 and Fig. 3 show the permissible spans for solid timber joists under ULS criteria correspond to conditions 1 to 4 and those under SLS correspond to conditions 5 to 11.

It can be seen that in Table 1, panel shear (S_P), and compression parallel to the grain ($C_{\parallel}$) and perpendicular to the grain ($C_{\perp}$) are not critical. The results for lateral stability (LS_b) are similar to those under condition 1 since k_{crit} is taken as 1. Similarly, shear and compression are not critical for solid timber joists (Table 2).

Under serviceability conditions, except the shallow engineered joists (150 and 200 mm), the permissible spans from the unit impulse velocity criterion are similar to those from the natural frequency criterion. This is because in Eq. (3) for calculating the velocity v, if the natural frequency is below 8 Hz then the equation will be violated. In other words, a natural frequency of 8 Hz is regarded as a lower limit for unit impulse velocity. As shown in Fig. 2, however, the permissible spans for the beam height of 150 and 200 mm based on the unit impulse velocity criterion (Condition 17) are lower than those under the natural frequency criterion (Condition 15).

3.2 Critical criteria under ULS conditions

For I-beams, rolling shear (Condition 7) is the controlling criterion. This can be improved by increasing the grooving depth so as to increase the glued area and enhance the rolling shear capacity. For the Double I-beams with the depth up to 300 mm, flange tension due to bending (Condition 3) is the controlling criterion. When the beam height is greater than 350 mm, web tension induced by bending (Condition 5) becomes dominant. Rolling shear will no longer be the controlling criterion since the glued area is doubled compared to I-beams.

Web tension induced by the bending moment (Condition 5) is critical for Box beams and Box I-beams. Compared to the Double I-beams, the side webs of the Box beams and Box I-beams have a larger overall depth and hence web tension becomes the controlling criteria.

For solid timber joists, bending is always the critical criterion under ULS condition and shear will not be decisive as the first moment of area is significantly higher than the engineered joists.

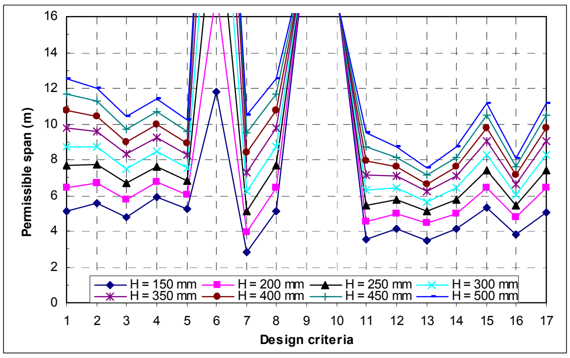
Table 1. Permissible spans for Box I-beams (s = 400 mm, G = 0.5 kN/m^2 and Q = 1.5 kN/m^2)

Profile	**Ultimate limit states (ULS)**										**Serviceability limit states (SLS)**									
												Vibration								
											Defl.	**Option A**			**Option B**			**Improv. for B**		
Condition	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**15 vs. 12**	**16 vs. 13**	**17 vs. 14**
$B_f \times H$	$B_{c/t,f}$	$C_{b,f}$	$T_{b,f}$	$C_{b,w}$	$T_{b,w}$	S_P	S_R	LS_b	$C_{\perp}$	$C_{\parallel}$	Δ	f_1	a	v	f_1'	a'	v'			
(mm)	**(m)**	**(m)**	**(m)**	**(m)**	**(m)**	**(m)**	**(m)**	**(m)**	**(m)**	**(m)**	**(m)**	**(m)**	**(m)**	**(m)**	**(m)**	**(m)**	**(m)**	**(%)**	**(%)**	**(%)**
90 × 150	5.70	6.25	5.40	4.80	4.30	11.65	14.95	5.70	19.65	51.00	3.90	4.35	**3.75**	4.35	5.55	4.15	5.50	29	7	19
90 × 200	7.30	7.60	6.55	6.15	5.50	17.05	20.60	7.30	19.50	50.65	5.05	5.25	**4.75**	5.25	6.75	5.10	6.75	28	6	28
90 × 250	8.75	8.85	7.65	7.40	6.60	22.40	26.10	8.75	19.40	50.30	6.10	6.05	**5.45**	6.05	7.75	5.85	7.75	29	5	29
90 × 300	10.15	10.05	8.70	8.55	7.65	27.70	31.40	10.15	19.25	49.95	7.15	6.80	**6.10**	6.80	8.70	6.55	8.70	28	5	28
90 × 350	11.40	11.20	9.65	9.65	8.60	32.90	36.55	11.40	19.10	49.55	8.15	7.45	**6.70**	7.45	9.55	7.20	9.55	28	5	28
90 × 400	12.65	12.30	10.60	10.70	9.55	38.00	41.50	12.65	19.00	49.25	9.10	8.10	**7.25**	8.10	10.40	7.80	10.33	29	4	29
90 × 450	13.85	13.35	11.55	11.70	10.45	37.70	46.30	13.85	18.85	48.90	10.05	8.70	**7.80**	8.70	11.15	8.35	11.15	29	4	29
90 × 500	15.00	14.40	12.45	12.65	11.35	36.95	51.00	15.00	18.70	48.55	11.00	9.25	**8.35**	9.25	11.85	8.90	11.85	28	5	28

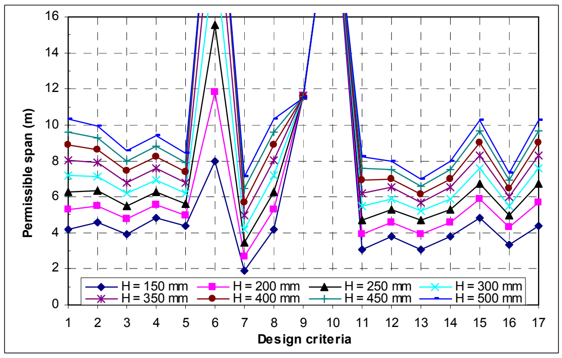
Note: B_f is the flange width; H is the beam height.

Table 2. Permissible spans for solid timber joists (s = 400 mm, G = 0.5 kN/m^2 *and* Q = 1.5 kN/m^2)

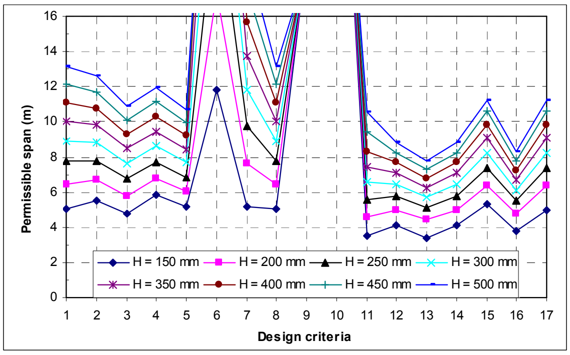
Profile	**Ultimate limit states (ULS)**				**Serviceability limit states (SLS)**									
					Defl.	**Vibration**								
						Option A			**Option B**			**Improvement for Option B**		
Condition	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**9 vs. 6**	**10 vs. 7**	**11 vs. 8**
$B_f \times H$	**B**	**S**	$\mathbf{C_\perp}$	$\mathbf{LS_b}$	Δ	f_1	a	v	f_1'	a'	v'			
(mm)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(%)	(%)	(%)
50 × 75	1.85	4.65	23.95	1.85	1.50	2.20	**1.45**	2.20	2.85	1.55	2.10	30	7	-5
50 × 100	2.40	6.15	24.25	2.40	2.05	2.75	**1.95**	2.75	3.50	2.10	2.80	27	8	2
50 × 125	2.95	7.65	24.55	2.95	2.55	3.20	**2.45**	3.20	4.15	2.65	3.50	30	8	9
50 × 150	3.45	9.10	24.85	3.45	3.05	3.70	**2.95**	3.70	4.75	3.15	4.20	28	7	14
50 × 175	4.05	10.55	25.10	4.05	3.55	4.10	**3.45**	4.10	5.30	3.65	4.90	29	6	20
50 × 200	4.60	12.00	25.40	4.60	4.05	4.55	**3.95**	4.55	5.80	4.25	5.80	27	8	27
50 × 225	5.15	13.40	25.70	5.15	4.50	4.95	**4.45**	4.95	6.30	4.70	6.30	27	6	27
75 × 200	5.55	17.55	37.15	5.55	4.55	4.95	**4.50**	4.95	6.30	4.75	6.30	27	6	27
75 × 225	6.25	19.55	37.45	6.25	5.15	5.35	**4.90**	5.35	6.85	5.15	6.85	28	5	28



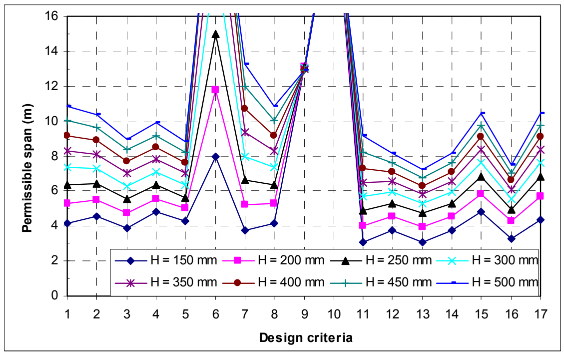
a) I-beams at s = 400 mm



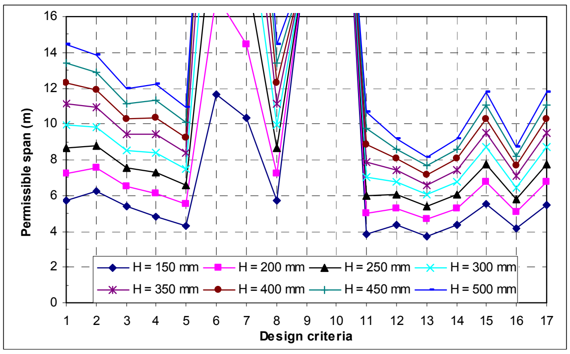
b) I-beams at s = 600 mm



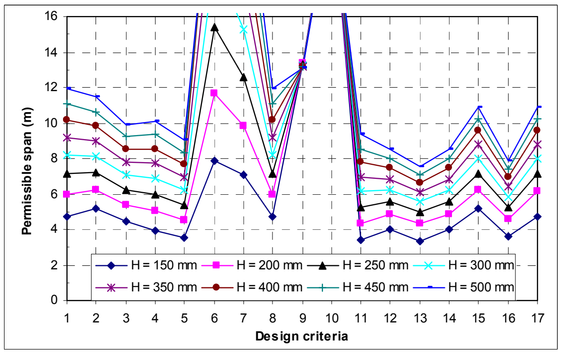
c) Double I-beams at s = 400 mm



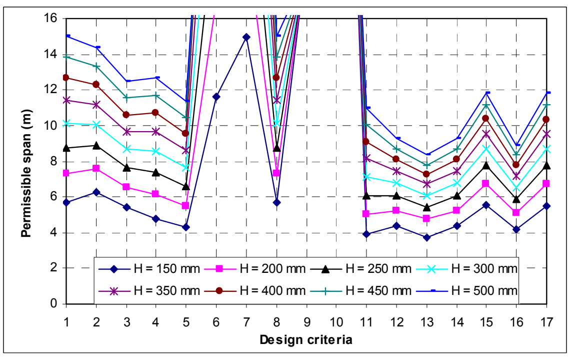
d) Double I-beams at s = 600 mm



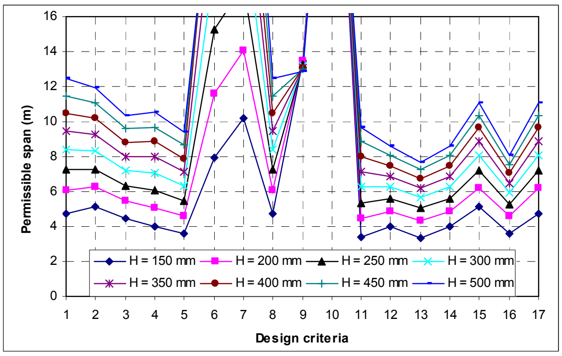
e) Box beams at s = 400 mm



f) Box beams at s = 600 mm

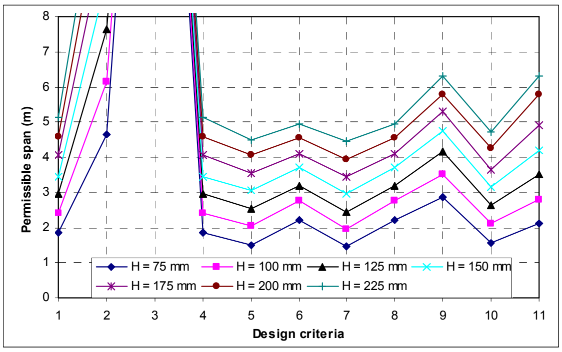


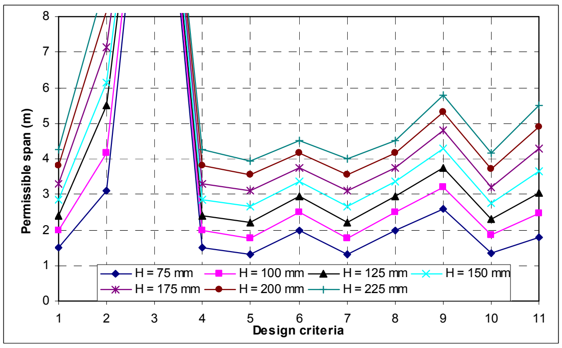
g) Box I-beams at s = 400 mm



h) Box I-beams at s = 600 mm

Figure 2. Permissible spans for various engineered joists based on different design criteria





a) Solid timber joists at s = 400 mm

b) Solid timber joists at s = 600 mm

Figure 3. Permissible spans for solid timber joists based on different design criteria

3.3 Critical criteria under SLS conditions

Static deflection and vibration categories are investigated under SLS. For both engineered and solid beams, the deflection under unit point load for Option A is the controlling criterion for the spacing of 400 mm. For solid timber joists with the spacing of 600 mm, static deflection becomes critical. Permissible spans for solid timber joists with 600 mm calculated to EC5 are lower than the values recommended by NHBC.

3.4 Design criteria for determining the permissible span

Table 3 shows the design permissible spans which satisfy both the ULS and SLS requirements. Controlling criteria for each case are shown in bracket. As demonstrated, permissible spans for the engineered joists except I-beams are governed by the unit point deflection criteria. For I-beams, permissible spans are controlled by rolling shear with the depth of 150 and 250 mm and the spacing of 400 mm, while the unit point load deflection becomes the controlling criterion for the height over 300 mm. For the spacing of 600 mm, permissible spans are governed by rolling shear.

Similarly, permissible spans of solid timber joists with the spacing of 400 mm are governed by the unit point deflection but for the spacing of 600 mm the static deflection governs.

3.5 Influence of Options A and B on the permissible span

Using the equations given for Option B will increase the values of natural frequency f_1 and the design limit of unit impulse velocity v_d , and lower the deflection under unit point load, a, and the unit impulse velocity response v. This in turn leads to the increase of the permissible span by 28% to the natural frequency and unit impulse velocity criteria and by 4 to 7% to the deflection under unit point load.

It is shown that except I-beams, the permissible span of engineered joists with the spacing of 400 mm increases by 7% if Option B is adopted while an increase of 4% can be achieved for the spacing of 600 mm. An increase of 3% can be found for solid timber joists with the spacing of 400 mm. Comparison of the permissible spans of solid timber joists calculated to EC5 with those recommended in BS 5268-7.1 shows that

EC5 method results in shorter span than the BS one. Using Option B will increase the effective span of I-beams by 4% for the spacing of 400 mm but has no effect for the spacing of 600 mm.

In general, increasing the permissible span reduces the cost and in turn benefits construction industries.

Table 3. Design permissible span table for different profiles

a) Engineered joists for s = 400 and 600 mm

Profile	**Option A**				**Option B**				**Option B vs. Option A**			
B_f×H	**I-beam**	**Double I-beam**	**Box beam**	**Box I-beam**	**I-beam**	**Double I-beam**	**Box beam**	**Box I-beam**	**I-beam**	**Double I-beam**	**Box beam**	**Box I-beam**
(mm)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(%)	(%)	(%)	(%)
***s* = 400 mm**												
90×150	2.80(S_R)	3.40(a)	3.70(a)	3.75(a)	2.80(S_R)	3.55(Δ)	3.85(Δ)	3.90(Δ)	0	4	4	4
90×200	3.95(S_R)	4.45(a)	4.70(a)	4.75(a)	3.95(S_R)	4.60(Δ)	5.00(Δ)	5.05(Δ)	0	3	6	6
90×250	5.10(S_R)	5.10(a)	5.40(a)	5.45(a)	5.10(S_R)	5.50(a')	5.80(a')	5.85(a')	0	8	7	7
90×300	5.65(a)	5.70(a)	6.05(a)	6.10(a)	6.05(a')	6.10(a')	6.45(a')	6.55(a')	7	8	7	7
90×350	6.20(a)	6.25(a)	6.60(a)	6.70(a)	6.60(a')	6.70(a')	7.10(a')	7.20(a')	6	7	8	7
90×400	6.65(a)	6.80(a)	7.15(a)	7.25(a)	7.15(a')	7.25(a')	7.65(a')	7.80(a')	8	7	7	8
90×450	7.15(a)	7.30(a)	7.65(a)	7.80(a)	7.60(a')	7.80(a')	8.20(a')	8.35(a')	6	7	7	7
90×500	7.55(a)	7.80(a)	8.15(a)	8.35(a)	8.05(a')	8.30(a')	8.70(a')	8.90(a')	7	6	7	7
								Ave	**4**	**6**	**7**	**7**
***s* = 600 mm**												
90×150	1.90(S_R)	3.05(a)	3.35(a)	3.35(a)	1.90(S_R)	3.10(Δ)	3.40(Δ)	3.40(Δ)	0	2	1	1
90×200	2.65(S_R)	3.95(a)	4.30(a)	4.35(a)	2.65(S_R)	4.05(Δ)	4.35(Δ)	4.45(Δ)	0	3	1	2
90×250	3.45(S_R)	4.75(a)	5.00(a)	5.05(a)	3.45(S_R)	4.90(Δ)	5.25(a')	5.30(a')	0	3	5	5
90×300	4.20(S_R)	5.30(a)	5.60(a)	5.65(a)	4.20(S_R)	5.55(a')	5.85(a')	5.95(a')	0	5	4	5
90×350	4.95(S_R)	5.80(a)	6.10(a)	6.20(a)	4.95(S_R)	6.10(a')	6.40(a')	6.50(a')	0	5	5	5
90×400	5.70(S_R)	6.30(a)	6.60(a)	6.75(a)	5.70(S_R)	6.60(a')	6.95(a')	7.05(a')	0	5	5	4
90×450	6.45(S_R)	6.75(a)	7.10(a)	7.25(a)	6.45(S_R)	7.05(a')	7.40(a')	7.55(a')	0	4	4	4
90×500	7.15(S_R)	7.20(a)	7.55(a)	7.70(a)	7.15(S_R)	7.50(a')	7.90(a')	8.05(a')	0	4	5	5
								Ave	**0**	**4**	**4**	**4**

b) Solid timber joists for s = 400 and 600 mm

	***s* = 400 mm**			***s* = 600 mm**		
B_f×H	**Option A**	**Option B**	**Option B vs. Option A**	**Option A**	**Option B**	**Option B vs. Option A**
(mm)	(m)	(m)	(%)	(m)	(m)	(%)
50×75	1.45(a)	1.50(Δ)	3	1.30(Δ)	1.30(Δ)	0
50×100	1.95(a)	2.05(Δ)	5	1.75(Δ)	1.75(Δ)	0
50×125	2.45(a)	2.55(Δ)	4	2.20(Δ)	2.20(Δ)	0
50×150	2.95(a)	3.05(Δ)	3	2.65(Δ)	2.65(Δ)	0
50×175	3.45(a)	3.55(Δ)	3	3.10(Δ)	3.10(Δ)	0
50×200	3.95(a)	4.05(Δ)	3	3.55(Δ)	3.55(Δ)	0
50×225	4.45(a)	4.50(Δ)	1	3.95(Δ)	3.95(Δ)	0
		Ave	**3**		**Ave**	**0**

4. CONCLUSIONS

Deflection of the floor under unit point load under serviceability limit states is governing the permissible spans of the Double I-beams, Box beams and Box I-beams.

Rolling shear is the controlling criterion for shallow I-beams with the spacing of 400 mm even though with the increasing beam depth the unit point load deflection becomes more critical for the remaining beams. Meanwhile rolling shear remains the controlling criterion for the I-beams with the spacing of 600 mm.

Using Option B form the UK National Annex leads to a less conservative limit for the unit point load deflection, which in turn results in enhancing the permissible spans governed by this criterion. Compared with Option A, the permissible span of engineered joist rises by 7 % for the spacing of 400 mm and 4 % for the spacing of 600 mm. Using Option B for solid timber joists with the spacing of 400 mm will shift the controlling criteria from deflection under unit point load to static deflection, which in turn increases the permissible span by 3% on average.

EC5 method results in shorter permissible span in comparison to those given by BS 5269-7.1.

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A REVIEW OF LASER TECHNIQUE APPLICATION IN CLEANING PROCESS OF POROUS CONSTRUCTION MATERIALS

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Abstract: This paper describes the review of laser cleaning methods for porous construction materials. The effects of laser radiation on substrate and the factors affecting the efficiency of graffiti removal are discussed. The laser cleaning (more precisely a degree of removability) depends on a large number of factors including surface roughness, porosity, cavity, moisture content, chemical/physical properties and thickness of graffiti, colour of graffiti, laser parameters such as energy, wavelength, duration and number of pulses, scanning speed (for continuous wave) and others. The most notable lasers already in use for laser cleaning are CO_2 laser, Nd:YAG laser, high power diode laser and a number of excimer laser systems. They have different properties and offer different advantages in practical applications. For example, excimer lasers can be used to remove varnish and unwanted paint layers successfully. Nd:YAG laser, which emits light of the wavelength of 1064 nm, can remove more material per pulse. On the other hand, high power diode laser is easy to use. Pop-out, cracking, cratering and/or glazing may occur in the case of laser cleaning, because substrate rapidly reaches high temperature when laser and substrate interact with each other. These problems are presented and discussed in this paper together with the advantages and disadvantages of these methods.

Keywords: cavity, graffiti, Laser cleaning, porous construction materials, surface roughness

1. INTRODUCTION

Over the last couple of decades graffiti has become a great problem particularly in the large agglomerations. It appears almost everywhere - on the external walls of buildings, girders and piers of bridges, underground passages, facilities in parks and roads. About 80% of graffiti is written with paint and marking pens on large walls, very often on historical objects (Matsui 2002). A considerable amount of money and time are spent annually on removing graffiti, City Councils have now begun to enforce regulations for keeping streets clean. According to these regulations, not only the person who wrote the graffiti is responsible for damage, but also the owner of the building on which the graffiti was written and unattended for a prolonged period of time. The traditional cleaning techniques are based on the use of a scalpel, abrasive dust, stream of fluid, or chemical agents. They may lead to the serious damage of the deeper layers of substrate.

Laser (Light Amplification by Simulated Emission of Radiation) cleaning is a good solution for removal of graffiti from surfaces, because the laser beam has unique characteristics than normal light, such as a single wave length (monochromaticity), is extremely parallel, it produces high power per unit area, coherence and it is highly directional. Furthermore, the laser cleaning process itself has several advantages, such as no mechanical contact, selectivity, localised action, no introduction of foreign contamination, less waste, flexibility, reliability and immediate feedback. However, laser cleaning process has some disadvantages as well, for example the capital cost is high and the laser cleaning should be done by the specialised/trained workers.

Although the method has been commercialised, there are no records of the comprehensive analysis of geometrical microstructure of cementitious composites and their effects on cleaning process. Highly developed surfaces of cement-based materials significantly complicate the mechanism of interaction between laser beam radiation and a base material. Even though it has been previously mentioned, no systematic approach has been adopted in analysing the process. It is also believed that some of the hydration products of Portland cement may be to some extent affected by a sudden increase in temperature. The presence of water in pore system adds even further complication to the process. This paper is a part of the larger project and aims to address only selected aspects of the laser cleaning. Special attention is paid to the effects of lasers and the geometrical microstructure of the cementitious composites.

2. EFFECTS OF LASERS

The selection of appropriate laser is the important role in the laser cleaning process. There are several parameters that should be considered for laser cleaning such as energy, wavelength, pulse duration and number of pulses, scanning speed (for continuous wave) etc. There are different types of lasers that can be used for laser cleaning such as CO_2 laser, Nd:YAG laser, high power diode laser and a number of excimer laser systems. The laser cleaning can occur photothermally, photochemically or both. In the photothermal process, the graffiti is removed by vaporization and it normally happens when the laser cleaning is done in the range of visible and infrared wavelengths. In the case of photochemical process, breaking of direct covalent bond of graffiti occurs. It happens when the laser cleaning is done in the range of ultraviolet wavelength (Cooper 1998).

2.1 Beam intensity

Beam intensity is the crucial parameter in laser cleaning process. If it is not correctly selected, it may damage the substrate. The beam intensity and their effects on the substrate and the graffiti are presented in figure 1 below:

Beam intensity	Increasing →			
Effects on the graffiti and substrate	No damage to material	Local damage and ablation of surface material	Melting	Ablation of material by 'explosive vaporization'
Temperature rise	Increasing →			

Figure 1: Effects of power density of Q-switched laser radiation (visible and infrared wavelengths) on the paint and the substrate (Cooper 1998)

The removal time of graffiti also changes according to the beam intensity. Following equation shows the relationship between paint removal time and beam intensity:

$$\Delta t = CI^{-n} \tag{1}$$

Where, Δt (sec) is the total irradiation time, I (W/cm^2) is the beam intensity and C and n are the positive constants for particular type of laser, paint thickness, paint colour and paint type (Liu 1995).

2.2 Wavelength of laser vs. colour of graffiti

The selection of wavelength of cleaning laser depends on the colour of graffiti and the type of graffiti. When wavelength of graffiti colour is similar to the wavelength of cleaning laser, absorption is low. Thus the wavelength of cleaning laser should not be same as wavelength of graffiti colour. Generally shorter wavelength is better than the longer wavelength because absorption coefficient decreases bit by bit when the wavelength of laser increases. Shorter wavelength (third harmonic) of Nd:YAG is much better than longer wavelength (fundamental wavelength) of Nd:YAG (Liu 1995, Costel 2003). The wavelengths of each laser types are given below (see Figure 2).

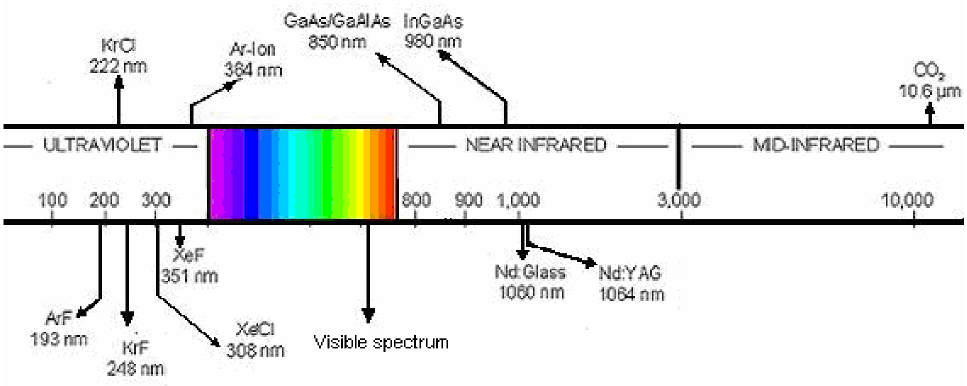

Figure 2: Wavelength of the lasers

2.3 Beam Area

Beam size is one of the factors that influence cleaning efficiency and time of cleaning. Relationship between the total area of paint removable and the beam area can be shown by the following equation:

$$A_T = \frac{1}{C}\left(\frac{E_0^{\,n}}{\delta t_p^{\,n-1}}\right) A_b^{\,1-n} \tag{2}$$

Where, A_T is the total area of paint that can be removed, A_b is the beam area, E_0 is the total laser energy and δt_p is the pulse width. Assuming that pulse width (δt_p) can be scanned over a paint sample (Liu 1995). A smaller beam size is normally good for laser cleaning process, because of the high removal rate and the less cleaning time. However, if the laser beam area is too small, it may damage the surface. Thus the beam size should be selected carefully.

2.4 Pulse duration

Pulse duration is the time it takes for the laser to emit one pulse (see figure 3). In the case of long-pulse lasers and continuous lasers, the removal of paint is done by vaporization. At the same time, ablation of paint material occurs in the case of high power short-pulse lasers, by acoustic shock waves created by the absorption of high-intensity laser energy (Liu 1995). A higher removal rate can be achieved in the case of short pulses for a fixed amount of laser energy.

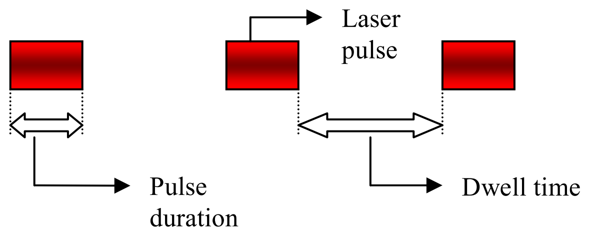

Figure 3: Illustration of laser pulses

If the pulse duration is too short, the cleaning is not efficient, at the same time if pulse duration is too long, substrate is affected by heat. Thus appropriate pulse duration should be selected (Crivella).

2.5 Pulse repetition rate

Pulse repetition is the number of pulses per second. If dwell time is too short (see figure 3), the dust from the graffiti and the laser pulse interfere with each other. Hence the laser pulses do not reach the target (see figure 4). If the pulse repetition rate is too long, the cleaning takes more time. Therefore pulse repetition rate should be selected as appropriate (Crivella).

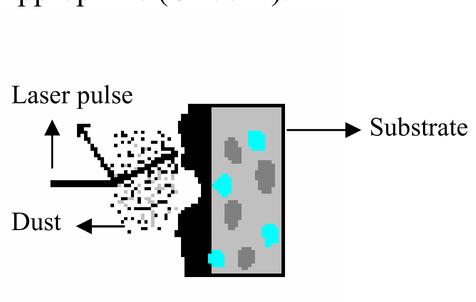

Figure 4: Laser and dust from the graffiti interaction

2.6 Number of pulses and scanning speed

Generally numbers of pulses are decided base on the thickness of the graffiti. If the thickness is high, the number of pulses required for cleaning graffiti is high for a given fluence. The relationship between number of pulses required for removing paint, pulse width and fluence is given by following equation:

$$t_b = N\delta t_p \tag{3}$$

$$I_b \delta t_p = F \tag{4}$$

$$N = C(\delta t_p)^{n-1}(F^{-n}) \tag{5}$$

Where, N is the number of pulses, t_b is the irradiation time required for removal of paint from the beam area (A_b) and F is the fluence (Liu 1995). When fluence increases the number of pulses required for cleaning decrease. Thus the time required for laser cleaning become less if the fluence of laser is high. However, the irradiation with low fluence with large number of pluses is better because it does not damage the surface (Matsui 2002). In the case of continuous laser, the scanning speed influences the efficiency of the laser cleaning process and the time of cleaning. Under high speed and low speed scanning by laser, the surface might not be cleaned and get damage respectively. Therefore scanning speed should be selected as appropriate.

2.7 Angle of incidence of the laser beam

There are two different way of laser cleaning other than conventional perpendicular laser cleaning, i.e. angular laser cleaning and shock laser cleaning. The angular laser cleaning means that laser is applied at a glancing angle, and the shock laser cleaning means that plasma shock wave is produced by breakdown of air near the cleaning surface; because of the high power pulse laser is used for cleaning, where the laser beam is parallel and close to the surface. These two methods have several advantages over the conventional perpendicular laser cleaning, such as cleaning area is high for same laser input energy, cleaning speed is high, cleaning threshold fluence is less and the risk of damaging the surface is less (Watkins 2003).

3. EFFECTS OF GRAFFITI

Basically, the type of graffiti to be cleaned influences the selection of laser parameter for cleaning. There are different types of graffiti materials such as spray paints, marking pens, lipsticks, adhesive label and physical scratching of surface. Each graffiti material has unique colour, thickness, physical properties and chemical properties. These factors affect the laser cleaning process.

3.1 Graffiti thickness

The thickness of graffiti mainly influences the cleaning time. More time is needed for thick graffiti. The relationship between removal depth by photothermal process and other parameters is given by the following equation:

$$H_V = \frac{\Delta t A P_d}{\rho\left(CT_v + L_f + L_v\right)} \tag{6}$$

Where, Δt (sec) is the beam/material interaction time, A is the material absorptivity, P_d (W/cm^2) is the laser power density, H_v (cm) is the depth of vaporisation, ρ (g/cm^3) is the materials density ,C (J/gK) is the specific heat of material, T_V (^{o}C) is the vaporisation temperature, L_f (J/g) is the latent heat of fusion, L_v (J/g) is the latent heat of vaporisation. The assumptions are the thermal losses by conduction and glazing of the remaining surface are neglected. In the case of cementitious materials and bricks, thermal conduction is low. Therefore the above assumptions are justifiable (Li 1994).

$$H_P = \frac{1}{\alpha} \ln \frac{F}{F_T} \tag{7}$$

Where, H_P (cm) is the removal depth per pulse by photochemical process, F (Jcm^{-2}) is the incident fluence, F_T (Jcm^{-2}) is the threshold fluence and α is the extinction (Schmidt 2003). In the above two processes, the removal time is influenced by the paint thickness.

3.2 Chemical/physical properties of paint

The chemical and physical properties of paint influence the selection of laser parameters for laser cleaning. In the case of photochemical ablation, laser cleaning is done by direct bond breaking. The energy should be fair enough to break the covalent bond of paints (see table 1). The photothermal ablation happens by vaporization. Therefore laser should provide enough energy to increase the temperature of the paint to evaporate (Cooper 1998).

Table 1: The average covalent bond energies (Cooper 1998)

Type of covalent bond	bond energy(J)
C-C	$5.76*10^{-19}$
C-O	$5.92*10^{-19}$
C-H	$6.88*10^{-19}$
O-H	$7.68*10^{-19}$
C=C	$10.24*10^{-19}$

4. EFFECTS OF SUBSTRATE

The effects of substrate properties such as surface roughness, cavity, porosity and moisture content of the substrate are regarded as very important surface parameter for laser cleaning (Matsui 2002, Rozniakowski 2001).

4.1 Surface roughness

The surface roughness is defined as the vertical variation over a measured distance. It can be defined by different ways such as average roughness (*Ra*), root mean square roughness (*Rq*) highest peak in the roughness profile (*Rp*), the depth of the deepest valley in the roughness profile (*Rv*) etc. In between these parameters, *Rq* is more related to the optical quality of a surface. Therefore the laser cleaning is believed to be related to *Rq* value more than the other parameters. Furthermore *Rv* may also influence the purity of the laser cleaning. If *Rv* is high, the paint can penetrate more. Thus laser cleaning may be difficult.

$$Ra = \frac{1}{a} \int_{x=0}^{a} |f(x)| dx \tag{8}$$

Where, *f(x)* is the surface height measured from the mean line and '*a*' is the total distance that surface roughness is considered. The root mean square roughness (RMS) is:

$$Rq = \left(\frac{1}{a} \int_{x=0}^{a} f^2(x)dx \right)^{1/2} \tag{9}$$

When average roughness increases (more than wave length of laser), absorption increases, because of the multiple reflections of laser. In the case of smooth surface, where average roughness is less than the wavelength of laser, absorptivity is fairly low. Furthermore adhesion increases with the roughness (*Ra*) (Mellali 1995). The laser cleaning process is influenced by not only adhesion of the graffiti but also the absorption of laser for the particular laser power. When adhesion increases, laser cleaning will be difficult. At the same time, laser cleaning will be easy when absorption increases for constant laser power. Both events happen at the same time in opposite directions. Therefore the effect of surface roughness on the laser cleaning might be a combination of the above two events.

In the case of carter formation and pop-outs, the surface roughness seems to be increased when compare to the initial roughness of cementitious material. At the same time, the surface roughness of the substrate decreases in glazing (Lawrence 2001). Pit-holes (little holes that appear on the surface of cementitious composites) may affect the surface roughness of the substrate and the laser cleaning process as well (see figure 5). If there are finer pit-holes, laser cleaning would be difficult.

Figure 5: Mortar surface

4.2 Cavity

Cavity is defined as a ratio of the lateral surface of the niche to the surface of the entrance to the niche. Cavity is measured as a ratio of real length (L_r) of the profile to the geometrical length (L_o) of the examined profile (see figure 6) (Wieloch 2004).

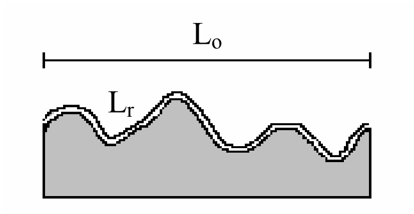

Figure 6: The cross section of the surface

The cavity is high means that it has more surface area per projected surface area. When the cavity is high, there are more surfaces to be cleaned, and sometimes more difficult to clean as well (see figure 7).

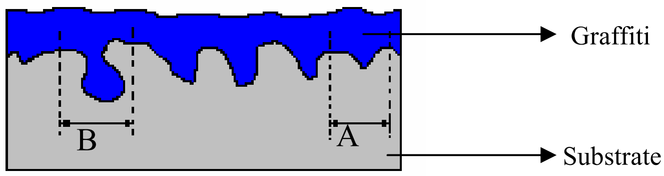

Figure 7: The profile of painted substrate. The region 'B' has a narrow opening (cavity is high). Therefore, the removal of graffiti is difficult. The region 'A' has a wide opening (cavity is low). Therefore, the removal of graffiti is easy.

4.3 Porosity and moisture contents

The porosity and the moisture contents work together and affect the laser cleaning. When high energy is applied to wet mortar with low porosity (low water cement ratio), pop-out occur. In the case of absolutely dry mortar with low water cement ratio, hair cracks occur in high energy irradiation. No damages occur in mortar specimens with high porosity (high water cement ratio) and low energy. Therefore graffiti removal should be done on dry surfaces if it is possible (Matsui 2002).

5. EFFECTS ON THE SUBSTRATE

Pop-out, cracking, cratering and/or glazing may occur on the substrate in the case of laser cleaning, because substrate rapidly reaches high temperature when the laser is applied. If concrete is heated up, the following physical and chemical changes occur:

Table 2: The temperature regions that damages occur (Schmidt 2003)

Temperature range	Effect
Up to 400 ^oC	Loss of physically bond water from pores and gel
400-540 ^oC	Dehydration of $Ca(OH)_2$
570-573 ^oC	Conversion of quartz from α to β phase
600-700 ^oC and above	Decomposition of C-S-H*
800 ^oC and above	Decarbonation of $CaCO_3$
1150-1200 ^oC and above	Melting

*C-S-H means amorphous calcium silicate hydrates

There are no comprehensive analyses of the effect of temperature on the cementitious materials due to laser cleaning. However, a lot of researches have been done on the effect of temperature rise on cementitious material within some considerable time (eg 20 minutes) (see table 2). In the case of laser cleaning, temperature rise occurs within a short time (ns) on the substrate. Sometimes it does not affect the deep part of the substrate, especially if laser parameters are selected correctly. Thermal conductivity of cementitious material is low. Thus when temperature rises on the surface for short time, heat may not affect the deep part of cementitious material.

OPC concrete contains 70% of $CaO\text{-}SiO_2\text{-}(H_2O)$ gel, 20% of well crystallised $Ca(OH)_2$, ettringite ($CaO.Al_2O_3.SiO_2.12(H_2O)$), calcium aluminate monosulfate hydrated ($4CaO.Al_2O_3.13(H_2O)$) and some minor phases. Dehydration start when the concrete surface is heated for considerable time and water will lose at 200 ^{o}C. The break down of hydrated chemical bond occurs at around 550 ^{o}C and it completely breaks down at 800-900 ^{o}C. However, further heating at around 1600 ^{o}C creates stable ceramic bond (glazing), such as $CaO.SiO_2$, 2CaO.SiO2, anorthite ($CaO.Al_2O_3.2SiO_2$), and rankinite ($3CaO.2SiO_2$) (Li 1994).

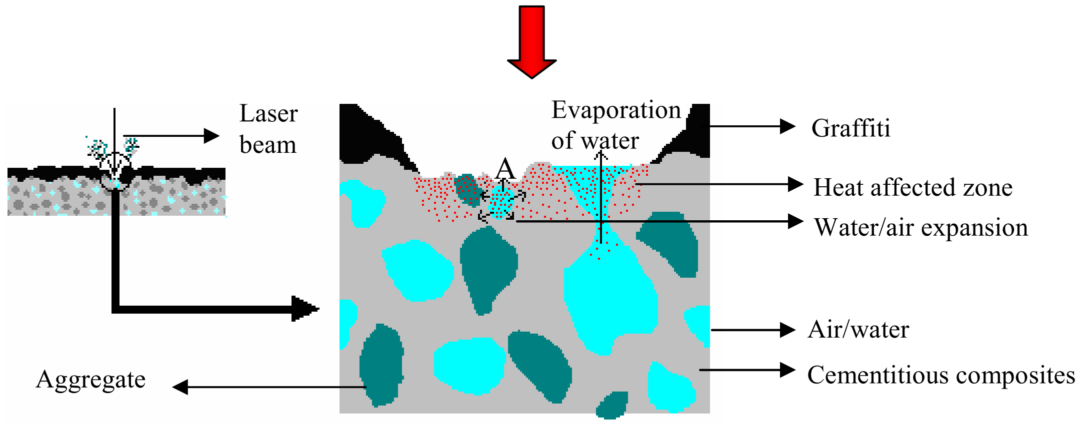

Figure 8: Effect of laser cleaning on the porous material. The point 'A' is the potential point that pop-out may occur

In the heat-affected zone, water/air in the pores absorbs the heat and try to expand. As a result out ward pressure build up inside the pores. If there are pores, which are exposing to atmosphere, water/air dissipates the pressure through those pores. Otherwise water/air inside the pores tries to break the weak section. When breakage happens - so called pop-out, all the pressure dissipates (see figure 8).Aggregates and cementitious composites have a different thermal expansion coefficient. Thus cracks may develop in between cementitious composites and the aggregates in the heat-affected zone.

6. FINAL REMARKS

The advantages and the disadvantages of each type of lasers depend on the laser parameters selected, the type of graffiti to be removed and the type of substrate to be cleaned. However, there are some unique advantages and disadvantages of these lasers. The Q-switched Nd:YAG laser is most effective and extremely reliable. It has a higher efficiency than the excimer lasers (Liu 1995) but controllability is less than the excimer lasers. All colors of the paints can be removed by CO_2 laser and the absorption of the CO_2 laser is high in ceramics and polymer (LI 1994). The high power diode laser is easy to operate, because the size of the laser is small and the excellent control of removal depth. The excimer lasers are used for removal of varnish and unwanted paints. These lasers have a higher degree of controllability than other lasers, but redeposition of the graffiti and low removal rates are the problem of these lasers (Schmidt 1999).

Although a lot of researches were carried out on laser cleaning, there are no records of the systematic analysis of geometrical microstructure of cementitious composites and their effect on the laser cleaning process. The effects of the surface roughness, the cavity, the pit-hole, the porosity and the moisture content on the laser cleaning process will be tested and analyzed in comprehensive manner in near future.

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LITERATURE REVIEW OF WEB CRIPPLING BEHAVIOUR

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Abstract: A review of literature on the area of the behaviour of thin-walled cold-formed steel structural members was carried out with an emphasis on the phenomenon of web crippling of beam members. Web crippling is a common mode of failure experienced by web elements of thin-walled beams under concentrated loads or reactions. Most of the studies done on web crippling behaviour are experimental and based on compression testing of beams to determine the ultimate web crippling strength. It has been identified that the theoretical investigation of web crippling behaviour is rather complicated due to localised collapse behaviour. However, some attempts have been made to develop theoretically based models to predict web crippling behaviour, and to obtain better understanding of the failure modes. Different theoretical studies, especially on elastic and plastic behaviour of plate elements were investigated with the intention of developing an analytical model to describe web crippling behaviour. It was found that almost all of the design codes around the world make design recommendations to predict the load at which web crippling would occur, based on equations obtained from web crippling tests conducted by various researchers.

Keywords: Cold-formed steel, Concentrated loads, Collapse behaviour, Thin-walled, Web crippling.

1. INTRODUCTION

Cold-formed steel (CFS) structural members are widely used in modern construction industry due to their inherent characteristics over conventional hot-rolled thick sections. Cold-formed steel members are usually thin members with large width-to-thickness ratios. Light in weight, high strength and stiffness, accurate section dimensions, and easy of prefabrication and mass production are some of the qualities of these members that create cost savings in construction (Yu 2000). Cold-formed steel members are commonly used as purlins, cladding rails, sheeting rails, wall studs, floor joists, sheets and decks, etc. in the building industry. Unlike heavy hot-rolled steel sections, cold-formed thin-walled sections tend to buckle locally at stress levels lower than the yield strength of the material when they are subjected to various loading conditions. However, these members do not fail at these stress levels and continue to carry further loads leading to what is called post-buckling behaviour.

Flexural members such as floor joists, purlins, and decks are often subjected to concentrated loads and reaction forces. These concentrated forces result in different modes of failures depending on the loading condition in the absence of stiffeners. Basically these failure modes can be identified as shear failure, web crippling, bending failure, and failures resulting from the interaction of two or more of the above mentioned failure modes. Among these failure modes, web crippling is a significant failure mode that may be experienced by beam members under concentrated loads or reaction forces. Web crippling behaviour is identified as a localised failure of web elements just under the bearing loads (Figure 1).

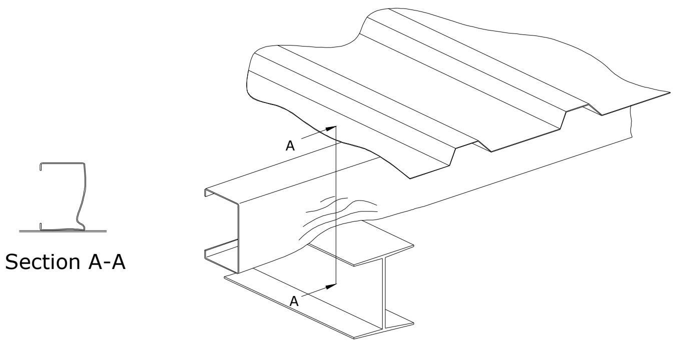

Figure 1: Web crippling at a support point (Rhodes 1994).

Web crippling may occur under various loading conditions; these loading conditions are defined based on the position of the load or reaction applied, and depending on whether the web is loaded through a single flange or both flanges. Based on the above definition, four basic loading conditions are defined in the AISI specification for a web crippling test, namely End-One-Flange (EOF) loading, Interior-One-Flange loading (IOF), End-Two-Flange loading (ETF), and Interior-Two-Flange loading (ITF) (Figure 2). Among these loading conditions Interior-One-Flange loading (IOF) condition occurs due to both concentrated loading and bending moment on the beam section that is considered.

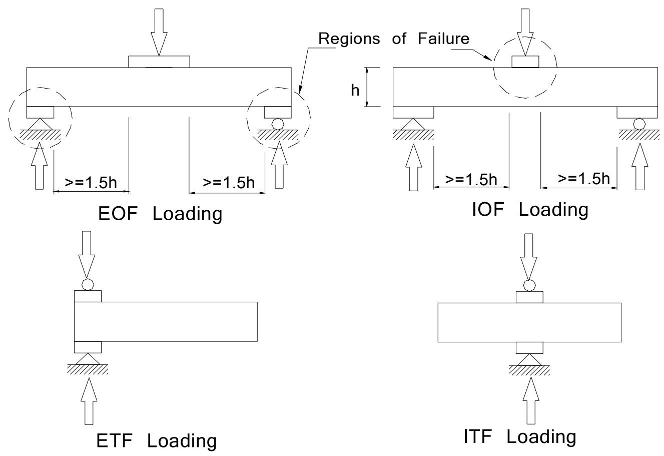

Figure 2: Loading conditions of web crippling tests (Yu 2000).

Almost all the design specifications around the world have design equations for predicting the web crippling strength based on empirical equations which were obtained by regression analysis of test results. These empirical equations are capable of predicting the web crippling strength for the range of parameters and the types of sections which were used in those tests to derive these equations, but often provide conservative or non-conservative results for other types of sections and section parameters.

The primary objective of this research is to investigate web crippling behaviour with the intention of improving the current design specifications for predicting web crippling strength. An experimental programme is intended to be carried out initially to get more understanding of the failure behaviour and study the influence of different parameters on the ultimate web crippling strength. The observed behaviour and the results will then be used to aid the development of reliable finite element models which are capable of predicting the ultimate web crippling strength. Finally, theoretical studies will be carried out based on the elastic and elastic-plastic behaviour of elements and members.

2. INVESTIGATION OF WEB CRIPPLING BEHAVIOUR

The study of web crippling behaviour of cold-formed steel flexural members has been going on since 1940s. Most of the research work that has been done on this area is based on experimental studies and the results have been used to develop the design formulae for calculation of web crippling strength. There have been some studies carried out on the theoretical analysis of web crippling behaviour despite the fact that it is extremely complicated because it involves the following factors (Yu 2000):

- Non-uniform stress distribution under the applied load.
- Elastic and inelastic behaviour of the web element.
- Local yielding in the immediate region of load application.
- Bending produced by eccentric load when it is applied on the bearing flanges at a distance beyond the curved transition of the web.
- Initial out-of-plane imperfection of plate elements.
- Various edge restraints provided by beam flanges and interaction between flanges and web elements.

2.1. Experimental Investigations

During the 1940s, the behaviour of web crippling was first examined experimentally by Winter and Pian at Cornell University in the United States. Since then there have been various experimental work done on web crippling behaviour on both single web sections, multi-web decks, and cassette sections to improve design codes and to validate various theoretical and numerical models developed by various researchers around the world. Experimental investigations provide the observations necessary to understand the failure behaviour. The present AISI design provisions for web crippling are based on the extensive experimental investigations conducted at Cornell University by Winter and Pian, and by Zetlin in the 1940s and 1950s, and at the University of Missouri-Rolla by Hetrakul and Yu in the1970s.

Winter used 136 test specimens with 18 different types of beams under all four possible loading conditions (IOF, ITF, EOF and ETF) for the experiments. The results of these tests were then evaluated and led to purely empirical formulae of a rather simple type which predicted, with reasonable accuracy, the web crippling strength for given dimensions. The test specimens were made out of channel sections by connecting channels in different arrangements using bolts and spot welding (Figure 3). The thicknesses of the sections varied approximately from 1mm to 3mm and the depth from

100mm to 200mm. Loads were applied over varying lengths of bearing ranging from 20mm to 90mm by means of steel plates. Span lengths were varied from 250mm to 900mm, but kept small enough to prevent failure by bending stress.

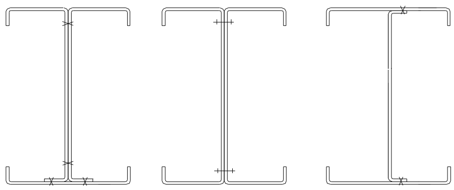

Figure 3: Typical cross section in Winter's experiment (Winter 1946).

Ultimate loads were recorded to analyse results and to obtain an equation for web crippling strength. Experiments indicated that the ultimate web crippling strength of I-section beams depends primarily on the actual bearing length ratio (N/t) and the yield strength of the material (σ_y). Further, within the test range, no influence of the depth of the beam on the crushing load of I-beams could be detected.
A general form of an equation that satisfied the test results was suggested:

$$P_{cr} = \left[A + B\left(\frac{N}{t}\right)^n \right] t^2 \sigma_y$$

Where, P_{cr} = ultimate web crippling strength, N = bearing length, t = thickness of the section, σ_y = yield strength, and A, B, n = empirical constants to be determined.

The interaction of web crippling and bending of C-shaped section steel joists was investigated by Ratliff in 1975. Ratliff proposed interaction formulae for web crippling and bending of C-shaped beams based on the results obtained from experimental investigations. In 1978, a similar experimental investigation was performed by Hetrakul and Yu at the University of Missouri-Rolla. In this research, the structural strength of cold-formed steel I-beams subjected to combined web crippling and bending was studied.

During 1982 to 1986, Wing and Schuster investigated a web crippling expression for multi-web deck sections with IOF, ITF and ETF loading conditions through experiments. The objective of the experiments was mainly aimed at determining the load resistance of multi-web deck sections under the aforementioned loading conditions. A test programme was conducted to provide experimental data to compare and evaluate the existing method of calculation of web crippling strength. More specifically, the study addressed the following important parameters: inside bend radius to web thickness ratio, bearing length to web thickness ratio and angle of web inclination. All of the specimens tested had unreinforced webs and the rate of the load application was uniform up to the failure load. Spreading of the web was prevented by bolting the lower flanges to the bottom bearing plate.

In 1986, Santaputra, Parks and Yu, investigated the web crippling strength of high strength steel beams with material yield strength up to 1310 MPa. High strength steels have been used for automotive structural components to achieve weight reduction while complying with safety standards. Because of this, additional design criteria for the use of a broader range of high strength steels were highly desirable. Tests were carried out to determine the web crippling strength of webs of cold-formed steel beams fabricated from high strength sheet steels commonly used in the automobile industry. Two types of sections were tested; hat sections were tested in order to study single unreinforced webs and I-sections to study the high degree of resistance against the rotation of the webs. Various loading arrangements were performed and new design criteria to prevent web crippling and combination of web crippling and bending were proposed based on the test results.

Another investigation was carried out by Studnicka in 1989, also aimed at predicting web crippling resistance of multi-web deck sections subjected to both one and two flange loading in both interior and end positions. The investigation was carried out experimentally and results were compared with the 1986 edition of the AISI specification and Canadian code. The test program was designed to encompass the most important parameter variations that influence the web crippling resistance of multi-web deck sections (Figure 4). For some specimens, spreading of the webs during loading was prevented by transverse tie rods which were bolted to the bottom flange of the profile. The test load was taken either as the largest load the specimen was able to sustain or the load which residual deformation of 1.0 mm developed, whichever was the lesser.

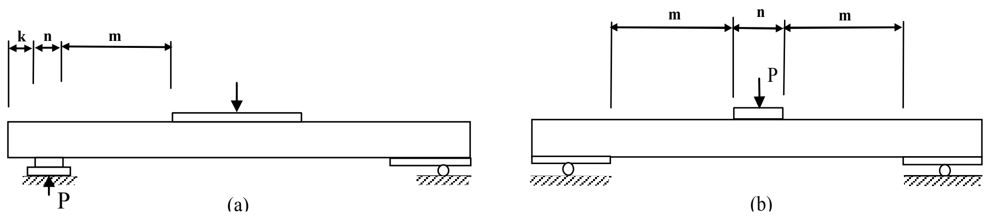

Figure 4: Test set-up for (a) end reaction (b) interior reaction.

40 specimens were tested for interior support condition and comments were made based on test results: test loads were not substantially different for normal orientation and inverted orientation of the deck sections, test results were almost linearly influenced by bearing width *n,* the test loads for specimens with ties were greater than without ties. The same comments were made for end support condition based on the test results. Further, two more comments were added to the end support loading condition: the influence of distance *m* on the test results is very small and when distance *k* is increased, the test load also increases, although the influence is not very strong.

In 1998, Young & Hancock carried out experiments to investigate the web crippling behaviour of cold-formed unlipped channels. Experiments were carried out under four loading conditions to the AISI specification. The concentrated load or reaction forces were applied by means of bearing plates which acted across the full flange width of the channel. Web crippling test results were compared with the AISI specification and the Australian/New Zealand standard for cold-formed steel structures. The design web crippling strength predictions given by the specification have been found to be unconservative for the unlipped channel sections tested.

A new design expression for web crippling strength of cold-formed flexural members was developed by Prabakaran & Schuster in 1998 based on the statistical analysis of experimental data published in various countries. All four loading conditions were considered for I-sections made of two channel sections back to back, Z-sections, channel sections and multiple web (deck) sections. Comparison was made with the expressions presented in the Canadian Standard and AISI specifications. The preliminary web crippling parameters considered were the web thickness (t), the web depth (d), the bearing length of the load (N), the inside bend radius (r), the yield strength (F_y) and the angle between the web and the bearing surface (θ). The new developed expression is nondimensional, therefore any consistent unit of measurement can be used such as empirical or SI. Certain unnecessary complexities existed were removed to simplify the web crippling expressions.

An experimental investigation of cold-formed steel stiffened C-and Z-sections subjected to web crippling was carried out by Beshara and Schuster in 2000. Two loading conditions were considered namely, ETF and ITF, with particular emphasis on large inside bend radius to thickness ratio R/t, (up to 12) and the specimens being fastened to the support during testing. They found that there was no experimental data available in the literature regarding the web crippling resistance of such members that are fastened to the support and having inside bent radius to thickness ratio greater than 2.7. Although most of the parameters of the test specimens were beyond the limits specified by the current AISI standards, the test results were compared with the calculated values of AISI web crippling design equations.

In 2003, an experimental investigation was carried out by Holesapple and LaBoube to find out the effects of overhang length on the web crippling capacity of clod-formed steel members. It was found that the current AISI design specifications for EOF web crippling capacity were conservative for overhang length ranging from 0.5h to 1.5h, where h is the web depth. A total of 27 specimens of channel and Z-sections were tested. All of the test specimens had an overhang or cantilevered extensions. A modified equation was obtained by analysing the test results for EOF loading condition.

2.2. Theoretical Investigations

The objective of the theoretical investigation of web crippling behaviour is to develop analytical models which can be used to determine the ultimate web crippling strength and to study the post-failure behaviour of a cold-formed section under different loading conditions. Although webs and flanges of the sections are interactive, it is also useful to study the behaviour of idealised separate rectangular flat plates loaded by localised in-plane edge forces. Elastic stability and plastic behaviour theories of plates are often used in analysis of thin-walled structures.

Elastic Behaviour of Plates and Sections:

Zetlin, in 1955, studied the behaviour of the rectangular plate which was simply supported its four edges and loaded on one edge of the plate. The energy method was used to analyse the plate and the formulated buckling load was given by $P_{cr}=K.\pi^2.D/L^2$, where, P_{cr} = critical elastic buckling load, K = buckling coefficient depending on the ratio of L/B and C/B, B = half-depth of the plate, C = half width of loading, D = flexural rigidity, L = width of the plate. In 1972, Khan and Walker also investigated similar problems of plate buckling as studied by Zetlin. They approximated the deflected shape of the plate by using a finite element solution and used them to solve the potential energy of the plate. The buckling load given by Khan and Walker was of the form $P_{cr}=K.\pi^2.D/2B$, where, B = half-depth of the plate, K = buckling coefficient depending on the ratio of L/B and C/B where L and C are length of the plate and the half-width of the plate respectively.

Plastic Behaviour of Plates and Sections:

The behaviour of plates under compression load was studied by Korol and Sherboune in 1972 using a plastic mechanism approach. According to their studies, the collapse loads of the plate can be obtained from the interaction of post-buckling loading paths and the rigid-plastic unloading lines. The elastic post-buckling path can be obtained by using the energy method while the rigid-plastic unloading or plastic mechanism can be obtained by considering the change in the plastic collapse load with geometric changes in the bent plate.

In 1980, Murray and Khoo studied the formation of local plastic mechanisms when thin-walled steel structures fail. Eight basic plastic mechanisms and three types of fully-plastic zones were observed in laboratory tests and characteristic equations were derived. Mahendran and Murray in 1991 and Mahendran in 1997 investigated the development of two types of local plastic mechanism in thin walled steel plates subjected to in-plane compression, namely the roof-shaped mechanism and the flip-disc mechanism. The type of mechanism initiated was identified from the location of first yield point shifted from the centre of the plate to the mid point of the longitudinal edge depending on the width-to-thickness (b/t) ratio, imperfection level, and yield stress of the steel. Both analysis and laboratory experiments were used to verify above fact.

Bakker in 1993 developed an analytical model to describe the web crippling behaviour and used test results to verify this model. The aim of developing this model was to obtain more reliable and more theoretical-based design formulae. From experimental research, two apparent failure mechanisms namely, yield arc mechanism and rolling mechanism were observed for hat sections under combined action of concentrated loading and bending moments. It was found that the yield arc mechanism occurs in members with small corner radii between web and loaded flange, and the rolling mechanism occurs in members with large corner radii. In this research, a model for members failing by the rolling mechanism was developed, and, according to this, the mechanism initiation load was determined as the point of intersection of an elastic curve and a rigid-plastic mechanism initiation curve. The elastic curve was taken simply as a straight line with a slope equal to the initial web crippling stiffness measured from a test. The rigid-plastic mechanism curve was derived by using generalised yield line theory.

In 1994, Setiyono developed a model to investigate the web crippling behaviour of plain channel sections under combined bending and concentrated loading. Ultimate web crippling strength was determined using an elastic loading curve based on the effective width approach and rigid-plastic unloading curve based on plastic mechanism approach.

Load capacity and post-failure behaviour of thin-walled beams were theoretically investigated by Kotelko in 2004. The problem of post-failure behaviour is solved by the rigid plastic theory taking into consideration strain hardening of the member's material. Based on the experimental results, theoretical models were developed to analyse plastic mechanisms of failure for different sections. Theoretical analysis was based on the principle of virtual work.

A new analytical model to predict the ultimate load of first-generation sheeting was developed by Hofmeyer in 2000. The model was based on two existing models, one was developed by Vaessen in 1995 on the elastic web crippling stiffness of thin-walled cold-formed steel sections and the other was based on the solution of Marguerre's simultaneous differential plate equations. Hat sections were considered for the analysis and testing instead of sheeting because they were easier to manufacture with varying dimensions. Three failure mechanisms were observed: rolling, yield arc, and yield mechanisms.

Design equations against web crippling for unlipped channels with stockier webs were proposed by Young & Hancock in 1998. It was assumed that the bearing load is applied eccentrically to the web due to the presence of the corner radii, which produces bending of the web of its plane causing a plastic mechanism, and then the plastic mechanism model was used to establish design formula. Proposed formula for channel sections were summarised as: $P_{pm} = M_p.N_m/r$, where $M_p = f_y.t^2/4$ (M_p is the plastic moment for unit length), P_{pm} is the web crippling strength predicted by the plastic mechanism model, r is the centreline corner radii, t is the thickness of the web, f_y is the yield stress, and N_m is the assumed mechanism length. The above equations for predicting web crippling strength were modified by the same researches to take the effect of the slenderness ratio into account, and the term $(1.44-0.0133(h/t))$ was introduced to the first equation by multiplying with this factor.

2.3. NUMERICAL INVESTIGATIONS

The objective of the numerical investigation is to develop computational methods to analyse the web crippling behaviour of thin-walled flexural members. Finite Element analysis (FEA) is considered as the most commonly used numerical method. FEA can be used to represent complex geometries and can be effective in treating difficult boundary conditions. Further, non-linear finite element techniques enable the inclusion of large deformation, large rotation and non-linear stress-strain characteristics (Sivakumaran 1989). FE modes are useful because they can partly substitute for expensive experiments for systematic variations of variables, they can be used to test a wide range of assumptions, and they can simulate experiments that are practically impossible to perform but worthy of studying (Hofmeyer 2000).

In 1989, Sivakumaran carried out a finite element analysis to analyse web crippling behaviour and to determine ultimate web crippling strength. He was able to analyse the web crippling behaviour extending up to ultimate load levels. The following points were highlighted when selecting the proper finite elements in his investigation: steel lipped channel sections were considered with very thin webs, flanges and lips, and were subjected to in-plane and bending action. Hence finite elements were able to represent membrane behaviour as well as the flexural behaviour. In this study, the finite element package called ADINA was used. Among the finite elements available in the ADINA library, degenerated isoparametric shell elements were considered for analysing this problem. The isoparametric shell element is a higher order degenerated isoparametric element with 16-nodes (5 degree of freedom per node). Half of the specimen was considered for the mesh generation because of the symmetry of the loading. In order to capture the local large deflection and local yielding in the region around the web crippling point, fine meshing was considered in this region. Further away from the loaded area, large elements were used. Results of the finite element analysis showed that the general deformation shape similar to experimental deflected shape and predicted ultimate loads which were well in agreement with the experimental values within a 9% tolerance.

3. CONCLUSIONS

A literature review was carried out with the intention of studying the various investigation techniques such as experimental, theoretical and numerical, for web crippling behaviour. It was found that most of the experiments were focused on testing flexural members against web crippling or combined bending and web crippling to determine the ultimate web crippling strength for various sections and parameters. However, these experiments were not capable of giving any observations or results for developing more reliable theoretically based design equations for predicting web crippling behaviour.

It is understood that there are still no totally reliable equations or models that are capable of predicting the ultimate web crippling strength. Almost all of the design specifications found predict web crippling strength based on equations obtained by empirical results. From the literature survey, it was identified that it may be possible to derive equations based on more experiments combined with accurate finite element modelling, giving more of an insight into web crippling behaviour for many different beam cross-sections. The next step of this research will be the design of an experimental program which is capable of giving the observations and results that can be further used for the development of finite element models, and analytical investigations.

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DEVELOPMENT OF A SOLAR AIR HEATING FAÇADE

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Abstract: A simple solar capture façade can be made by covering standard profiled wall elements with glass sheeting. Solar energy heats the air in the profile channels and generates air movement, while the insulated wall prevents uncontrolled heating of the building.

A mathematical model has been developed to predict the exit air temperature, air mass flow, air velocity and power output from such a system. Initial experimental work has taken place to verify the air flow component of the model. This has involved predicting the pressure drop along the length of four prototype ducts using the Darcy equation. These predictions have been found to over estimate the system pressure drop. It was found that using the Darcy equations with an adjusted hydraulic diameter (increased by 9.75%) gave a better match to the actual data for the geometries and flows considered.

Keywords: façade, heating, modelling, solar, ventilation .

1. INTRODUCTION

Finite fossil fuels resources and legislation regarding carbon emissions indicate that reduced energy consumption and alternative energy sources are required. Water heating, space heating and ventilation in buildings are major consumers of energy. Using solar air/water heating and ventilation systems would be one method of reducing carbon emissions and fossil fuel usage.

The concept of a simple solar capture façade, made from profiled steel sheeting covered with glass, is illustrated in Figure 1.

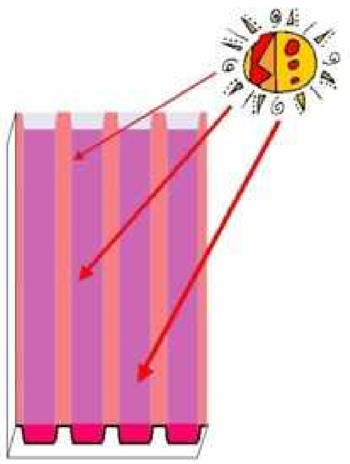

Figure 1: Concept of glazed profiled steel used as a passive solar heater

In 2003, 1400 million m^2 of precoated coil was sold in Europe (ECCA, 2003). Of this total, approximately 280 million m^2 was used in a position with potential for solar energy capture, e.g. on roofs and south facing walls. The average insolation level for Europe has been calculated as 3.6 kWh m^{-2} day^{-1} (Whitlock and et al, 2000). Thus, annually, the solar energy falling on one year's production of precoated coil can be estimated at over 367,000 GWh. This is greater than the electricity produced from gas in the United Kingdom in a year (DTI, 2002), indicating the potential which exists for significant building integrated solar energy.

2. ENERGY BALANCE

The glass sheet covering the profiled façade effectively forms several vertical ducts. To estimate the performance of such a façade, an energy balance analysis can be carried out on an individual duct. This enables the outputs of the duct: i.e. air exit temperature (tex), mass flow rate of air ($\dot{m}$), velocity of air (V) and power output (P) to be calculated.

Energy enters the system as solar irradiation transmitted through the glass layer (Q_g). This can be estimated from the incident solar radiation for a location, the glazing transmission characteristic and the backing panel absorptance. Energy can leave the system through the glass, through the insulation or through the air:

1) Since glass is not a perfect insulator there will be some energy losses (Q_F) associated with the glazing, characterized by its "U-value". The calculation for Q_F is shown in equation 1 (ASHRAE, 1989):

$$Q_F = A_g U_g (t_m - t_o) \qquad 1$$

2) There will also be small heat losses associated with the insulated back and sides of the duct (Qi) determined by the backing material and degree of insulation. In this scenario Qi is assumed to be negligible, due to backing insulation on the panel.

3) The remaining energy (Q_V) heats the air within the duct and generates air movement through solar induced stack effect. Q_V can be calculated from the resulting mass flow rate of air through the device (ASHRAE, 1989):

$$Q_V = \dot{m} C_p (t_m - t_o) \qquad 2$$

An energy balance requires the energy in to equal the energy out. In this case, assuming thermal mass to be negligible:

$$Q_g = Q_F + Q_i + Q_V \qquad 3$$

Substituting equations 1 and 2 into equation 3 and rearranging for $\dot{m}$ provides an equation for air flow rate:

$$\dot{m} = \frac{Q_g - A_g U_g (t_m - t_o)}{C_p (t_m - t_o)} \qquad 4$$

The air movement is a result of buoyancy. Models for the flow of heated air through a duct have been proposed by several authors (Ho and Loveday, 1997, Hollands and Shewen, 1981, Brinkworth et al., 2000). However, Brinkworth et al., (2000) have provided a model for buoyant ventilation which takes into account skin friction as well as buoyant forces. The following equation for buoyant ventilation is based on their work:

$$\dot{m}^3 = \frac{2S(\rho_o A_c)^2 gL\beta \sin\theta}{C_p\left(K_{f1} + K_{f2} + f\dfrac{L}{D_h}\right)} \qquad 5$$

The buoyancy term (β) in equation 5 is defined in terms of the mean air temperature in the duct (t_m). The stratification parameter (S) is assumed to be 0.5 (i.e. the increase of temperature with length of duct is linear). Values for the friction coefficients are found in Brinkworth et al., (2000) and those appropriate for the system under consideration are $K_{f1} = 0.5$ and $K_{f2} = 1.0$.

Previous work (due to be published in November 2005) has confirmed that the friction factor (f) can be defined for this geometry using the following equation (ASHRAE, 1989):

$$f' = 0.11\left(\frac{\varepsilon}{D_h} + \frac{68}{\mathrm{Re}}\right)^{0.25} \qquad 6$$

if f' ≥ 0.018: f = f'
if f' < 0.019: f = 0.85 f' + 0.0028

The hydraulic diameter can be defined generically as (ASHRAE, 1989):

$$D_h = \frac{4A}{P} \qquad 7$$

Since we are considering an air system, all four sides of the rectangular duct are wetted and included in the perimeter.

Simultaneous solution of equations 4 and 5 allows the mean air temperature and mass flow to be calculated for a given geometry and external condition. Due to the non-linearity of the terms, this solution must be determined iteratively. The exit air temperature (t_{ex}) is determined from the mean air temperature, assuming a linear variation along the length of the duct.

Once the mass flow and mean temperature are known, the air velocity can be calculated using:

$$V = \frac{\dot{m}}{A_c \rho_o} \qquad 8$$

and the power generated by the system can be calculated using:

$$P = C_p \dot{m}(t_m - t_o) \qquad 9$$

The mathematical model had been used to predict the likely air exit temperature and air mass flow through a variety of duct geometries in different weather conditions. From this information a matrix of promising duct geometry / length combinations was selected for experimental work. A likely spread of target air mass flows between 0.0015 and 0.025 kg s^{-1} was selected in a similar way.

3. EXPERIMENT

The ability of these equations to predict flow and energy will depend greatly on a correct identification of the pressure losses in the system. The pressure loss of the duct will be a vital parameter in optimising the geometry of the system, as well in determining whether the system can operate as a passive collector, through buoyancy forces alone or require fan assistance. It is therefore important that the prediction of the duct pressure drop be accurate.
The aim of the experiment reported here was to verify the pressure drop calculations within the model by comparing measured and predicted pressure losses under imposed flows. Ideally the calculation of pressure drop should be applicable across a range of duct geometry, duct length and air mass flow.

Within the model already described, the pressure drop along the duct length L can be calculated using the Darcy equation (Brinkworth et al., 2000)

$$p_{fr} = f\frac{L}{D_h}\frac{\rho V^2}{2} \qquad 10$$

using the symbols defined in section 2.

3.1 Experiment Equipment

Four ducts were manufactured from precoated steel. 6mm clear float glass was attached to the ducts using a silicone sealant. The dimensions of the ducts, as chosen from the prototyping procedure outlined in section 2, are shown in Table 1.

Table 1: Dimensions of Ducts

Duct ID	Width (m)	Depth (m)	Length (m)	D_h (m)
A	0.1	0.034	2.4	0.0507
B	0.1	0.0625	2.4	0.0769
C	0.15	0.033	2.4	0.0541
D	0.15	0.063	2.4	0.0887

The air was drawn through the ducts using a vacuum fan. The air flow was controlled using ball valves. The mass flow rate was calculated with an uncertainty of 1.5% from the pressure difference across an orifice plate prepared to BS EN ISO 5167-1&2:2003 (British Standards Institution, 2003a, British Standards Institution, 2003b). The experimental equipment is illustrated in Figure 2.

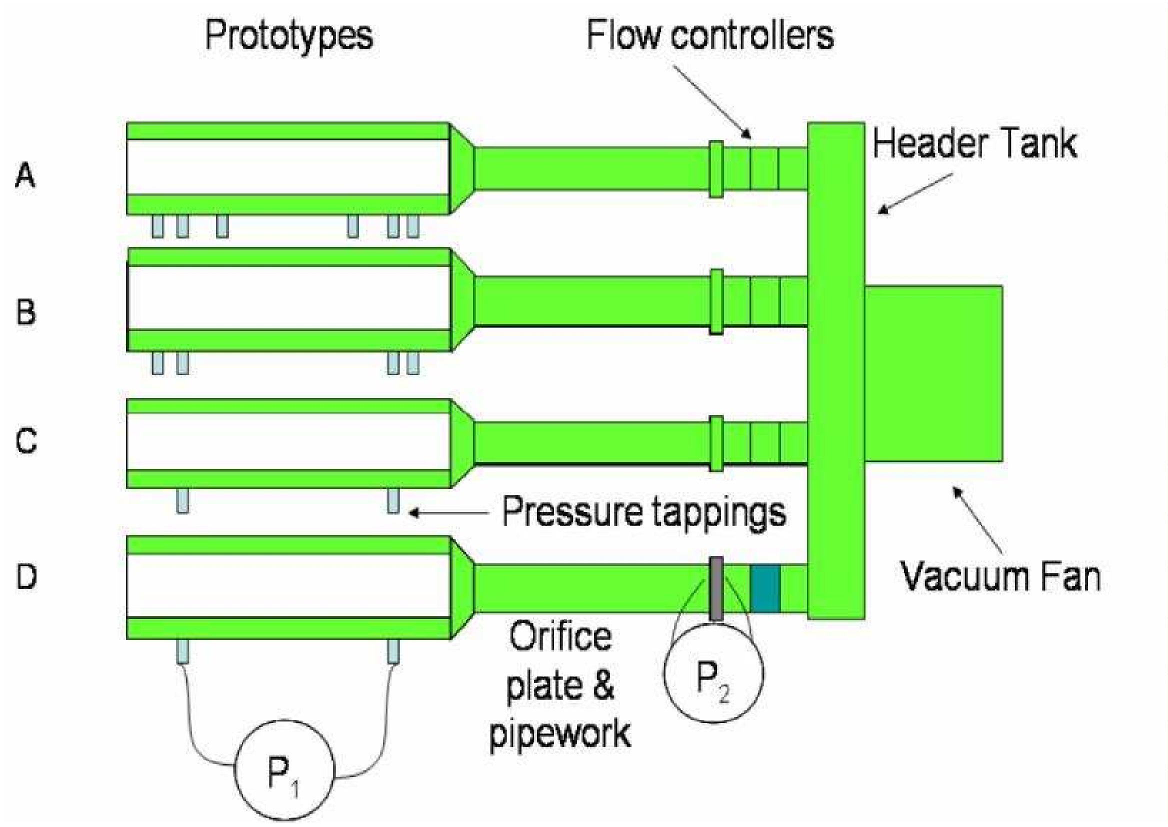

Figure 2: Schematic showing layout of experimental equipment

In order to present stable flow to the ducts, flow straighteners were placed at inlet and outlets. Although the ducts were 2m long, pressure tappings were not attached within the entry or exit areas (assumed to be less than six times the depth of the duct). Therefore all four ducts had pressure tappings attached 1.58m apart. The pressure drop across this duct length was measured, using a micro-manometer, to an accuracy of 0.1 Pa. Previous tests on ducts A and C had shown that there was a well established linear relationship between pressure drop and distance along the duct. Therefore it was considered valid to determine the duct pressure loss characteristic from a single position.

4. RESULTS AND DISCUSSION

4.1 Pressure Difference for Varying Air Mass Flow

The air mass flow through the duct will vary depending on duct geometry as well as available solar energy. Air mass flows between 0.0015 and 0.025 kg s^{-1} are expected. The pressure drop over 1.58m length was measured for all four ducts for flows within the expected range. The expected pressure drops were calculated using the Darcy Equation (equation 10). The comparison between predicted and actual pressure drops are shown in Figures 3. The repeatability was calculated by grouping data from 0.0095 to 0.0105 kg s^{-1} for 0.01 kg s^{-1}, and from 0.0175 to 0.0185 kg s^{-1} for 0.018 kg s^{-1} and calculating the root mean standard error (RMSE). The number of data points this includes and the resulting RMSE is shown in Table 2 for all four ducts. The error bars in Figure 3 indicate the variance in the actual pressure drop for each duct at these flows.

Table 2: Dimensions of Ducts

Duct ID	0.01 kg s^{-1} flow		0.018 kg s^{-1} flow	
	No of data points	RMSE (Pa)	No of data points	RMSE (Pa)
A	15	0.29	4	0.36
B	6	0.06	6	0.15
C	6	0.23	4	0.74
D	6	0.07	4	0.13

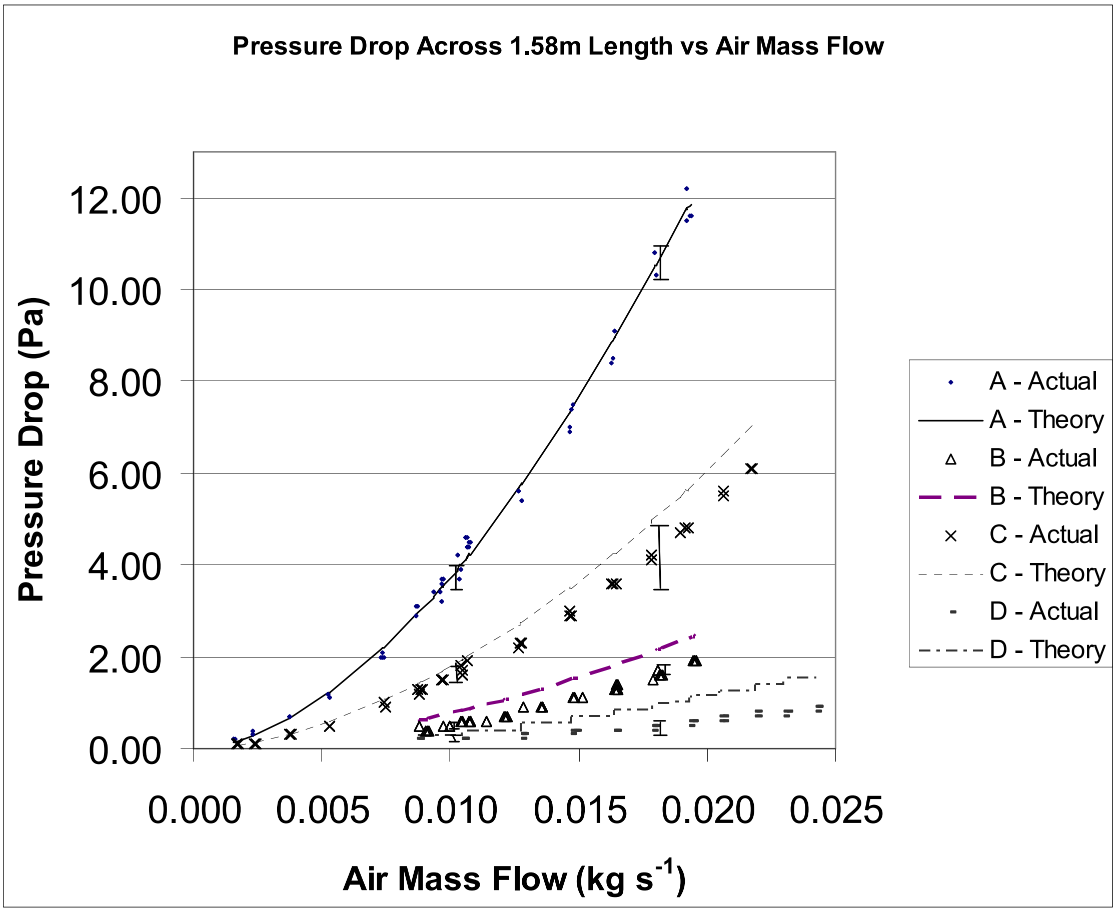

Figure 3: Relationship between pressure drop and air mass flow for 1.58m length – ducts A to D

As shown in figure 3 there is a good correlation between the pressure drop predicted using Darcy's equation and the measured values for duct A (the smallest duct of the four tested). However, pressure drop is overestimated for ducts B, C and D. Although it is beneficial that the actual pressure loss be less than expected (so promoting greater passive flows or requiring lesser fan power), it is of interest to determine where the predictive theory is inadequate for these geometries, and where possible to tune the prediction equations.

4.2 Discussion

The flows for the four ducts had Reynolds numbers ranging between 1,000 and 18,000 – indicating that the flow is mainly transitional. Flows in this area are not well understood and there are no well established models. The Darcy equation is accepted for turbulent flow, but unproven for transitional flow. This may account for the difference between predicted and measured pressure drop values.

Potential candidates for the systematic error in the Darcy equation calculations are roughness (ε), friction factor (f) and hydraulic diameter (D_h). These values were varied within a reasonable limit, and the effect on the predicted values observed. Changes were assessed using mean bias and RMSE between 240 measured values and the corresponding predictions. Ideally, across the four duct geometries studied, both factors could be minimised by adjusting these parameters.

Three measurements of the surface roughness of the precoated material used in the ducts indicated a typical surface roughness of 3μm ± 10%. The effect of varying ε within these limits did not make a significant difference to the pressure drop results. Therefore, it appears that ε is not the source of the difference between the actual and predicted pressure drops.

Table 3 shows a comparison of the mean bias (%) and RMSE (%) for the variations in f and D_h. The effect of varying f by ± 10% was considered, from this the percentage of f which would generate the lowest bias was calculated. The bias (%) and RMSE (%) for f – 11% are shown in Table 3.

The effect of varying D_h by ± 10% was considered, from this the percentage of D_h which would generate the lowest bias was calculated. The bias (%) and RMSE (%) for D_h + 9.75% are shown in Table 3.

For a rectangular duct, it is possible to calculate the circular equivalent diameter (D_e) as an alternative to D_h. D_e is defined as (ASHRAE, 1989), where a and b refer to the duct section dimensions:

$$D_e = 1.3\frac{(ab)^{0.625}}{(a+b)^{0.25}} \qquad 11$$

The mean bias (%) and RMSE (%) for D_e is shown in Table 3. The bias for D_e is high in comparison to the other factors considered. For this reason the effect of varying D_e by ± 10% was considered, from this the percentage of D_e which would generate the lowest bias was calculated. The bias (%) and RMSE (%) for D_e – 10.3% are shown in Table 3.

The least bias and rms errors were achieved by either reducing f by 11% or increasing D_h by 9.75%. Since f is inversely dependent on D_h (equation 6), this is logical; it is concluded that adjusting D_h is the most appropriate tuning mechanism.

Table 3: Bias and RMSE for Factors Affecting the Darcy Equation

Ducts	Error	Darcy Equation	– 11% f	+ 9.75% D_h	D_e	-10.3% D_e
A	Mean Bias (%)	190	1,005	1,003	1,780	933
	RMSE (%)	9.3	15.4	15.4	24.5	14.7
B	Mean Bias (%)	-2,194	-1,369	-1,371	-1,234	-2,185
	RMSE (%)	42.6	27.3	27.4	24.9	42.4
C	Mean Bias (%)	-998	-162	-164	1,286	514
	RMSE (%)	19.7	11.5	11.6	21.4	12.8
D	Mean Bias (%)	-3,122	-2,240	-2,242	-1,689	-2,647
	RMSE (%)	65.4	47.6	47.6	36.5	55.8
All	Mean Bias (%)	-5,992	-31	-42	6,114	-11
	RMSE (%)	27.8	22.1	22.1	26.4	26.5

With this adjustment, the pressure drop of the ducts could be predicted to within 22% across all four duct geometries, even though the flows were in the transition region. The comparison between actual pressure drop and that predicted using D_h + 9.75% is shown in Figure 4. Agreement across all cases can now be seen. Although, at an error of 22%, the predictive power is not high, it is considered sufficient to predict system performance and to distinguish between alternative system geometries in an optimisation process.

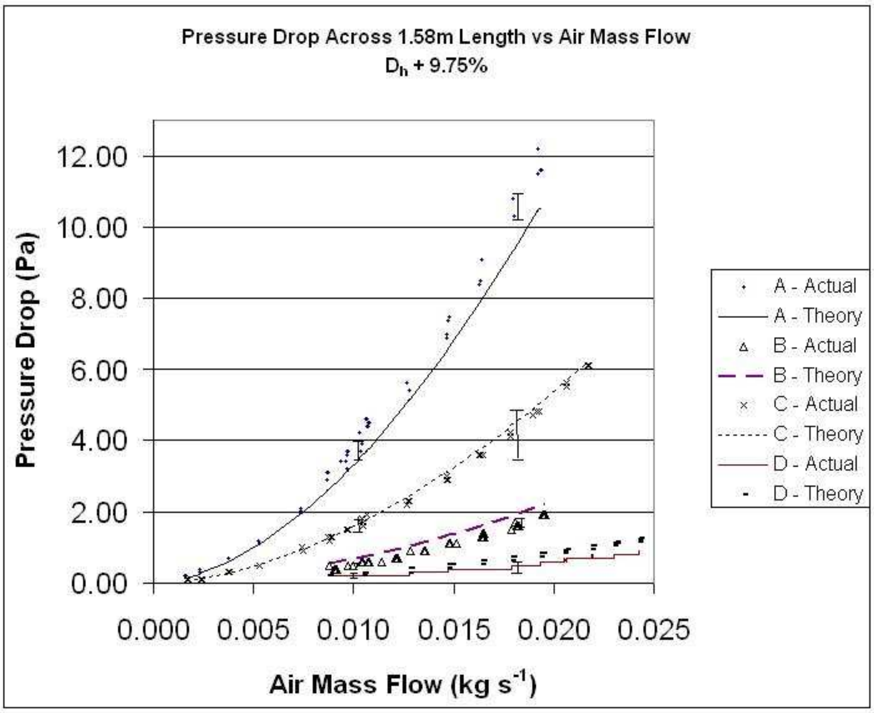

Figure 4: Relationship between pressure drop and air mass flow for 1.58m length with D_h increased by 9.75% – ducts A to D

5. CONCLUSIONS

The calculation of pressure drop due to surface friction in a prototype solar collector system was compared to measurements. For the larger duct dimensions, under the flow-rates considered, the Darcy equation was found to over estimate the system pressure drop. It was found that using the Darcy equation with an adjusted hydraulic diameter (increased by 9.75%) gave a better match to the actual data for the geometries and flows considered, reducing the mean bias as well as the rms error in the predictions. Across the range of duct geometries and flowrates considered, pressure loss due to friction could be predicted to within 22%.

The ability to predict system pressure losses will be important to a passive air heating system, since a system with a low pressure drop per metre in length is more likely to operate without the assistance of a fan.

6. NOMENCLATURE

A_c cross-sectional area of duct (m^2)
A_g area of glazing (m^2)
C_p specific heat capacity of air
D_h hydraulic diameter (m)
f friction factor
f' friction factor approximation
g acceleration due to gravity
K_{f1} pipe fitting pressure drop loss coefficient
K_{f2} pipe fitting pressure drop loss coefficient
L length of solar absorbing layer (m)
$\dot{m}$ mass flow rate of air (kg s^{-1})
P power output of duct (W)
p_{fr} pressure drop due to friction (Pa)

Q_F rate of heat transfer lost across glazing (W)
Q_g rate of heat transfer across glazing (W)
Q_i rate of heat transfer lost across insulation (W)
Q_V rate of heat transfer lost through ventilation (W)
Re Reynolds number
S stratification parameter
t_{ex} temperature of air exiting duct (^oC)
t_m mean temperature of air in duct (^oC)
t_o temperature outdoors (^oC)
U_g U-value of the glazing (W m^{-2} K^{-1})
V air velocity (m s^{-1})
β cubic expansivity (K^{-1}) = $1/t_m$(K)

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RFID IN THE BUILT ENVIRONMENT: BURIED ASSET LOCATING SYSTEMS

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Abstract: RFID tags (radio frequency identification devices) are in essence transceivers consisting of three components that make up a sophisticated transponder. Once activated, the tag transmits data back to a receiving antenna: the technology does not require human intervention and further benefits from the fact that no line of sight is needed to control/operate the system.

The tags can have both read and write abilities and their performance characteristics can be tailored/changed to accommodate a range of situations.

As RFID becomes ubiquitous, the proliferation of RFID system suggests that it will be all pervasive and there is no doubt that RFID is to have a tremendous impact on all major construction projects and built environment facilities. As the systems become more widespread, so the technology itself becomes smaller and cheaper. Some popular RFID applications include: supply chain management, baggage handling, library information systems, rental car, inventory control, hospitals and animal identification

Within this paper we argue that utility provision (the hidden services) is an area where RFID technology would be able to identify location of buried pipes and others underground equipment. Results from field trials are considered and issues and concerns relating to developing such an application of RFID are discussed.

Keywords: Buried asset, Built environment, RFID, Technology, Tracking

1. INTRODUCTION

1.1 Key features of RFID:

Radio Frequency Identification (RFID), also called Dedicated Short Range Communication (DSRC), is a wireless system which is capable of uniquely identifying objects, animals or people. RFID systems include devices called tags (the transponders), antennae and readers (the transceiver). This technology benefits from the fact that 'line of sight' is not required to control/operate the system or other devices attached to the tags.

The technology is based on a range of radio frequency (RF) waves as outlined in ***Table 1***. These frequencies bring with them a spread of operational characteristics which are also shown in ***Table 1***.

Operating on lower frequency means less absorption by moisture, better omni-directional capability, less impact from the presence of metal, but shorter signal range and slower reading. Higher frequency means longer range, higher speed, but more influence from metal. Efficiency of the energy transferred from the reader to the tag and the data rate are also affected by frequency (MICROLISE, 2003).

Table 1. Frequency specifications:

Frequency Range	**LF 125 KHz**	**HF 13.56 MHz**	**UHF 868 – 915 MHz**	**Microwave 2.45 GHz & 5.8GHz**
Typical Read Range (Passive Tag)	<0.5 m	~ 1.0 m	~ 3.0 m	~ 1.0 m
General Characteristics	Low frequency requires a longer, more expensive copper antenna. Low susceptibility to performance degradation from metal and liquids. Read range is very short.	Relatively short read range and slower data rates when compared to higher frequencies.	Large volumes are cheaper than LF and HF tags. Offers good balance between range and performance – especially for reading multiple tags.	Similar characteristics to UHF tag, but with faster read rates. This waveband is susceptible to performance degradations due to metal and liquids.
Tag Power Source	Generally passive tags using inductive coupling	Generally passive tag using inductive or capacitive coupling	Generally active tags with integral battery	Active tags with integral battery
Typical Application	Access control, animal tracking, and vehicle immobilizers.	"Smart Cards", Item tracking, baggage handling, libraries	Pallet tracking, electronic toll collection, baggage handling	SCM, electronic toll collection

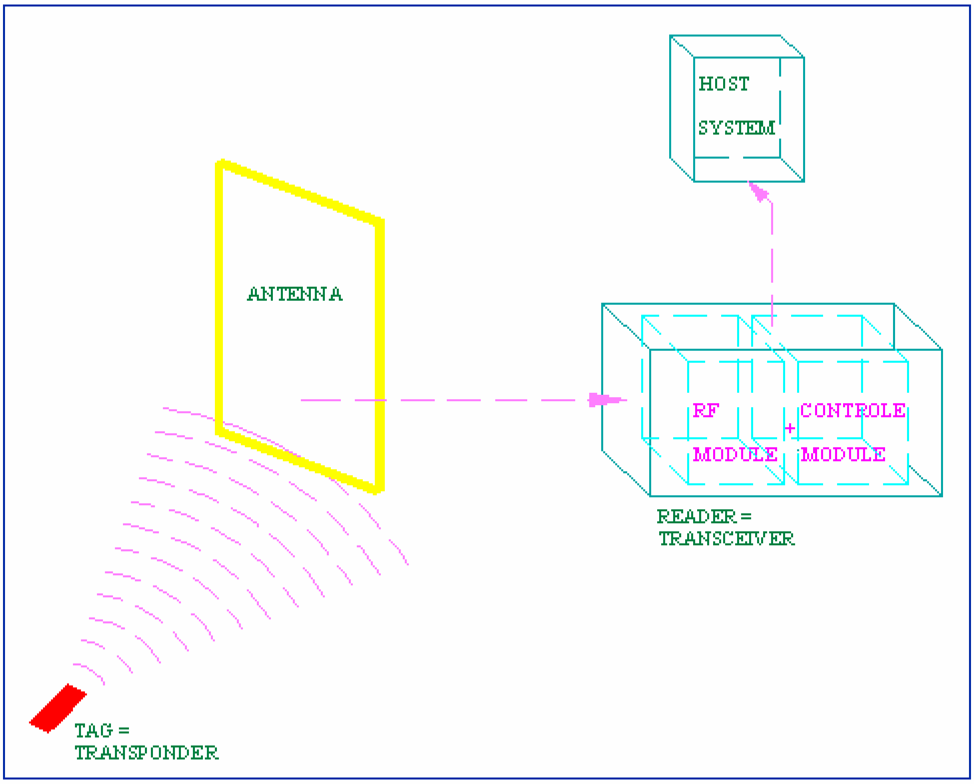


Figure .1 System operation.

As the **Figure 1** shows, the antenna uses RF waves to transmit a signal that activates the tag (the tag enters a read zone). Once activated, the tag transmits data back to the antenna. The data is captured by the reader and can be transferred through standard interfaces to a host computer or other electronic programmable device for storage or use (Susy d'Hont, TI).

1.2 RFID Components:

TAGS

A **transponder,** commonly called tag, is a combination of the words **trans**mitter and res**ponder**. The tags consist of integrated circuitry, some memory and RF antenna ***(Figure 2)***. Every tag own unique identification number. Depending on the tag specification it can have the ability to store data. The passive tags can store data up to 512 bytes and active tags up to 32Kb. Depending on the design, the tag memory can be as follow:

- Read Only (RO) – this tag can be only readable;
- Reads/Writes (R/W) – user programmable but with ability to dynamically change the data stored on the tag;
- Write Once Read Many (WORM) – user programmable.

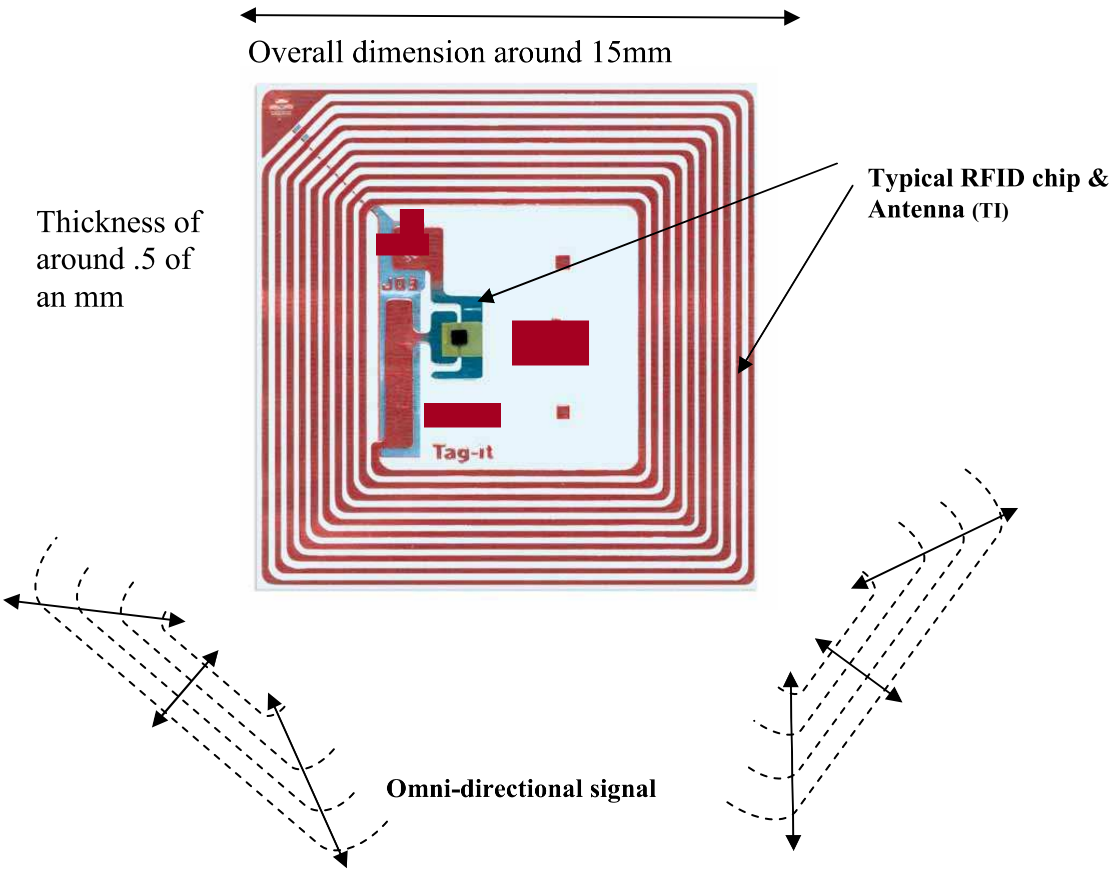


Figure 2 Schematic layout of a basic RFI Device.

RFID tags come in a wide variety of size, shapes, and forms and read ranges (***Table 2***). Transponders can be either passive or active. Passive tags rely upon the reader to provide the power necessary to generate the response signal. Generally passive tags are smaller and lighter than active tags, which are powered internally by a battery. Passive tags are also maintenance free and will last almost indefinitely. From the other hand active tags can benefit from the fact that their signal can reach up to 100 meters instead of up to 1.5 meters for passive tags (MICROLISE, 2003).

Table 2 Sizes and shapes of RFID devices.

Label	The tag is flat, thin, flexible form.
Ticket	A flat, thin, flexible tag on paper
Card	A flat, thin tag embedded in tough plastic for long life
Glass bead	A small tag in a cylindrical glass bead, used for applications such as animal tagging (e.g. under the skin)
Integrated	The tag is integrated into the object it is tagging rather then applied as a separate label, such as molded into the object
Wristband	A tag inserted into a plastic wrist strap

An Antenna

An **antenna** is a specialized transducer that converts RF fields into alternating current (AC) or vice-versa. There are two types of the antenna:

- **Receiving** antenna – this device intercepts RF energy and delivers AC to electronic equipment;
- **Transmitting** antenna – which is fed with AC from electronic equipment and generates an RF field.

The orientation of the tag to the antenna is significant in the ability to read the tag. That is why antenna design is a fundamental and unique part of any installation and always requires to be customized to the particular application. Antenna designs can vary from hand held devices to large freestanding or fixed installations (MICROLISE, 2003).

Reader

The RF **transceiver** (the reader) is a combination of the words **trans**mitter and re**ceiver**. If the passive tag is used, the RF field created from the antenna energises the tags and picks up their RF transmission of data. Reader captured the data and works as an information encoder. Nowadays, various kinds of readers are on the market, such as desktop, hand-held, embedded into mobile devices or fixed readers.

The **host system** controls the data flow between the readers and tags. The system can be very simple such as a personal computer connected to the reader by a serial cable. There are also more complex systems, which include many readers located in different places/areas transfer data to host servers through LANs or even over the Internet (UPM Rafsec, 2004).

1.3 RFID Applications:

RFID technology is broadly implemented in many areas and we can hear about RF smart devices almost every day by reading daily newspapers. Two main areas of RFID applications include: Proximity (short-range) and Vicinity (long-range). Within Proximity there are mainly applications such as access control and mass transit ticketing. Long-range applications include: supply chain management, parcel and mail management, garment tags, library and rental sectors and baggage tagging (UPM Rafsec, 2004).

This technology can be implementing to monitor use and maintenance of construction equipment. Hours of operation, critical operating data (such as temperature or oil pressure), maintenance schedule, maintenance history and other relevant data can be gathering and store on the tag for use by safety and maintenance personnel. RFID can also increase the service and performance of the construction industry with applications in materials management, tracking of tools and equipment, automated equipment control, jobsite security, maintenance and service, document control, failure prevention, quality control, and field operations.

Table 3 Highlights a number of application areas where RFID can improve the overall efficiency of Facilities Management (FM) systems.

Table 3RFID applications

Application	Target activity	Tag type
Access Control of the overall facility.	Doorway entry at various points on a Building	Passive/ Active
Asset Tracking	Locating vehicles within a freight yard	Active
Asset Tagging	Tracking corporate computing hardware	Passive
Baggage/Mail Tracking	Positive bag/envelope matching	Passive
Supply Chain Management (SCM) (Container Level)	Tracking containers at distribution terminals	Active
SCM (Pallet Level)	Tracking each pallet in yard/store	Active/ Passive
SCM (Item Level)	Identifying each individual item/package	Passive

One of the new RFID applications is utility area. The companies are looking for a solution which provides a more accurate and comprehensive method of locating and marking modern flexible plastic pipes. They are also interested in data management methods that will facilitate the collection, storage and updating of information concerning the utilities (Statement of need, 1999).

Currently, various methods are used to pinpoint the location of buried assets. Some of these approaches utilise destructive methods, such as soil borings, test pits, hand excavation, and vacuum excavation. There are also geophysical methods, which are non-destructive: these involve the use of waves or fields, such as seismic waves, magnetic fields, electric fields, temperature fields, nuclear methods and gas detection, to locate underground assets (Statement of need, 1999).

The most effective geophysical method is Ground Penetrating Radar (GPR) (Olheoft, 2004). This technique has the capability of identifying metal assets but is not able to give accurate data about the depth of the object, which is important information for utility companies. The GPR approach is likely to be affected by other metallic objects in close proximity to the asset being sought.

Another widely used method of locating underground infrastructure is Radio-detection, which is based on the principle of low frequency electromagnetic radiation. This technique is unable to detect non-metallic buried plastic, water, gas and clay drainage pipes. Some pipe materials are non-metallic and more difficult to locate with conventional pipe location technologies (Radio-detection, 2003). Combining Radio-detection with GPR opens up the possibility of locating non-metallic pipes (Stratascan, 2005). However, the technique becomes more complicated and expensive.

Unfortunately, thus far none of these methods is able to provide accurate and comprehensive data on the location of non-metallic buried pipes (ITRC, 2003). The shortcomings of the above methods are summarized below:

- They cannot locate non-metallic utilities.
- They cannot be used in all types of soils.
- They cannot penetrate to required depths.
- They use perilous/dangerous/complex equipment that increases risks and costs of
  operation.

By applying RFID technology to/within the provision and management of utilities, we undertook to find a solution of how best to identify the location of non-metallic buried pipes and other underground equipment. Results from field trials are considered and issues and concerns relating to developing such an application of RFID are discussed.

2. OBJECTIVES OF THE RESEARCH

PRIMARY OBJECTIVES:

- To identify the location (depth) of buried assets up to 3m within an accuracy of +/-5cm and to relate the location of buried assets to a Global Positioning System (GPS), Geographic Information Systems (GIS), and UK's Ordnance Survey (OS) framework and be able to record it to the UK's Digital National Framework (DNF)

SECONDARY OBJECTIVES ARE AS FOLLOWS:

- To construct and synthesise a detailed body of knowledge on the current approaches to buried asset location.
- To develop a route forward for a novel approaches using RFID.
- To develop a prototype system and trial in the field.
- To collect field data and analyse using appropriate statistical and drawing packages.
- To refine the system and relate to the developed body of knowledge.
- To validate the system developed and report on the work.

3. RESEARCH METHODOLOGY

There are two main types of research methodologies, qualitative and quantitative. The main difference between them is that the first one uses descriptive methods and the second numerical methods. Choosing the proper method for the research study depends on the subject and character of the problem. This research is founded on a quantitative research methodology using an experimental design method. General principles of the usage of quantitative analysis in research are that it facilitates (Leedy, D Paul, 2001):

- Planning the analysis before undertaking it
- Ensuring familiarity with the methods of analysis in the field of study
- Deciding upon the method of analysis to be used
- Deciding on the use of computer package(s) (if necessary) for the analysis
- Gathering data around this method of analysis
- Analysing the gathered data
- Testing the results to ensure reliability

The field methodology was bifurcated into two phases:

Phase 1

This phase determined an appropriate RFID tag/antennae and reader configuration which would give accurate depth and location indications at up to, and including, 2.0m below surface level.

In this phase a range of passive tags were fixed to a small wheeled ‘chariot’, which was lowered into the pipe using a tape measure. The tag’s return signal was received using a LF antenna and reader on the surface. The chariot was lowered until it reached the point of signal loss and from that maximum read depth was determined. Afterwards the chariot was located at pre-determined depths and the surface antenna was raised until the point of signal loss. The distance between the surface and the antenna was noted and this enabled the ground depth of a tag to be determined.

Phase 2

After the basic principles of the location system have been proven in Phase 1, Phase 2 will focus on the following steps:

- Improving the tag reading performance to 3m below ground.
- Improving depth and positional accuracy to 5cm.
- Make the locating system mobile.
- Providing more accurate data on performance through differing types of ground/soil material.
- Providing a GPS system fix for the asset.
- Overlaying the depth and track data onto an Ordinance Survey (OS) map and GIS system.

Further improvement to the operating system can be envisioned using active rather than passive tags as the latter provides a much greater signal range. Using an active tag to optimize the performance of the system at a lower than standard frequency will require a custom manufactured tag.

4. FINDINGS

4.1. TESTS IN THE AIR

Initial air tests were carried out at a training facility near Glasgow.

A series of air tests were run with the aim being to ascertain the connectivity between each of the three tags (transponder) with each of the four antennae. The data generated from these test is presented below:

Table 3 *Tag's specification*

SYMBOL	TRANSPONDER
T1	LTag
T2	MTag
T3	STag

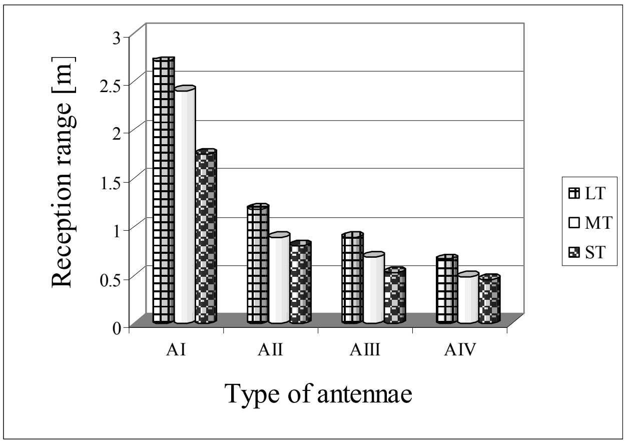
Table 4 *Antennae's specification*

SYMBOL	ANTENNAE
AI	L1
AII	L2
AIII	M1
AIV	S1

Initially 12 tests were run to determine the greatest signal reception range between the antennae and the tags. The best results are summarized in the ***Table 5*** below. It should be noted that due to weather constraints the general number of tests both in air and below ground were curtailed and will be expanded at a later date.

Table 5

	L tag	**M tag**	**S tag**
	metres	metres	Metres
AI	2.7	2.4	1.75
AII	0.664	0.485	0.455
AIII	0.895	0.69	0.53
AIV	1.185	0.885	0.805



4.1.1. DATA ANALYSIS

To make sure that the measurements are accurate the distance presented in **Table 5** was taken when the signal sent from the antennae to the tag was continuous, without any interference.
Results in **Table 5** showed that the longest acceptable signal reception ranges can be achieved when antenna AI is connected with T1 or with T2. Air tests also showed that the worst performances are between antennae AII when tested in conjunction with all tag types. Hence, AII was eliminated from further examination. Antennae AI, AIII and AIV were then tested with an underground signal.

Air tests allow testing effective performance of each tag and reader combination and create zones of magnetic field between each of the tags with each of the antennae. This information shows the range of magnetic field within which the technology can operate.
With the aid of AutoCAD (design program) and data from the air tests, we created the range of the signal patterns between all the antennae and tags.

Figures: 3, 4 and 5 present a range of signal patterns created between antenna AI and tag T2 depending on the antenna position.

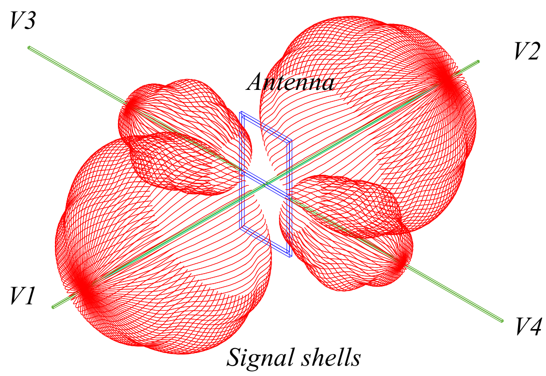


Figure 3 Antenna positioned vertically.

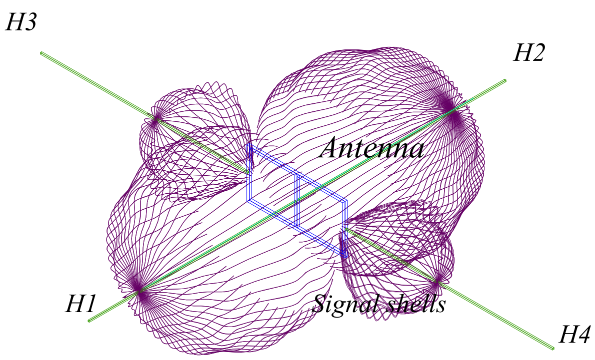


Figure 4 Antenna positioned horizontally

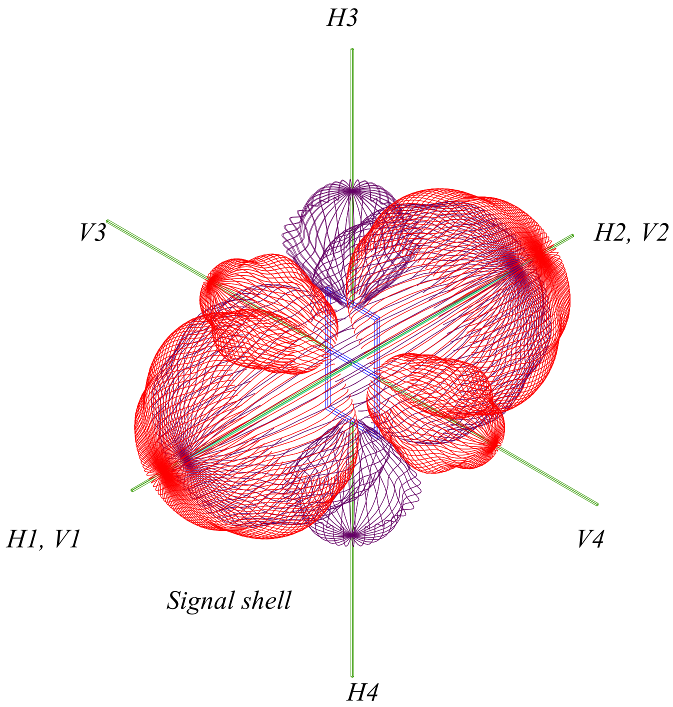


Figure 5 Superimposed reception shells.

In **Figure 3** antenna was positioned vertically. We can see that there are two sizes of shells. Bigger shells lay on axes V1 and V2 and smaller on V3 and V4. The reason behind this is the size of the antenna: the larger the antenna is, the greater the capture of the magnetic field/signal generated by the tag.

Figure 4 shows the antenna in horizontal orientation. The description is similar to the one given in **Figure 3.** Again we can observe two sizes of the shells which show the reception range of the signal in this orientation.

Figure 5 Indicates the combined reception shells for both orientations. It is clear that the antenna is capable of directionally locating the tag. This directional capability allows us to eliminate spurious signals and so concentrate on the desired signal from the tag i.e. the larger signals can be attenuated.

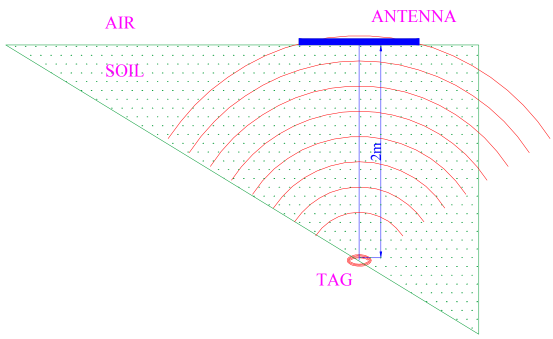
4.2. UNDERGROUND TEST

Due to weather and operational constraints, we have only been able to execute one series of field tests.

At this early stage of the field trials we have successfully tested antenna AI with tag T2. Tests were carried at increasingly different depths until the required 2m depth was achieved.
An implicit part of the investigation is aimed at ascertaining the extent of soil conditions that could affect the reception of test findings.

For completeness we carried out and compared tests when:

- the separation between the tag and antenna was only soil (***Figure 6***)
- half of the distance was in soil and the other half was air (***Figure*** *7*)



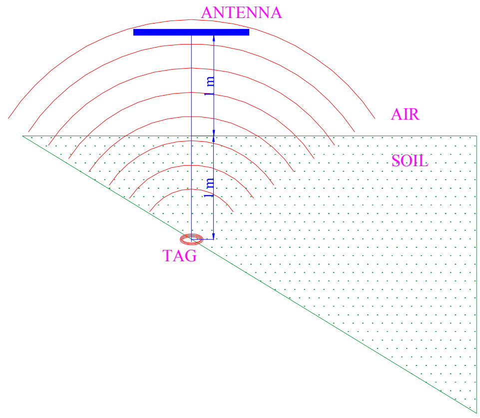


Figure 6 Only soil.

Figure 7 Mixed.

The first test showed that the presence of soil had only a slight/negligible effect on performance. However, in the United Kingdom there are six general types of soil: clay, sandy, silty, peaty, chalky, and loamy. All of them have their own characteristics. The most important properties of soil are: hydraulic conductivity, soil moisture retention and pathways of water movement (Jarvis, 2004). And it is possible that different soil condition/types can affect the performance and its accuracy.
Future work will focus on the impact of varying soil conditions on reception and accuracy. The future work also include examining antenna AI with two more tags as well as antennae AIII and AIV with all tags. It is anticipated that this will result in indications as to the size and shape of antenna which can achieve the required depth and accuracy. Upon completion the tests will be repeated to ensure that the data collection is accurate.

More tests will be carrying by changing the soil conditions and pipe types respectively. Upon completion of this range of field trials and analysis of the generated data, we will have an overview of the system and its efficiency.

5. CONCLUSIONS

From the air tests, we developed the ideal combination between antennae and tags. These tests also allowed us to establish reception shells and expected reception ranges.

Underground tests let us establish reception at a range of depths through one soil type. As the tests progressed we were able to receive a signal at the target depth outlined in ***Phase 1*** (2m). We also discovered that soil characteristic may not affect the reception.

These early results are encouraging, and they seem to indicate that an answer to identifying non-metallic underground/buried assets does lie in the use of RFID technology.
As stated earlier, a considerable amount of development work is still to be done to arrive at a fully operational system. A successful beginning has been made at last. Our next step will focus on improving the accuracy of reception range.

RFID technology is becoming ubiquitous: the proliferation of RFID systems suggests that they will be all pervasive, and there is no doubt that RFID is set to have a tremendous impact on all major industries. As RFID systems become more widespread, the technology itself becomes smaller and cheaper.

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EVALUATION OF AUTOCLAVED AERATED CONCRETE (AAC) AS A REPAIR MATERIAL FOR TIMBER FRAMED HISTORICAL STRUCTURES

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Abstract: In the recent repair works of historical structures, autoclaved aerated concrete (AAC) started to be used, especially in timber framed historical structures as an alternative material to the original mudbrick, brick or stone infill. For its proper use in maintenance and repairs of historical structures, the material properties of AAC, its compatibility with the historical materials and within the structure should be discussed. This study was conducted to understand the material properties of AAC fabricated in Turkey in order to discuss its compatibility as a repair material in historic structures. Analyses were done to determine its basic physical, mechanical, durability and compositional properties. The properties of AAC were compared with those of historical mudbrick, brick, timber, mortar and plaster samples and its compatibility with the historic fabric was discussed. It was concluded that further studies are needed to allow its use in repairs of historic structures.

Keywords: autoclaved aerated concrete (aac), compatibility, infill material, material properties, timber framed historical structures.

1. INTRODUCTION

Autoclaved Aerated Concrete(AAC) is being preferred as a building material due to its several advantages such as its light weight, low thermal conductivity, high fire resistivity and soundproofing properties (Taşdemir & Ertokat, 2002; Grutzeck, Kwan & Di Cola, 2004; Narayanan & Ramamurthy, 2000a; 2000b). It is also observed that AAC has recently started to be used as a repair material alternative to original mudbrick, brick and stone infill, especially in Turkey.

Even though there are some studies on AAC (Taşdemir et al., 2002; Grutzeck et al., 2004; Narayanan et. al., 2000a; 2000b), there is need for more extensive and comprehensive studies both on its material properties and its compatibility with the neighbouring materials in historic structures, which is vital for their long term survival (Sasse & Snethlage, 1997).

This study was conducted to better understand the material properties of AAC and its compatibility as a repair material for timber-framed historical structures with the emphasis on its basic physical properties as total porosity, bulk density, drying behaviour and water vapour permeability in terms of water diffusion resistance coefficient(μ), mechanical properties as dynamic modulus of elasticity (Emod) and uniaxial compressive strength (UCS), wet-to-dry strength ratio (UCSwet/UCSdry) as a durability parameter and its pozzolanicity. It is suggested that μ, Emod and UCS were among the most important parameters of compatibility (Sasse et al., 1997). Any material introduced into the historical structure should not have lower μ and higher Emod or UCS. Water vapour permeability is an important physical property that has to be taken into account in order to prevent condensation problems in the structure after repairs. Other important issues of compatibility between the repair material and the original materials of the building are the bonding properties and the dilatation properties under variable atmospheric conditions such as temperature and humidity changes (Mertz, 2004). Pozzolanic activity is a property which is closely related with the bonding capability of AAC with lime mortars which are more suitable repair materials than cement containing mixtures (Sasse et al., 2004). The compatibility of AAC with the historic materials and the structure was discussed by comparing its determined physical, mechanical and bonding properties with those of historic materials such as , mudbrick, brick, timber, lime mortars and plasters.

2. MATERIALS AND METHODS

The properties of repair materials should be similar to those of original ones within a certain range so that their compatibility with the neighbouring materials is achieved (Sasse et al., 2004). Therefore, the selected material properties of AAC were determined by laboratory analyses, then, the data obtained were used to compare its properties with those of historical materials.

Two types of AAC, one produced as infill material (G2) the other produced as load-bearing unit (G4) were examined . The samples were produced from the AAC blocks of 25 x 30 x 60 cm according to the TS EN 678 (1995) and TS EN 453 (1988) standards. Additional samples were also prepared from core and exposed(wire-cut) surfaces to clarify the differences between those parts.

The physical properties bulk density (D), porosity (P), water absorption capacity (WAC), saturation coefficient (S), water vapour permeability, drying behaviour and evaporation rate were determined according to ASTM (1993), RILEM (1980) and Turkish Standards (TSE, 1995; TSE, 1988). In addition, examination of thick sections by optical microscopy were done. Water diffusion resistance coefficient, μ value was determined for the samples with varying thickness from the wire-cut surface, such as 1.25, 2.5 cm (TSE, 1990).

Modulus of elasticity value (E_{mod}) of AAC samples were determined indirectly by ultrasonic pulse velocity measurements (UV) since it is an important mechanical property which shows the deformation ability of a material under external forces. (RILEM, 1980; ASTM 1990; ASTM, 2003a; 2003b). For this purpose, a pulse generating test equipment, PUNDIT Plus, with its probes, transmitter and receiver of 220 kHz and 50 kHz, was used. E_{mod} values of the samples were then calculated with certain equations including both their D and UV.

Uniaxial compressive strength values(UCS) of the samples were determined by using ELE International Compact-1500 UCS Instrument as direct measurement. In addition, point load strength index (Is) was also determined by using Point Load Testing method using appropriate equations as indirect measurement (Topal, 1995; Topal, 1999/2000, ISRM, 1985). The correction factor, *k* (UCS/Is) was then determined by using UCS measurements and the Is values. (Broch and Franklin, 1972; Anon, 1972; Bieniawski, 1975; Anon, 1977; Beavis et al., 1982; Foster, 1983; I.S.R.M., 1985; Topal, 1995; Norbury, 1986).

Durability properties were examined in terms of saturation coefficient (S), and wet-to-dry strength ratio based on UCS (R_{UCS})(Winkler, 1986, 1997; Topal, 1995; Topal and Doyuran, 1997). UCS values of wet samples were determined to clarify the reductions on the saturated samples after soaking in water for 5 days. The changes in E_{mod} values in relation to water were also followed. For this, E_{mod} values were measured on the dry samples during 2 cycles of wetting and drying. E_{mod} values were also measured on the dry samples which were left in water for 20 days after being saturated under vacuum.

Mineral composition of the samples were determined by the analyses of pozzolanic activity and X-Ray Diffraction (XRD). Pozzolanic activity indicated the reaction ability of AAC with calcium hydroxide by producing the calcium–silicate-hydrate (C-S-H) network, in fact the bonding capacity with lime mortar. The pozzolanic activity of AAC were examined by using the Luxan method (Luxan et al., 1989) for its fine grains lower than 125μ diameter using the powder produced during cutting of the samples. The pozzolanic activity of the aggregates lower than 125μ used in the production of AAC was also examined. They were provided by the manufacturer of AAC. In the analysis, 1.25 gr sample in powder was mixed with 50 ml saturated $Ca(OH)_2$ solution and the change in the electrical conductivity of the mixture was measured by using Metrohm AG Herisau, Konduktometer E382. The decrease in the electrical conductivity within 2 minutes were used for the evaluation of pozzolanic activity. For the XRD analysis, the powder samples were analysed by using Phillips Model PV 3710 X-Ray Diffractometer with Cu K α X-Rays.

3. RESULTS AND DISCUSSIONS

The combined interpretation of the results obtained from the laboratory analyses were done to define the material properties for AAC and to discuss whether it is a proper material for repairs of historic timber framed structures.

The bulk density and porosity of G2 and G4 samples were found to be 0.4 g/cm^3 and 78%, and 0.6 gr/cm^3 and 68%, respectively. Water absorption capacity (WAC) for both G2 and G4 was found to be extremely high with values of 193% and 114%, respectively (see Table 1). AAC, used as an infill, G2, and load bearing purposes, G4, were found to be very porous and lightweight materials while G4 was, expectedly, denser and less porous than G2. The samples taken from the wire-cut (exposed) surfaces of AAC blocks within the 2.5 cm thickness were found to have slightly less porosity (see Figure 1).

Table 1: Basic Physical and Mechanical Properties of G2 and G4 samples

Properties	G2	G4	Properties	G2	G4
D (gr/cm^3)	0.4	0.6	UCS (MPa)	1.88	2.76
UV (m/s)	1965	1962	WAC (% by weight)	193	114
E_{mod} (Gpa)	1.4	2.1	P (%)	78	69
S (0-1)	0.46	0.62	R_{UCS} (%)for the samples which were left in water for 5 days after being saturated	58.5	54.4

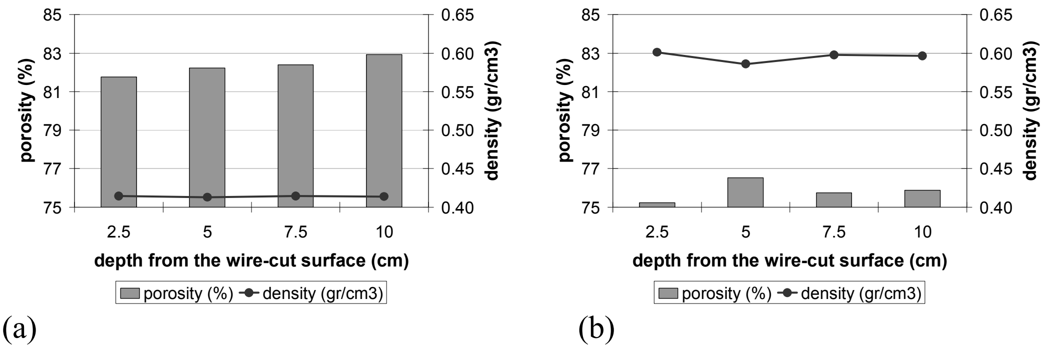
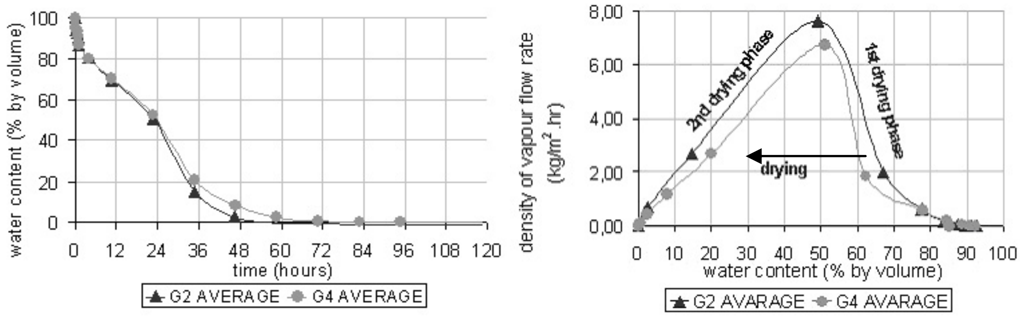


Figure 1: bulk density and porosity values for the (a) G2 samples and (b) G4 samples of 2.5 cm, 5 cm., 7.5 cm and 10 cm depth from the wire-cut surfaces. The samples taken from the wire-cut surfaces until 2.5 cm depth have the lowest porosity.

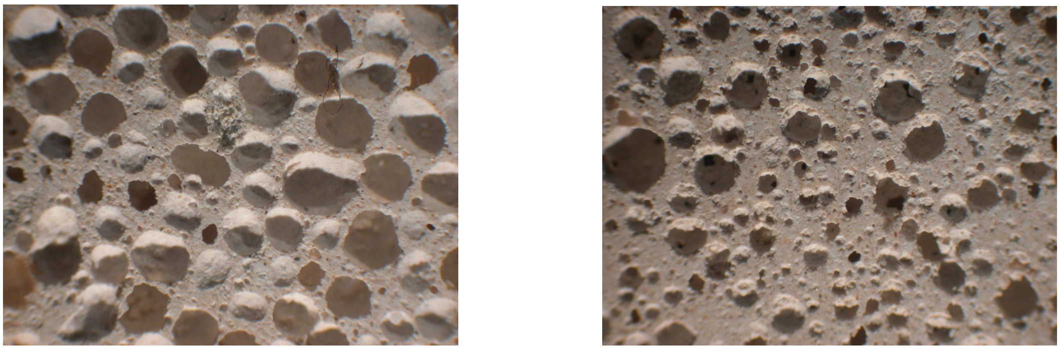
The laboratory analyses on evaporation rate(kg/m2.hr), drying curve (water loss as % by volume) and saturation coefficient(S) defined as the ratio of free sorption to the sorption under vacuum gave some information on pore size distribution characteristics of AAC. The saturation coefficient of G2 was found to be lower than that of G4, with the values of 0.46 and 0.62, respectively (Table 1). This indicated that G4 should have higher proportion of fine pores when compared to G2 since a high value of saturation coefficient indicates presence of high proportion of fine pores allowing water to be absorbed by capillary action (BRE, 1997; RILEM, 1980; Winkler, 1997). At 20oC and 40% RH conditions, the curve of evaporation rate showed two different drying phases. At the first drying phase the evaporation had an increasing rate and after at a critical point, the second drying phase had a decreasing rate (Figure 2b). Evaporation during the first drying phase depends solely on the exposed climatic conditions while during the second drying phase it depends on the material properties (Massari and Massari, 1993; Torraca, 1982). The critical point, corresponding to the critical moisture content level, was found to be about 50% by volume for both G2 and G4 samples. 50% critical moisture content was a high value when compared to porous historic materials (Massari and Massari, 1993; Tuncoku, 2001; Tuncoku et al., 1993). This showed that AAC retains water more than historic brick, brick mortar and stone mortar. The evaporation rates of G4 and G2 samples were found to be in the range of 0.03 – 6.73 kg/m2h and 0.03 – 7.61 kg/m2h respectively (Figure 2b). G4 samples, with 3 days of drying period, dried out slower than G2 samples with 2 days of drying period (Figure 2a). G4 samples that dried out slower had higher saturation coefficient than G2. Both drying experiment and saturation coefficient determinations support each other and indicate that G4 has higher proportion of finest pores than G2.



(a) (b)

Figure 2. (a) Drying curve by decrease in volume versus time at 20^{o}C and 40% RH conditions;
(b) Variation of evaporation rate as a function of moisture content by volume; showing that G4 dries out slower than G2.

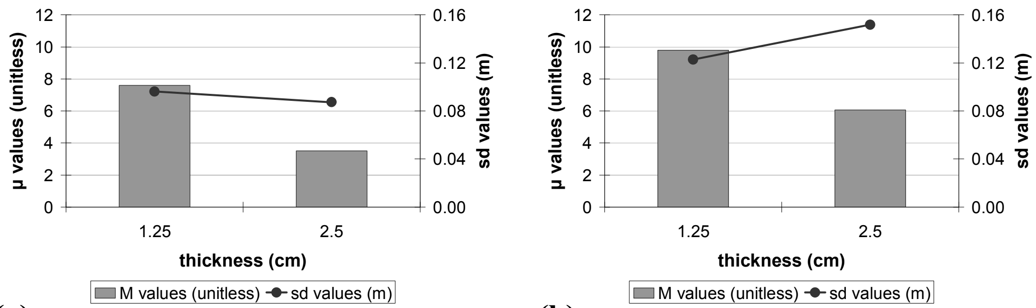
Microscopic examination of thick sections supported those conclusions. G2 appeared to have higher proportion of large pores than G4, therefore dried out quicker (see Figure 3)



(a)G2 **(b)**G4

Figure 3. Thick sections showing large pore size distribution of AAC. Longer side of the micrograph: 1 cm.

μ values of G2 for 1.25 cm and 2.5 cm thickness were found to be 7.59, 3.52 and and μ values of G4 were 9.78, 6.06 respectively. It was observed that there is a reduction in μ values with the increasing thickness from the exposed(wire-cut) surfaces. This reduction is more recognisable for G2 when compared to G4 (see Figure 4). Considering the thickness of the walls in timber framed structures as 10 cm, by using the obtained μ values for 2.5 cm thickness, the SD values of G2 and G4 blocks were calculated to be 0.35 and 0.61 respectively. However, the real SD of the blocks should be lower than those.

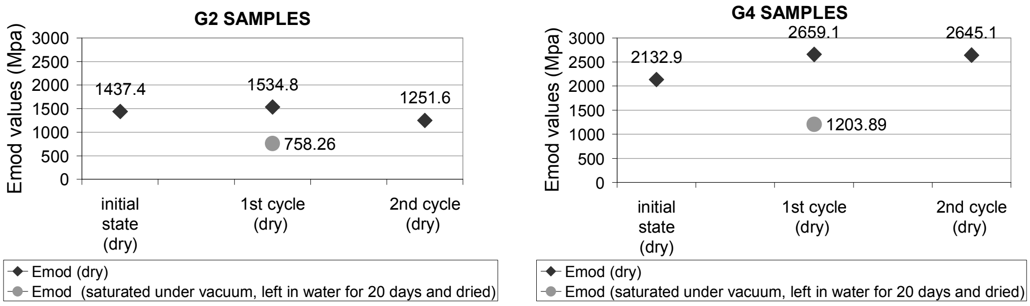


(a) **(b)**

Figure 4. The equivalent air thickness of water vapour permeability ***(SD)*** and water diffusion resistance coefficient**(μ)** values for G2(a) and G4(b) samples with 1.25 and 2.5 cm thickness.

Ultrasonic velocity values(UV), E_{mod},and UCS were found to be 1965 m/s, 1.4 GPa and 1.88 MPa for G2 while 1962 m/s, 2.1 GPa and 2.76 MPa for G4, respectively (see Table 1). UCS values of AAC material was found to be within the acceptable range defined for AAC products by RILEM (1993). According to prEN 12602 standards (1999), G2 was in the class of AAC 2 while G4 was in the class of AAC3. k value, UCS/ Is , was found to be 4.7 and 3.9 for G2 and G4, respectively. Those values were observed to be close to those for the weak rocks (Topal, 1999/2000; Topal, 1995).

Considerable changes in mechanical properties were determined on saturated AAC samples. Wet-to-dry strength ratio based on UCS for the G2 and G4 samples which were left in water for 5 days after being saturated were found to be 58.5% and 54.4 % respectively. According to Winkler's classification (Winkler, 1993), both G2 and G4 samples seemed to be unsafe materials for frost and hygric forces. The E_{mod} values of both G2 and G4 started to fall after the first wetting drying cycle. In addition, a significant reduction was observed on the E_{mod} values of the dry samples which were previously left in water for 20 days after being saturated under vacuum (see Figure 5).



(a) **(b)**

Figure 5. Modulus of Elasticity values, E_{mod}, as a function of wetting-drying cycles for G2 (a) and G4(b) samples.

Mineral composition of the samples were determined by the pozzolanic activity and XRD analyses. The pozzolanic activity values of G2 and G4 samples were found to be 0.85 to 0.95 mS/cm, respectively, and of aggregate used in the production of AAC as the raw material was found to be 0.27 mS/cm. According to the classification defined by Luxan *et.al* (1989), the powdered AAC samples were determined as variable pozzolanic while its aggregate was non-pozzolanic material. Examination of XRD traces showed that the main minerals detected were 11 A^{o} Tobermorite and quartz, and the rest were muscovite and biotite (Figure 6).

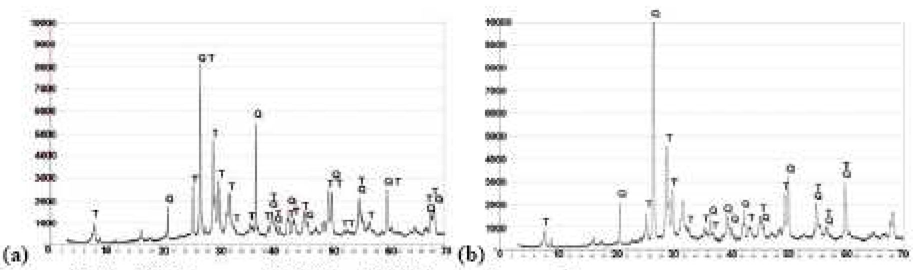


Figure 6. The XRD traces of G2 (a) and G4(b) powder samples

3.1. Comparison of AAC with Historic Building Materials

The properties of AAC and historic building materials were given in Table 2. In comparison to historic brick, mudbrick, mortar and plaster, AAC was found to be less dense and more porous with very high water absorption capacity, however its bulk density was close to that of timber (Tuncoku, 2001; Tuncoku et al., 1993; Akkuzugil, 1997; Güdücü, 2003; Eriç, 1980; Richardson, 1976). AAC seemed to absorb and retain water. Therefore, it should be well protected from water in any repair work to prevent deteriorations. It was understood that AAC samples dry much faster than some historic bricks and some historic mortars (Tuncoku 2001, Tuncoku, 1993; Tuncoku et al., 1993). Both G2 and G4 blocks with a thickness of 10 cm were found to have similar water vapour permeability characteristics with the historic mudbrick, brick, brick mortar, some plasters and timber. In addition, G2 seemed to be more suitable for repairs of these historic materials with its higher water vapour permeability (Akkuzugil, 1997; Güdücü, 2003; Akyazı, 1998; Kumaran et al, 1994:6; Yıldırım Esen, 2004). The UCS and Emod values of AAC samples were found to be within the range for those of historic mudbrick, brick, stone mortars, brick mortars and some plasters, however, they were a bit lower than those of historic bricks (METU MCL Studies, 2004; Eriç, 1980; Olivier et al., 1993; Eriç et al, 1980; Güdücü, 2003; Yıldırım Esen 2004; Tuncoku 2001; Tuncoku et al., 1993; Kahya, 1991). A significant reduction in the mechanical properties of AAC in relation to the presence of water was observed. This clearly indicated that AAC material should be avoided from direct water exposure to maintain its inherent mechanical properties. In addition, AAC seemed to be less pozzolanic than some of those historic stone and brick masonry mortars. This may lead to bonding problems at the interface of AAC with repair materials such as pozzolanic lime mortars and plasters within the historical structure. The pozzolanic activity of fine aggregates of AAC was found to be non pozzolanic while the aggregates of historic mortars and plasters were good pozzolans. Such a result showed the necessity for further studies to examine its bonding with the historic fabric.

4. CONCLUSIONS

Results of this study showed that AAC was found to be less dense, more porous than historic materials and it has very high water absorption capacity, however its density is close to timber. The water vapour permeability is also within the range of those for historic materials. AAC dried much faster which seemed as an advantage. In terms of mechanical properties such as E_{mod} and UCS, AAC is similar to historic materials within an acceptable range. However, it loses its inherent mechanical properties considerably in the presence of water. In addition, its aggregates are far less pozzolanic which may lead weak or no bonding with the historic fabric when used with lime mortars.

Consequently, it is clear that further studies are necessary in order to permit the use of AAC as a repair material in timber framed historic structures as an alternative to mudbrick or brick infill.

Table 2. The Comparison Of Material Properties Of AAC With Those Of Historical Materials

MATERIAL PROPERTIES	AAC	**HISTORIC MUDBRICK**	**HISTORIC BRICKS**	**HISTORIC MORTARS,**	**PLASTERS and TIMBER SAMPLES**
Density (gr/cm^3)	0.4-0.6	1.2-1.6 (Eriç, 1980) 1.17-1.63 for burnt mudbrick (Güdücü, 2003)	1.3-1.8 (Tuncoku et al, 1993; Tuncoku, 1993), 1.16- 1.64 (Tuncoku, 2001)	1.29 for burnt mud-plaster and 1.51 for burnt mud-mortar (Güdücü, 2003) 1.39-1.85 for stone mortars (Tuncoku, 1993), 1.25-1.74 for brick mortar (Tuncoku, 1993)	0.97 – 1.84 for lime plasters (Yıldırım Esen et al., 2004) 1.28-1.78 for lime plasters, 1.33-1.73 for gypsum plasters (Akkuzugil, 1997), 0.3-0.8 for wood(Richardson, 1976),
Porosity (%volume)	68.0-78.0	31.6-54.62 (Güdücü, 2003)	28.1-49.6 (Tuncoku, 1993) 33.9-57.4 (Tuncoku, 2001)	29- 59for mortars (Yıldırım Esen et al., 2004), 40.1 for mud-mortar (Güdücü, 2003), 27.36-45.88 for stone mortars (Tuncoku, 1993) 27.81-52.26 for brick mortars (Tuncoku, 1993)	23.52-41.38 for gypsum plasters, 32.05-47.82 for lime plasters (Akkuzugil, 1997)
WAC (%weight)	192 for G2 114 for G4	33.5-76.34 for burnt mudbrick (Güdücü, 2003)	12-37 (Tuncoku, 1993; Tuncoku et .al. 1993)	63.08-78.82 for burnt mortars(Güdücü, 2003)	19.75-38.54 for lime plasters, 11.39-31.43 for gypsum plasters (Akkuzugil, 1997)
(*SD*) for 10 cm thickness (m)	<0.35 for G2 <0.61 for G4	0.28-0.32 (Akkuzugil, 1997) 0.06 for burnt mudbrick (Güdücü, 2003)	0.9- 1.29		0.23-1.62 for lime plasters 0.21-0.37 for mud plasters 0.68 for horasan plasters 0.8 for timber
μ	<3.52 for 2.5 cm G2 <6.06 for 2.5 cm G4	2.75- 3.23 (Akkuzugil, 1997) 0.57 for burnt mudbrick (Güdücü, 2003)	9.06- 12.85 (Akyazı, 1998)		2.3-16.2 for lime plasters (Yıldırım Esen et al., 2004), 9.84 for lime plasters and 2.09 for mud plasters(Akkuzugil, 1997), 11.9 for lime plasters and 3.69 for mud plasters and 6.77 for horasan plasters (Akyazı, 1998) 8 for timbers (Kumaran et. al., 1994)
Duration of drying at 20^{o}C an 40% RH (days)	2 for G2 3 for G4		~10 for historic bricks (Tuncoku et .al. 1993)	5 or 6 for some stone and brick mortars (Tuncoku, 2001)	
Drying rate (kg/m^2.hr)	0.03 – 6.73 for G4 0.03 – 7.61 for G2		1.08 (at max)(Tuncoku, 1993)	~1.87 (at max)(Tuncoku, 2001)	
Emod (GPa)	1.4 for G2 2.1 for G4	0.7 (METU-MCL studies Fall 04'-REST 556), 1.2- 2.1 (Güdücü, 2003)	3.1 - 5.2 for bricks (Yıldırım Esen et al., 2004)	2.3-3.6 for brick mortars (Yıldırım Esen et al., 2004), 0.6-10.2 for stone mortars (Tuncoku, 2001), 0.6-3 for brick mortars (Tuncoku, 2001)	0.7-6.6 for lime plasters (Yıldırım Esen et al., 2004)
UCS (Mpa)	1.88 for G2 (UCS) 2.76 for G4 (UCS)	5.69 Mpa (METU-MCL studies Fall 04'-REST 556), 0.3-2Mpa (Eriç, 1980), 0.5-2 Mpa for non stabilized earth (Olivier, et. al. 1993), 1Mpa for normal mudbrick according toT.S. 2514 (Eriç et. al, 1980)	17 (Kahya, 1991)		
$Is_{(50)}$(Mpa)	0.4 for G2 0.7 for G4	0.1- 2.8 for burnt mudbrick (Güdücü, 2003)	2.96- 3.34 (Yıldırım Esen et al., 2004)	0.06- 1.83 for stone mortars 0.09- 0.72 for brick mortars (Tuncoku, 2001)	0.02-0.15 for plasters (Güdücü, 2003)
R_{Emod} (%)	63.5 for G2 and 100 for G4 23.5 for G2 and 36 for G4 for the samples left in water for 20 days after being saturated				
R_{UCS} (%)	58.5 for G2 and 54.4 for G4 for the samples left in water for 5 days after being saturated	50-60 for burnt mudbrick (Güdücü, 2003)			
pozzolanic activity (mS/cm)	0.85 for G2 and 0.95 for G4 0.27 for the aggregate	3-5.7 for burnt mudbrick (Güdücü, 2003)		9 for the aggregates of mortars (Yıldırım Esen et al., 2004), 0.4-1.5 for brick mortars (Tuncoku, 2001) 1.7- 3.3 for stone mortars (Tuncoku, 2001)	7 for the aggregates of plasters(Yıldırım Esen et al., 2004) 1.8- 6.4 for burnt plasters (Güdücü, 2003)

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THE EFFECTS OF PORE STRUCTURE OF AIR-ENTRAINED CEMENT-BASED MORTARS ON FREEZING AND THAWING DETERIORATION

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Abstract: Manufacturing of concrete resistant to freezing and thawing requires an in depth understanding of the mechanisms triggering deterioration. Despite numerous attempts, a definitive and fully explanatory model of this phenomenon is yet to be formulated. This paper presents part of a study which examines the influence of pore structure of cement-based matrix on the frost durability of Ordinary Portland Cement mortar. The research was based on an empirical investigation of five air-entrained and one non-air-entrained mortar subjected to almost 2200 freezing/thawing (F/T) cycles. Various concentrations of air-entraining admixture were used to differentiate the pore-structure of mortar and distinguish its critical parameters. The examination of the microstructure and composition of the cement paste was performed by means of Scanning Electron Microscope (SEM) and Mercury Intrusion Porosimetry (MIP). Presented results demonstrate the magnitude of alterations in pore configuration due to pure freezing/thawing and its effect on the mechanical characteristics (compressive/flexural strength). Finally, on the grounds of apparent transformation, a generic pore size distribution of frost resistant cement-based, air-entrained matrix is proposed.

Keywords: durability, freezing and thawing, microstructure of cement-based materials.

1. INTRODUCTION

The design of concrete endeavours to create a material able to withstand physical, mechanical, chemical and/or thermal conditions without deterioration over a long period of time. The destructive conditions might occur both internally and externally. The external circumstances causing the damage include weathering, extreme temperatures, abrasion, electrolytic action and attack by natural/industrial gases. Internally, concrete is threatened by alkali-aggregate reactions, volume changes caused by different thermal properties of its constituents, and permeability which is considered by many to be the most important property (Neville 1987).

Evaluation of the microstructure of deteriorated concrete provides an invaluable, and in many instances, the only method to determine the causes and principles of deterioration. The detrimental impact on the phase transition of water–ice processes depends on the microstructural characteristics of a cementitious composite, such as; pore size distribution, the length and the dimensions of capillaries, volume and spatial distribution of air-filled voids, and hence governs the resistance to weathering. The quantitative analysis of the microstructure therefore should advance the understanding of mechanisms taking place during subsequent freezing and thawing cycles.

Concrete, as with many porous materials, absorbs and retains moisture which makes it particularly vulnerable when exposed to repeated freezing and thawing cycles (F/T).

As a consequence of water expansion (~9 per cent), the structure suffers from internal microcracking and/or superficial scaling. Although higher strengths appear to improve the freeze-thaw resistance of concrete, they cannot always guarantee sufficient performance. Even highly valuable air-entrainment does not preclude the occurrence of frost damages to the concrete-made structures. The phase transition of water into ice is a continuous process dependent upon ambient conditions such as: rate of temperature changes, relative humidity, air pressure, chemical impurities in water/vapour. The temperature of transition, however, is primarily governed by microstructural characteristics of the porous body (Hilling and Turnbull 1956; Klemm and Klemm 1997). Initiated within macropores growth of ice is prohibited below -78 °C in the gel pores (with their diameters below 3 nm) (Centre d'Information de l'Industrie Cimentiere Belge 1957). The size, shape and continuity of pores control the amount and the rate of water absorption. Furthermore, they control the rate at which the excessive water is expelled from the voids under progressing ice interface (Klemm, Wieloch et al. 2004).

Morphology of concrete and its behaviour can be analysed at different levels. Consideration of concrete as a two-phase conglomerate (cement matrix and aggregates) is inadequate and suffers from its simplicity. More advanced models distinguish three or four levels of materials structure. A three-level classification put forward by Podvalnyi is established on the basis of two-phase conglomerates: aggregates (rigid inclusions) bonded by the matrix (Podvalnyi 1976). The first level of classification–concrete, is a cement-sand mortar (matrix) with inclusions of coarse aggregates. Second level: cement-sand mortar consists of cement paste and fine aggregates. The lowest, third level comprises hydrated mass and inclusions of clinker relicts. Any structural alterations occurring at level I or II due to continuity of transitions from level to level are apparent also at level III.

Assessment of structural properties presented in this study corresponds with the three-level model. Clear physical explanation of the origins of each category and the resultant porosity evident from MIP advocated such choice. The three-level classification was also applied in studies carried out by Beddoe and Setzer (Beddoe and Setzer 1988), and by Kukko (Kukko 1992). The pore size classification employed in this model is as follows:

- Macrolevel (with inclusions of coarse aggregate) air pores are larger than
- 10 μm in diameter,
- Mesolevel (with inclusions of fine aggregate in cement paste matrix) pores in the range between 10 μm and 50 nm,
- Microlevel (hardened cement paste) capillary pores with diameter range from 1-50 nm (the lower limit being usually between 4-5 nm).

According to classical frost action theories (Revertegat and Bernaudat 1986) the capillary porosity is the driving factor in frost deterioration processes. The capillary pores play a major role in frost resistance estimation (Kukko 1992). Early findings of Walker and Hiseh indicated the best correlation between pores and F/T durability (of various kinds of aggregates) for the range of pores greater than 8 μm in diameter (Walker and Hsieh 1968). Such observation partly coincides with findings of Litvan (Litvan 1983), who confirmed enhanced F/T durability of mortar due to the presence of air voids larger 10 μm. The gel pores do not participate in development of frost defects for reasons discussed earlier. They contribute, however, to the generation of shrinkage forces and consequent deformations. A few-millimetres-long mesopores have an adverse effect and reduce strength and elasticity of concrete (Mehta 1986; Neville 1995). Pores in the range of 300 – 3000 nm have been recognised as the most important from the point of view of damage due to F/T cycles (Lesniewska and Pogorzelski 1976; Feldman 1986). Nevertheless, some investigations suggest, that the capillary flow takes place mainly in pores having diameters in the narrower band of 250 – 1400 nm (Ravagnioli 1975). Because the pores with diameters greater than 1400 nm do not reach a state of full saturation, they are able to accumulate volume changes without causing any damage (Klemm and Klemm 1997). Pores having smaller diameters (resulting from a significant effect of the friction forces) and bigger diameters (due to the effect of gravitation) are said to affect the capillary flow to a lesser degree (Bentz and Garboczi 1991; Klemm 1994).

Lange and Modry (1969), contradictory to Ravagnioli directed his attention towards the range 200–2000 nm, which in significant volumes was assumed to be responsible for improved F/T resistance of limestone aggregates. Similar indications were made later by Koh and Kamada (1973) who found good relation between frost resistance and the 150-1500 nm pore range. Studies by Litvan on cement-based mortars further corroborated such statement. Increased volume of pores in the range 350-2000 nm was considered to be responsible for the improved F/T durability.

Considering the influence of PSD on mechanical properties, it was found that pores with diameters smaller than 20 nm impose negligible effect on compressive strength (Robler and Odler 1985). Linhua and Yugang (1999), however, claimed that pores from the range of 20-50 nm, rather than with diameters greater than 100 nm, have greater influence on compressive strength (Linhua and Yugang 1999). It must be added, that main differences in pore size distribution between air-entrained and non air-entrained paste correspond to the range of pores with 100-2000 nm in diameter (Cebeci 1981).

The discontinuity of a pore system is also found to be beneficial from the point of view of frost resistance as it prevents from a deep ingress of water into the structure of concrete. Bentz and Garboczi suggested that regardless of water/binder ratio and the rate of hydration, a porosity of 18% is required to provide a discontinuous system of capillaries (Bentz and Garboczi 1991). Useful information of the overall durability is also given by the threshold width of capillary pores. It has been found that it strongly affects the permeability and diffusion phenomena within a porous cement matrix (Garboczi 1990). Furthermore, O'Farrell et al. formulated a hypothesis that compressive strength is insensitive to threshold diameters greater than 200 nm (O'Farrell, Wild et al. 2001).

Since porosity reflects on the magnitude of permeability, which in turns is crucial from the point of view of durability, its estimation is absolutely necessary. It is widely recognized, however, that it is the pore size distribution, rather than total porosity that controls durability of cementitious materials (Ravagnioli 1975; Mehta and Manmohan 1980; Nyame and Illston 1980; Revertegat and Bernaudat 1986).

2. OBJECTIVES OF THE STUDY

The aim of this study is to identify/assess microstructural characteristics properties (porosity, pore size distribution, void ratio) of air-entrained cement-based mortars subjected to extended trials of pure freezing and thawing cycles. It is endeavoured to evaluate the contribution of modified pore size distribution (PSD) to protection against freezing and thawing deterioration and to determine the influence of PSD on mechanical properties. The primary methods of data acquisition of pore structure reconfiguration utilized in this investigation were MIP and SEM. Mechanical properties assessment (flexural and compressive strength) was carried out with application of destructive testing procedures. The above parameters are established for mortar subjected to alternated climate conditions as well as a corresponding set of samples cured in the laboratory.

3. EXPERIMENTAL INVESTIGATION

3.1. Materials and Applied Methodology

For the purpose of this experiment, six different mixes of mortar were designed. The Ordinary Portland Cement was mixed at 1:1 ratio with fine sand (majority of particles smaller than 0.6 mm). Throughout the investigation an even water to cement ratio of 0.4 was maintained. To ensure adequate variation in the microstructure, the air-entraining agent complying with BS 5075 Part 2 was used at various concentrations: 0, 4, 7, 10, 13 and 16% (by weight of cement content). The mix proportions and applied nomenclature are presented in Table 1.

Table 1. *Cement mortar composition.*

Mix code	**R-Reference**	**A**	**B**	**C**	**D**	**E**
Water/Cement	0.4	0.4	0.4	0.4	0.4	0.4
Sand/Cement	1:1	1:1	1:1	1:1	1:1	1:1
Air-entraining agent [%]	0	4	7	10	13	16

The mortar prisms (160 x 40 x 40 mm), after curing for 28 days in laboratory conditions (50±5% RH and 23±2deg C), were exposed to freezing and thawing cycles with ambient temperature decreasing from 20 to -20 deg C. The minimum temperature recorded in the centre of the sample was -17.8 deg. C. The programmed relative humidity in the Climate Control Chamber was maintained at the level of 80% at positive temperatures throughout the whole experimental procedure. Further modifications of the microstructural characteristics, namely porosity, pore size distribution and threshold diameter were achieved by regular assessment (every 3 months throughout 18 month period) of the samples stored in the alternated conditions concurrently with the laboratory cured material. The following results were obtained for samples of the age (days): 28, 58, 118, 208, 388, 566 with corresponding sample exposed to: 122, 366, 732, 1464, 2196 F/T cycles.

The analysis of mechanical properties was performed using standardized procedures for compression and flexural tests; BS 1881-119:1983 and BS 1881-118:1983 respectively. Microstructural examinations were carried out with the use of Porosimeter Autopore II 9230 by Micromeritics with a pressure range up to 60000 psi. The Scanning Electron Microscope - Leo 1530 further advanced the micro-scale analysis.

4. RESULTS AND DISCUSSION

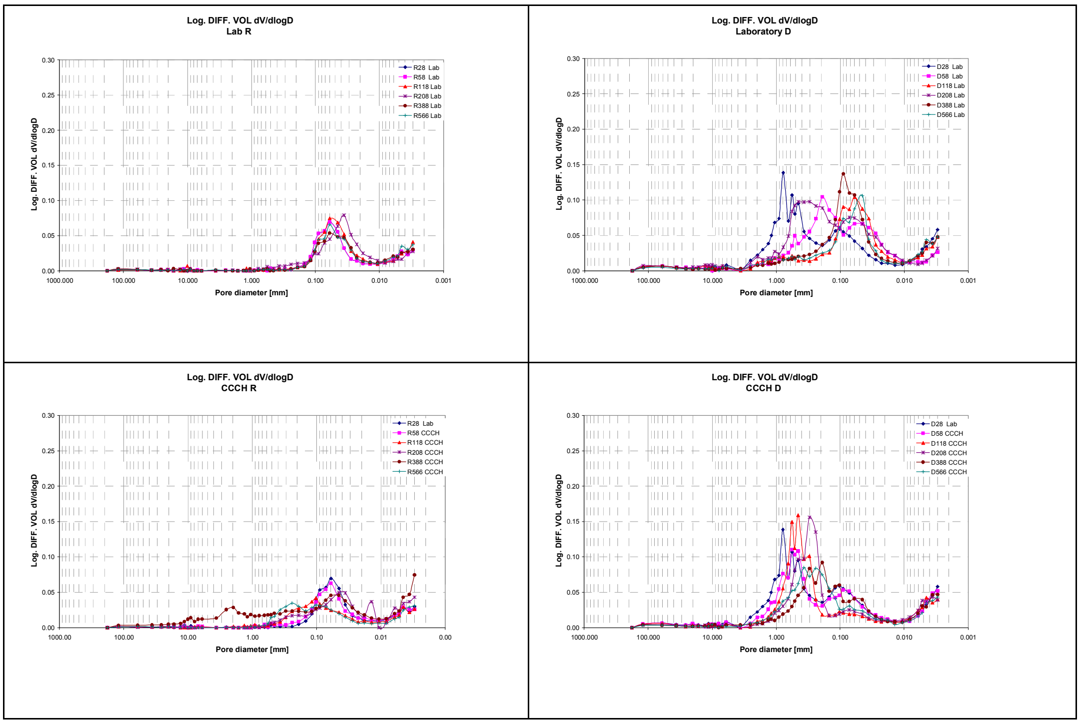

Figure 1. Pore size distribution curves of samples R and D cured in the laboratory (top row) and in the climate control chamber (CCCH) (bottom row).

Figure 1 portrays microstructural alterations which occurred in the structure of non-air-entrained mortar (sample code R) and among the samples with the second-highest content of air-entraining agent (sample code D). The extremes of the range considered here illustrate the trend of transformations that took place as a result of exposure to F/T cycles. Coarsening of the microstructure is more clearly perceptible from classification shown in Figure 2. The meso- and micro level of the three-level discussed earlier model was subdivided into smaller ranges in order to perform quantitative assessment of the incurred changes. Chosen division points correspond with the pivot diameters observed due course of the MIP examination, as well as with findings of some earlier studies. Initially, a four-range classification (chosen results presented in Fig. 2a) was considered:

- Microlevel: d<50 nm,
- Mesolevel: 50<d<300 nm, 300<d<1650 nm and d>1650 nm.

At later stage, a refined classification was applied to evaluate more precisely the influence of F/T cycles on the pore size distribution. The classification (example of which is shown Fig. 2b) comprised seven sub-pore-ranges:

- Microlevel: d<10 nm, 10<d<50 nm,

- Mesolevel: 50<d<100 nm, 100<d<300 nm, 300<d<1000 nm, 1000<d<2500 nm and d>2500 nm.

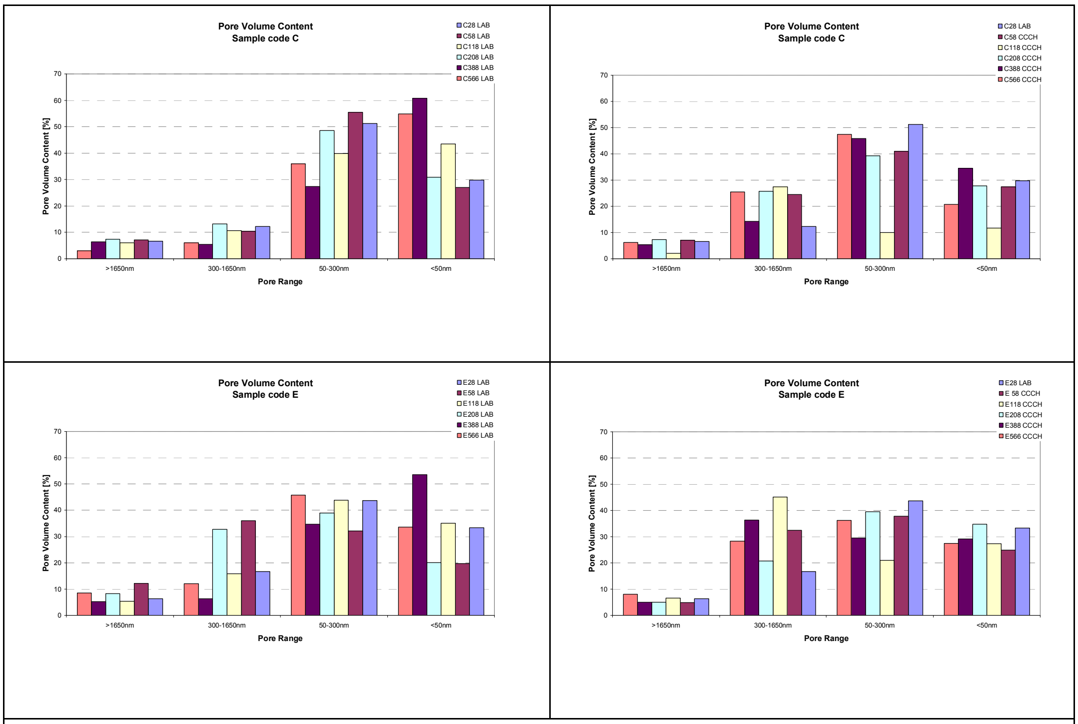

Figure 2a. A four-level classification of pores. Mortar type C and E cured in laboratory and exposed to F/T cycles.

As indicated in the introductory part, the threshold diameter of pore size distribution can be correlated with compressive strength as it is presented in Figure 3.

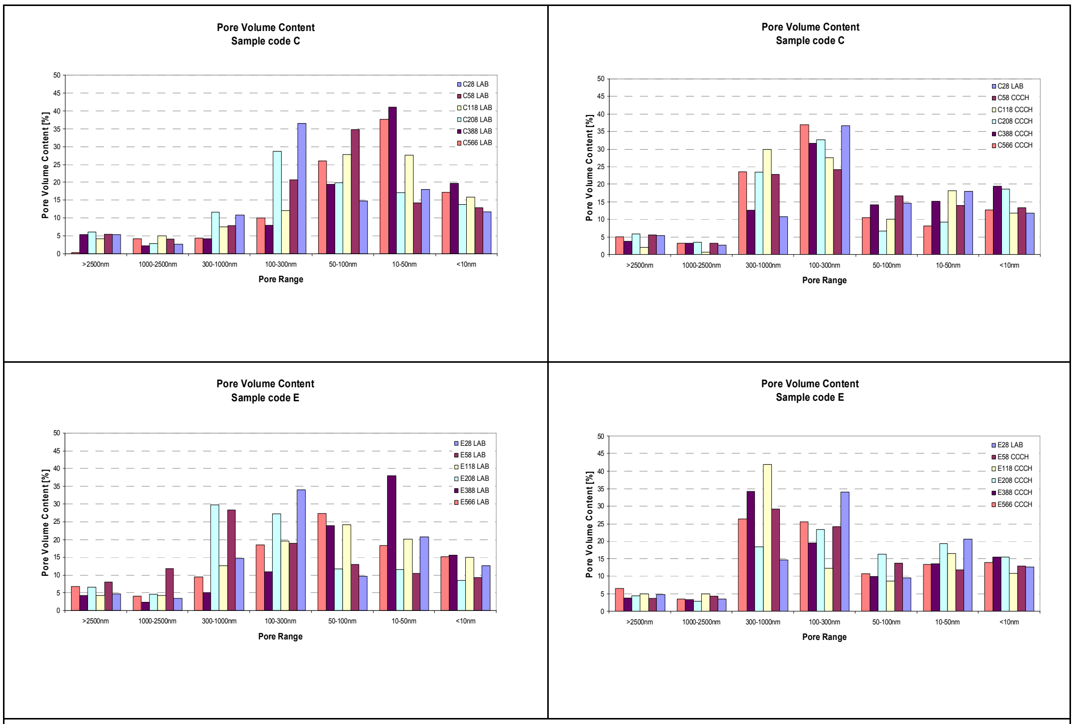

Figure 2b. A seven-level classification of pores. Mortar type C and E cured in laboratory and exposed to F/T cycles.

Although the method of the threshold diameter determination is not precisely formulated, the concept of the first, high average intrusion increment was applied in this study (i.e. $average(F_{n+1} - F_n, F_{n+2} - F_{n+1})$ Attempt was made also to establish the threshold diameter by application of the relative increments of intrusion, or with the tangential lines to the Total Volume Intrusion curves. Those methods, however, produced unsatisfactory results and are not reported in this paper. It can be seen from Fig. 3, that compressive strength is insensitive to threshold diameters greater than 200-250 nm. Below this range, similarly to findings of O'Farrel and Wild, a rapid increase in compressive strength was observed.

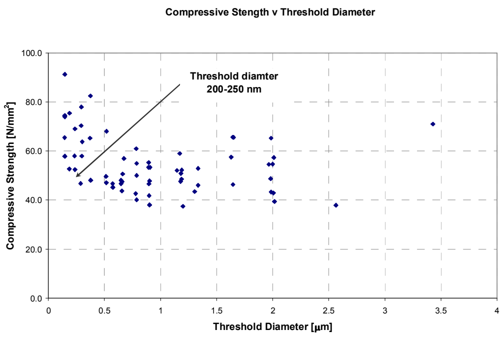

Figure 3. Relationship between compressive strength and the threshold diameter.

Correlation analysis of the pore size distribution with the mechanical characteristics revealed the "weak" points of the air-entrained microstructure. In general, according to the four-level pore classification only voids of diameters smaller than 50 nm enhance both compressive and flexural strength. The correlation coefficients determined individually for the laboratory and the alternated climate conditions are shown in Figure 4. The prevailing effect of voids smaller than 50 nm in diameter, however, was examined in more details through a seven-level classification analysis. The analysis revealed almost equal influence of pores from the range of <10 nm and 10-50 nm The range of 50-100 nm in diameter was also found to enhance compressive strength (correlation coefficient 0.44 for laboratory cured material and 0.28 for mortar subjected to cyclic F/T), which is in line with previously discussed observations of Linhua and Yugang. High negative values of correlation coefficients, however, (0.73 and 0.61 in laboratory and after F/T cycles respectively) were recorded for the range of 300-1000 nm. Slightly lower, yet negative, coefficients were also found for the 1000-2500 nm range (0.57 and 0.23 for laboratory and mortar exposed to cyclic F/T). Such unfavourable condition i.e. poor mechanical performance could be alleviated by lowering the input of those pores in the total porosity. The largest considered here range within the mesolevel (d>2500 nm) was found to have an ambiguous influence on samples cured in different conditions. A negligible effect (no correlation) was exerted by this range of pores on compressive strength of mortar exposed to cyclic F/T. The coefficient of correlation obtained for the laboratory cured material, albeit low, reached almost -0.3 (30 times higher than in the case of the exposed material).

The analysis presented above suggests that the micro- and the lower-mesolevel rather than macrolevel influence mechanical performance of air-entrained, cement-based mortar. Large pores (for instance larger than 10 μm as suggested by Litvan) were found to make a small contribution to mechanical performance. Such a conclusion is also supported by the order of established earlier value of the threshold diameter.

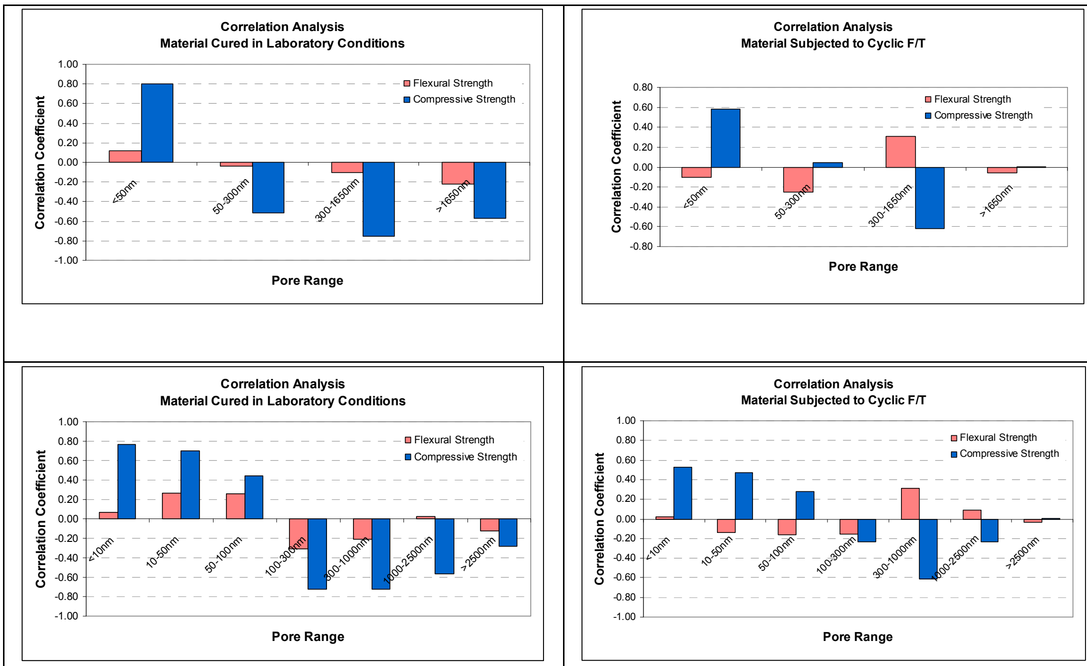

Figure 4. Correlation of mechanical characteristics with the four- and the seven-level classifications.

Freezing and thawing resistance is interpreted in this study on the basis of mechanical characteristics i.e. flexural and compressive strength. Figure 5 illustrates relative alterations in strength due to F/T cycles recorded systematically over a period of 566 days. Despite of erratic character of both the flexural and the compressive strength, one particular feature can be distinguished; namely relationship between air-entraining agent and the loss of strength. Mortar with higher content of air-entraining admixture (coded C, D, E) suffers from lower strength reduction (compressive strength in particular) when exposed to F/T cycles. The higher the air-entrainment, the lower the compressive strength losses were detected. Hence, it is possible to conclude that by superposition of the MIP results obtained for the aforementioned mortars, a model of a microstructure with improved freeze-thaw resistance can be proposed (see Figure 6). Constraining the Total Volume Intrusion curves with tangential lines the following is believed to correspond with the freezing and thawing resistance:

- Less than 10 per cent of pores with diameter >1000 nm,
- ~60 per cent of pores in the range 100-1000 nm,
- ~10 per cent of 35-100 nm,
- Minimum 20 per cent of pores with diameter <35 nm.

Considering the aforementioned results of correlation between compressive strength and the established pore ranges it is sagacious, however, from the point of improved F/T resistance, to reduce the volume of pores from the range 100-1000 in favour of the smaller pores.

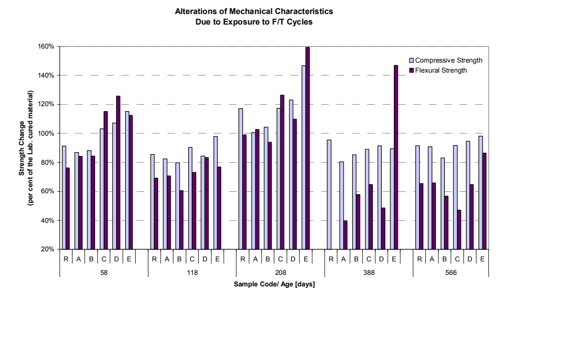

Figure 5. Relative alterations of air-entrained mortar exposed to cyclic freezing and thawing.

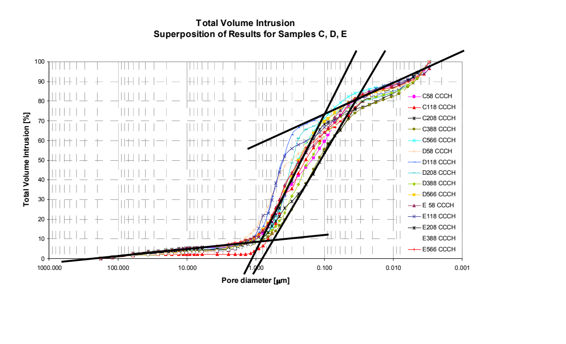

Figure 6. Formulation of a model of microstructure with improved frost resistance.

5. CONCLUSIONS

The following conclusions were drawn on the basis of microstructural examination performed with the Mercury Intrusion Porosimetry:

- The threshold diameter of air-entrained mortar lies in the range of 200-250 nm,
- Compressive strength is insensitive to threshold diameter larger than 200-250 nm,
- Large volumes of pore with their diameters in the range 100-2500 nm have detrimental effect on mechanical performance of cement-based, air-entrained mortar,
- Pores greater than 2500 nm exert negligible effect on compressive strength (no correlation was found between volume of pores from this range and compressive strength),
- Pores smaller than 100 nm (smaller than 50 nm in particular) significantly contribute to compressive strength. A minimum of 6 per cent is necessary to provide freezing and thawing resistance,
- Heavily involved in freezing and thawing resistance are also pores in the range: 35-100 nm. Their volume should be in excess of 10 per cent, whilst the volume of mesopores (100-1000 nm) should be less than 60 per cent.

It is understood that the presented results are valid for the air-entrained, cement-based mortars. Presence of coarse aggregates-cement paste matrix interface in concrete and characteristics of individual phases may produce a somewhat distinct microstructure. Presented results must be also viewed from the perspective of the operating principles/constraints imposed by the MIP test method itself.

Regardless of its limitations, the proposed model of microstructural composition provides important information for concrete designers. It sets out the direction for mix specification that will potentially result in a reduced degree of disruption due to freeze/thaw cycles and, ultimately, enhance long-term performance of air-entrained cementitious mortars.

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SELECTED METHODS OF ANALYSIS OF GEOMETRICAL MICROSTRUCTURE OF POROUS MATERIALS-REVIEW

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Abstract: This paper describes different measurement methods and analysis of geometrical microstructure of porous materials. The geometrical microstructure of porous materials can be measured using optical and contact methods. The most common contact method is the stylus method. In this method the sharp point is dragged across the surface and a surface profile is recorded by computer or machine. The second method is the optical method which can be done by measuring the distribution of intensity of scattering light or using the speckle correlation method. The optical method is a promising method for surface roughness measurement because of several advantages over the mechanical method such as no physical contact with specimen and instrument, high speed of response, greater accuracy and reliability. The porous materials like brick, concrete and rock have a high absorption coefficient. Because of this, the intensities of scattering light from the test specimens are very weak. It is very difficult therefore to capture the reflected laser beam by a detector when a low power laser (<1mW) is used in an open space. The paper presents special experimental set up to overcome above problem for surface roughness measurement of porous materials involving low power laser in an open space. Some experimental results from the contact methods have been presented.

Keywords: concrete, Optical method, porosity, Stylus, Surface roughness,

1. INTRODUCTION

Surface Roughness is defined as the vertical variation over a measured distance, which is normally measured by a stylus device (contact method), where the sharp point is dragged across the surface and computer or machine records a surface profile. This method has several disadvantages and limitations such as the surface of the work piece may be damaged, stylus can not be able to penetrate fully to the bottom of the valley in some part of the work piece, where the size of the deep valleys are smaller than the tip radius (Hashmi 1997) and surface roughness value obtained from different stylus instrument may differ in the case of soft material.

The second method is the optical method, where the laser light is applied to the surface and scattering lights from the specimen are captured and analysed. This method has several advantages; such as no physical contact with specimen and instrument, high speed of response, greater accuracy and reliability (Yilbas 1999).

Although the optical method has been used for surface roughness measurement of metals there are no records of the comprehensive analysis of the surface roughness of highly porous materials like mortar.

2. SURFACE ROUGHNESS PARAMETERS

Surface roughness parameters can be defined in different ways such as average roughness (*Ra*), root mean square roughness (*Rq*) highest peak in the roughness profile (*Rp*), the depth of the deepest valley in the roughness profile (*Rv*) etc. Surface profile is a combination of surface roughness and waviness (see figure 1). The waviness has a longer wavelength than roughness, which is superimposed on the waviness. The main surface roughness parameters are *Ra* and *Rq* .The definition of *Ra* and *Rq* are shown by equation (1) and (3).

$$Ra = \frac{1}{a}\int_{x=0}^{a} |f(x)| dx \tag{1}$$

Where *f(x)* is the surface height measured from the mean line and '*a*' is the total distance that surface roughness is considered.

$$\int_{x=0}^{a} f(x) dx = 0 \tag{2}$$

$$Rq = \left(\frac{1}{a} \int_{x=0}^{a} f^2(x) dx \right)^{1/2} \tag{3}$$

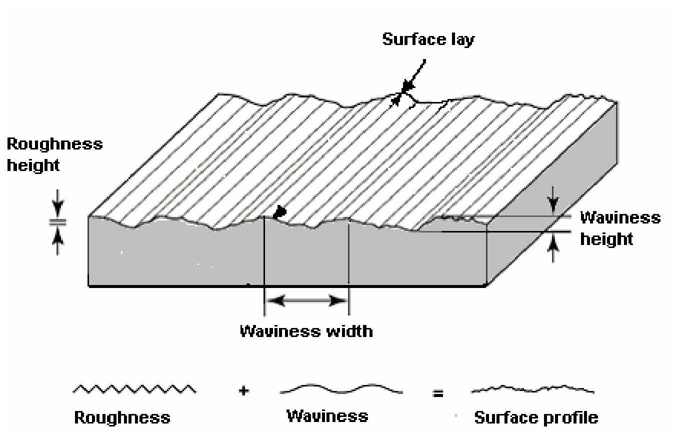

Figure 1: Roughness and waviness.

3. ROUGHNESS SCALES

The roughness of a surface can be measured in different scales such as: macro roughness (0.1 to 1.0 mm), micro roughness (0.001 to 0.005 mm) and ultra-micro roughness (>0.005 mm). Thus the roughness values vary with the roughness scales (see figure2).

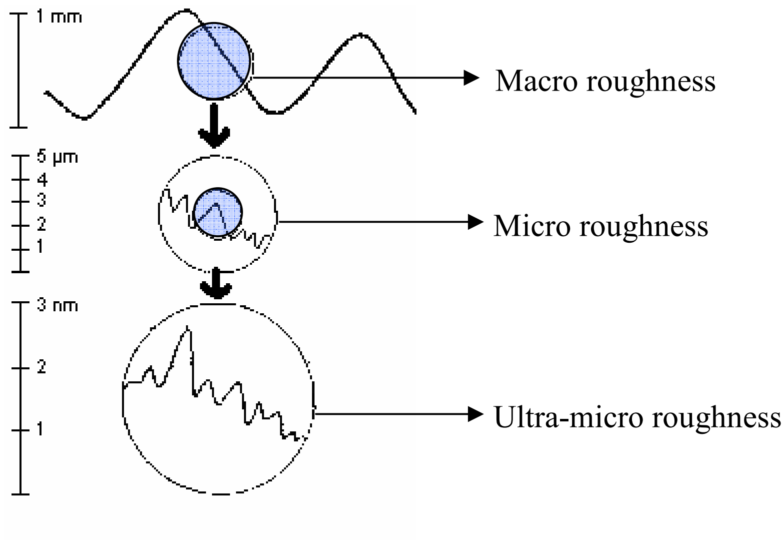

Figure 2: Roughness Scale

4. CONTACT METHODS

The most common contact method is the stylus method. The diagram of stylus is shown in figure 3. Shape of diamond stylus tips is generally conical with either 60 or 90 degree included angle. The radius of tips is usually 2, 5 or 10 microns (BS1134-1). The surface deviations traced by the stylus are converted to a digital value by means of an electro-mechanical device called a pick up.

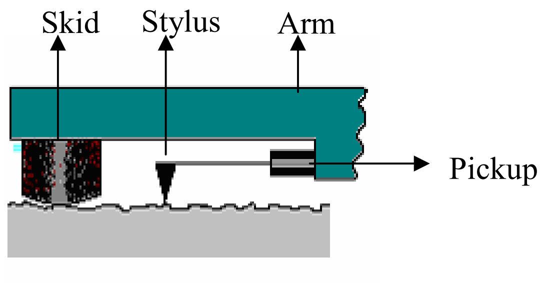

Figure 3: The diagram of stylus

Authors investigated a variety of mortar samples as a part of the study. The mortar specimens had the following composition: cement/sand 1:1 and w/c ratio 0.4. Micro roughness of the samples was considered in the contact method. Surface roughness was assessed with application of two different stylus instruments. The surface roughness slightly changed with the stylus instruments (see figure 4). The difference in the roughness readings in the instrument 2 with respect to the instrument 1 readings are 4.18% for sample 1,-24.97% for sample 2, 9.19% for sample 3 and -5.2% for sample 4. It may be due to irregularity of the surface. The profiles of the samples are shown in figure 5. In the case of mortar samples, the surface roughness cannot be read in some points where the value of surface roughness is out of range of the instrument. This is mainly due to pit-hole. Pit-holes are little holes that appear on the surface of cementitious composites.

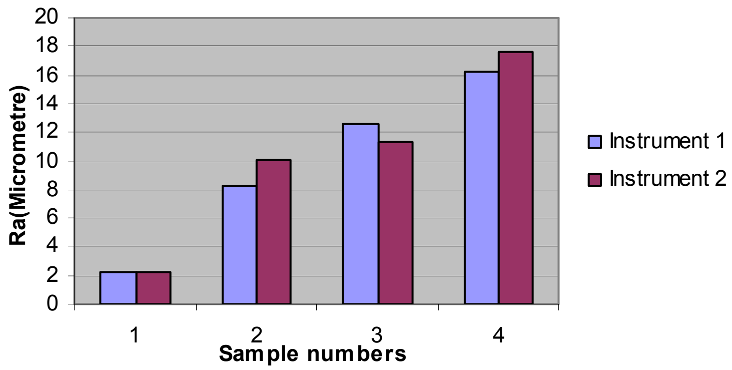

Figure 4: The surface roughness were measured by the two different stylus instruments

The stylus tip size, filter cut-off, and bandwidth are likely to affect the measurement result. When stylus tip size is high, it broadens the peak of the profile and narrows the valleys. Surface roughness is separated from waviness by means of a filter that rejects wavelengths longer than a specified cut-off wavelength. The concept of "bandwidth" is used to improve the comparability and consistency of surface roughness measurements. The roughness filter bandwidth is defined as the ratio between a long wavelength filter and a short wavelength filter.

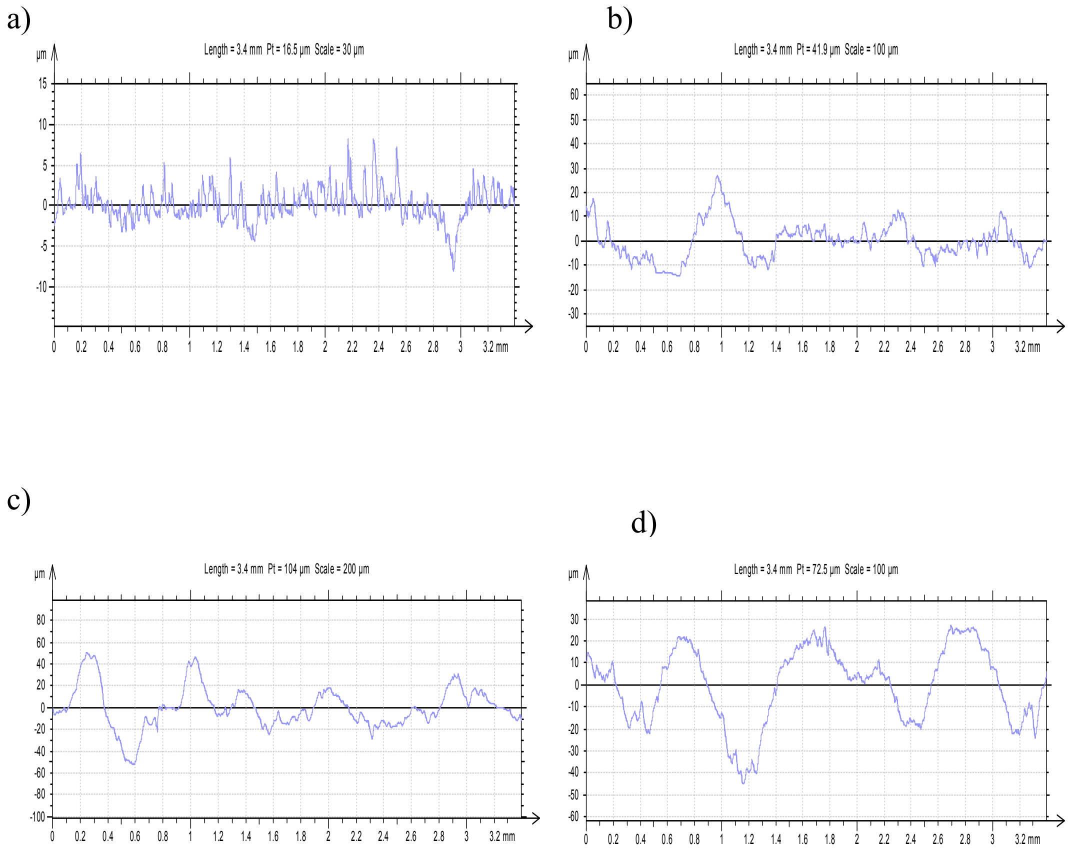

Figure 5: The profile of the samples where the samples were measured by instrument 2 (a) sample 1 (b) sample 2 (c) sample 3 (d) sample 4

5. OPTICAL METHODS

The second method is the optical method which can be done by measuring the distribution of intensity of scattering light or using the speckle correlation method. The main source of light that is generally used in the optical method is helium-neon laser. Analyses of results that are generated from optical methods are as follow:

I. When a laser is applied to the rough surface, it get scattered (see figure 6).The distribution of the scattered light intensity is used to indirectly determine the surface roughness. The intensity of the scattered laser light depends on the scattering angle. Variance of scattering angle is to be an indicator of surface roughness. Copper and aluminium plates were tested for roughness (*Ra*) in the range of 0.005 to 6µm (Tay 2003).

$$p(\varphi)=\frac{I(\varphi)}{\int_{-\pi/2}^{\pi/2} I(\varphi)d\varphi} \tag{4}$$

Where φ is scattering angle, *I(φ)* is intensity distribution function and *p(φ)* is probability density function of the scattering angle (Jolic 1994).

$$S=\int_{-\pi/2}^{\pi/2} p(\varphi)\left(\varphi-\overline{\varphi}\right)^2 d\varphi \tag{5}$$

Where *S* is variance of the scattering angle and $\overline{\varphi}$ is the mean scattering angle

$$\overline{\varphi}=\int_{-\pi/2}^{\pi/2} \varphi p(\varphi)d\varphi \tag{6}$$

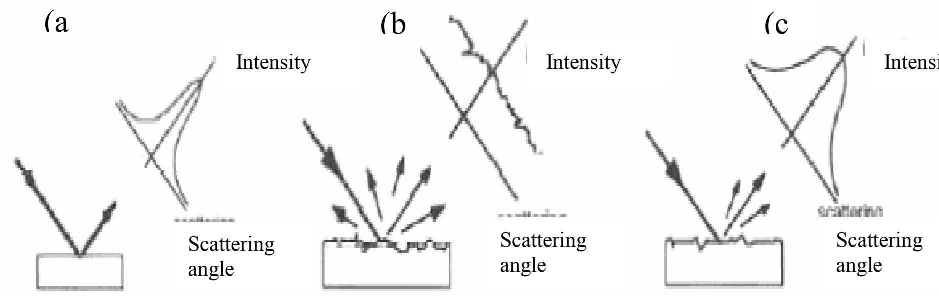

Figure 6: The intensity distribution of scattered laser light (a) Very smooth surface (b) Very rough surface (c) Intermediate surface, where variance of (a) < variance of (c) <variance of (b) (Jolic 1994).

II. The collimated white-light source is used to illuminate the surface and machine vision system is used to record the image directly. The frequency distribution of the scattered light intensity is used to identify the roughness -so called grey level histogram, which is a graph of the number of pixels with a particular intensity,

versus their intensity (see figure 7). Copper and brass specimens were investigated. The surface roughness up to 2.15 μm was considered (Luk 1989).
Figure 7 shows the grey-level histogram of the patterns of scattered light from the three different samples with different roughness.

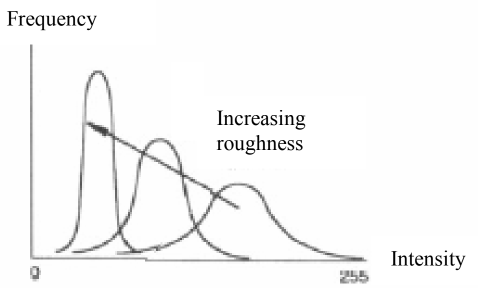

Figure 7: Effect of roughness on the histogram (Jolic 1994).

The mean value and variance of the histogram decrease with increasing roughness.

$$R = \frac{\text{Root mean square value of histogram}}{\text{Standard deviation of histogram}} = RMS/SD \tag{7}$$

Where R is the roughness

$$RMS = \left(\frac{1}{256}\sum_{i=0}^{255} Fi^2\right)^{1/2} \tag{8}$$

Fi are the individual intensity frequencies (256 grey levels are used)

$$SD = \left(\frac{1}{N-1}\sum_{i=0}^{255} Fi(Xi - X)^2\right)^{1/2} \tag{9}$$

Where *N* is the total number of pixels in the image, *Xi* is the grey level intensity (0…255) and *X* is the mean grey level value. Here entire image is used to calculate the roughness.

III. The surface roughness can be found by using Kirchoff principles. The intensity of reflected light in a mirror direction is given below. This method is more suitable for relatively smooth surface. Figure 8 shows the schematic diagram of the experimental set up.

Where $r(\Theta_1)$ is the coefficient of reflection from ideally smooth surface, I_o is the intensity of light at the incidence angle Θ_1, λ is the wave length of the laser, σ is the mean deviation of profile and I_z is the intensity of reflected light in a mirror direction.

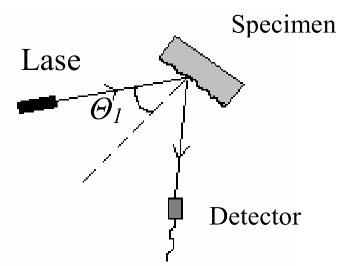

Figure 8: Schematic diagram of laser beam reflection

$$I_Z = r(\Theta_1) I_o \exp\left[-\left(\frac{4\pi\sigma}{\lambda}\right)^2 \cos^2 \Theta_1 \right] \tag{10}$$

If the component of the diffusive reflection in mirror direction is smaller than mirror component, the following equation can be used to derive the value of σ.

$$\sigma = \frac{\lambda}{4\pi \cos\Theta} \tag{11}$$

IV. The surface roughness is measured by speckle correlation method, in which the speckle patterns that are obtained before and after rotating the surface by a small angle (*δθ*) are considered. The surface roughness between 1-30µm can be measured precisely by using this method. A collection of metallic samples were considered for this investigation (Rebollo 1995).

$$C_I(\delta\theta) = \exp\left[-\sigma^2 \left(\frac{4\pi}{\lambda}\sin\theta\right)^2 \delta\theta^2 \right] \tag{12}$$

Where C_I is the speckle intensity correlation, σ is the surface roughness, λ is the wave length, θ is the initial incidence angle and $\delta\theta$ is the rotation angle. A personal computer is used to analyse the data. The speckle intensity correlation C_I of the successive speckle distributions is calculated by using a digital mathematical algorithm.

$$C_I(n) = \frac{\frac{1}{n}\sum_{j=1}^{n}\left[I_{0J} - \langle I_0\rangle\right]\,\left[I_{Ij} - \langle I_I\rangle\right]}{\left[\frac{1}{n}\sum_{j=1}^{n}\left[I_{0j} - \langle I_0\rangle\right]\right]^{1/2}\left[\frac{1}{n}\sum_{j=1}^{n}\left[I_{Ij} - \langle I_I\rangle\right]\right]^{1/2}} \tag{13}$$

Where

I_{0j} = initial intensity recorded by the j detector

I_{Ij} = intensity recorded by the j detector when the porous surface is rotated an angle $\delta\theta$

n = 1, 2, 3,…………, $2\Delta_I$ ($2\Delta_I$<N)

N is the number of detectors in the CCD camera.

$$\langle I_0 \rangle = \frac{1}{N}\sum_{i=1}^{N} I_{0i}$$

$$\langle I_I \rangle = \frac{1}{N} \sum_{i=1}^{N} I_{Ii}$$

V. The surface roughness can be found by the Hensler and Tanner equation for RMS roughness of relatively smooth surface. Stainless steel plats were considered for this investigation (*Ra* <0.4μm).

$$\frac{I_X}{I_O} = \exp\left[-\left(\frac{4\pi\sigma_O}{\lambda} \right)^2 \cos^2 \alpha \right] \tag{14}$$

Where, I_X and I_O are the reflected intensity of the relatively smooth test surface and the perfectly smooth surface of the same composition respectively, λ is the wavelength of the laser, σ_0 is the RMS roughness and α is the incident angle (Whitley 1987)

All the optical methods that mentioned above are for metal surface and relatively smooth surface except method IV. In method IV, the speckle correlation method was used; it covers wide range of roughness values. The porous materials like mortar, concrete, brick and rock have a high roughness value. The proposed method is to measure the surface roughness of porous material with the high surface roughness (*Ra* =2.39 to 16.73μm) by measuring the distribution of intensity of scattering light. Thus method I is more suitable method among the methods mention above for measurement of materials like concrete, mortar, concrete, brick and rock because it covers considerably wide range of roughness values.

6. EXPERIMENTAL SET UP

The porous materials like brick, concrete and rock have a high absorption characteristic. Because of this, the intensity of scattering light from test specimen is very weak. Therefore it is very difficult to capture by a detector when low power laser (<1mW) is used in the open space. The open space means that there are several light sources -so called light noises that can affect the scattering light. The main advantage of using low power laser is the reduced cost for laser safety. If the power of the laser is less than 1mW (class II laser), an interlocking system is not necessary. Such an experimental set up is easy to handle because it is operated in the open space. In the case of high power laser (>1mW) it is very easy to capture the scattered beam from the specimen. However, it should be done in the enclosed area with the interlocking system for a safety purpose.

Based on method I in section 5, an experimental set up has been developed as depicted in figure 9. According to the set up, intensity of the light that comes from the specimen is measured by changing the position of detector. This experimental set is designed to satisfy the above conditions. An incident laser is set at 45^o to the test specimen. Laser pulses are produced by chopper from the continuous laser to get the unique signal. The frequency of the chopper is selected in a prime number because the frequency of incident beam should not be a multiplication of frequency of noise light to avoid the overlaps of signals. A reference beam is obtained from the incident beam using a beam splitter to reduce the effect of changes in the laser power over the time. The ratio of the intensity of scattered light to the intensity of reference beam is calculated to eliminate the oscillation in the incident beam. Lock in amplifier is connected to chopper to get the reference signal, which is the signal that can be read by the lock in amplifier. The lock in amplifier provides a DC (Direct current) signal proportional to the AC (Alternative current) signal that comes from a detector. Digital multiple meter is connected to lock in amplifier to get the digital reading of DC out put. The results obtain from this method can be then verified by results obtain from contact method and correlation index can be determined.

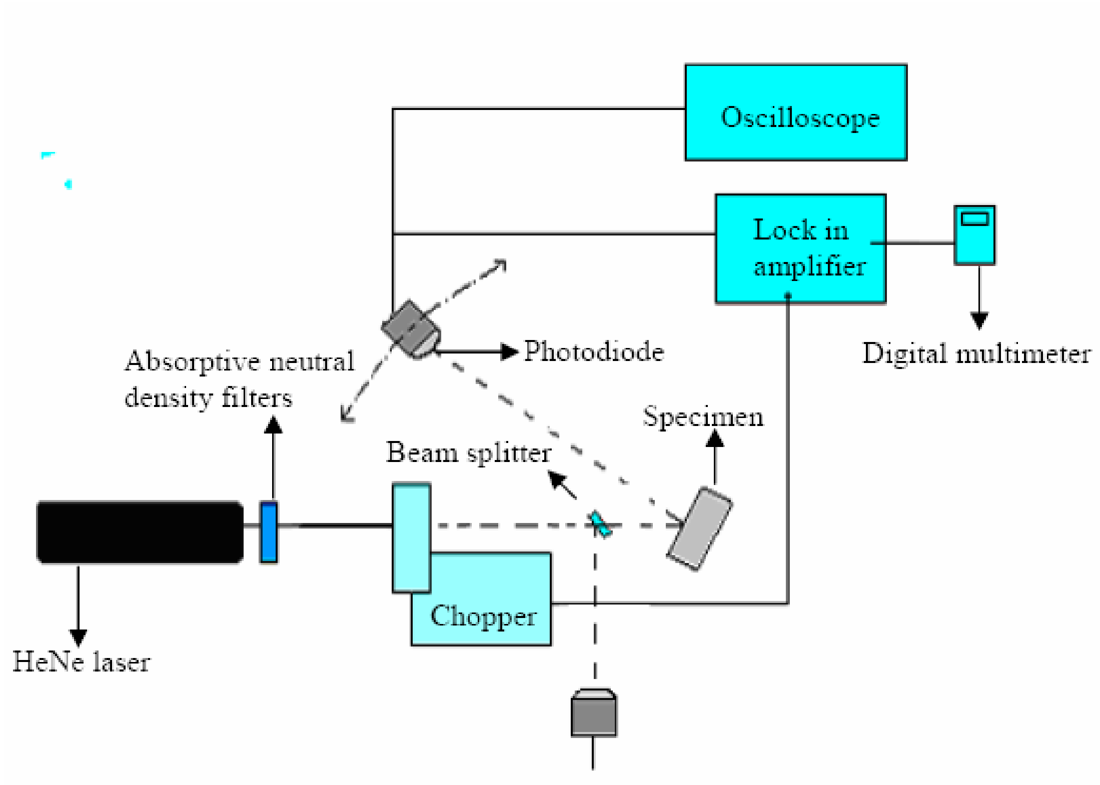

Figure 9: Experimental set up

7. SUMMARY

- Theoretical principles of both contact and optical methods for the analysis of surface roughness have been presented in this paper.

- Contact method was discussed and used experimentally to determine surface roughness parameters for different mortar samples. Two different stylus instruments have been used for this purpose. The obtained results seem to be very similar. However, when two different instruments are used: stylus tip size, filter cut-off, and bandwidth should be same for both instrument to get the comparable result.

- Five different optical methods of analysis were also presented in this paper. A special attention was paid to the method I, which is based on measurement of the distribution of intensity of scattering light. Since the surfaces of cement-based materials have a high absorption characteristic, the scattering lights from test specimen are very weak. It is very difficult, therefore to capture the signal when a low power laser (<1mW) is used in the open space. Due to the restrictions imposed by the health and safety regulations, not allowing the use of class III lasers in an open space, an attempt was made to design the experimental set up, which would use low energy lasers (see figure 9).

- Experimental results are due to be obtained in near future. They will be analysed and compared with results obtained from contact method and presented at the conference.

8. ACKNOWLEDGEMENTS

The authors would like to thank Dr Peter Wallace for numerous useful discussions related to laser safety and experimental set up.

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INFORMATION TECHNOLOGY USAGE IN THE TURKISH CONSTRUCTION INDUSTRY

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Abstract: The business world is continuously changing due to the rapid developments in technology. Companies from any industry feel the need to change their way of doing business in order to succeed in today's competitive business environment. Information Technology (IT) plays a vital role in the day to day business within most of the industries such as construction. Construction is one of the most information-dependent industries. So, IT provides great advantages for this industry since it facilitates the exchange and management of information. Construction companies in developing countries such as Turkey are slow in adopting IT. Most of the construction business processes are based on traditional methods in the Turkish construction industry. In this study, a survey was conducted among major Turkish construction contractors. The specific objectives of the survey were to find out the current use of IT in these firms; advantages of IT for them; barriers to implement IT tools in their organization, and their plans for future investment in IT. Moreover, the purpose, benefits and disadvantages of using Internet; reasons for establishing a website and problems faced in establishing a website are examined. According to the survey results, it was found that the firms do not fully utilise the potential of IT.

Keywords: Information Technology, internet usage, construction industry, survey, Turkey.

1. INTRODUCTION

Information Technology (IT) has created many advantages and opportunities for the construction industry in operation speed, collaboration, accessibility and exchange of information between organizations involved in a construction project [1]. Especially the internet has opened a new era and provided great advantages in business activities.

The construction industry is one of the largest major industries in the world and plays an important role in the development of economy in both developing and developed countries. It has a multi-party nature. No other industry has such a great complexity and number of products and services involved like the construction industry. Due to the involvement of many different parties including such as the client, general contractors, specialized contractors, material suppliers and manufacturers, there is an enormous amount of information exchange among them even in small-sized construction projects [2]. Construction is one of the most information-dependent industries; with its diversity of forms of information including detailed drawings, contract documents, cost analysis sheets etc. [3]. As construction projects become increasingly complex, companies are forced to find new methods to do business with their partners and other parties effectively. However, most of the construction business processes are heavily based on traditional means of communication and exchange of documents in paper format that lead to inefficiencies in these processes [1]. The industry seems not to be sufficiently adopted the new technologies compared to many other industries. Lacking network connectivity is a major liability that results in diminishing market share or lost opportunities [4]. It is obvious that the companies insisting on traditional business strategies will not survive in business world in the near future. Adopting new applications that can improve efficiency in doing business should be the major principle for any party involved in this industry [5].

Time is one of the major important facts for the construction industry like all other industries. Traditional methods such as phone or fax communication between parties, performing construction transactions manually or submitting bid proposals in paper format leads to an enormous amount of time consuming. IT tools enables companies to speed up their business activities. It enables companies to be more productive and work more cost and time effectively [6].

In this study, the current use of IT and internet in the Turkish construction industry has been examined. A questionnaire survey was conducted among major Turkish construction contractors in order to determine both IT and internet usage within these firms. According to the survey results, it was found that the firms do not fully utilise the potential of IT.

2. THE SURVEY

The survey was conducted during the period February – June 2005 among major Turkish construction contractors which are all members of the Turkish Contractors Association (TCA). The survey was carried out face-to-face in order to obtain more reliable responses. Experienced staffs like general managers, business development managers, bid proposal managers, and IT managers were chosen for the survey in order to get more detailed information. The survey questionnaire of both IT usage and internet usage contained 8 questions. Since internet usage and IT usage are entirely different, the results have been distinguished and given separately as internet usage and IT usage, respectively. The surveys referred were conducted in the UK [7, 8], Scandinavia [9], Canada [10], Malaysia [11] and USA [12].

3. RESULTS OF INTERNET USAGE

3.1 Importance of Internet

All of the respondent companies have access to the internet. All of the participants responded that internet is very important to their firms and the Turkish construction industry. They stated that without the use of internet it would be impossible to improve their businesses and agreed that internet is an indispensable tool for doing work. This result is not surprising since internet provides great advantages in business activities for all the firms involved in every industry like construction.

3.2 Usage of Internet

In this study, it was determined that the main purpose for using the internet is exchanging and sharing documents and information via e-mail (Fig. 1). Bidding of projects is not widely used and this result correlates with the survey conducted by Mui et al. [11] in Malaysian construction industry where only 16% of the firms were involved in bidding of projects through internet. The bidding process is still mostly based on paper format. Moreover, the companies that are involved in bidding of projects through internet are participating only for international biddings since online bidding is not extensively used in the Turkish construction industry.

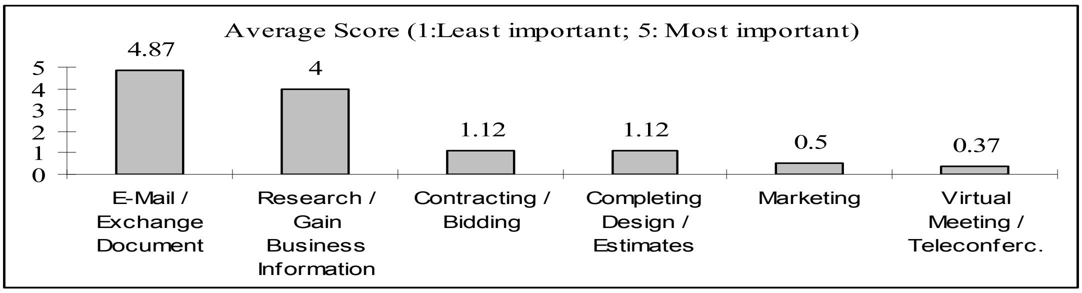

Figure 1: Purpose of Using Internet

The results show that even though the high rate of accessibility to the internet, the usage is limited with only some business activities such as exchanging and sharing documents via e-mail.

3.3 Benefits of Using Internet

The most important benefit for the firms of using internet is stated as time saving in the business activities (Fig. 2). This result correlates well with research done in Malaysia, where 60% of respondent firms replied that the most important benefit of using the internet was time saving in their work [11].

The second important perceived benefit of using the internet is indicated as improving the efficiency. Most of the firms stated that the internet gives them the opportunity to access data simpler and faster. This result also correlates well with survey done in Malaysia [11], in the UK where the received benefits of IT systems is summed up as more efficiency in doing business [7], and in Canada where respondents stated that they increased the quality of speed in their work [10].

Cost saving is addressed as the other important benefit in using internet in business actions. Cost saving could be attributed to the reduction in document exchanges in digital format. Traditional methods in exchange of documents (via fax, post etc.) are eliminated through the use of internet.

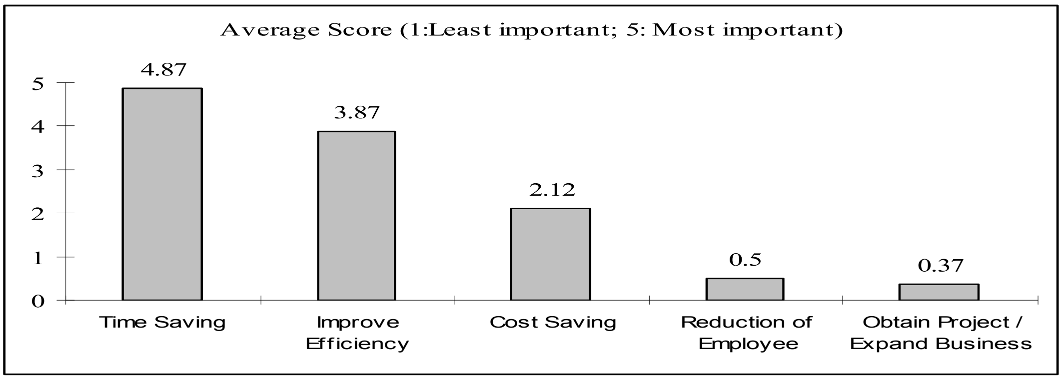

Figure 2: Benefits of Using Internet

3.4 Disadvantages of Using the Internet

Besides the advantages of using the internet, it has been asked to the respondents to indicate the possible disadvantages while using the internet. The frequency in line cut-off is determined as the major shortcoming of using the internet (Fig. 3). Although the firms have an adequate infrastructure of the Internet Service Provider, the participants indicated that sometimes they faced with internet connection problems which slow downs their activities in doing work. The other problems are indicated as downloading problem and virus problem, respectively. One main difference between the results of this study and the one conducted in Malaysia [11] is that the Turkish contractors respondents would not faced any problem by finding the necessary information through internet whereas in Malaysia 27% of the firms responded this as a major problem.

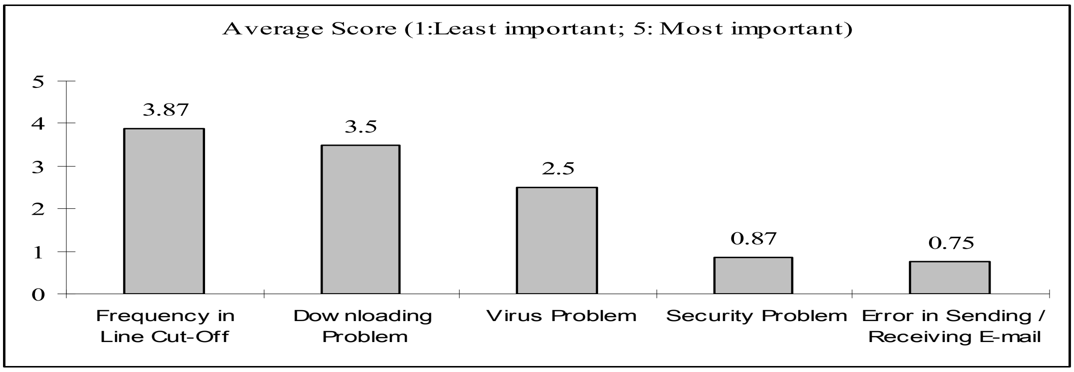

Figure 3: Disadvantages in Using Internet

3.5 Reasons for Having a Website

The firms surveyed were asked the reasons for establishing a website. A majority of respondents replied this as the company image / status (Fig. 4). All respondents agreed that the internet platform could be an opportunity for improving the image of their companies.

3.6 Problems in Setting up a Website

The respondents were asked to indicate the problems in setting up a website and they were allowed to choose more than one answer. Although several reasons were written in the questionnaire, all the respondents mentioned the security in having a website as the major shortcoming. Other problems such as time consuming for establishing a website, high cost of setting up a website were not seen as major problems.

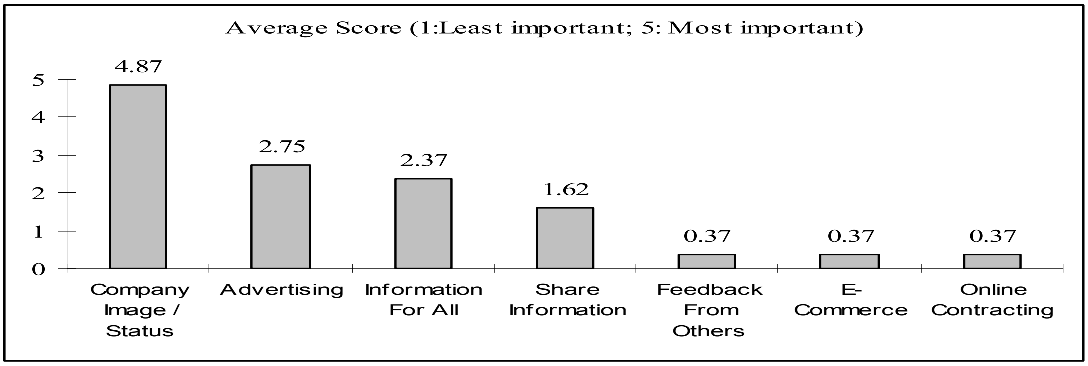

Figure 4: Reasons for establishing website

4. RESULTS OF IT USAGE

In this part, the IT usage in major Turkish Contractors has been investigated and the results have been compared with the research done in Canada by Rivard [10], in USA by Issa et al. [12] and in the UK by the IT Construction Forum [8].

4.1 Computer Usage in Business Processes

The first question was to find out how computerized the business processes are in the firms' specific activities. The answers were classified into three categories; highly computerized, partially computerized and mostly manual. As can be seen from Fig. 5, technical calculations and specifications are completely computerized. Invoicing, materials control, scheduling, costing and budgeting, are almost completely computerized. On the other hand, the tendering process is still done mostly manually and based on paper format.

When compared to the results of the research done in Canada [10], some similarities in business processes could be observed as highly computerization in invoicing, specifications and bookkeeping. However, in contrast to this study, the tendering process shows a much more percentage in computerization in the Canadian construction industry. E-tendering is still not widely used in the Turkish construction firms.

4.2 E-Business Initiatives

The respondents were asked to indicate the adoption of e-Business applications. The most used e-Business applications in these firms are accounting / finance, internet infrastructure, project management and extranet / intranet, respectively (Fig. 6). These findings correlate well with research done in USA [12], where project management was the most used e-Business application (70%), and extranet / intranet, internet infrastructure and accounting / finance the following applications, respectively.

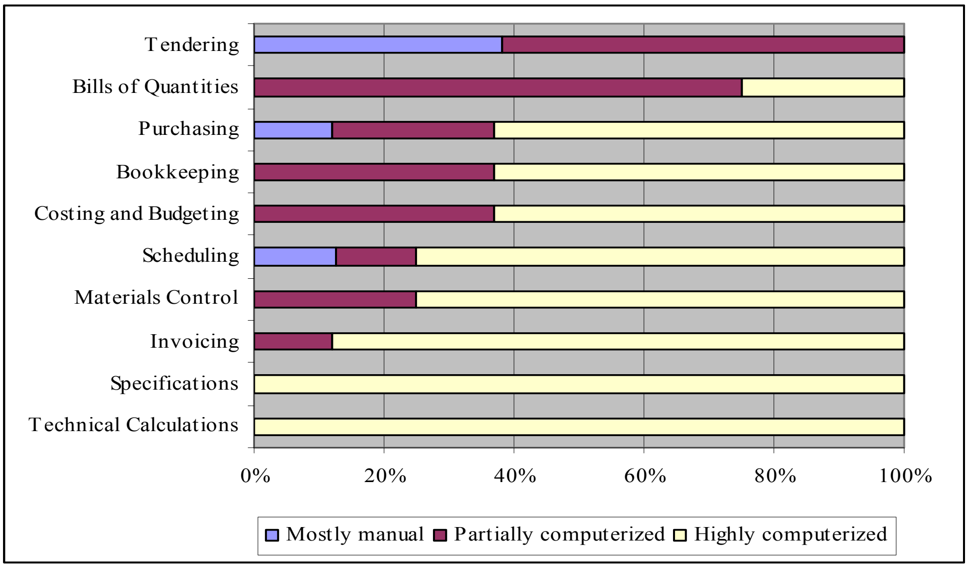

Figure 5: Extent of computerisation

However, in contrast to the high rate of e-Business applications such as project collaboration, knowledge management and e-commerce in US firms, there is a lack of adoption of these applications in the major Turkish firms. E-Business applications in these firms are mostly concentrated in specific areas like project management which leads to inefficiencies in doing other works.

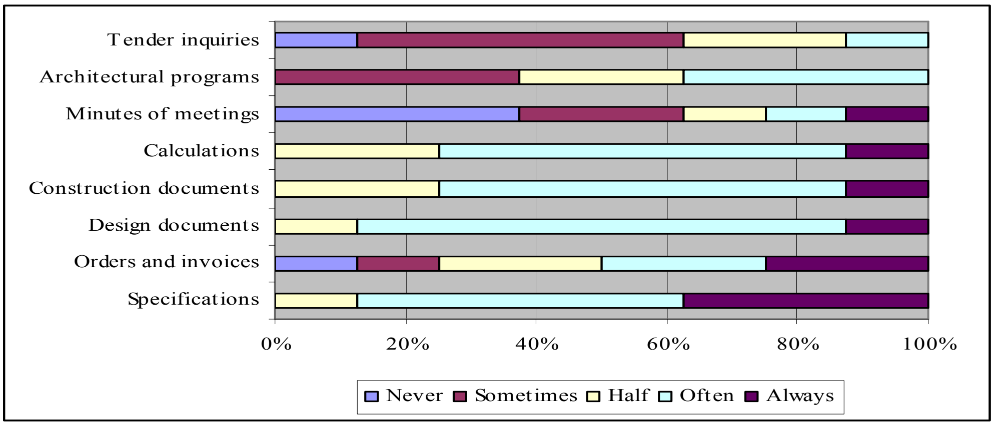

Figure 6: E-Business applications

4.3 Digital Exchange of Documents

Exchanging documents in electronic format is important for time and cost saving. The study investigated the level of exchanging documents in electronic format in these firms. The answers were classified into five categories as never, sometimes, half, often and always. Design documents, construction documents, calculations and specifications were indicated as the most used documents to exchange in digital format (Fig. 7). Although these documents are not fully exchanged in digital format, the high rate shows that these firms are improving their processes in these related areas. When compared to the survey in Canada [10], where most documents in the industry were exchanged by traditional means, it could be stated that the major contractors in Turkey have been successful in exchanging the related documents. However, the same thing could not be said for the document exchange of minutes of meetings, architectural programs, orders and invoices, and tender inquiries. These are still exchanged by traditional means, i.e. in paper format.

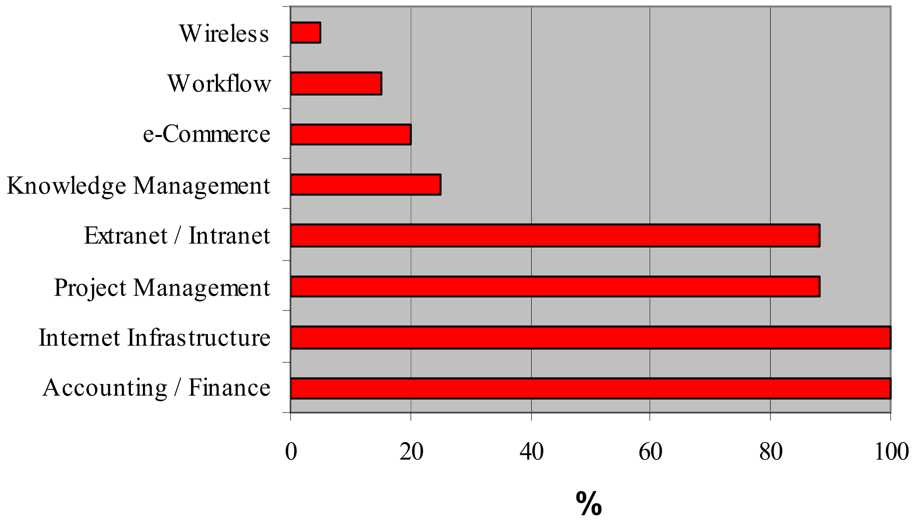

Figure 7: Digital exchange of documents

4.4 Communication Tools

The participants were asked of their communication tools in order to determine the type of connections of the firms with their suppliers, partners and customers. As seen from Fig. 8, phone and fax are the most widely used communication tools which are both traditional ways to communicate with other parties. E-mail is also frequently used but not the same level as phone. The results show similarities with the survey done in USA [12], where traditional means were also very common in communicating with other parties.

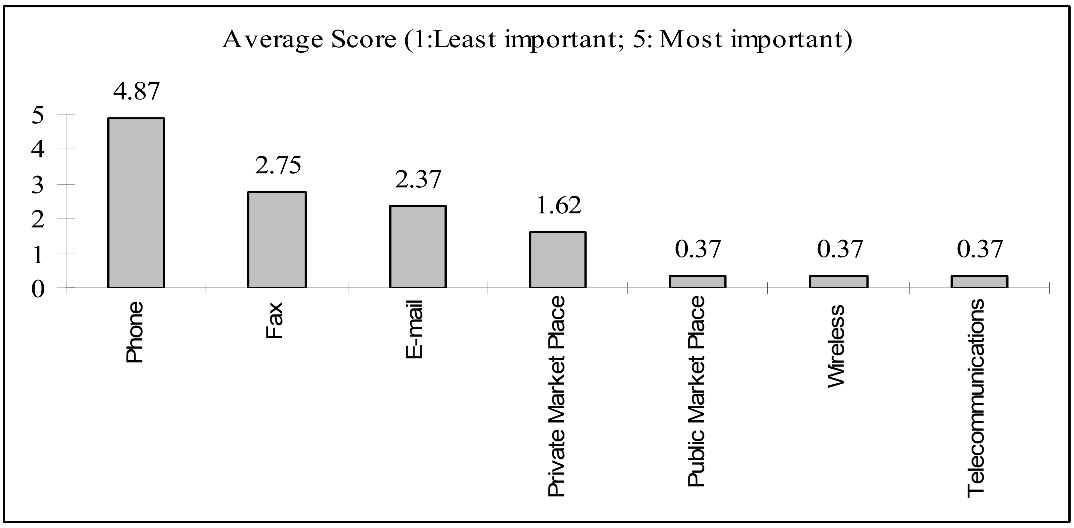

Figure 8: Communication Tools

4.5 Benefits of IT

The respondents were asked about the benefits they achieved through using IT. All the respondents indicated that the main benefit of using IT as the increase in speed of working (Fig. 9). This result correlates well with the survey done in the UK [8], where the increase in speed of working was also considered as the single biggest benefit. Also the result shows similarity with the research done in Canada [10], where performing work more quickly was the second main benefit after achieving better quality work.

The participants stated that doing work quicker, achieving better quality work and saving cost during the processes should be the ultimate goals of using IT tools.

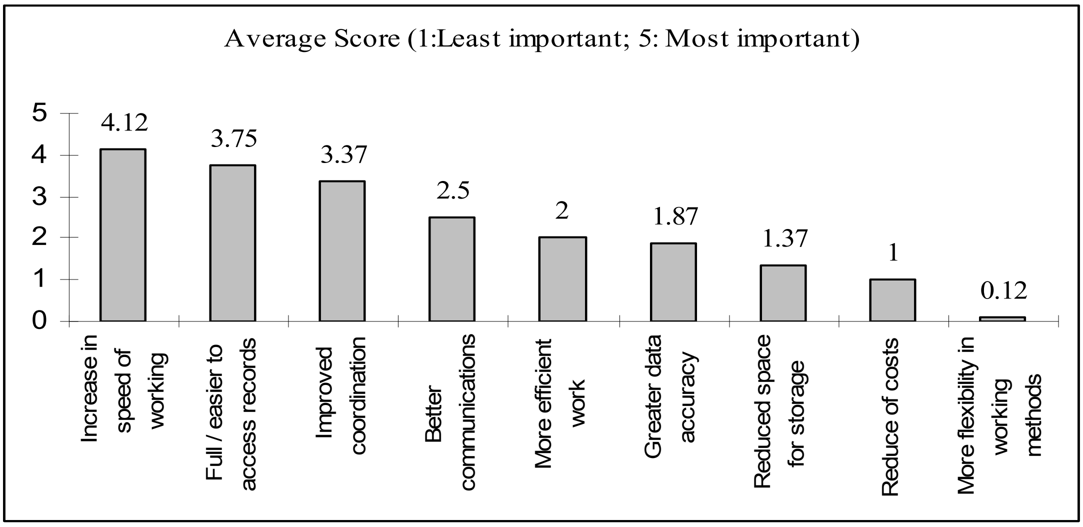

Figure 9: Benefits of IT

4.6 Barriers to the Use of IT

One of the specific objectives of this study was to find out the potential barriers to greater use of IT in the firms. The results, as seen in Fig. 10, shows that the respondents mainly dealt with two main barriers; unavailability of inadequate impartial advice and the cost of technology. The other reasons such as quick changes of technology, the need of new ways of working for new technology and the cost of training for technology use were not considered as much important barriers as they were indicated by UK organizations [8]. Most of the participants in this survey stated that they would know much more information about the technologies they will adopt to their firms. Additionally, they would also know if the related technology will fit their business needs.

4.7 Encouraging Greater Use of IT

The respondents were asked what items would be helpful for greater use of IT in their firms. The most significant item was considered as the availability of more user-friendly systems (Fig. 11). More training related to the technologies was indicated as the second important item. In UK organizations [8], reduction in cost of IT was considered as the most important subject for greater use of IT. In Turkish firms however, more user-friendly systems and more training were considered as more important factors than the reduction in cost of IT. This shows that the firms are willing to implement IT tools even though the high cost, but the vital factors are providing them training about using these tools and user-friendly systems.

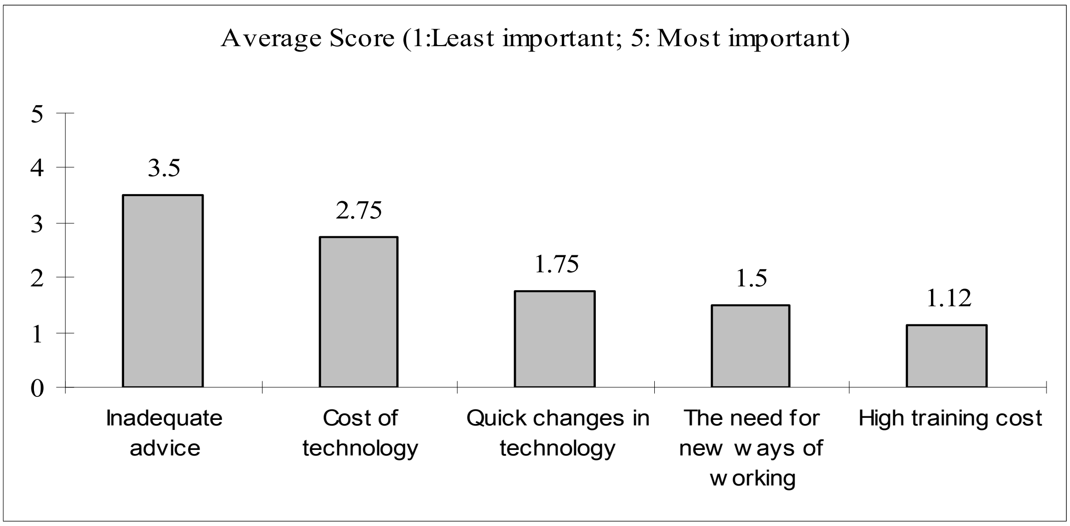

Figure 10: Potential barriers to the use of IT

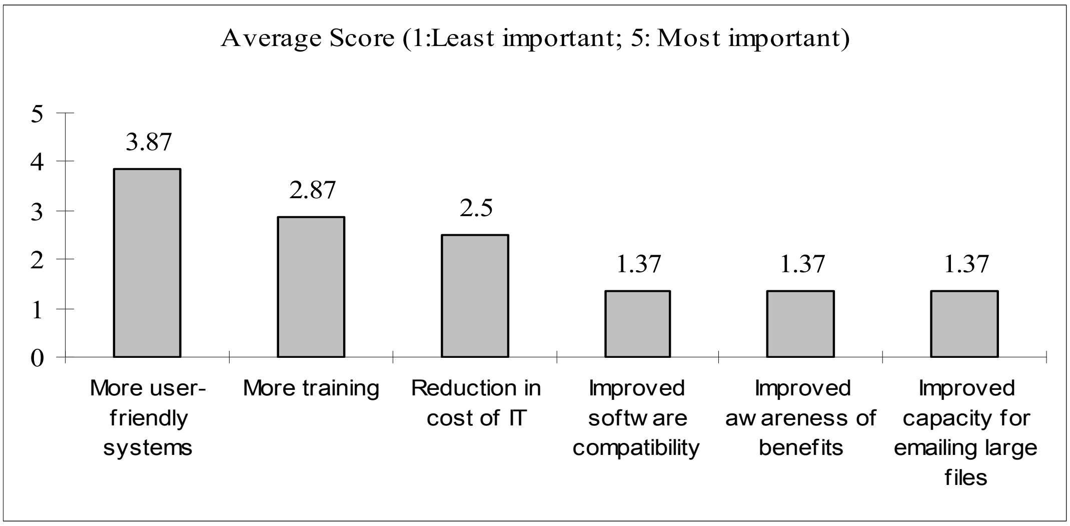

Figure 11: Items that would encourage greater use of IT

4.8 IT investment

The respondents were asked how much they will invest in IT in the next 3 years, compared to the last 3 years. The IT investment in the next 3 years will be more than the current levels in these firms (Fig. 12). The results correlates well with the research done both in UK [8], where respondents were addressed the IT investment in the next 3 years as 42% more, and in Canada [10] where the participants responded the IT investment as 64% more in the next 2 years than the current level.

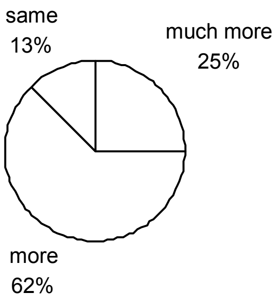

Figure 12: IT investment in the next 3 years

5. CONCLUSIONS

IT benefits include better communications, decrease in communication errors, increase in speed and quality of work, better financial control, and simpler and faster access to common data [13]. Therefore, effective use of IT increases construction companies' market share and chance of surviving in the construction industry's competitive business environment [14].

In this study, IT and internet usage in the major Turkish construction contractors have been examined. The internet is widely used in these firms. However, the usage of it is limited with only some specific business activities such as exchanging and sharing documents via email. It was determined that other activities like tendering were not frequently used. Traditional methods are still heavily used in these areas. Therefore, the full potential advantages of internet are still not achieved by these firms.

Some business processes are highly computerized in these firms. However, there have been still some activities performed mostly manually. Although some e-business applications have been implemented by these firms, lack of adoption in some fields like knowledge management are still exists.

One of the main benefits of IT is providing a decrease in communication errors. However, the firms included in this survey are still mostly using traditional means of communication, i.e. phone and fax which may lead to an increase in possible communication errors. On the other hand, significant investment in IT is planned in the next 3 years by these firms to improve the business activities. In conclusion, the major construction firms in Turkey are not fully utilise the potential of IT, but they feel the need to catch up with IT, and therefore they are willing to implement IT tools more in the future.

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SELECTED ASPECTS OF RENDERING PERFORMANCE BASED ON IN-FIELD ASSESSMENT

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Abstract: Rendering contributes to the fulfilment of facade functions (e.g. suitable for specific uses, control rain penetration, water vapour flow / dampness, durability and aesthetics) in terms of its mechanical and superficial strength, water and humidity resistance, adhesion and surface condition properties. This paper characterizes relevant aspects of rendering performance in-use, in real service conditions, using expedite and suitable on-site techniques, commonly used. The preliminary results from field assessment in four cases studies and laboratorial tests on models and standards specimens intend to discuss the importance of on-site measurements to the characterization of anomalies type and extension (degradation levels) and performance requirements (standards, technical documents or manufacturers' declarations). In order to help diagnosis and decision of maintenance strategies, the ongoing research (first author's PhD study) aims at contributing to in-use the performance assessment through threshold matrixes with field parameters that may complement standards requirements.

Keywords: field assessment, performance in-use, rendering, testing.

1. INTRODUCTION

The envelope is a key element of a building and it influences its comfort, safety and aesthetics. To judge a façade, its global performance has to be derived from the performance of its components: separation, support and facilities (Hermans, 1995). Rendering is a current system for Portuguese façades cladding. According to Portuguese national statistics (INE, 2001), rendering represents 61.6% of 2,561,227 Portuguese buildings built between 1946 and 2001 (81% of all Portuguese buildings), followed by architectural concrete (21.3%), stone (11.3%), ceramics (5.5%), and others (0.8%). This system directly contributes to the fulfilment of the main function of the façade, i.e. to serve as a barrier between the indoor and outdoor environments (resistance to keep heat, moisture, air and other flows within acceptable limits). Its adequate choice, application and maintenance are important aspects to the salubrity, comfort, durability, and aesthetic appearance of the façade as a whole (Veiga, 1997).

Portuguese conventional rendering is a "multi-coat" system that begins with an under-coat mortar that fulfils the technical requirements (e.g. mechanical strength) and ends with a finishing mortar that guarantees weatherproofing and aesthetics demands (e.g. colour, texture) (Fernandes et al, 2005). The recent developments and the technological innovations undergone by the building industry, have significantly affected the field of render for external and internal walls. Thus, in the last decade, factory-made ready-mixed dry renders and their mechanical application have been introduced in many countries, such as Portugal, with a consequent reduction of the application time and potential increase of the render quality (Gasparoli et al, 2003) (Duarte and Alvarez, 2001). This type of renders is applied in a single coat (with average thickness between 1.5 and 2 cm), usually coloured, which fulfils all the functions of a multi-coat system used externally (CEN, 2003), and is made from a mixture of inert, mineral binder and some specific additives able to grant some required properties regarding the product either in the fresh or hardened state (Fernandes et al, 2004).

The performance approach reflects a need for integral quality assessment and assurance not only during the building process, but over the life cycle of the building from the design stage, through construction to use, retrofit, demolition and recycling. In order to make full use of the concept, performance assessment needs to be quantitative or at least capable of quantitative interpretation to provide a workable and unambiguous basis for performance-based appraisal (CIB, 1995), (ISO, 1980). The methods of assessment can be through measurements, calculation, testing, expert judgment or a combination of the previous ones (Foliente, 2000), (ISO, 1980). Only a comprehensive performance assessment methodology leads to the implementation of rational strategies in-use phase, maintenance scheduling and a better knowledge of the end of service life (ISO 15686, 2000).

The in-field evaluation of performance over time (the relationship which describes how performance level of the chosen characteristics varies over time) is important to asses if a building design solution is considered reasonable, i.e. when it meets or exceeds performance requirements over time that have been drawn up specifically for a certain project. The comparison of required performance level (the minimum performance level that must be provided at a certain moment in time) with supplied performance level (the maximum quantity of a performance which can be provided by a building component at a certain moment in time) over time can be made if both supply and demand for components are expressed in the same way (Hermans, 1995). The lack of performance information provided by the manufacturers, the complexity of building process and the difficult relationship between users requirements with the products requirements, have led to in-field assessment based on methodologies focused on defect analysis, instead of quantitative performance requirements, among other criteria.

Despite the increase of rehabilitation works in Portuguese façades’ elements in the last few years, the absence of periodic inspection and interventions records has not allowed data collection, essential to improve the knowledge of façades’ elements performance in service conditions. In addition, visual observation of façades is the commonest technique to assess performance in-use, always occurring after several claims from the users and in urgent situations, associated with high degradation levels. In this context, more effort is needed to assess the performance of each element / exposure environment under in-use conditions, notwithstanding the application of new construction solutions, more durable and with improved behaviour for specified service conditions.

The ongoing research is based a methodology for rendering performance assessment. The assessment of in-use performance of rendering is based on systematic fieldwork surveys, including visual assessment and field testing, following the establishment of inspection parameters and of correlations between anomalies, degradation levels, laboratory testing and performance requirements. Integrated assessments based on inspection parameters - degradation parameters (visible and non-visible) and performance parameters, with suitable and expedite tests, aims at improving the performance assessment and opting for more realistic and better adapted maintenance strategies for rendering facades.

2. RENDERING PERFORMANCE ASSESSMENT

European standard EN 998-1 (CEN, 2003) establishes final performance requirements for rendering mortar based on inorganic binders use on walls (different fields of use and exposure conditions require mortars with different properties and performance levels). Table 1 identifies the functions and properties required of a hardened rendering mortar, based on European standards, Portuguese provisions, and other international issues. These functions are directly linked to façades functions.

Table 1: Relevant properties of hardened rendering concerning façades functions (CEN, 2003), (CCFAT, 1990), (LNEC, 1995), (CSTB, 1993), (Veiga, 1997), (EOTA, 2003)

Façade functions	Render functions	Render relevant properties (prescriptive specification)
Safety and suitability for specific uses	Mechanical strength	Compressive and flexural strength
	Superficial strength	Impact, scratch and abrasion resistance
Rain penetration, water vapour flow and dampness control	Water and humidity resistance	Capillary water absorption
		Water permeability
	Cracking susceptibility	Dynamic elastic modulus
		Flexural strength
		Shrinkage (restrained)
	Water vapour permeability	Water vapour permeability coefficient or thickness of air layer of equivalent diffusion
Durability and aesthetics	Adhesion to the substrate	Adhesion strength
	Surface condition (resistance to humidity, chemical, dirty pollutants and micro-organisms growth)	Water content
		Salts contamination
		Crazing and cracking
		pH on surface
		Colour changes
		Surface roughness
		Surface hardness
		Superficial temperature

The characterization of each property includes the identification of performance requirement (minimum performance below which the render cannot under any circumstances be considered fit for that use), acceptance criteria, method of assessment and test type. Table 2 characterizes the properties of hardened mortar that are assessed through laboratory tests on apparatus where the specimens are moulded or tested on substrates prepared in laboratory (standard methods of assessment).

The methodology analysis will be carried out independently for each requirement by visual observation, expedite in-situ measurements and complementary laboratory tests. The drawbacks are related with the selection of appropriate measurement of on-situ tests techniques and the balance between the accuracy of methods and their simplicity, intrusiveness and cost. Data collected by visual field evaluations will be recorded, such as anomalies characterization (e.g., cracking, crazing, efflorescence, scaling, general appearance and micro-organisms growth - ASTM, 1996), their location on the wall, extension and gravity, and measured properties change (e.g., hardness, colour uniformity, surface texture, thickness of coats, integrity of planes, angles, corners, joints, among others - ACI, 1993).

A set of on-situ tests will be carried out on several envelopes rendering for evaluation and measurement of on-site properties of hardened rendering, in order to establish possible correlations in the following terms: correlations between field parameters and anomalies extension and type; correlations between field parameters, through on-site techniques, and laboratory measurements; and correlations between field parameters and performance requirements established at the design stage (these correlations can be direct if the in-use property measure is directly linked to the performance requirement or indirect if the in-use property measure is related to performance requirement).

Table 2: One-coat hardened rendering properties, acceptance criteria, methods of assessment (CEN, 2003), (LNEC, 1995), (CCFAT, 1990), (CSTB, 1990), (CSTB, 1992), (CSTB, 1993), (CCFAT, 1991), (DIN, 1985) (BSI, 1998_a) (BSI, 1998_b)

Properties	**Specification and acceptance criteria**	**Specifications Doc. reference**	**Tests methods Doc. reference**
Compressive strength (R_c)	Categories: CSI (R_c = 0.4 to 2.5 N/mm^2), CSII (R_c =1.5 to 5 N/mm^2), CSIII (R_c =3.5 to 7.5 N/mm^2), CSIV ($R_c \geq 6$ N/mm^2)	EN 998-1	EN 1015-11 EN 196-1
Flexural strength (R_f)	$R_f \geq 1.5$ to 2 N/mm^2 (wall with high exposure to impact loads)	Cahiers 2413, 2401 LNEC 289/95	Cahier 2669-4 EN 196-1 DIN 18555 EN 1015-11
Capillary water absorption (C)	Categories: W1 to W2 $C \leq 0.4$ or ≤ 0.2 kg/m^2.min$^{0.5}$	EN 998-1	EN 1015-18
	$C \leq 2$ to 4 g/dm^2.min$^{0.5}$ C = 1 to 2.5 or < 1.5 g/dm^2.min$^{0.5}$ (wall with high exposure to rain)	Cahiers 2401, 2477, 2413	Cahier 2669-4 NF B10-502
Water permeability (W_P)	≤ 1 ml/cm^2 after 48 h	EN 998-1 CSTB (1992) Cahier 2401	EN 1015-21
Dynamic elastic modulus (E_d)	$E_d \leq 7500$ to 14000 N/mm^2 $E_d \geq 5000$ to 10000 N/mm^2 (wall with high exposure to impact loads)	Cahiers 2401, 2413, 2477	Cahier 2669-4
	$E_d \leq 10\,000$ N/mm^2	LNEC 289/95	Cahier 2669-4 NF B10-502
Stresses induced by shrinkage (restrained)	Classification: class cracking susceptibility: little ($S \geq 1$ and $R \geq 1$) or medium ($S \geq 1$ and $0.6 \leq R < 1$), where S (safety coefficient to the opening of the first crack), R(resistance coefficient to cracking evolution)	Veiga (1997)	Veiga (1997) DIN 52450
Water vapour permeability	Water vapour permeability coefficient $\mu \leq$ declared value	EN 998-1 Cahier 2401	EN 1015-19
	Thickness of air layer of equivalent diffusion to 0.1 m of render $S_d \geq 0.15$ m	LNEC 289/95	DIN 18555-Part1
Adhesion on substrates	≥ 0.3 MPa or cohesive fracture pattern (at least in 80% of the area)	EN 998-1 CSTB (1992) Cahier 2401	EN 1015-12 LNEC 289/95
Durability	No visible degradation after weathering cycles tests, checking compatibility of one coat rendering with substrates (adhesion and water permeability)	LNEC 289/95 EN 998-1	EN 1015-21

In Table 3, properties, on-site techniques, laboratory tests and correlations to be studied are characterized. Additionally, several in-situ tests will be performed in order to evaluate surface condition of renderings (durability properties), according to the following parameters and techniques: water content (moisture meter), salt contamination (conductivity / TDS meter, test strips for semi-quantitative determination of sulphate, nitrate, chloride ions and total hardness), cracking (optical microscopy), pH (pH meter), colour changes (colorimeter) and superficial temperature (infrared radiation pyrometer).

Table 3: Properties, in-situ techniques, laboratory tests and correlations to be studied

Properties	**On-site techniques**	**Doc. Reference**	**Correlations to be studied**
Compressive strength (R_c)	Drilled or cut-off cores of rendering on walls	EN 1015-11 (RILEM, 2004)	R_c (drilled cores) ↔ R_c (standard prisms)
Hardness index (I_h)	Pendulum hammer to measured hardness index (I_h)	(RILEM, 1997) (NCPTT, 1999)	I_h ↔ render anomalies ↔ surface hardness ↔ R_c (standard prisms)
Flexural strength (R_f)	Drill or cut-off cores of rendering on walls	EN 1015-11 (adaptation)	R_f (drilled cores) ↔ R_c (standard prisms)
Dynamic elastic modulus (E_d)	Pulse velocity using ultra-sound equipment (V), expressed in m/s	(Subramaniam et al, 2005), (Santos et al, 2003), ASTM C597	V ↔ render physical changes ↔ E_d (standard prisms) ↔ R_c (standard prisms)
Impact resistance (Ir)	Sphere and cut-off shock by Martinet-Baronie apparatus on walls	Cahier 695, LNEC FE Pa 25, FE Pa 26, (Magalhães et al, 2002)	Diameter of the concussion made by sphere ↔ Ir ↔ anomalies The fall of a percentage of small squares ↔ Ir ↔ anomalies
Scratch and abrasion resistance	Cohesion tests by Martinet-Baronie apparatus on walls	LNEC FE Pa 27, FE Pa 28, (Magalhães et al, 2002)	Deepness of the scratch and quantity of material removed from the surface ↔ Ir ↔ anomalies
Capillary water absorption (C)	Drilled or cut-off cores of rendering on walls	EN 1015-18 (adaptation)	C (drilled cores) ↔ C (standard prisms)
	Absorption of low pressure water through Karsten tube	(LNEC, 2002) RILEM Test NºII.4	$C_{karsten}$ ↔ $C_{capillary}$ (standard prisms)
Water vapour permeability (μ)	Drilled or cut-off cores of rendering on walls and saturated in laboratory	EN 1015-19 and DIN 18550 (adaptation)	Mass variation (during drying) ↔ μ
Adhesion on substrates	Testing machine for direct pull tensile force test	(RILEM, 2004) EN 1015-12	Adhesion $_{O\ cores}$ ↔ Adhesion $_{\square\ cores}$ (O = circular), (□ = square)

3. PRELIMINARY IN-FIELD ASSESSMENTS AND DISCUSSION

The preliminary in-field assessment statements presented in this paper are the result from visual inspections and tests, performed in different renders (conventional multi-coat and one-coat cement renders), in buildings' envelopes in different locations (North and Centre of Portugal), using common in-situ techniques. The laboratory tests were applied to standard specimens and also to samples collected in-situ or from prototypes prepared in laboratory.

3.1 Field parameters related with type and extension of anomalies

Three case studies for one-coat colour cimentitious render with 1 year (case I), 6 months (case II) and 9 months (case III) of age are exemplified. The type of anomalies and on-site techniques performed are represented in Table 4. For each case a level of degradation (LD) was identified, based only on visual observation and existing literature (Shohet et al, 2002; Gaspar and Brito, 2005) → LD0 (no visually detectable degradation), LD1 good (surface staining), LD2 (light degradation, with localized fungi, salts, moisture, capillary cracks < 0.1 mm), LD3 (broad degradation, with visible cracks > 0.2 mm and up to 5% of the total cladding area, surface damage) and LD4 (extensive degradation, extensive cracking > 0.5 mm, detachment, spalling).

Other program testing was performed in a multi-coat render over 30 years old (case IV). The type of visible anomalies on façade east-oriented is biological colonization and cracking (Figure 1, left). The results of moisture measurements in biological colonization stains (Figure 1, right) vary with height, between 10 and 50%. Reference values of moisture meter scale showed no direct correlation with real moisture content of render. To correlate this non-destructive technique values with real moisture content, a gravimetric analysis should be performed in samples collected on the field (Henriques, 1995). On-site techniques were performed in these stained areas, involving a set of measurements: apparent pulse velocity (Figure 2, left), average pendulum hammer hardness index (72), average adhesion strength (0.6 N/mm2), sphere and cut-off shock (without any damage effect) and salts content by kit salt tests ([Cl-] = 22 mg/l, [NO3-] = 7.5 mg/l and [SO32-] = 600mg/l).

Table 4: Characterization of visible anomalies and results from on-site measurements (average values) in one-coat cimentitious render (cases I, II and III)

Nº	Description of visible anomalies (type and extension) - LD_i (level of degradation *i*)	On-site measures using ultra-sonic tests, pull-off tensile force test, sphere and cut-off shock by Martinet-Baronie, Karsten tube and salts test trips					
		Apparent pulse velocity (m/s)	Adhesion strength (N/mm^2)	Notch diameter (mm)	Detachment of small squares (%) for 250, 500 or 1000 g	Water absorption, 60 minutes (ml)	Salts contents (mg/l)
I	Extensive chalking and localized cracks < 0.5 mm LD_3	1688 (visible chalking and cracks)	0.1 (brick substrate); cohesive fracture	17	100% (250 g)	0.1	18.5 [Cl] 9.7 [NO_3] 430 [SO_3]
II	Extensive cracks (< 0.3 mm) and localized detachments LD_4	1536 (visible cracks) 2253 (no visible anomalies)	0.1 (brick substrate); adhesive fracture	No test performed (N/A)	N/A	N/A	19.5 [Cl] 6.5 [NO_3] 550 [SO_3]
III	Localized cracks (< 0.2 mm) and gaps (loss of material) LD_2	2165 (visible cracks) 2253 (no visible anomalies)	0.6 (brick substrate); adhesive / cohesive fracture	14	48% (250 g) 65% (500 g) 100% (1000 g)	0.5	N/A

3.2 On-site techniques and laboratory tests

An initial set of laboratory tests was performed in order to help the interpretation of on-site techniques results. For characterization of the hardened single-coat coloured render mortar, a total of 5 models (1.5 cm of render + brick substrate with dimensions 49 x 19 cm2), with different percentages of mixing water, were prepared in laboratory. This variation goes from difficult workability (compact) conditions to a fluid mortar due to water in excess. The correspondence between mixing water (%) and w/c ratio is: 18% H20 → w/c=1.20; 19% H20 → w/c=1.27; 21% H20 → w/c=1.40 (Fernandes et al, 2005). Additional standard prisms 4 x 4 x 16 cm3 were prepared in metallic moulds to perform standard tests. The results from on-site techniques for the prototypes and laboratory tests for the samples are represented in Table 5.

The compressive strength and capillary coefficient of three samples collected from 20% H20 model (using pull-off cores, 4 x 4 x 1.5 cm3) led to the following medium values: 3.8 N/mm2 and 0.011 kg/m2.min0.5, corresponding to a reduction of 4.5% and 32% respectively in relation with the standard prisms tests (Table 5).

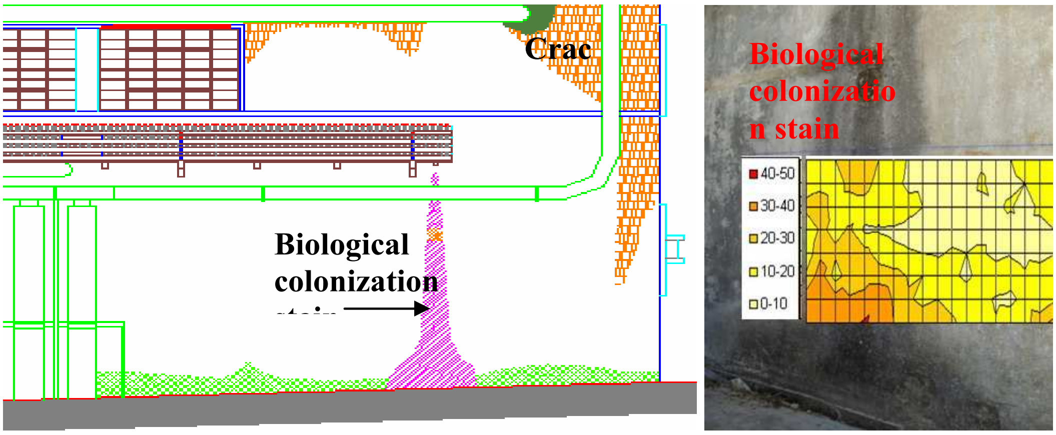

Figure 1: Schematic representation of anomalies in east façade (left) and colour mapping representation of moisture values on biological stain (right)

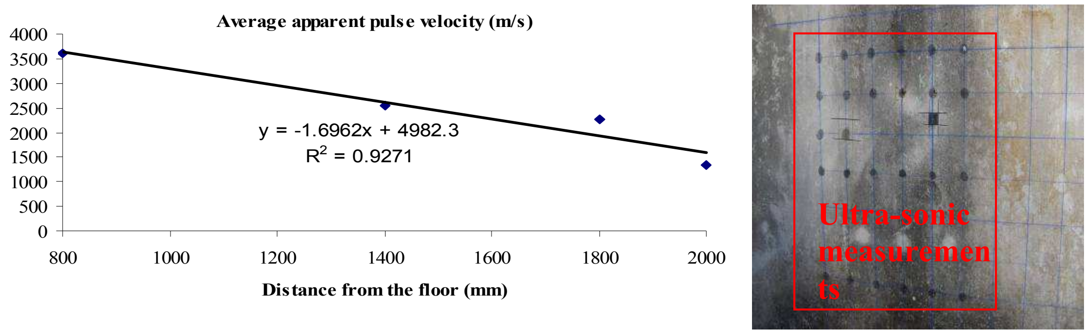

Figure 2: Variation of average apparent pulse velocity (left) with distance from the floor within the stained area (the measurements start near the top), and location of ultra-sonic measurements (right)

Table 5: Results from measurements within a laboratory program testing of a set of single-coat renders with different percentages of mixing water (w/c ratios)

One-coat renders	**On-site measures techniques and laboratorial tests on models and standards samples**						
	Compressive strength (N/mm^2)	Adhesion strength (N/mm^2)	Notch diameter (mm)	Fall of small squares (%) for 250, 500 or 1000g	Water absorption (Karsten tube) 60 min (ml)	Water absorption (Karsten tube) 48 hours (ml)	Capillary coefficient (10 and 90 min) ($kg/m^2.min^{0.5}$)
18% H_20	7.06	0.43 (adhesive)	13	40% (500g) 100% (1000g)	0.1	0.6	0.035
19% H_20	7.03	0.53 (cohesive)	14	23% (500g) 73% (1000g)	0.1	0.8	0.039
20% H_20	3.98	0.34 (cohesive)	16	70% (500g) 100% (1000g)	0.1	0.9	0.034
21% H_20	2.83	0.31 (cohesive)	16	54% (250g) 100% (500g)	0.1	0.9	0.046
22% H_20	2.67	0.30 (cohesive)	20	100% (250g)	0.1	0.8	0.052

3.3 Discussion of results from in-field assessment

The results from in-field assessment have identified and selected relevant aspects of rendering performance (single-coat and multi-coat renders) that are now discussed.

Lower ultra-sound transmission velocity values were obtained for the three case studies (I, II and III), Table 4, in degraded areas when compared with areas with no visible anomalies; this parameter reaches its lowest value (1536 m/s) in the case with the highest degradation level (case II, LD4) and increases for the other degradation levels, LD3 and LD2 respectively. The differences seem to have a direct relation with macro and micro-cracking and less with other types of anomalies (chalking, localized detachments, gaps). In fact, this indirect method may eventually remain unaffected by anomalies located deeper (Santos et al, 2003).

The average value of 2253 m/s (Table 4) obtained in non-degraded areas of single-coat renders is 27%-31% lower, when compared with other studies in multi-coat cementitious renders, 3100 to 3289 m/s (Magalhães et al, 2003). This situation is possibly related with the characteristics of this type of materials, usually with less compressive strength (< 5 N/mm2) that conventional renders (> 5 N/mm2). In fact, the apparent pulse velocity for case IV (multi-coat with conventional cementitious render) is higher within the stained area (Figure 2, left). Therefore, for a better interpretation of ultra-sonic results in the same material, the comparison of areas with and without damage is recommended.

The sphere and cut-off shock by Martinet-Baronie (originally to test painted surfaces - CSTB, 1966), and more recently adapted in LNEC to assess gypsum plasters (Lucas, 1986) are surface tests and give information about deformability and surface cohesion of the material (Magalhães et al, 2002). The acceptable values for gypsum values plasters (Lucas, 1986) are: diameter of the concussion made by the sphere (steel sphere of 50 mm of diameter impact) < 20 mm and no detached material on the area hit by the cutting element (cut-off impact producing 16 small squares, using masses of 250, 500 and 1000g) for a mass of 250 g. The results from laboratory tests (Table 5) point out to a diameter of the concussion (notch diameter) ≤ 16 mm and 54% of detachment of small squares for a 250 g mass or 70% for a 500 g mass; since these results correspond to current compressive strengths (≈ 3.50 N/mm2), these criteria should be used for single-coat renders (although more tests are necessary to validate this statement) instead of the one proposed by Lucas.

The Karsten tube laboratorial tests were performed during 60 minutes according to Test Nº II.4 of RILEM (LNEC, 2002), proceeding until 48 hours when an average value of 0.8 ml was obtained (Table 5). Considering a contact area of 5.7 cm2, the value for 48 hours was 0.14 ml/cm2, which seems to be satisfactory since the values of capillary of these products are acceptable according to standard EN 998 (Table 2). However, more tests are necessary to validate the comparison between the previous value and the criterion in standard EN 998 (Table 2) for water permeability: 1 ml/cm2 (notice that a different technique of assessment is used).

From the laboratory results mentioned in this paper it can be concluded that the hardened mortar characteristics were affected by the mixing water amount, mostly the mechanical properties. If, on one hand, there is water in excess leading to mortars with weak mechanical strengths, possibly with problems of cohesion during application, on the other hand, there are also mortars with a deficit in mixing water, causing lower entrained air amounts and, hence, resulting in a harder material with probable problems of mechanical incompatibility with the support (Fernandes et al, 2005). Additionally, the compressive strength tests of samples collected from prototypes, using cores from adhesion tests, have shown a good relation with compressive strength of standard prisms but a significant difference in capillary tests. These testing procedures should be validated in order to establish corrective factors.

The on-site techniques in a area of 1.2 x 1.5 m2 (case IV), with 19 to 56 measurements, depending on the technique used, instead of a minimum number of tests (5 to 10) recommended on technical documents, have shown for the same anomaly (biological colonization stain) different measurements of moisture content by humidimeter (Figure 1, right), apparent pulse velocity and hardness index, in different heights. Going down the stained area, the moisture contents and average apparent pulse velocity increase, but the hardness index from the pendulum hammer has a descending trend (despite the few values). These results are similar to those expected on concrete (de Brito, 1987). However, more tests need to be performed to prove these trends on rendering walls.

In all cases studied the sulphate salts content was significant (> 430 mg/l) compared with chloride and nitrates salts contents (< 22 mg/l) and with the minimum scale of sulphate test strips (< 200 mg/l). More tests need to be performed in order to correlate these concentrations with technical documents, e.g. nitrates salts content > 0.1% and chloride salts content > 0.09% of mass in tests are responsible for high concentration of hygroscopic salts and therefore serious damage on render (Henriques, 1995).

The information collected on case I allows the comparison between adhesion strength declared by the manufacturer (0.2 N/mm2) and standard requirements (Table2), in this case pointing to non-compliance.

4. CONCLUSIONS AND FUTURE WORK

On-site techniques used in field assessment are usually difficult to apply, due to the irregular shape and the integrity of samples collected, to the test conditions on site and also to the lack of adequate test standards or specifications (Magalhães et al, 2002). The preliminary results from the research carried out allow the conclusion that the techniques tested seem to be adequate to the proposed aims.

The in-field assessment has shown that the classification of anomalies through degradation levels based only on visual observation may not be enough to understand the possible causes of degradation, and to relate anomaly type / extension with render performance characteristics changes. The on-site techniques have characterized different performance characteristics associated with several anomalies (cracks, chalking, detachments, gaps, biological colonization) in four cases classified with three levels of degradation, based on visual assessment (case I - LD3, case II - LD4, case II and IV - LD2). In case I, the low results from ultra-sonic, superficial impact and adhesion (cohesive fracture) tests foretell high deformability and low internal cohesion of the material, affecting only mechanical strength (water resistance is still satisfactory). In case II, the low values of the adhesion test and good results in compressive strength tests of cores collected on-site (5.64 N/mm2) are probably due to extensive cracking because of lack of adherence. In case III, the low values of ultra-sonic tests have pointed out to the reduction of integrity / quality of render due to localized cracks and gaps, although the superficial impact results are not affected (water resistance is not conclusive). In case IV, the good results of ultra-sonic and pendulum tests (value >55 is very hard according to RILEM, 1997) have shown that the existence of biological colonization and high levels of moisture contents have not affected the internal and superficial mechanical properties in that area.

Since the impact of performance is a significant factor to measure the "seriouness" of a defect (Chew and De Silva, 2004) and consequent influence on the decision for maintenance strategy, the establishment of levels of degradation should include quantitative performance parameters, using on-site techniques. These procedures can reduce the subjectivity of the inspections (based only on visual observation) and help the criteria assessment during service life. The ongoing research study will continue to analyse the possibilities and limits of on-site techniques, and to establish possible correlations with performance requirements, in order to create a set of threshold values matrix that will help performance assessment of rendering / façades based on in-field techniques. In Table 6 a matrix is presented, using the results and statements mentioned in this paper. Although it needs to be validated, it aims at triggering discussion.

Table 6: Example of threshold matrix for performance characteristics based on-site techniques

	Render relevant properties (Table 1)				
Parameters measured on-site (Table 3)	Compressive strength	Superficial strength	Water resistance	Adhesion on substrate	Surface condition
Compressive strength on cut-off cores (N/mm^2)	$> 3.5 \times f_1$ **$< 3.5 \times f_1$**				
Apparent pulse velocity (ultra-sound) (m/s)	> 2253 **< 2253**			Good **Bad**	
Sphere shock by Martinet-Baronie (mm)		≤ 16 **> 16**			
Cut-off shock by Martine-Baronie (mass in g and % of detachment of squares)		≥ 250 (≤55) **<250 (>56)**			
Capillary coefficient on cut-off cores ($kg/m^2.min^{0.5}$)			$< 0.4 \times f_2$ **$> 0.4 \times f_2$**		
Water absorption (Karsten tube) (ml/cm^2) after 60 minutes			$\leq 0.14xf_3$ **$> 0.14xf_3$**		
Adhesion by pull-off tensile force test (N/mm^2) and type of fracture (% of contact area)				≥ 0.3 or CF (80%) **< 0.3**	
Water content by portable moisture meter (%)					≤ 12 **> 12**
Sulphate content by analytical test strips (mg/l)					< 200 **> 200**

* Note: f_1, f_2 and f_3 are corrective factors that would be validate; CF is cohesive fracture

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CREATING SAFER COMMUNITIES: THE VALUE OF SITUATIONAL CRIME PREVENTION

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Abstract: In the United Kingdom there has been a growing interest in the economic costs and benefits of preventing crime. Research suggests that Situational Crime Prevention (SCP) is an economically efficient strategy for preventing crime but little is known about its absolute value.

This paper examines the value of SCP in reducing crime in a community context. SCP seeks to prevent crime by changing the situational and/or spatial features in the environment so that it is harder to commit a crime and/or easier to detect an offender. The assumption is that offending behaviour is opportunistic and therefore situational features can be more easily manipulated than the behaviour of offenders to inhibit crime. Consequently the focus is on the environmental setting in which crimes occur not the criminal act itself.

The research uses a mixed methods approach to place an economic, social, political and environmental value on the prevention of crime using SCP measures. Secured by Design (SBD) case studies are used to highlight the value of SCP.

Key words: Secured by Design, Situational Crime Prevention, Urban Design, Value.

1. INTRODUCTION

The media and crime trend statistics have, in recent years indicated a rise in all types of crimes. With traditional methods of intervention, such as the police and the criminal justice system, seemingly powerless to halt the escalation of crime, interest has been renewed in understanding the crimogenic characteristics of the built environment and what affect it has on crime. Emphasis has been placed on the importance of design as a deterministic and therefore preventative factor in crime. Research has indicated that the appropriate design and effective use of the built environment can lead to a reduction in both the opportunity for crime and fear of crime.

The main objective of this research is to examine the value that good urban design has in reducing crime. This will be done by combining both qualitative and quantitative methodologies to examine the concept of good urban design and its potential social, economic, political and environmental value when used for in association with crime prevention. The expected conclusion of the research is clarity of the exact value in using SCP to prevent crime. This paper reports on the findings of a survey undertaken in the course of PhD research examining the value of situational crime prevention (SCP).

1.1 Background to the Research

SCP involves preventing crime by changing or modifying the situational or spatial features present in the environment so that they make it harder to commit a crime or make it easier to detect the offender. Research has indicated that the appropriate design and effective use of the built environment can lead to a reduction in both the opportunity for crime and fear of crime. Situational crime prevention, also known as physical crime prevention or target-hardening, involves preventing crime by changing the situational or spatial features present in the environment so that they make it harder to commit a crime or make it easier to detect the offender. Crawford defines it broadly as involving “the management, design or manipulation of the immediate physical environment so as to reduce the opportunity for specific crimes.” (1998, p. 18). Hough et al concur with the standard definition of situational crime prevention that was set by Clarke (1984) but in addition define it as:

I. “measures directed at highly specific forms of crime;
II. which involve the management, design or manipulation of the immediate environment in which these crimes occur;
III. in as systematic and permanent a way as possible;
IV. so as to reduce the opportunity for these crimes;
V. as perceived by a broad range of potential offenders.” (1980, p. 1)

Situational Crime prevention “introduces discrete managerial and environmental change to reduce the opportunity for crimes to occur … seeks not to eliminate criminal or delinquent tendencies through improvement of society or its institutions, but merely to make criminal action less attractive to offenders.” (Clarke, 1997, p. 2) Therefore the focus is on the environmental setting in which crimes occur and not on the act itself. Clarke goes on to define situational crime prevention as “… a preventive approach that relies, not upon improving society or its institutions, but simply upon reducing opportunities for crime.” (1992, p. 3) This is achieved by modifying, manipulating or managing the environment.

It was suggested by Clarke (1997) that situational features are more open to manipulation and are therefore more susceptible to change. SCP factors – spatial, design and environment – are more easily manipulated and modified than offenders. Crawford (1998) points out that situational crime prevention is based on the assumption that crime is opportunistic and that offenders apply the rational choice model of decision-making when committing a criminal offence.

Situational crime prevention developed partly as a result of Opportunity Theory which professed that individuals who committed crimes were “heavily influenced by environmental inducements and opportunities and as being highly adaptable to changes in the situation.” (Clarke, 1999, p. 57) Situational crime prevention theory is based upon an opportunity reduction model as seen in table 1 and advocates the principle of deterrence and emphasises the certainty that offenders will be detected. The focus therefore is on detection instead of severity of punishment.

Table 1: Situational Crime Prevention Opportunity-Reduction Techniques

Increasing Perceived Effort	**Increasing Perceived Risk**	**Reducing Anticipated Rewards**	**Removing Excuses**
1.Target Hardening	5. Entry/Exit Screening	9. Target Removal	13. Rule Setting
2.Access Control	6.Formal Surveillance	10.Identifying Property	14.Stimulating Conscience
3.Deflecting Offenders	7. Surveillance by Employees	11.Reducing Temptation	15.Controlling Disinhibitors
4.Controlling Facilitators	8.Natural Surveillance	12. Denying Benefits	16.Facilitating Compliance

Source: Clarke (1997, p. 18)

2. SURVEY

A wide range of participants from the police, the community safety sector, architects, urban designers, local and national government, Designing out Crime Association (DOCA) and other crime prevention related agencies were approached. Figure 1 shows the breakdown of participant occupation. Participants were asked to complete the survey consisting of 57 statements concerning both general and specific issues in crime prevention, that were extracted from the findings of an extensive literature search of both community and crime prevention theory.

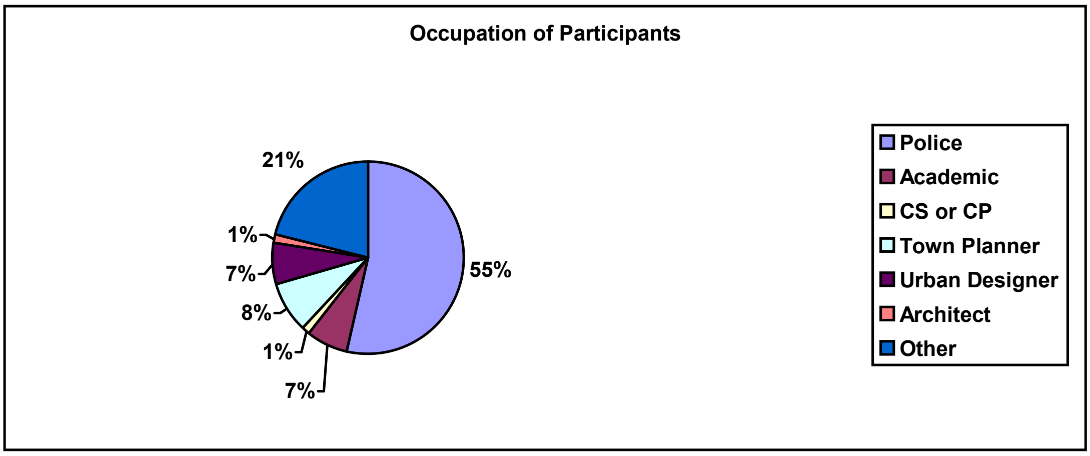

Figure 1: Occupation of Participants

There are numerous ways of measuring and quantifying data but for the purposes of this research a Likert-type scale was used. The Likert Scale technique is commonly used for measuring opinions, attitudes and beliefs. Likert (1967) surmised that the degree of agreement with an intentionally polarised statement can serve to measure attitude about the issue under study. The statements in this survey were measured on a numbered continuum from 1-5, where 1 meant that participants strongly agreed with the statement and the further point, 5, meant that they strongly disagreed. In order to code the survey it was necessary to work out whether each statement was positive or negative as negatively worded statements require reverse coding. The item scores and then added together to obtain the total score which will be in the range of 57 – 295. (Mid-point is 176) The total score minus the item score is then used to work out the correlation co-efficient.

When designing the Likert Scale survey it was essential that there was a clear understanding of what was being measured. The statements were constructed so that they contained only one idea so that participants can respond to the statement without any ambiguity. (Roberts *et al*, 1999) It was important that the statements were not socially appropriate or in appropriate to ensure that participants felt free to give their own personal beliefs and not simply what they believed that the survey sought to discover. (Patton, 1990) Each statement was carefully constructed so that participants were not unnecessarily dependent upon certain facts for an accurate appraisal option as if the participant had to be informed about a given fact in order to express an opinion, then that response becomes random rather than a reflection of their actual opinion. (Miles and Huberman, 2002) The statements were piloted with a small group of individuals, whose attitudes and opinions concerning the subject of crime prevention were well known, in order to eliminate any ambiguities. (Miles and Huberman, 1994)

2.1 Findings

The survey response rate was approximately 56% and Standard Deviation (STDEV) was used to rank the results according to their STDEV value. Statements that had the lowest STDEV value were found to have the highest levels of agreement. Table 2 shows the statements ranked according to their STDEV value. Standard Deviation is a measure of how widely values are dispersed from the average value (mean). The formula is:

$$\sqrt{\frac{\sum(x - \bar{x})^2}{(n-1)}}$$

x = Sample mean average
n = Sample size

Table 2: Survey Ranked using STDEV.

Rank	Statement No.	Statement	STDEV	Average
1	26	It is possible to manipulate the physical environment so that it prevents crime and fear of crime.	**0.40**	**1.80**
2	22	The appropriate design of the urban environment will lead to reductions in crime and fear of crime.	**0.57**	**2.31**
3	39	Situational crime prevention measures have economic, social, political and environmental value.	**0.67**	**1.88**
4	52	Access control is the most important factor in crime prevention.	**0.71**	**3.43**
5	25	Improving street lighting has little effect on crime.	**0.73**	**2.00**

-	31	All types of cul de sacs enhance opportunities for crime.	**0.73**	**1.98**
-	47	Crime is not necessarily a harmful feature of society.	**0.73**	**4.15**
6	5	Situational crime prevention measures have no value.	**0.75**	**1.51**
-	49	Physical determinism is a feature of all situational crime prevention measures.	**0.75**	**2.90**
7	42	Changing the physical environment has a positive effect on crime and fear of crime.	**0.76**	**1.87**
-	44	The loss of community has contributed to the crime problem in modern society.	**0.76**	**3.80**
-	57	Secured by Design prevents crime in residential areas.	**0.76**	**1.92**
8	21	Lack of commonality in communities increases risk of criminal victimization.	**0.77**	**2.36**
-	36	Crime can be prevented by reducing opportunities.	**0.77**	**1.94**
9	17	Urban design can be seen as a mechanism through which the probability of certain behaviour occurring can be manipulated or altered.	**0.80**	**1.93**
-	53	The physical design of the urban environments exhibits cues that effect behaviour.	**0.80**	**2.09**
10	3	Situational crime prevention is an economically sustainable strategy for reducing crime.	**0.82**	**1.76**
-	28	CCTV is the panacea in the fight against crime.	**0.82**	**4.14**
-	34	Crime can be sustainably reduced using situational crime prevention measures.	**0.82**	**2.10**
11	1	It is necessary to strike a balance between designing for crime prevention and designing for the effective use of the environment.	**0.83**	**1.71**
12	33	It is not possible to generalize using situational crime prevention measures.	**0.85**	**3.07**
-	38	CCTV causes displacement.	**0.85**	**3.11**
13	37	A measure of crime is an inevitable and unpreventable feature of any society.	**0.86**	**3.51**
14	32	Improving the physical design of the urban environment can alleviate social problems such as crime, disorder and community pathology.	**0.87**	**2.03**
-	35	Displacement is specifically a side-effect of situational crime prevention measures.	**0.87**	**2.58**
15	45	Surveillance is the most important factor in crime prevention.	**0.88**	**2.82**
-	55	Crime destroys communities.	**0.88**	**2.37**

16	24	Crime and fear of crime are reduced in areas that exhibit a strong sense of territoriality.	**0.89**	**2.07**
-	41	Crime is a pathological characteristic of modern society.	**0.89**	**3.27**
17	9	Communities prevent residential crime and associated anti-social behaviour.	**0.90**	**2.35**
18	18	Situational crime prevention penalizes law-abiding citizens.	**0.91**	**2.02**
19	40	Environmental cues deter crime.	**0.92**	**2.30**
20	19	Street lighting is a low cost crime reduction solution.	**0.94**	**2.32**
-	50	Crime preventing designs should take preference over aesthetic design.	**0.94**	**2.81**
21	12	Situational measures advocate social exclusion.	**0.95**	**2.56**
-	46	Good urban design costs more.	**0.95**	**2.46**
22	13	Design-based situational crime prevention measures exaggerate the influence that the physical environment has on behaviour.	**0.96**	**2.56**
23	4	Good urban design adds value to developments.	**0.97**	**1.51**
-	16	Crime strengthens communities by encouraging community co-operation and community action.	**0.97**	**3.33**
24	48	Situational crime prevention diverts attention away from tackling the ‘root causes’ of crime.	**0.98**	**2.57**
25	43	Situational crime prevention measures must only be tailored to specific crime problems.	**0.99**	**2.93**
-	51	Displacement is a side-effect of all crime prevention measures.	**0.99**	**2.58**
26	10	Crime displacement should be viewed as a potential tool of crime control policies rather than an unwanted constraint on crime prevention programmes.	**1.00**	**2.66**
27	30	Opportunity causes all crime.	**1.01**	**2.97**
28	8	Residential crimes can be eliminated in urban areas by encouraging mixed-use developments.	**1.02**	**3.01**
29	14	Poor quality urban environments exist in response to various social and economic threats.	**1.03**	**2.71**
30	20	The form of the urban environment creates opportunities for crime.	**1.04**	**2.05**
-	23	There must be greater co-operation between the professions involved in shaping and developing the urban environment.	**1.04**	**1.51**

31	2	More evaluations are required concerning 'What Works' in situational crime prevention.	**1.05**	**1.77**
-	11	It is not possible to design out residential crime.	**1.05**	**2.01**
32	6	Law-abiding citizens are the largest unused resource in crime prevention.	**1.06**	**2.24**
-	54	Situational crime prevention causes displacement	**1.06**	**2.90**
33	15	Crime can only be altered using social crime prevention techniques.	**1.12**	**2.37**
34	29	More quality research is required concerning the value of design-based situational crime prevention measures.	**1.15**	**2.06**
-	56	It is the role of the criminal justice system and its associated agencies to prevent crime.	**1.15**	**2.61**
35	27	'Nothing Works' in the fight against crime.	**1.32**	**1.74**
36	7	It is the duty of the police to prevent crime.	**1.34**	**2.39**

The results were also categorized as either police or non-police according to the respondent's occupation. Figure 2 demonstrates the combined STDEV of both the police and non-police categories. Figure 3 shows the variations between the two categories according to their standard deviation scores.

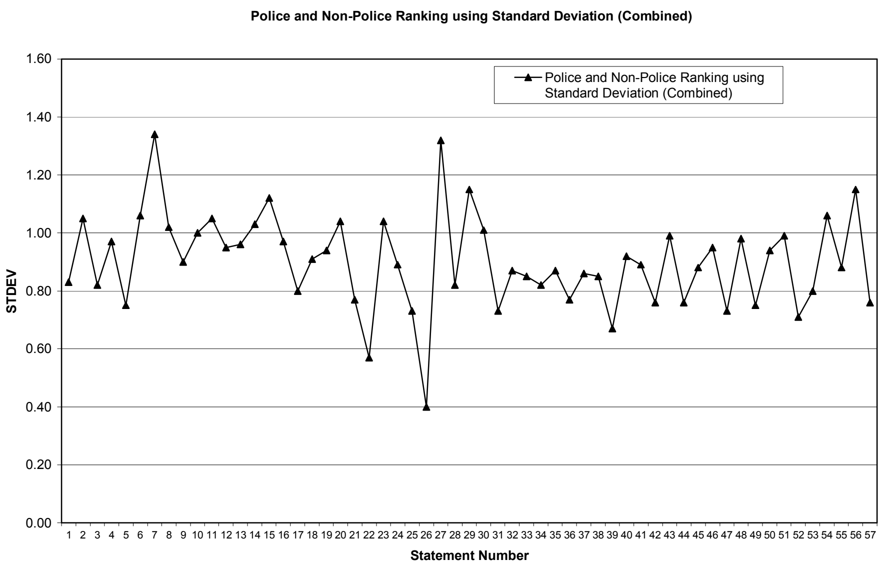

Figure 2: Police and Non-Police Categories Combined STDEV

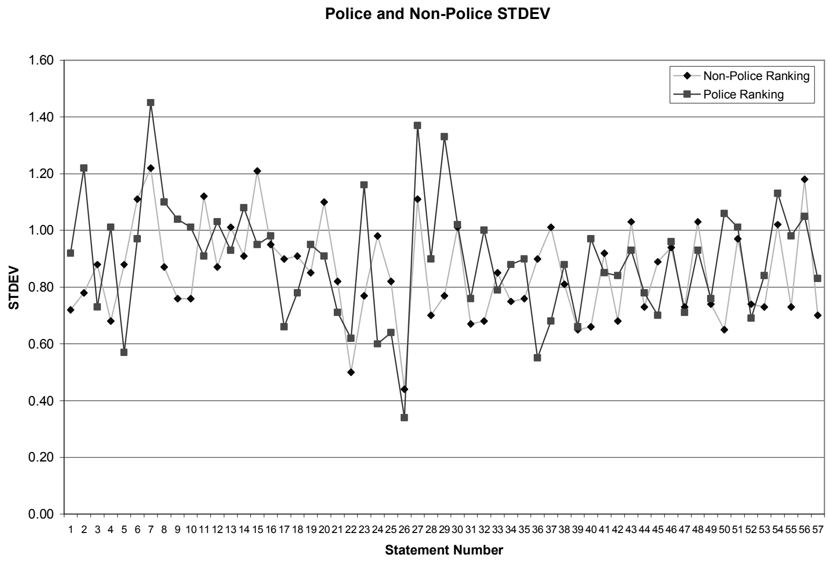

Figure 3: Category Variation According to STDEV

The results of the survey were analysed and the following sections concisely highlights some of the main points from which The Value of Situational Crime Prevention Model was developed.

2.2 SCP Findings

It was found that 58% and 28% agreed and strongly agreed respectively that situational crime prevention measures have economic, social, political and environmental value. Another strong response was provoked by the statement stating that situational crime prevention measures have no value. 94% of the respondents strongly disagreed or disagreed with this statement.

2.3 Community Findings

The statement crime is not necessarily a harmful feature of society provoked a strong response with 82% of respondents choosing to disagree (44%) or strongly disagree (38%) with the statement. The statement that the loss of community has contributed to the crime problem in modern society caused over half of all respondents (53%) to agree with this statement while 20% neither agreed nor disagreed. Exactly half of respondents (50%) agreed with the statement that a lack of commonality in communities increases risk of criminal victimization. Over half (52%) of all respondents agreed with the statement that a measure of crime is an inevitable and unpreventable feature of any society. 41% of respondents believed that crime destroys communities. 46% of respondents agreed that crime is a pathological characteristic of modern society. 47% of respondents agreed that communities prevent residential crime and associated anti-social behaviour. 42% of respondents disagreed with the statement that crime strengthens communities by encouraging community co-operation and community action.

2.4 Design Findings

The survey found that 43% of respondents disagreed with the statement that access control is the most important factor in crime prevention. 36% of respondents neither agreed nor disagreed with the notion that surveillance is the most important factor in crime prevention, only 32% agreed.

86% of respondents agreed (61%) and strongly agreed (25%) with the statement that urban design can be seen as a mechanism through which the probability of certain behaviour occurring can be manipulated or altered. 79% of respondents agreed (62%) and strongly agreed (17%) with the statement that the physical design of the urban environments exhibits cues that effect behaviour. 17% of respondents felt that they could neither agree nor disagree with the statement. 89% of respondents agreed (49%) and strongly agreed (40%) with the statement that it is necessary to strike a balance between designing for crime prevention and designing for the effective use of the environment. 83% of respondents agreed (64%) or strongly agreed (19%) with the statement that improving the physical design of the urban environment can alleviate social problems such as crime, disorder and community pathology. Only 38% of respondents agreed that crime preventing designs should take preference over aesthetic design.

45% of respondents disagreed that good urban design costs more. The statement design-based situational crime prevention measures exaggerate the influence that the physical environment has on behaviour, caused a split in the opinions of respondents 49% disagreed with the statement, 20% agreed with the statement and 20% neither agreed nor disagreed. More than half of all respondents (61%) strongly agreed that G
good urban design adds value to developments.

85% of respondents agreed (43%) and strongly agreed (42%) that situational crime prevention is an economically sustainable strategy for reducing crime. Physical determinism is a feature of all situational crime prevention measures caused a rather neutral response as 55% of participants neither agreed nor disagreed, and only 21% agreed. 76% of respondents agreed (48% and strongly agreed (28%) that the form of the urban environment creates opportunities for crime.

75% of respondents agreed and 22% strongly agreed with the statement that it is possible to manipulate the physical environment so that it prevents crime and fear of crime. 51% of respondents agreed with the statement that the appropriate design of the urban environment will lead to reductions in crime and fear of crime, but 40% of respondents neither agreed nor disagreed.

2.5 Difficulties

The most common problem encountered when undertaking the survey was that certain participants tended to give the most neutral answer possible, i.e. 3, mid-way between the two extremes. (Thurstone, 1928) A possible way around this problem would have been to use an even number of options so that the participant if forced to choose either a positive or negative option. The difficultly arises in forcing participants to choose an option when they perhaps do not have an opinion about the statement or issue under consideration. Therefore for this reason an odd number of options were used in the survey.

3. CONCLUSIONS – THE FUTURE?

The Value of Situational Crime Prevention Model based on the results of the survey, currently being fine tuned before being tested using multiple case studies and interviews with interested parties in the fields of planning, design and crime prevention/community safety. A number of Housing Associations have already expressed an interest in using the model to identify and prioritise crime prevention issues in their local communities and to employ SCP techniques that adhere to the contemporary 'What Works' ideology. More importantly the model highlights the value of design-based situational crime prevention measures, not just the monetary savings that can be made by using a specified SCP measure, but the environmental and social value that can be added to communities and neighbourhoods through working in harmony with local communities.

There is little doubt that crime is rapidly destroying our communities and is provoking a disabling fear of crime. The findings of the survey highlight the need for greater co-operation between the professions involved in shaping and developing the urban environment and the people who live there. By working in partnership, adhering to the values of SCP and taking a firm moral stance against criminality we can fight back and reclaim our communities – together.

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EVALUATION AND COMPARISON OF POST-DISASTER HOUSING IN TURKEY; LESSONS FROM IKITELLI AND SENIRKENT

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Abstract: Most of the cities and towns in Turkey are located on the active seismic regions; however the buildings are generally not designed to be earthquake resistant. Thus there is a big earthquake threat for public life. Not only earthquakes but also other natural disasters like floods and landslides threaten the public who are vulnerable to disasters. In this study two case studies; a rural post-disaster housing settlement example of Senirkent and an urban post-disaster housing settlement of Ikitelli were examined.Some similarities can be observed in the design and construction processes of post-disaster housing in the rural and urban settlements. On the other hand, there have been crucial differences between the dwellers of those settlements in terms of socio-cultural and economic specialities. The ultimate goal of this study is to evaluate and compare the new settlements in terms of design, construction, and post-occupancy problems.

Keywords: disaster, post-disaster housing, post-occupancy problems, socio-cultural.

1. INTRODUCTION

The aim of the study is to compare two case-studies which were conducted independently from each other in different years by the author. However, both of the case studies investigated the post-occupancy problems of the post-disaster housing in Turkey. The problems were investigated mainly under the items of design, construction, management, and socio-cultural problems. The current study aimed to evaluate and compare the problems found out from the case studies according to their differences and similarities.

The following section (Section 2) summarizes the disaster events, and methodologies and findings of the case studies. The third section compares the case studies. The study ends with a comment of the report as the conclusion part.

2. THE CASE STUDIES

The investigations of post-occupancy evaluation of the two cases were conducted in different regions of Turkey. One of the regions is a district of Ikitelli in the metropolis of Istanbul in Marmara Region and the other is a small town of Senirkent in Central Anatolia. The findings from both studies show that the methodologies and strategies for both cases were similar in terms of design and construction periods. However, the post-occupancy problems have presented overlapping cases. These similarities were unexpected results because the regions in which the post-disaster settlements were constructed are crucially different from each other in terms of demographical, physical, climatic, economical, and socio-cultural characteristics. The present study aims to understand the impacts of similar applications of post-disaster housing which were built by the government of Turkey for two regions, and to compare the similar problems in order to find out better solutions for future applications.

2.1 Marmara Earthquake of 1999 and Ikitelli post-disaster housing example

The earthquakes which hit the Turkish towns of Izmit and Duzce in 1999, known collectively as the Marmara earthquakes, not only took a terrible human toll, they also cost the country around US$20 billion in damage alone, equivalent to over 10 per cent of annual gross domestic product (GDP). Two earthquakes of 1999 left up to 20.000 people dead and 50.000 injured in north-western Turkey (World Disaster Report, 2002).

After the disaster, a huge emergency sheltering and temporary sheltering demand occurred. It took some time to solve these problems, during the same time Turkish government began to study the rehabilitation of the region and to construct post-disaster housing (permanent housing). As the impact of the disaster was very huge, the need for post-disaster housing was also very big which could be said that thousands of dwellings were needed urgently. However, it was clear that all the needs could not be met in a single region, so the government firstly started to study on finding suitable districts for building post-disaster housing settlements.

Ikitelli district, which is located on European Side of Istanbul, is one of the selected districts for application of post-disaster housing project. In June 2000, the construction started under the control of The Ministry of Public Works and Settlement. The project was composed of 810 dwellings (Figure 1). Both the project and the construction were entrusted to the contractor firms by The Ministry of Public Works and Settlement. The selected firms - UBM, Yavuzlar, Uralsan - finished the first 650 dwellings in September 2001; and the rest, 160 dwellings, were finished at the end of year 2002 (Özden et al, 2003).

Figure 1: Scenes from Ikitelli Post-disaster Housing settlement

2.2 The Case Study of Ikitelli Post-disaster Housing

At the end of year 2002, in October and November, a case study was conducted in Ikitelli post-disaster housing area in order to evaluate post-occupancy problems. The methodology of the study was based on site observations and application of the household survey, consisting of 50 questions, addressing, among other things, (1) demographic characteristics of the household; (2) sequence, duration, and number of household movements post-disaster; (3) satisfaction levels with former houses (pre-disaster housing) and satisfaction levels with post-disaster housing: (4) satisfaction levels with pre-environment and current environment.

The survey instrument was prepared under the control and supervision of the instructors from Istanbul Technical University, Social Sciences Institute – Masters Program of Housing and Earthquake (Özden et al, 2003). The survey was conducted by a group of architects including the author. Thirty households participated in the survey. During the research period, the occupancy ratio of the dwellings was nearly 40 per cent. The rest of the dwellings were empty because of some problems which will be mentioned in the following. From both the survey and site observations, some important problems affecting the success of the project and adaptation period of victims to their new dwellings and environment were confirmed and established. These problems are listed below with general points for this study:

The uncompleted infrastructure (road and streets, natural-gas lines, telephone etc.), low construction quality of houses and difficult transportation problems were the primary problems which the households complained. It was observed that some households preferred to come and settle in their new houses very late because of such problems. The delay in settling also had been causing the delay in adaptation to new environment of the victims (Özden et al, 2003).

The construction problems of post-disaster housing; water installation systems (especially bathroom installations) were causing some serious problems almost in every dwelling. The exterior walls, facades were not water-resistant (rain, snow etc.) and there was always water leakage from exterior walls of the dwellings. The building materials were of low quality (installations, windows, doors, paintings etc.). Water leakage and humidity were some of the problems faced in basement floors.

The design problems of post-disaster housing; some of the buildings were constructed without basement floors. On the other hand, after the 1999 earthquakes, the building codes and legislations were changed and the basement floors had become a must in new buildings. So, Ikitelli Municipality authorities did not give building inhabiting licence yet at the time of the study to those buildings according to new building codes. Heating systems of the buildings were planned according to natural-gas heaters, unfortunately natural-gas infrastructure (pipe lines) had not been constructed to the area yet. So households could not use this system. They had to establish a traditional-old system, stoves in which wood and coal were burned. However, there were not adequate numbers of chimneys designed in the dwellings.

Infrastructure problems; the roads connecting the area to the main roads and district were not completed yet. Natural-gas and telephone lines were not finished. There were not any public transportation vehicles in the area such as inner city buses.

Institutional problems; there were not any social, cultural, educational, religious or health institutions in the region. The nearest one of these institutions was a few kilometres away, which was out of reach of especially elderly and children. All people had to reach those places with their own resources or vehicles.

Proximity to work; most of the work-places and offices of occupants were generally around the pre-disaster housing areas which were about 10 or more km. away from the post-disaster area. Hence it was hard to reach their jobs from post-disaster housing areas.

Cultural problems; as mentioned above, some of the households did not prefer to settle in post-disaster housings, or they settled there after a long period of time. They generally preferred to rent their houses to other people. However, the houses were rented to immigrants coming from eastern parts of Turkey who belonged to generally low socio economic status. They emigrated generally from rural areas. On the other hand, most of the households of the post-disaster housings belonged to middle and upper socio economic status, and had been living in urban areas, in Istanbul for a long time. Both the financial and cultural differences caused important conflicts between the residents, the households and tenants. Households generally complained about insensitive behaviours of tenants.

Security problems; households generally did not feel secure against crimes such as theft. They thought that environmental security was very insufficient in their living area.

Coordination and management problems; households generally complained about the lack of an authority to talk about their problems and needs. Neither contractor firms, nor The Ministry of Public Works and Settlement authorities established a communication line with households. In addition to this, the firms and authorities generally did not take the responsibility for the problems of post-disaster housing and they accused each other.

The author also had a chance to reach one of the contractor firms and ministry authorities in Istanbul during the research, and carried a short conversation with both of them. From these conversations, it was learned that the most important point which caused problems in post-disaster housing areas was the insufficient time table for design and construction of post-disaster housings and the urgency of the event. On the other hand, there should be another research in order to see and understand the problems and approach of post-disaster housing from the ministry side because the limited time of conversation was not seen enough to reach an opinion. So it should be the subject of another research.

The following section explains the second case study very briefly.

2.3 Senirkent Flood Disaster of 1995 and Senirkent Post-disaster Housing Example

The town of Senirkent is located in a geography where Central Anatolia and Mediterranean region intersect, near one of the biggest lakes of Turkey, the lake of Eğirdir. The town is 1010 meters high from the sea level. The population of the town is 10.738 (Özden, 2004).

On 13th of July, 1995, soon after a heavy rain at the evening hours, a huge and destructive mud flood destroyed a total number of 320 dwellings, of which 195 were completely destroyed, 18 moderately destroyed, and 107 lightly destroyed. The disaster killed 74 people and injured 46 people (Figure 2). Dwellings that were constructed with mud-brick could not resist to the flood, also called as *cold lava* by the authorities (Özden, 2004).

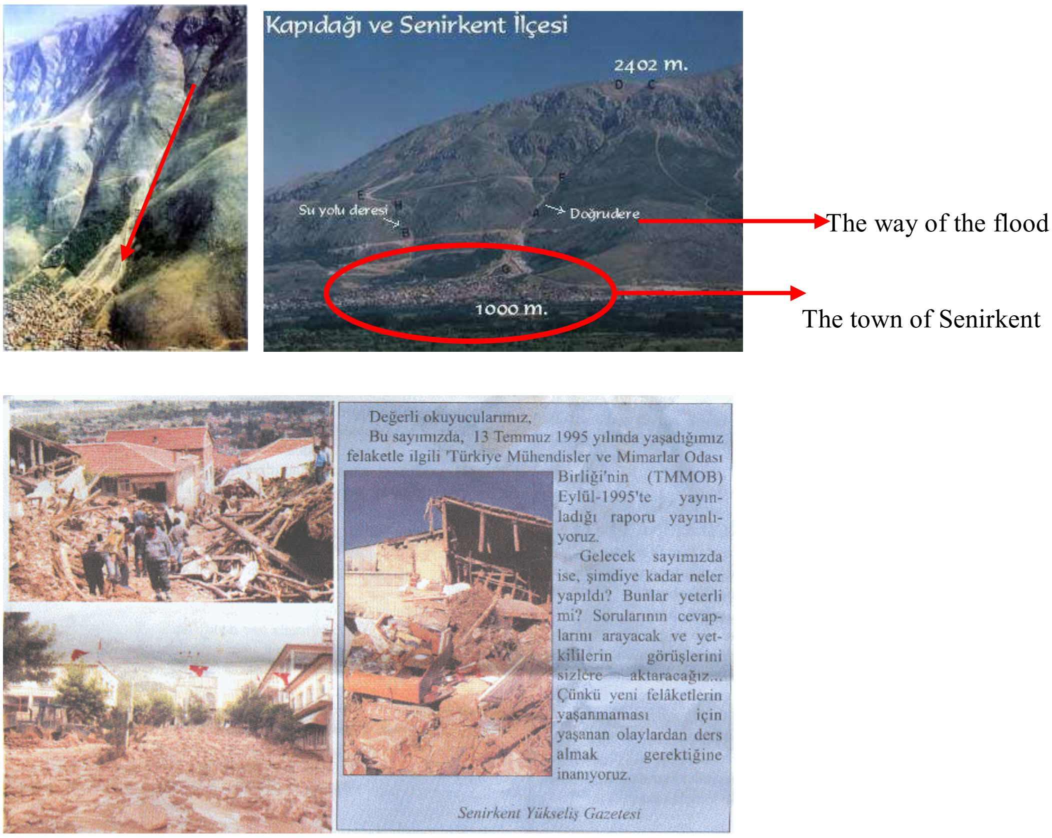

Figure 2: Scenes from Senirkent Flood Disaster

Soon after the disaster, The Ministry of Public Works and Settlement started to look for an area for constructing post-disaster housing. The main criterion was its flatness and being far from the flood area for choosing the area. The methodology and approach for post-disaster housing project and construction were the same as in Ikitelli example. The ministry entrusted and gave the job to a firm for construction. In fact the projects had been designed for another post-disaster housing area previously, so the revision and application to the new area would not take the authorities of the ministry too long. They could finish the projects nearly in 10 or 15 days, and send to the contractor firm. The construction started in August 1995 and finished in December 1995. 188 dwellings were constructed which were composed of 16 blocks, 15 of which were three-storey blocks and one of which was two-storey (Figure 3).

Figure 3: Scenes from Senirkent Post-disaster Housing settlement

2.4 The Case Study of Senirkent Post-disaster Housing

In July and August in 2003, the author conducted a survey in the region. The methodology of the survey was very similar to the one employed in Ikitelli example. It was based on observations in the region and application of the household survey, consisted of 31 questions which were taken from the Ikitelli survey. As mentioned before, Ikitelli survey questionnaire was composed of 50 questions, but for the Senirkent some of the questions were discarded because they were not necessary for this research.

Findings indicated that about 18 per cent (35 dwellings) of the 188 dwellings were not being used by the households (or victims). Some of them were rented by the households to other people and the others were empty (Özden, 2004). From the demographic data and conversations with the households living in the region, it was determined that the mean age of the households was above 50. Therefore, it could be said that the majority of the residents was elderly people.

In fact 15 households participated in the survey. Additionally, the researcher found the chance to chat and sometimes make longer conversations with the households except the ones who participated in the survey during the research in the region. These conversations sometimes were more useful to get more information on certain cases. So, not only the survey instruments but also the conversation notes established the study report.

The general problems and complaints of households which were found out from the research could be determined briefly as follows;

- The projects were designed without meeting the residents' social, economical, and cultural needs,

- During the design and construction period, the users' thoughts were not taken into consideration by the authorities,

- The decision in the place (area) preferences was thought to be completely wrong, the useful and productive agricultural areas were used in building apartment blocks,

- The infrastructure was very weak and insufficient,

- The quality of construction and building materials was very low,
- The post-disaster settlement was far away to the town centre so this caused difficulties in reaching the town centre and bazaar of the town, especially for disabled people, and elderly people,

- The lack of a (site) management was always mentioned by the households because they could not find any authorities who could listen and help them with their problems. If a management model could have been established by the authorities, people would have been able to find better solutions to their problems.

3. LESSONS FROM THE EXAMPLES OF POST-DISASTER HOUSING

There were, in fact, very deep differences between the victims (households) of two examples in terms of demographic, economic, and socio-cultural characteristics. On the other hand, their problems relating to post-disaster housing, often coincided and many similar points can be observed.

Ikitelli district is located in the metropolis of Istanbul, which is the commercial and industrial centre of Turkey. The life standards, habits, economic life of the people of the region were crucially different from the residents' who were living in a town such as Senirkent. Ikitelli post-disaster housing households had been used to living in apartment blocks for a long time; on the other hand, victims of Senirkent flood disaster had been living in independent-adobe houses for nearly 200 years (Figure 4).

Figure 4: The traditional adobe houses of Senirkent

The authorities had designed the nearly same types of post-disaster housing for both cases, for the metropolis of Istanbul and the rural district of a small Anatolian town of Senirkent. This was, perhaps, the beginning of the problems mentioned before.

However, the other problems which were given for both examples generally gave the similar cases. Both of the regions' households complained about low construction quality and building materials, insufficient infrastructure, lack of socio-cultural institutes, transportation problems, management problems etc.

Mostly, post-disasters in Turkey, victims are relocated by the government to the new environments and dwellings. Relocation outside and away from the community and neighborhoods can compound victims' readjustment and recovery problems. Victims who were relocated must find new jobs, enroll their children in a different school district, and develop social ties to their new surroundings. For those victims that remained rooted in their home community while living in a new community, they must deal with transportation issue (Cole, 2003).

Researchers believe that the vast majority of victims attempt to relocate with relatives, and, if feasible, to return and resettle on the pre-disaster housing site (Cole, 2003). This view was observed from the results of both cases. The answers related to the questions which asked about whether the victims prefer to live in pre-disaster housing or post-disaster housing, gave the same results for both cases that vast majority prefer to live in pre-disaster housing and site. During the research period, many households were still thinking to resettle in their pre-disaster housing sites, even the same houses.

Especially in rural areas, the ties between relatives and neighbors are very strong. When the victims began to lose those ties, the adaptation period to their new environment becomes very hard and continues long which begins to turn into a painful process. This will cause psychological, social, and cultural problems, even some conflicts among the victims and environment. Therefore, housing recovery process or reestablishing of permanent housing process ends up as a failure. So, as can be seen the relocation approach of victims has been causing more problems than solutions for victims. During one of the conversations in the Ikitelli case study, a household said that "we did not understand that we were victims of a disaster during the emergency and temporary housing periods because we could reach everything, we were living with our relatives and rented houses in the regions where we wanted, just when we resettled to post-disaster housing site, than we understood that we were really victims".

Similar problems were met in other parts of the world. For example in Japan, after big Kobe earthquake of 1995, the researchers had suggestions that they had to use city centers where victims had been living in pre-disaster housing units. They had similar problems in relocation and some of their suggestions can be pointed out as follows (Miyamoto, 1995);

- Communities should be revived in the heart of the city. To this end, the centre of the metropolis should be devoted to residential and not business use to lure residents back,

- Green open space must be created. In order to revive the inner city, residents and local corporations need to work together to create mid-rise housing and business space that harmonize with open space with green belts and water,

- Through improved land measures, residents should be given the opportunity to rebuild their homes at their previous place of residence or in the surrounding area. To this end, a policy should be enacted to release idle land held by private corporations, as well as publicly owned lands, and the government should rent private housing to residents without homes.

An important point which was generally forgotten by the authorities for both cases in Turkey was the situation of disabled victims, and the elderly people. None of the design and environment was suitable for those people. The importance of universal design, design for all people had never been taken into consideration. The adaptation process of these people could probably be harder than the other ones.

4. CONCLUSIONS

The improvement and welfare of human built environment should be the goals of sustainable development. In relation to this, new settlements are the steps to achieve this ideal. Post-disaster housing should be seen also in this process not only as a part of urgent need but also a part of healthy and sustainable architecture which will improve human life quality in natural and built environment.

Most importantly, policies for reconstruction must create conditions which enable residents to return to their previous location of residence, rebuild their lives, and cooperate in the restoration and reconstruction effort by being the main force behind it. Administrative and financial systems for the future should be created that enable residents and local corporations to independently advance the reconstruction policy (Miyamoto, 1995).

For both cases, Ikitelli and Senirkent, the authorities did never think on the rehabilitation of the areas which were affected from the disasters. The approaches and studies of the authorities were depending on relocation or resettlement of the victims. On the other hand, the methodology and projects of the rehabilitation and restoration, even reconstruction of the buildings in the disaster areas could have been given as a chance or alternative way for the victims in housing recovery process. When the damaged city or town areas could not be used and rehabilitated efficiently post disasters, those areas would become to be useless and unwanted areas of the cities. The value of the land is very high today, and it seems better to rehabilitate and open to people usage of city centers instead of relocation and resettlement of people far away from the city centers. Also it is expensive to open a new settlement area than to rehabilitate the former one because it is urgently needed infrastructure and institutions in the new area, and this way was very high costs especially for developing countries such as Turkey. If there are not enough areas suitable for settlements in the city centers, of course it is certain to use new areas, but if there is a chance to use the disaster areas it is better to choose that way.

It is seen clearly from the experiences that in the design-construction-occupancy periods of post-disaster housing process, both the pre-disaster and post-disaster characteristics of victims and environment should be taken into consideration in order to develop healthy, sustainable and disaster-resistant communities and environments. Finally, in every step of post-disaster housing process, user participation should be taken into consideration as well.

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MANAGING CORPORATE SOCIAL RESPONSIBILITY KNOWLEDGE FOR IMPROVED COMPETITIVENESS: A CONCEPTUAL FRAMEWORK

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Abstract: The pace of change experienced by modern businesses is phenomenal. The responsibilities of businesses and their impact on communities in which they operate and seek to serve are more important now than ever before. Global competition, the knowledge economy, and the potential offered by emerging technologies along with environmental pressures and growing societal commitment to the principle of sustainable development pose profound strategic challenges for business. Businesses today have to abandon many of the principles that have guided generations of managers, and develop a new set of objectives and rules that will enable them to successfully manage change and guide them to transform into 21st century organisations. As organisations try to meet these change challenges, they need to be innovative and to produce knowledge-intensive services desired by the market so as maintain competitive advantage. Many organisations are convinced that they benefit from encouraging responsible business practices. Corporate social responsibility concerns the management of an organisation's total impact upon its immediate stakeholders and upon the society within which it operates. This paper is based, primarily, on a review of literature as part of an on-going PhD research study of 'the contribution of knowledge and change management to competitiveness in sustainable urban environments'. It reviews the key drivers, challenges and benefits associated with managing corporate social responsibility knowledge. It also presents a conceptual framework for managing corporate social responsibility knowledge. The paper concludes that managing corporate social sustainability knowledge is an integrated and complex process. This has culture, people, technology, communication, leadership and organisational structures at its core. It is suggested that qualitative research is necessary to uncover many of the complex and intricate issues associated with managing corporate social responsibility knowledge.

Keywords: Corporate Social Responsibility, Knowledge Management, Stakeholders, Sustainability, Urban Environment.

1. INTRODUCTION

As we enter the 21st century, the concept of corporate social responsibility (CSR) has captured the attention not only of corporate leaders but also society. The corporate scandals associated with Enron and WorldCom in the USA. Also with Parmalat and Vivendi in Europe, together with the collapse of Arthur Andersen, the respected accounting, auditing and consulting global giants have significantly reduced worldwide public trust in the corporate community. The World Economic Forum's 2004 survey on trust revealed that only 7% of respondents consider that global companies operate in the best interest of society. Organisations are seen as profit-generating and wealth-enhancing for the select few stakeholders only. The force of public outcry against unethical behaviour has turned the spotlight on the importance of CSR, so ensuring that organisations focus on social and environmental issues as well as economic returns (Weymes, 2004). Corporate social responsibility is another dimension of sustainable development (SD) and sometimes referred to as the third bottom line (Elkington, 1997). Likewise, CSR is the latest strand of the fabric of sustainability which comes after economic and environmental responsibility (Hart, 1997).

A growing group of companies is acknowledging this trend towards CSR (Hoffman, 2000). However, they are faced with the problem of how to incorporate concept into practice. Corporate social responsibility concerns the management of an organisation’s total impact upon its immediate stakeholders and upon the society within which it operates. Corporate social responsibility is the continuing commitment by business to behave ethically and contribute to economic development while improving the quality of life of the workforce and their families as well as of the local community and society at large (WBCSD, 2002). For the purpose of this paper, CSR is defines as “a sustainable approach to business that seeks benefits for the company and its stakeholders”.

Many management scholars and consultants have argued that CSR offer terrific opportunities for progressive organisations and innovation is one of the primary means by which companies can achieve sustainable growth (Porter and Vander Linde, 1995; Hart, 1997). But the reality is that managers have had considerable difficulty dealing with CSR pressures. In particular, their innovation strategies are often inadequate to accommodate the highly complex and uncertain nature of CSR demands. Corporate social responsibility innovation is therefore usually more complex (because there is typically a wider range of stakeholders) and more ambiguous (as many of the parties have contradictory demands). As organisations try to meet these challenges, knowledge is increasingly being seen as important for innovation and for producing knowledge intensive services desired by stakeholders and society so as to maintain competitive advantage. The management of knowledge is therefore increasingly considered an important source of sustainable competitive advantage (Hamel and Prahalad, 1994; Nonaka and Takeuchi, 1995).

Companies that actively manage knowledge and respond to a wide range of sustainability indicators (economic, social, and environmental) are better able to create value for all these stakeholders over the long term (Funk, 2003). The key challenges for organisations to manage CSR knowledge is how to identify, map, assimilate, disseminate, and apply critical knowledge to practical solutions. In particular, capturing, sharing and mapping of knowledge between different actors (supply chain, shareholders, community, employees, etc.) with a different perspective (economic, environmental, legal, social, etc.) and purpose (profit maximisation, corporate philanthropy, ethics, waste minimisation, minimum price, etc.) is a key challenge.

Knowledge Management (KM) is the process of creating value from an organisation’s intangible assets. It deals with how best to leverage knowledge internally in the organisation and externally to the customers, suppliers, society and shareholders. For the purpose of this paper, KM is defined as a systematic and integrative process of coordinating the organisation wide activities of: creating, mapping, storing, and sharing knowledge by individuals and groups in pursuit of the major organisational social responsibility goals. It is the process through which organisations create and use their institutional and collective knowledge. Competitive advantage can be gained through corporate environmental and social responsibility along with economic responsibility (David, 1993).

As discussed by Porter (1998), competitiveness derives from innovation leading either to enhanced operational effectiveness or to superior strategic positioning. For the purpose of this research, the term “competitiveness” is defined as the potential for environmental and social responsiveness to improve long-term profitability of an organisation through managing sustainability change and related key knowledge. For example, by managing social sustainability change and related key knowledge, social sustainability responses that improve competitiveness include improved workplace, marketplace, supplier and community relation. In the study reported here, four standard industry classification sectors are identified based on the environmental, social and economic account of the urban environment. The sectors considered for this study are utility, transportation, construction, and not for profit (NPOs) sector.

The review of literature also suggests that there is few, if any, empirical studies on managing knowledge which have been carried out specifically within a CSR context. Therefore, there is a need to explore the complexities and challenges associated with managing CSR knowledge. One of the focuses of this on-going PhD study is to investigate and document the main challenges associated with implementing knowledge management initiatives in small, medium and large organisations from a sustainable urban environment perspective.

2. RESEARCH OBJECTIVES

This paper draws from an on-going doctoral study entitled ‘the contribution of knowledge and change management to competitiveness in sustainable urban environments’. The aim of this study is to explore the extent to which knowledge and change management, six sigma and the capability maturity model contributes to competitiveness in sustainable urban environments. The objectives of the study are:

- To identify the underlying philosophies of knowledge and change management and their interplay from both general and sustainable urban environment perspectives.
- To investigate and document the main challenges associated with implementing knowledge and change management initiatives in SME's and large organisations from a sustainable urban environment perspective.
- To examine the capability maturity model and six sigma issues for knowledge management implementation in a sustainable urban environment context.
- To examine and document the ways in which knowledge and change management influence the overall performance of organisations from a sustainable urban environment perspective.
- To analyse the strengths and weaknesses of knowledge and change management applications in developing an appropriate framework for knowledge mapping within and across organisation(s).
- Develop a framework for knowledge management, change management, six sigma and capability maturity model implementation within sustainable urban environments.
- Use appropriate case studies to demonstrate and test the applicability of the developed framework.
- Develop appropriate training and educational programmes on knowledge mapping for a sustainable urban environment for use in appropriate Continuing Professional

Development (CPD) programmes and for appropriate modules to benefit undergraduate and postgraduate curricular.

This study is still in its early stages. In this paper, much of what is presented is based on a thorough review of literature.

3. RESEARCH METHODOLOGY

In achieving the aim and objectives of this research, a robust methodology is being developed. Broadly, the research process is identified into three key phases within its flexible boundaries. The three phases are, namely, the literature review, the pilot study and the main study. The development of the research work started with the literature review. A thorough review of extensive literature is ongoing in the areas of knowledge management, change management, sustainable urban environments, six sigma and the capability maturity model. Good sources have been identified in journals, books, internet databases, periodicals, government reports, workshops, seminars and conference proceedings. The review of literature consists of the background study, issues, challenges, critical success factors, benefits and gaps in the respective areas and will result in a theoretical framework. The literature review is an ongoing process, which will be carried out simultaneously along with a pilot study and a main study to capture new issues and gaps in the literature. Prior to the main field study, a pilot study will be undertaken. The pilot study gives the researcher an opportunity to identify challenges and to modify the research method before embarking on the main study. The pilot study would also help with the refinement of data collection plans, with respect to both the contents of the data and the procedure to be followed (Yin, 1994). Data for the pilot study will be collected through interviews and questionnaires. Collected data will be analysed. The results derived from the data analyses will enable the modification of developed theoretical framework, based on the literature review in phase one. The main study is planned to involve both qualitative and quantitative research approach. The collected data will be analysed using the Statistical Package for the Social Sciences (SPSS) and the Non-numerical Unstructured Data Indexing Searching and Theorising (NUD*IST) software. The results derived from the data analyses will enable the development of CSR knowledge management model. The outcomes of the research will be CSR knowledge management model, an Information Technology based awareness-training tool, and guidance document on process improvements through knowledge management initiatives.

4. KEY DRIVERS FOR MANAGING CSR KNOWLEDGE:

Managing CSR is increasingly considered an integral part of core business values and strategy, rather than an isolated function within organisations dealing with risks of non-compliance or damage to reputation from negative publicity or scandals. The major driving forces behind the managing CSR and its relevant knowledge include globalisation, sustainable development and knowledge economy.

Globalisation: The effect of globalisation has been in creating a mindset of the world as a single market. This has created substantial uncertainty in the competitive landscape by bringing about fundamental changes in the traditional boundaries of nations, industries and companies. Such changes continue to challenge the traditional rules of competition (Hitt et al., 1998). Throughout the late 1980s and 1990s, the new, knowledge-based economy generated millions of new jobs and a rash of innovative products and services for consumers. The offset of this has been to expose a wide range of labour, human rights and environment abuses, creating disjunction between meeting people's needs, protecting natural resources and enhancing corporate profits, and a perfect trigger for anti-globalisation demonstrations. Therefore, the business world has realised that it must be able to demonstrate the corporate contribution to economic, social and environmental progress.

Sustainable Development: As economies develop and environmental pressures mount, people attach higher priority to the preservation and improvement of the natural and built environment. The Government also has a key role in ensuring that the future pattern of development is sustainable. Sustainable development has become more pressing as the realisation has spread that current patterns of human behaviour are unsustainable. This was demonstrated at the UN World Summit on SD (WSSD, 2002) in Johannesburg, when leaders from around the globe reaffirmed their commitment to SD to address the pressing problems of society and environmental degradation. All these factors imply increasing pressure on firms to reduce their dependence on the physical components of production, limit pollution and give a greater role to innovation, creativity and technical sophistication.

Knowledge Economy: Knowledge has been recognised as one of the main assets of organisations (Drucker, 1999). The knowledge driven economy is a more general phenomenon, encompassing the exploitation and use of knowledge in all production and service activities. Investors increasingly recognise the growing importance of knowledge assets in the way they value firms (DTI, 1998). The market place is increasingly competitive and the rate of innovation is rising, therefore knowledge must evolve and be assimilated at an ever-faster rate.

Other drivers for managing CSR knowledge range from corporate awareness of its intrinsic importance for future business success, to external pressures in forms ranging from stakeholder activism, client demands, investors demand, socially responsible investment and externally developed codes of conduct, to self-governance standards or codes developed by business organisations.

5. THE POTENTIAL BENEFITS OF MANAGING CSR KNOWLEDGE

World Business Council for SD supports the view that a coherent CSR strategy based on sound ethics and core values offers clear business benefits. These accrue from the adoption of a broader worldview, which enables business to monitor shifts in social expectations and helps control risks and identify market opportunities. Such strategy also helps to align corporate and societal values, thus improving reputation and maintaining public support (WBCSD, 2002). Similarly, Marsden (2000) pointed that socially-responsible companies are much more likely to attract good recruits, grow and retain loyalty, be preferred suppliers, and be given the benefit of the doubt when things go wrong. Table 1 highlights some of the potential benefits of managing CSR knowledge for different stakeholders.

Table 4: Potential benefits of managing corporate social responsibility knowledge

Stakeholders	**Potential Benefits**
Corporate	• Socially responsible companies continually position themselves to perceive of, and adapt to, competitive pressures and changing context. Improved information and knowledge on own business activities and on stakeholder interests. Provides credible framework to benchmark own and competitor's performance. • Socially responsible re-design and reengineering of products can significantly cut operational costs, including material and energy use. • The enhanced brand equity and reputation that comes with more socially responsible business practice attracts customers and talented employees while increasing shareholder value.
Customers	• Improved information and knowledge about suppliers and products. • Facilitates purchasing decisions.
Suppliers	• Increased information and knowledge on industry standards, with potentials for enhancing product quality and brand protection. • Enhance trust in supply chain.
Employees	• Increased information and knowledge about employer policies, practices and performance. • Provides framework for employees to contribute to improve social sustainability performance. • Enhance trust in management. • Improved relations with trade unions
Investors	• Increased information and knowledge to assess intangible aspects of performance and value, allowing comparability and benchmarking. • Enhance trust in management and governance.
Community	• Increased information and knowledge enables improved monitoring and comparison of performance, and framework to provide feedback. • Charitable contributions. • Employee volunteer programmes. • Corporate involvement in community education, employment and homelessness programmes.
Government	• Increased information and knowledge enables cost-effective monitoring of own and corporate performance, and improves basis to make sound policy decisions. • Enhance trust in capital market.
Environment	• Greater material recycability. • Better product durability and functionality. • Greater use of renewable resources. • Integration of environmental management tools into business plans, including life-cycle assessment and costing, environmental management standards, and eco-labelling.

6. FRAMEWORK FOR MANAGING CSR KNOWLEDGE:

Too often, CSR is regarded as the panacea which will solve the global poverty gap, social exclusion and environmental degradation. It is useful to point out several dimensions in the CSR agenda. The European Commission in its Green Paper (2001) emphasises on CSR dimensions: business has to learn how to operate within interfering coordination mechanisms, with blurred boundaries and surrounding layers of varying degrees of responsibility, overlapping one other. Nowadays, governments increasingly leave societal issues within the authority of corporations. The internal dimension: within the company socially responsible practices primarily involve employees and relate to issues such as investing in human capital, health and safety, and managing change, while environmentally responsible practices relate mainly to the management of natural resources used in the production; The external dimension: CSR extends beyond the doors of the company into the local community and involves a wide range of stakeholders in addition to employees and shareholders such as business partners and suppliers, customers, public authorities and NGOs representing local communities, as well as the environment. For this research, based on a thorough review of literature and discussion with practitioners a conceptual framework is developed for a profit making organisation. Broadly, five CSR dimensions are identified namely, workplace, community, marketplace, suppliers, and built and natural environment.

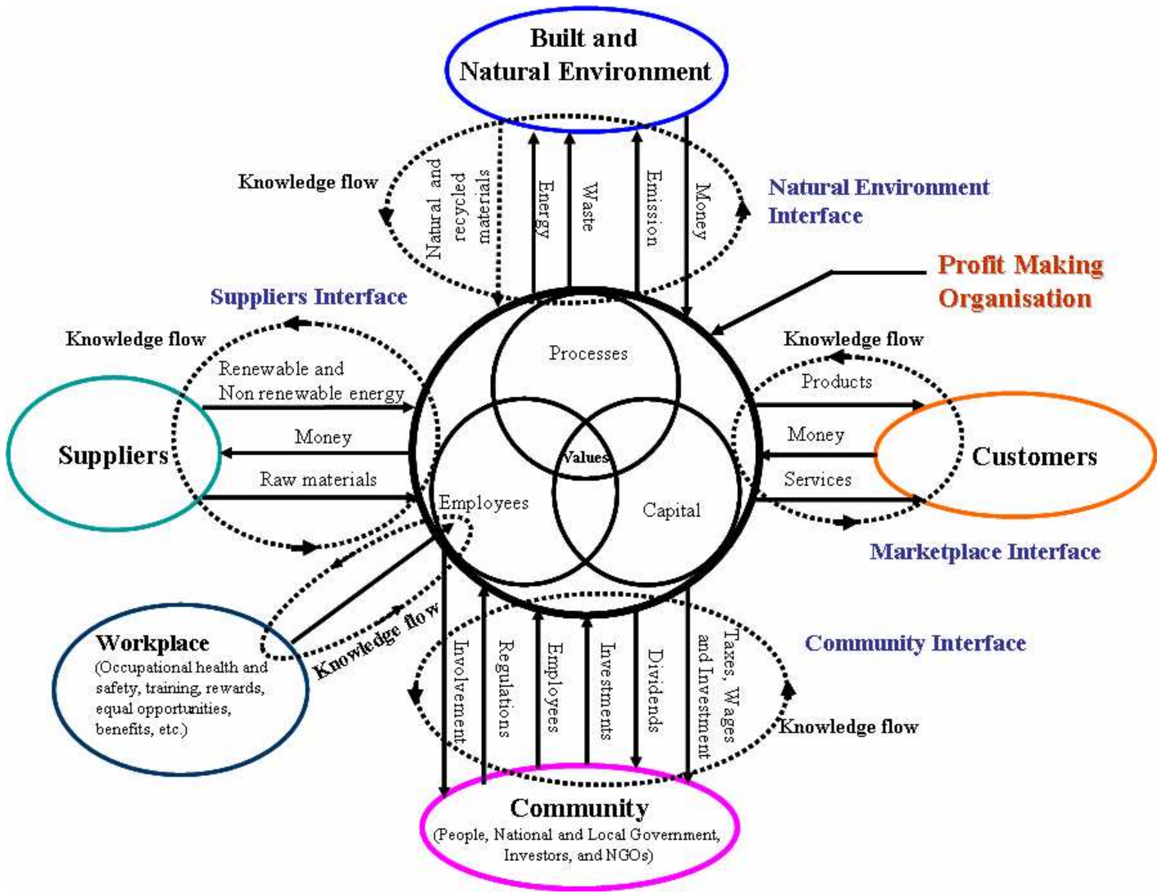

Figure 1: A Conceptual Framework for Managing Corporate Social Responsibility Knowledge

As shown in Figure 1, the circle at the center of the diagram represents a profit making organisation. Inside that circle are its employees, capital, and processes. At the core is the organisation's vision, mission and values. Organisations typically interact with employees, suppliers, customers, built and natural environment, and community. Employees come from the communities in which organisations are located. Their wages return to the community's economy. Organisation's capital comes from a sector of the community and money flows in the other direction in the form of dividends, interest, and capital appreciation to shareholders. Government is part of community too. Organisations are connected to it through laws, regulations and money flows in the other direction through taxes. Every organisation is part of a supply chain with suppliers and customers. Products or services flow through that supply chain in one direction; money flows in the other direction. The supply chain is connected to Earth's lithosphere for organic and inorganic materials. A very small amount of raw material is natural, coming from the biosphere. Organisation processes are connected to Earth's biosphere by the waste-streams and emissions that produced by organisation. The products that make at the end of their useful lives go to landfill creating further pollution load for Earth's biosphere.

In Figure 1, the dotted ellipse represents the knowledge flow between organisation and the identified five CSR dimensions. Supply chains are normally complex and characterised by interrelationships between different organisations. Organisations are affected by the actions of their direct and indirect suppliers and vice versa. The problem associated with transparency in supply chain relationships-the two way exchange of information and knowledge between suppliers, customers and organisation itself-represent chronic difficulty for managers.

Current competitive challenges induced by globalisation and advances in information technology have forced companies to focus on managing marketplace in particularly customer relationships, and customer satisfaction, in order to efficiently maximise revenues. According to Romano (2000) organisations should explore and refine customer relation knowledge management methods in order to get value-added knowledge for themselves and their customers and understanding not only customer purchasing patterns and trends but attitudes and preferences as well. Customer-related knowledge, level of customer service and customer satisfaction are especially regarded significant in retaining the competitive advantage of the firm (Porter, 1985).

Companies are increasingly expected to address environmental impacts of their facilities as well as the throughout the entire product lifecycle, from sourcing, production and transportation to marketing, use and disposal. Many writers suggest that current business practice will prove inadequate in addressing these problems (Hart, 1995; Porter and Van Der Linde, 1995). Thus, not only must the business community face the challenges of this green imperative but they must also capture the resources and develop the skills and capabilities to remain competitive in this new, dynamic, green environment.

The last decade has produced major changes in workplace practices and management. Global markets and competition, advances in technology and the fast pace of business change require employers to foster innovative, diverse and flexible workforces that understand company values and contribute to a common corporate culture and goals. Still, many employees expect less job security than before, but demand more training and responsibilities that serve long-term job skills. Investor and consumer groups now increasingly holding companies accountable for creating a fair and productive workplace. Media coverage has simultaneously given greater visibility to so-called "best places to work," out-sourcing and how companies address key issues such as equal opportunity, diversity, domestic partner benefits and employee safety. Still, in this changed work climate, evidence shows that companies with strong workplace practices enjoy faster growth, higher stock values and greater productivity.

An alternative perspective to the economic perspective is to view an industry as a social system in which not only firms but also other actors, such as community, government, non government organisations, universities and other religion institutions, interact (Stefanou *et al*., 2003). Stakeholders are increasingly calling upon companies–as powerful societal players – to help develop communities and create economic opportunity. Pressure is growing for companies to engage with communities not only in headquarter locations, but also where companies source and distribute their products, both domestically and around the world, to share wealth and skills and improve the quality of life for the residents. Traditionally, environmental compliance and social welfare expenditures were viewed as costs that correlate negatively with returns. However, recent studies suggest that there are several opportunities for competitive advantage and increased profits by engaging in strategic sustainability initiatives (Reinhardt, 1999). This reasoning reflects a shift from viewing business expenditures in a static world to viewing them in a dynamic one based on innovation. The following section elaborates on the challenges identified from literature that influence managing CSR knowledge within organisations.

7. CHALLENGES OF MANAGING CSR KNOWLEDGE

According to Nonaka and Takeuchi (1995), information is the "flow of message", and knowledge is created when this flow of messages interacts with the beliefs and commitments of its holders. Also they argued that organisations cannot create knowledge without individuals, and unless individual knowledge is shared with other individuals and groups, the knowledge is likely to have limited impact on organisational effectiveness. Few challenges are highlighted for managing CSR knowledge in the following section.

Stakeholders and Trust: The capability to build interpersonal trust is essential if stakeholders with diverse interests and perspectives are to commit to a common cause that involves the exchange and development of information and knowledge across teams or networks. The way trust is built is unique for each organisation. It includes: the capacity to act with discretion, consistency between words and deeds, frequent and rich communication, fair and transparent decisions, establishment of shared visions and language or the recognition of the contribution of different professional 'languages'. Roome (2001) suggests that trust 'is informed by the perception of outcomes'. This in turn is supported by people assuming accountability for trust, their personal connections, the contribution of things of value, and the disclosure of expertise and limitations (Abrams, 2003). Building trust in teams involving highly diverse stakeholders is problematic because of opposed interests and points of view. There is a greater potential for disputes and power struggles, and of unmanageable agendas dominated by clashing ideologies (Selman, 1999).

Innovation: It has been argued that the concrete goals and instruments of the concept of SD should be formed in discussion among all parties involved (Sharma, 2003), as this contributes to a process of balanced integration. Thus, collaboration in networks and alliances of firms, suppliers, customers, citizens, governments and NGO's contribute to the practical realisation of CSR. A firm's capacity to collaborate and innovate for CSR while maintaining their competitiveness is regarded as a specific organisational competence. Moreover, the innovative capabilities of a company may be enlarged through co-production of knowledge with partners at all levels in the organisation. It has been suggested that this might be through domestic and international inter-firm collaboration (Cooke and Wills, 1999), and technology alliances that help a company to develop new competencies faster than through internal development (Doz and Hamel, 1997).

Knowledge Sharing Challenges: As businesses' operations become more globalised, the task of capturing information and knowledge to support decision-making is becoming more difficult. An increased focus on corporate governance is another factor, driving firms to seek better information and knowledge on the risks they face, and on how different parts of the business are performing (Ernest-Jones, 2005). The challenge of deploying the knowledge assets of an enterprise in creating competitive advantage and ensuring a sustained business edge is important. CSR requires that an organisation acquire and make use of more knowledge about the surrounding environment, and its stakeholders demands. For example, a middle manager's institutive sense of market trends becomes the catalyst for important advancements in product stewardship. Similarly, a shop floor worker draws on years of experience to create a new process innovation that improves quality and reduces waste. In each case, an individual's personal knowledge is transformed into organisational knowledge to the company as a whole (Nonaka, 1994). Therefore, organisation ability to effectively leverage its knowledge is highly dependent on its people, who actually create, share, and use the knowledge. Leveraging knowledge is only possible when people can share the knowledge they have and build on the knowledge of others. However, in practice, the lack of knowledge sharing has proved to be a major barrier to the effective management of knowledge in organisations (Davenport and Prusak, 1998).

Supply Chain Challenges: The challenge of capturing, organising, and disseminating CSR knowledge throughout the aggregate supply chain is a huge undertaking. Complexity increases by several magnitudes when one considers a multi-tiered supplier chain in which numerous dynamic interactions happen between several suppliers and manufactures, distributors, and clients. The flow of knowledge between these interfaces is critical to the success of the supplier chain (Desouza *et al.*, 2003). The amount of knowledge transferred from a person within an organisation to the partners will be influenced by the level of trust between the two organisations (Davenport and Prusak, 1998). For the supply chain to be optimised all elements of the supply chain must be connected to enable the flow of knowledge. Connectivity is the first attributes to allow the flow of knowledge throughout the supply chain. The second attribute is the communication of this CSR knowledge in a fashion that allows all the users in the supply chain to make business decisions that maximise client value while reducing social and environmental impact. The third attribute of supply chain KM systems is the ability to collaborate in a real-time fashion, encouraging knowledge sharing and allowing the supply chain to adjust to market changes in a more ethical way. There are many problems with finding key knowledge assets in the supply chain and being able to exploit the knowledge in an efficient and cost-effective manner.

8. CONCLUSIONS

It is clear that managing CSR knowledge is a complex process. Knowledge in organisations is dynamic in nature and is dependent on social relationships between individuals for its creation, sharing, and use. Managers would continue to strive for productivity, innovation, profitability, and other competitive goals-but, they would do so more effectively by harnessing the knowledge of their stakeholders. Conversely, stakeholders would continue to strive for social benefits-but they would achieve more by sharing knowledge and forming pragmatic relationships with management. This paper has highlighted some of the complexities and challenges associated with managing CSR knowledge for improved organisational competitiveness. A background to CSR, KM, and competitiveness has been documented. The proposed research aim and objectives, research methodology have been discussed. In addition to this, a conceptual framework for managing CSR knowledge have been developed and discussed.

Today's challenge for the practitioners lies in attaining levels of comfort with respect to social, economic, and environmental values, while protecting the heritage of future generations. The review of literature reveals that achieving sustainability means change for the industry, and that such a process of change depends on the ability of stakeholders and individual organisations to manage and work with new knowledge (Doppelt, 2003). Therefore, there is a need to institutionalise the new combination of management strategies, such as knowledge and change management in order to understand and improve the competitiveness of their business. The paper concludes that managing CSR knowledge is an integrated and complex process. This has culture, people, technology, communication, leadership and organisational structures at its core. It is suggested that qualitative research is necessary to uncover many of the complex and intricate issues associated with managing CSR knowledge.

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TOWARDS GREEN AND INTELLIGENT BUILDINGS: THE ECONOMIC AND ENVIRONMENTAL IMPACT - A UK PERSPECTIVE

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Abstract: The global construction industry is flourishing with construction spending forecast to grow substantially by 70% up to 2013. China and UK are among those of major contributors to the prosperity. However, the construction industry has long been claimed as a resource-consumer and construction related activities are one of the major causes to environment pollution. Previous research findings indicated that the implementation of green and intelligent buildings could play a fundamental role in energy saving and reduction of natural resource consumption and ultimately improve building performance. While there exists a broad spectrum of information on the implementation of the concept, the real benefits and the appropriate approaches have not been clearly identified and the implementation itself is still evolving. This research presents a quantitative analysis on the economic and environmental impact of green and intelligent buildings and the literature is examined aiming to improve the understanding of the concept and identify major approaches adopted in practice. It is revealed that green design, whole life cycle costing techniques and strategic regulations are major approaches adopted in practice leading towards a green and sustainable construction industry.

Keywords: building performance, China, global construction, strategy, sustainability.

1. INTRODUCTION

Construction activities nowadays play a crucial role in macro-economic development. The world construction spending is forecast to grow substantially from US$3.5 trillion in 2003 to US$6.2 trillion in 2013, a leap of more than 70% (IC, 2005). China and the UK, the world's third and seventh largest construction market respectively, are expected to grow significantly within the next ten years and make major contributions to the world's economic growth.

However, the construction sector has long been claimed as a resource-consuming sector and a significant contributor to environment pollution. Construction and property are the major consumers of resources including energy, raw materials and land.

In the UK almost 60% of total carbon dioxide (CO2) emissions are related to the construction and occupation of buildings and 60% of timber used are for the construction industry (DTI, 2002). Construction and occupation of properties in the UK also consumes more than 50% of all energy and produces 70 million tonnes of construction waste per annum, 17% of UK total. These hard facts have prompted impetus to radical changes that need to be implemented to achieve a fully innovative and sustainable construction industry.

Previous research findings indicated that the implementation of green and intelligent buildings could play a fundamental role in energy saving and reduction of natural resource consumption and ultimately improve building performance (Bruntland, 1987). The concept of green and intelligent buildings and its implementation have increasingly been accepted as a guideline of improvement and innovation for future development in the global construction sector (Bruntland, 1987; MOC, 2005).

Investors are now becoming more selective in organisations to which they provide financial support and clients are increasingly looking for value-added construction solutions to reinforce their commitment in sustainability. Forward-looking players who recognise the huge potential of sustainability in the construction industry will see the benefits in the coming years.

Moreover, government regulations and legislation also add power to the drive to sustainability. A number of initiatives have been established in the UK such as INTEGER- Intelligent & Green in buildings, Environment Profiles and Sustainable Community etc. to achieve wide-ranging improvements aiming at a sustainable construction industry (BRE, 2004; Integer, 2005; ODPM, 2005).

However, the long-term benefits of the implementation of green and intelligent buildings and the appropriate approaches have not been clearly identified and the implementation itself is still evolving.

This research aims to investigate the economic and environmental impact of green and intelligent buildings through quantitative analysis methodology and identify major approaches adopted in practice. The literature is examined focusing on to improve the understanding of the concept and its strategic impact on the construction industry.

2. DEFINITIONS

The term of green and intelligent buildings, also labelled as eco-buildings, or to a wider extent, sustainable construction, has various versions of its definition. It generally defines buildings that are designed and constructed with green solutions and advanced technology including intelligent building services such as integrated fire protection system and communications etc. aiming at energy-saving and less natural resources consumption (DETR, 1998b; Integer, 2005). The implementation involves meeting the needs of present generations without compromising the needs of future generations to meet their own needs and provide a comfortable, energy-saving and human-friendly environment for occupiers (Bruntland, 1987; MOC, 2005).

A number of factors from outside the construction sector may act as the driving force behind the continuing prominence of sustainable construction. Increasing public awareness of, and commitment to, the issues encapsulated by sustainability has led companies to realise that it may in fact be advantageous to actively pursue these principles. In practical terms, issues of sustainable construction can be categorised as economic sustainability, environmental sustainability and social sustainability.

The concept of green and intelligent buildings promotes the use of green and intelligent innovation in buildings to achieve wide-ranging improvements in performance and value through developed innovation themes such as green design, construction technology, intelligent building services, environmental technology, financial control techniques e.g. whole life costing and strategic regulations etc. to achieve a sustainable construction industry.

3. GREEN DESIGN

The combination of economic and environmental assessment tools to obtain 'best value' solutions in both financial and environmental terms has the potential to make a significant contribution to achieving sustainable building design (Edwards *et al*., 2000).

Green design is concerned with the full range of economic and environmental issues related with sustainable buildings. Most sustainability drivers relate to various design approaches. The principles of a green building design can be implemented wherever possible through the following aspects which almost all have economic and environmental impact on sustainability:

- Low energy consumption. Key design elements include natural ventilation by adopting narrow floor plates, a high wall-to-floor ratio, a high proportion of opening vents and avoidance of subdivision of internal space etc., minimising effect of solar heat gain and glare through insulation or external shading and maximising day lighting by adopting high ceiling, perimeter light shelves and control of solar glare etc.
- Low-embodied energy. Embodied energy is concerned with the manufacture, transport and assembly of a building. Key design elements include selecting material with relatively low-embodied energy and controlling the use of sensitive materials such as aluminium, cement and plastics etc., use of local labour and materials, reuse of materials and on-site disposal and management of recycling including the design of components for future reuse and the building for adaptation.
- Prefabrication and construction waste control. Key design elements include use of prefabricated or modular components to minimise variations, errors and waste and management of recycling of construction waste.
- Low water consumption. Key design elements include specification of low consumption fittings, e.g. spray taps, low –flush appliance and automatic controls and rainwater harvesting e.g. providing water for WCs.
- Renewable energy sources. Key design elements include solar collectors for water heating, use of ground water as a source of heating or cooling and power supply from wind energy etc.

The implementation of green design principles would let the building meet its environmental targets as well as keeping its occupants satisfactory. In addition, maximum use of products made of recycled and waste materials may facilitate buildings to attain better performance in terms of energy consumption and aesthetic issues.

4. WHOLE LIFE COSTING

The integration of whole life costing (WLC) technique and life cycle assessment process presents a powerful route to improving the sustainability of the construction industry. The WLC technique is identified as a tool to assist in assessing the cost performance of construction work throughout its life cycle, from inception to completion and disposal. The whole life costs of a project usually consist of capital costs, operational costs, maintenance costs and disposal costs.

Visible construction costs i.e. capital costs account only for a small proportion of the life cycle costs and post-construction costs such as operational, maintenance and disposal costs form largely the "underwater" part of the whole life costs "ice-burg" and invisible at project development stages. In general, about 75-95% of a building's operational and maintenance costs have been determined once the design is completed (Khanduri *et al*., 1993, 1996; Mackay, 1999). Figure1 illustrates the whole life costs ice-burg.

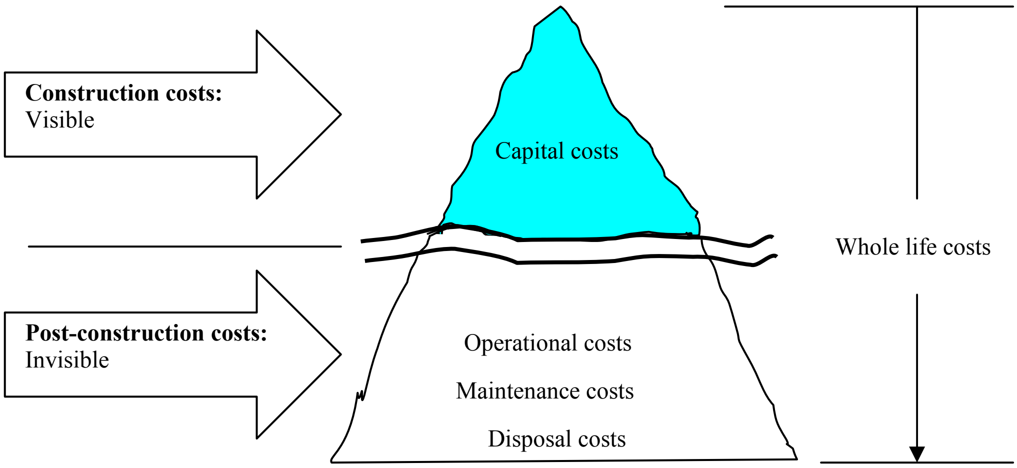


Figure1: The whole life costs ice-burg

The following sections analyse the capital and WLC costs of the case projects and demonstrate the economic impact of green buildings compared to typical non-green design buildings.

4.1 Case Project A: an office building

The cost analysis compares the capital costs of two office buildings, one with a green design solution and the other with a typical business park office building design, and illustrates the economic impact of green design. It is revealed that a green and sustainable design approach can be adopted with an additional 10% of capital costs as demonstrated in Table 1 below:

4.2 Case project B: a residential building

Based on the assumption of installation of a typical three-bed semi-detach house with a gross floor area of 125 m2, Table 2 demonstrates a comparison of capital costs and operational costs savings across various categories of green solutions based on sustainable design principles.

Table 1: Capital costs: green building Vs typical building

Element	Typical design building			Green design building		
	Cost £	£/m2 GFA	% of total	Cost £	£/m2 GFA	% of total
Substructure	316,400	44.56	3.55%	745,400	104.99	7.56%
Superstructure	3,659,100	515.00	41.10%	4,322,100	609.00	43.85%
Internal finishes	852,000	120.00	9.57%	708,600	100.00	7.19%
Fitting and furnishings	147,500	20.77	1.66%	147,500	20.77	1.50%
Building services:						
-sanitary appliance	41,800	5.89	0.47%	59,500	8.38	0.60%
-disposal installations	40,800	5.75	0.46%	174,400	24.56	1.77%
-water installations	67,700	9.54	0.76%	**	0.00	0.00%
-space heating & air treatment	810,400	114.14	9.10%	414,800	58.42	4.21%
-electrical installations	512,100	72.13	5.75%	646,000	90.99	6.55%
-gas installations	17,900	2.52	0.20%	17,900	2.52	0.18%
-lift installations	146,000	20.56	1.64%	40,000	5.63	0.41%
-protective installations	12,600	1.77	0.14%	**	0.00	0.00%
-communication installations	107,800	15.18	1.21%	107,800	15.18	1.09%
-special installations	126,700	17.85	1.42%	184,200	25.94	1.87%
-builder's work	68,000	9.58	0.76%	68,000	9.58	0.69%
External works and services	672,200	94.68	7.55%	744,600	104.87	7.55%
Preliminaries/contingency/OHP	1,305,000	183.80	14.66%	1,475,000	207.75	14.97%
Total	8,904,000	1,254.08	100%	9,855,800	1,388.14	100%

*** - Services elements integrated into other elements or not needed under green design.* (DLE and MGW, 2003)

Table 2: Capital costs and operational costs savings

Green Solutions	**Capital Costs (£)**	Savings of Operational Costs
Solar powered hot water supply	2,134	70%
Intelligent lighting system	1,120	35 - 45%
Intelligent heating system	978	10 - 20%
Grey water recycling	1,324	14%
Efficient taps	50 - 100	3%
Efficient shower heads	50 - 75	4%
Dual low flush WCs	200 - 300	9%

(F+A, 2003)

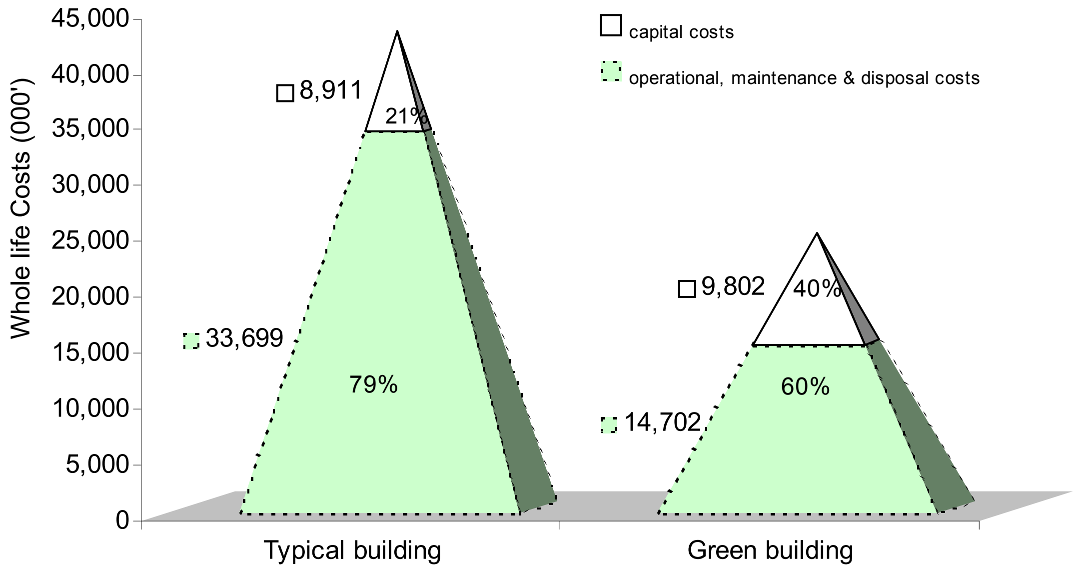
4.3 Whole life costs comparison

There are existing barriers to the adoption of whole life costing techniques and sustainable materials and systems (Kishk *et al*, 2003). The difficulty in obtaining reliable cost data from different sources including historical data of operational, maintenance and disposal costs hinder users from producing sound whole life cost estimations. The perception of increased capital costs with potential benefits being either minimal or none in financial terms may prevent players from committing themselves into adoption of sustainable solutions. However, there are more long-term benefits that can be attained if the whole life costs, i.e. the operational costs, maintenance costs and disposal costs etc. are taken into account.

Figure 2 below illustrates the comparison of indicative whole life costs between a green office building and a typical business park office building over a life span of 50 years.

The two buildings are aimed to fulfil similar functioning requirement and are directly comparable. The estimate for the typical office building is based on the assumption of construction costs at £1,255 per m2 with a gross floor area of 7,100 m2. The green building of the same gross floor area however adopted green design solutions, with a capital cost of £1,380 per m2 (DLE and MGW, 2003).

Figure 2. Whole life costs (WLC) comparison



It indicates that a green building, which typically incurred slightly higher capital costs, will benefit the building owner in the longer-term with low maintenance costs, simplified building operation and long-term competitiveness.

5. ENVIRONMENTAL IMPLICATIONS

BRE (2004) has developed a UK national database, Environmental Profiles of Construction Materials and Components which provides access to environmental impact data of all type of construction materials and products, to enable architects, specifiers and clients to make informed decisions about construction materials and components.

By developing a method for providing independent, "level playing field" information about the relative environmental impacts of different design options, the approach is a practical, consistent and comprehensive method for the life cycle assessment of all types of building materials and components. Similar schemes such as the EU eco-label scheme help contribute to the efficient use of resources and a high level of environmental protection (EU, 2000; Powell and Craighill, 2001).

The methodology adopted describes in detail the consistent approach to the identification and assessment of the impacts of all construction materials and components over their life cycle (BRE, 2004). The environmental implication i.e. Environmental Profiles or other schemes based on life cycle assessment, may be calculated for materials, components and building elements. They are measured on a basis of per tonne or per m2, taking into account of their maintenance, replacement and disposal rates for a nominal life, e.g. sixty years. Materials producers can add new Profiles for additional products at any time and the database will be regularly updated. It has been widely accepted that these schemes set a benchmark for environmental performance of buildings and provides a wide range of benefits (Powell and Craighill, 2001).

5.1 Case project C: INTEGER - Westminster Tower

The strategy of INTEGER for the refurbishment of the 40-sty Glastonbury House in Westminster of central London was devised around the requirement for innovation in several key areas related to social housing. The following analysis demonstrates the environment impact of the green building including sustainability, low energy, water and waste.

- **Energy** - target 50% energy savings and a 50% reduction in carbon emissions through more efficient heating and lighting systems, improved building insulation and use of renewable energies such as solar water heaters, photovoltaic and wind turbines.
- **Water** - target 40% water savings by efficiency measures including rainwater harvesting, use of spray taps and grey water recycling.
- **Waste** - reduce waste in construction by closer management and off-site fabrication. Introduce pre-contract specifications for re-cycling. Reduce waste in use by considering waste separation, compaction and other technologies**.**
- **Microclimate** - Improve the microclimate around the base of the building through intelligent landscaping and the introduction of wind-deflectors. Make the balconies of the flats more habitable through enclosure and also reducing the number of pigeons.

6. STRATEGIC REGULATIONS

The Chinese government has established a long-term strategy to improve the overall performance of buildings in the context of green and sustainable construction (MOC, 2005). By 2020 all new buildings are set to achieve the target of 65% energy-saving and their total consumption of non-renewable resources will be reduced by over 30%, compared to the current level of consumption.

In contrast, a number of initiatives have been established in the UK and the government has taken regulatory measures to encourage the adoption of sustainable practice including the revisions to Part L of Building Regulations, the climate change levy, landfill taxation and enhanced capital allowances etc.

6.1 Building Regulation Part L

Part L is the section of the Buildings Regulations dealing with energy conservation in the technical requirements. The recent revision of Part L, came into effect on 01 April 2002, is part of the Government's strategy to give practical guidance to designers and builders on compliance with the requirements and to deliver real improvements in reducing CO2 emissions by conserving use of fuel and power (ODPM, 2005).

It has been subdivided into Part L1, covering dwellings, and Part L2, covering other type of buildings such as schools, hospitals, offices, and factories. In Part L1, the requirement applying to heating and hot water systems has been changed to encompass overall system performance rather than just controls and boiler seasonal efficiency and inspection and commissioning are covered.

The prime objective of the new regulations is to improve the insulation and air-tightness of buildings, the efficiencies of the heating, lighting, ventilation and cooling systems installed in them, and also the information available to enable owners to use buildings efficiently and successfully.

6.2 The climate change levy

The Climate Change Levy (CCL), introduced by the UK government in April 2001, is an additional tax on use of energy in industry, commerce and the public sector businesses to address the environmental problems resulting from energy production and consumption, the consequent pollution and increase to the average global surface temperature. The intention of the tax is to encourage businesses to reduce their polluting energy consumption and reduce greenhouse gas emissions by 20% over 1990 levels by 2010, with an estimated reduction of 2.5 million tonnes of carbon a year.

The CCL will affect all non-domestic consumers of energy with certain exclusions including fuels used by the transport sector, the production of other forms of energy e.g. electricity generation and registered charities for non-business use etc. There are also several exemptions from the levy such as electricity generated from renewable energy sources e.g. wind and solar power. The Levy is charged at flat rates on per kWh of energy consumed depending on the type of energy from 0.43p/kwh for Electricity to 0.15p/kwh for natural gas etc. The revenue raised by this tax is to be redistributed back to businesses by reducing the level of National Insurance contributions.

However, the impact on businesses may vary depending on the size of the business and its energy consumption. A business with many employees and a small energy requirement will obviously benefit, whilst a company with a high-energy requirement and few employees will feel the financial effect of the increased taxation. On average the Levy adds between 10% and 20% to the fuel bills of most small to medium-sized businesses and raises about £1 billion in the first year.

6.3 Landfill tax

Landfill is the largest source of anthropogenic methane emissions identified in the UK, contributing 1.7 million tonnes of methane per year, 46% of the UK total (DETR, 1998a). The sheer volume is increasing and landfill is hence a very significant contributor to climate change impacts (BRE, 2000; 2004). The Landfill Tax Regulations 1996, came into force in August 1996, requires an additional environmental tax that is paid on top of normal landfill rates by any company or local authority that wishes to dispose of waste including construction waste through a landfill site. The landfill tax is collected through landfill operators and then paid as a tax to the central government.

It is aiming to reduce the production of waste in landfill sites through increasing the cost of landfill and to increase the use of more environmentally friendly waste management techniques such as recycling. Currently the landfill tax rate is set at £13 per tonne of household waste and will increase by £3 per tonne from 2005/6.

The landfill tax credit scheme (LTCS) was also introduced in 1996 alongside the landfill tax. The scheme is designed to support moves to more sustainable waste management practices. The LTCS enables landfill site operators to contribute up to 6.5% of their landfill tax liability for the year to environmental bodies approved by the scheme's regulator ENTRUST. In return for providing funding for these projects, landfill operators receive a 90% tax credit on their contribution.

The tax is effectively an externality charge on the provision of waste disposal services which are directly associated with generation of landfill externalities (Tuner *et al*, 1998) and there are some evidence that the tax scheme has raised the profile of recycling amongst industries and commerce (Powell and Craighill, 2001).

7. CONCLUSION

The concept of green and intelligent buildings promotes the use of innovation in buildings to achieve wide-ranging improvements in performance and value through developed innovation themes in the construction sector. A number of measures have been established as significant drivers towards green and intelligent buildings. Green design, whole life cycle costing techniques and strategic regulations are amongst those that have been identified as major approaches adopted in practice to improve the overall performance of buildings leading towards a green and sustainable construction industry.

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BUILDING DECONSTRUCTION: A CONTRIBUTION TO SUSTAINABLE BUILDING

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Abstract: Other than Rationalization of Resource Consumption and Improvement of Environmental and Energetic Performance, the pursuit of Sustainability in the European construction industry is also centred on Management of Construction and Demolition Waste. One of the best options for managing CDW would be the prevention of its creation. In the case of buildings this can be achieved by promoting re-use at distinct levels: at the materials level, by maximizing recycling; at the component level, by promoting re-use; and at the spatial level, by maximizing flexibility and adaptability. Research in these areas has been termed "Building Deconstruction". This integrated approach in all levels can be a decisive contribution for the achievement of the European Union's long-term factorial objectives of resource use optimisation. This paper presents the concept of Deconstruction, its relationship to sustainability in building construction and an overview of current studies on different aspects of Deconstruction (policy, design and technology).

Keywords: sustainability, deconstruction, durability, flexibility, design.

1. PURSUIT OF SUSTAINABILITY

1.1 Overview

The need for overall sustainability has been widely demonstrated since the late nineties. This is particularly true in relation to the construction industry due to the extensive negative environmental impacts associated with the sector (damage to ecosystems, depletion of resources, emissions, excessive use of energy and production of waste). Kibert (1994) defined Sustainable Construction as "the creation and responsible management of a healthy built environment based on resource efficient and ecological principles".

The search for sustainability in construction has actually various focuses according to socio-cultural differences between regions, countries and continents. In the European Union, the pursuit of Sustainability in the Construction Industry is currently anchored on three main fields: Promotion of Environmentally Friendly Materials, Improvement of Energetic Performance, and Construction and Demolition Waste Management.

Great progress has been made in the former two, but Agenda 21 on Sustainable Construction (citing the second assessment of Europe's environmental problems), referenced waste as the only of the 12 key issues in sustainable construction where there had been no positive evolution.

Construction and Demolition Waste (CDW) accounts for one third of all waste going to landfills, resulting in severe negative landscape and ecological impacts, with the filling up of dumps, with emissions and leaks, and the recurrence of illegal dumping. But more than the direct problems it poses, CDW represents the loss of vast amounts of embodied energy and various often irreplaceable natural resources.

1.2 Construction and Demolition Waste Management Options

The "Delft / Lansing Ladder" (see Table 1), established by the Dutch Government in the eighties as a development of Industrial Ecology's "3 R" principle (Rehabilitate, Reuse, Recycle) ranks several options for waste management (independently of type) according to a logic of resource and energy conservation.

This hierarchy is not strictly rigid, allowing for change in the desirability of the available options due to other aspects (costs, associated environmental impact, etc.).

Table 1: Preferable Waste Management Options according to Delft / Lansing Ladder (Kowalczyk, 2000)

1	Prevention (avoid waste production)
2	Renewal (reduce waste production)
3	Reuse (of components)
4	Reuse (of materials)
5	Adequate use (of materials, for other than original purposes)
6	Immobilization with adequate use (only for dangerous waste)
7	Immobilization (only for dangerous waste)
8	Incineration with energy recuperation
9	Incineration
10	Landfill

In the case of CDW, current management strategies range from options 10 to 4. Efforts are being made to reduce production of waste through improved management, namely through selective demolition which has become more popular in recent years, usually through favourable cost / benefit. The release of the EU funded Waste Manual for Building Construction (WAMBUCO) may be of great help in this area, by presenting a range of indicators to ease building construction waste management.

However, it can be considered that the best way to manage CDW would be to prevent its creation in the first place. Ideally, CDW management should "go up the ladder" to options 1, 2 and 3 of the above referenced ladder, which means that (whenever possible) building demolition should be avoided, by promoting reuse and renewal. There are obvious limitations to this approach, since limitations to building (or component) reuse are numerous: defects due to ageing, poor quality of materials, sub-standard workmanship, economical pressure for redevelopment, changing regulations, excessive costs, etc.

Nevertheless, it can be argued that promotion of options 1, 2 and 3 other than reducing waste, also would allow for the conservation of (embodied) energy in building, and the saving up of material resources, all of which decisively contribute to sustainability.

1.3 Putting Objectives into Perspective

While the struggle for Sustainability is inevitable and urgent, the objective goals of such effort are mostly undefined. And objectives are essential since they are the only way to measure success, provided that they are defined and verifiable.

As of yet, the EU has no time framed objective goals for sustainable construction, other than the hypothetical factorial objectives put forward in the Agenda for Sustainable Construction in Europe (2001): a fourfold increase in resource use efficiency in the short term (20 to 30 years) and a tenfold efficiency increase in a longer term (50 years or more).

While the shorter term objectives may be possible within current building stock and through currently available strategies, longer term objectives will probably depend on future buildings being both more durable and flexible.

1.4 Durability and Flexibility

There is a common assumption that buildings will last longer if they are more resistant and durable. Excluding historically valuable buildings, this may not be forcibly true, for contemporary buildings' longevity tends to be lower than could be expected when considering the structural system life cycle.

Recently presented North American studies have demonstrated that buildings are demolished mainly because of changing land values, lack of suitability of the building for present needs and lack of maintenance in several non-structural aspects rather than structural failure (Horst, 2005).

In the referenced study, 50% of steel and concrete structure buildings demolished were just 25 to 50 years old. Unsuitability for use motivated demolition in 22% of the buildings studied; while area redevelopment and poor condition were responsible for demolition of 65% of stock (35% of the buildings demolished due to "poor condition" had no structural problems).

Although a vital requirement for longevity, durability alone will not guarantee survivability to buildings. It must be accompanied by adaptability and flexibility, allowing buildings to adjust to change in standards or nature of use.

Naturally, not all buildings need to (or must) be adaptable to all uses, something which will depend on the significance and type of use. Even within a single building type, absolute adaptability may be unreachable as DEGW office building experts concluded during London's Broadgate preliminary studies (Duffy, 1997).

If buildings undergo constant change during their lifetimes for a variety of reasons (upgrade, change of use, renewal, and refurbishment) and if it is impossible to accommodate all changes, then other than flexibility and adaptability, building design and construction must also provide the means to avoid total loss of materials and energy upon the buildings' end of life.

2. DECONSTRUCTION

2.1 Definition

The reuse of whole buildings, components and materials has been recurrent throughout human history: Rome's Coliseum materials being used in other buildings, the use of roman cut stone columns in early North African Muslim mosques or the adaptation of abandoned monasteries for other uses (hotels, hospitals, schools, etc.).One can describe those processes as the maximization of durability of whole buildings, components and materials to the full extent of their technical life cycle, for economical, social and environmental reasons, through the promotion of spatial flexibility and (limited) disassembly capacity. One can call it Deconstruction. Various conditions contributed decisively to historic habits of reuse, including sheer necessity, limited constructive complexity and reduced functional / programmatic definitions, all of which have greatly changed. In order to contribute to the time related sustainability objectives, deconstruction studies must address current paradigms of the prevailing building design and construction assumptions and habits.

2.2 Policy Framework

Great efforts have been made to contextualize the contribution of deconstruction for an Ecology of Construction and its importance as a potential unifying concept for conflicting priorities for building sustainability (energy, materials, etc.), while fostering maintenance.

On an policy defining level, Deconstruction has been considered mainly as ranging in meaning from "design for recycling" (Dorsthorst, 2002) to "design for reuse" (Steward, 2004), putting more focus on management of demolition activities and by-products, than setting standards for future building's disassembly capability.

As component and material reuse, Deconstruction is already an appealing concept in countries such as Netherlands and New Zealand by reducing the demand for landfill and promoting environmental concerns, and for countries such as the USA and Japan, whose wooden framed residential market struggles with high price and scarcity of quality materials. Deconstruction Studies have been running under Florida University based CIB TG 39 which has already held three meetings. Other than these, other conferences on deconstruction have taken place in the US (DECON 04, to be followed by DECON 05).

2.3 Design Guidelines

Design must naturally consider distinct priorities due to building use, significance and purpose, aspects which will decisively influence Deconstruction's possibilities and necessities. Table 2 (Durmisevic, 2002) correlates possible End of Life Scenarios (ELS) considering relationships between Technical and Functional Life Cycles, defining the main priorities for design for Deconstruction when applied to various levels of building (complete buildings, components and materials).

Table 2: End of Life Scenarios according to relationship of technical and functional Life Cycles

Functional Life Cycle < Technical Life Cycle	→ Reuse
Functional Life Cycle > Technical Life Cycle	→ Replace
Functional Life Cycle = Technical Life Cycle	→ Recycle

The main obstacle to these logics, and a major argument for impossibility of change in buildings, is the still prevailing interdependence between building components with different longevities and performances. Thus, all studies in design for deconstruction focus on the nature of the connections between "layers" (Brand, 1994) as the key for promoting and achieving reuse (see Figure 1).

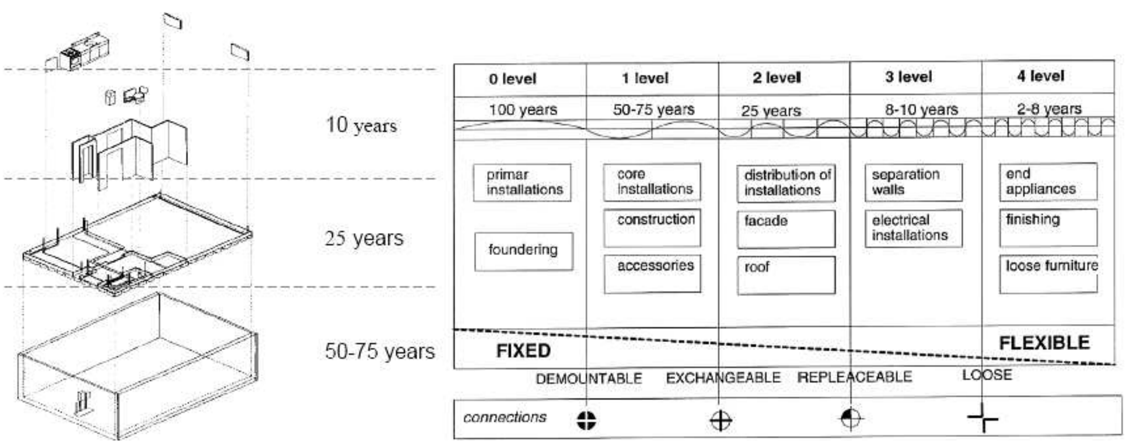

Figure 1: Proposal for systematization of building systems and their interfaces according to the different life cycles (Durmisevic, 2002)

Other than "layers", management of current building complexity in design also needs to consider the concept of "levels" as "bundles of parts and decisions", proposed by Open Building Studies (under CIB commission W104, anchored on Ball State's University), as the definition of different levels of control over layers by those involved with designing, constructing and using the building (see Figure 2).

Other than theses conceptualizations, research for design for deconstruction incorporates lessons from areas of industrial production, from historical examples (of spatial flexibility) and comparative research in an effort to define integrated designer guidelines (Crowther, 2000), akin to Environmental Preference Reference Tables (Anink, 1996), with which to balance conflicting priorities for design (embodied and use energy, environmental profile of material, etc.).

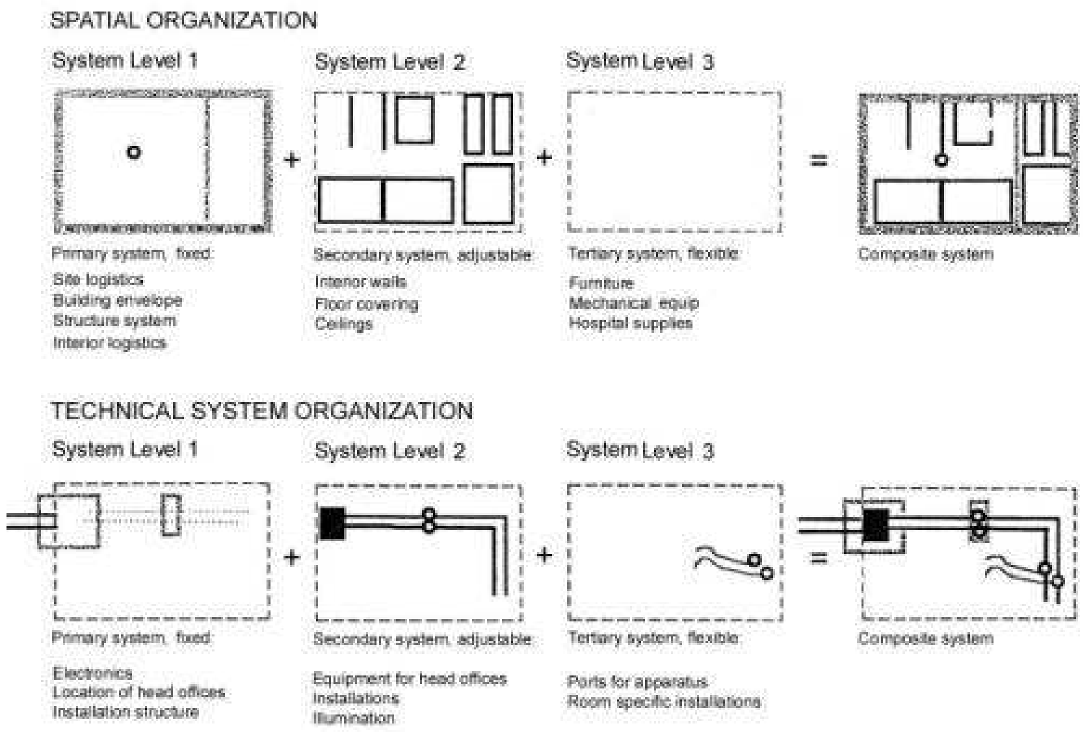

Figure 2: Organization of Design on Levels of the INO Hospital, Bern, Switzerland (in Study Mission Report, Building Futures Institute, Ball State University, Indiana, 2002)

2.4 Technical Solutions

Great emphasis has been put into promotion of selective demolition techniques and methodologies, a pressing field given current patterns of built fabric renovation in the more industrialized European and G8 countries, anchored on cost / benefit analysis. Building Deconstruction Assessment tools are already under development (Guy, 2002). Another primary field of research is the development of technical solutions for reusable components and material reuse, especially mineral debris (concrete, clay, stone), dimensions where contributions by other fields of research may prove decisive, namely in terms of easy to disassemble concrete structures.

Life Cycle Assessment Studies can help foster future reuse of components, by aiding in the definition of Deconstruction Certification Standards (Guy, 2004), necessary to fully implement reuse.

Life Cycle Assessment and Embodied Energy Studies knowledge is also considered vital to inform options and priorities for study of reuse of materials and components, since “recycling” of numerous materials actually corresponds to downcycling, with materials and components losing performance and importance upon reuse for loss of adequate technical solutions (structural timber is used for window framing, crushed concrete is used for road base layers, etc.).

3. CONCLUSION

Although it emerged as a concept directed mainly at preventing and reducing CDW by increasing recycling and reuse, Deconstruction should not be seen neither as just the promotion of “selective demolition”, nor (in the other end of the spectrum of possibilities) as just promotion of “fully disassemblable buildings”.

In effect, the reuse of materials, components and whole buildings, not only reduces CDW but also saves resources and energy (embodied), directly linking to the other two main areas of promotion of sustainable construction (resource management and energy efficiency). But since Deconstruction can be achieved at several levels (material, component and whole building), the extent to which a building can (and should) be “deconstructable” will vary greatly, depending on various local conditions: the building’s urban and symbolic importance, the expected longevity of its layers, foreseeable changes, structural and technical characteristics, costs, etc.

More than a novel concept, “Deconstruction” can be regarded as an embracing conceptual framework incorporating and linking methodologies, techniques and concerns which already exist in building design and construction, but that are not systematically correlated due to very different focuses.

Since building design and promotion are the moments where the degree of possible deconstruction will be defined, the success of Deconstruction as an effective contribution to sustainability will depend on surmounting various obstacles in these fields.

At the promotion level, generalized “Green” Building difficulties are to be expected for pro-deconstruction approaches, namely unproven economic benefit, perception of superior initial costs and lack of demand (Ning, 2003). This is an area where case studies and whole life costs studies will prove decisive.

Since buildings are more and more appreciated on the same basis as other “fashionable” shorter lived items such as clothing or cars (Wang, 2003), Building Designers may not feel inclined to Deconstruction, especially if they sense a conflict between “reverse buildability” and architectural expression. In order to “mainstream” deconstruction into actual design and building paradigms, it is especially important to demonstrate the compatibility between these two last aspects (This is the author’s current field of PhD research, considering “heavy and wet” building matrixes such as those in Southern European countries, where concrete structures are predominant and where the concept of “whole building reuse” through increased flexibility and adaptability is especially important).

Truly sustainable construction will have to incorporate Deconstruction as a concern to a higher degree than today, as an approach aimed at minimizing the loss of matter, energy and time during a building’s life, thus “closing the loop”.

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SOURCES OF CONSTRUCTION MATERIAL WASTAGE IN SRI LANKAN SITES

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Abstract: The amount of construction waste is significant in most of the countries which has challenged the performance of the industry and its sustainable goals. Construction waste can originate at any phase of the construction process, and its roots may lie in design decisions, method of construction or even with attitudes of people. The nature of construction itself supports the generation of waste as well as obstructs the implementation of waste management practices. Waste minimisation improves the performance of the construction industry and benefits the environment and the whole society by preserving natural resources, minimising harmful effects to the environment. Thus, importance of minimising the construction waste has been highlighted. Identification of the reasons behind the generation of waste is a key point in any waste management strategy. Thus, this paper provides the findings of a study carried out in Sri Lanka to identify the sources of construction material waste.

Keywords: Construction industry, capacity of contractors, sources of waste, waste management.

1. BACKGROUND

Achieving the sustainable goals of the construction industry is being challenged by the generation of constriction waste which has even given a bad image to the industry (Kwan, 2003). Evidence shows that, approximately 40% of waste generated globally originates from construction and demolition of buildings (Holm, 1998) and this has taken a major portion of the solid waste discarded in landfills around the world. For instance, in the USA it is approximately 29% (Bossink and Brouwers, 1996) and in Australia 44% of landfills by mass (McDonald, 1996). Further, research indicates that 9% of the totally purchased material end up as waste (by weight) and every single material from 1% to 10% contributes to the solid waste stream of the site (Bossink and Brouwers, 1996).

Construction can be considered as one of the major sectors which consume a major portion of natural resources in the world. Ganesan (2000) states that materials account for the largest input into construction activities, in the range of 50% - 60% of the total cost. According to Holm (1998), approximately 40% of the produced materials are utilized in buildings and construction work. Further, the construction industry consumes 25% of virgin wood, and 40% of the raw stone, gravel, and sand used globally in each year.

As a result of the construction waste, contractors are at a lost due to extra overhead cost, delays and extra work on cleaning, lower productivity etc. (Skoyles and Skoyles, 1987). Cost on waste blunts the competitive edge of contractors, making their survival more difficult in the competitive environment (Macozoma, 2002). CIRIA (1995, cited in Teo and Loosmore 2001) estimate that companies that produce a higher level of waste are at a 10% disadvantage in tendering. Thus, Alwis et al (2003) argues that construction waste can significantly affect the performance and productivity of the organisation. Further, construction waste has become a burden to clients, as they have to bear the costs of waste eventually (Skoyles and Skoyles, 1987). Construction waste is also a cost to the environment that threatens its resilience. The unavailability of dumping sites to accommodate the higher volumes of debris from construction sites is becoming a serious problem (Chan and Fong, 2002) and there may be a day that restrictions are imposed on construction waste disposal.

The above context illustrates the problems associated with construction waste. Improving the quality and efficiency of the construction industry is highlighted by Egan (1998) where, one way of achieving this target is stated as reduction of waste at all stages of the construction process. Further, the report “Better Public Buildings” (DCMS, 2002) identifies measuring efficiency and waste as one of the priority areas for the industry to improve its performance. Thus, it can be seen that, construction waste management has become an important area to improve the performance of the industry in terms of economic, quality, sustainability aspects.

4.1 Construction waste in the context of Sri Lanka

Cost of waste has a significant impact to the Sri Lankan construction industry. Thus, a number of studies have been carried out in this context. According to Jayawardane (1994), concrete and mortar showed 21% and 25% of wastage respectively due to the excessive use of materials in rectification of inaccuracies. Even though it has been identified that minimisation of waste to a certain extent is unavoidable (Skoyles and Skoyles, 1987), Jayawardane (1994) states that the wastage of materials in most of the construction sites in Sri Lanka is beyond the acceptable limits. This fact has been further proven by a study carried out by Rameezdeen and Kulatunga (2004) which identified the wastages as Sand (25%), Lime (20%), Cement (14%), Bricks (14%), Ceramic Tiles (10%), Timber (10%), Rubble (7%), Steel (7%), Cement Blocks (6%), Paint (5%) and Asbestos Sheets (3%).

Accordingly, this paper reports the findings of a survey carried out in Sri Lanka to evaluate the significance of waste sources towards the generation of waste. Section 2, and section 3 describe the literature review on construction waste and sources of construction waste respectively. This is followed by the research methodology in section 4. Data analysis is presented in section 5 followed by the conclusion.

2. CONSTRUCTION WASTE

The Building Research Establishment (1982, cited in Skoyles and Skoyles 1987) defines construction waste as the difference between the purchased materials and the used in a project. According to Hong Kong Polytechnic (1993) construction waste is the “by-product generated and removed from construction, renovation and demolition work places, or sites of building and civil engineering structures”. Further, construction waste has been defined as “building and site improvement materials and other solid waste resulting from construction, re-modelling, renovation, or repair operations" (Harvard Green Campus Initiative, 2004).

Although, resource optimization is one of the main objectives of any organization, less attention is paid on construction waste minimisation even though it has a great contribution to the aforesaid objective. This is due to the perception regarding waste which "has no value and which the junkman can take away (Leenders et al. 1990). However, it can be argued that construction waste does not fall under this definition, as it is has a residual value and is avoidable.

3. SOURCES AND CAUSES OF WASTE

Construction waste stems from construction, refurbishment, and repairing work. Many wasteful activities can be taken place during both design and construction processes, consuming both time and effort without adding value to the client (Love, 1996). Generation of the stream of waste is influenced by various factors.

3.1 Natural waste

Natural waste is the wastage that will cost more than what is saved if tried to prevent. There is a certain limit up to which, waste of materials can be prevented. Beyond that limit, any action taken to prevent waste will not be viable, as the cost of saving will surpass the value of materials saved. Thus, natural waste is allowed in the tenders. Amount of natural waste is subjective to the cost effectiveness of the approaches used to manage it. The approaches vary from one scenario to another and so do the natural waste. For instance, cost of preventing wastage in a project with a good material controlling policy will be lesser than that of a project, which lacks such a policy. Thus, the acceptable level of natural waste in the former situation will be lesser than the later.

3.2 Direct waste

"Waste that can be prevented and involves the actual loss or removal and replacement of material" is called as direct waste (Skoyles and Skoyles, 1987). Most of the time, the cost of direct waste dose not end up in the cost of material, but followed with the cost of removing and disposing. Thus, by preventing direct waste straightforward financial benefits can be obtained. Direct waste can be occurred at any stage of the construction process before the delivery of material to the site and after incorporating the materials at the building. Categories of direct waste can be summarised as in Table 1.

Table 1: Categories of direct waste (Skoyles and Skoyles, 1987)

Category	**Reason**	**Example**
Delivery waste	During the transportation of material to the site, unloading, and placing in to the initial storage	Bricks, glassing
Cutting and conventional waste	Cutting materials in to various sizes and uneconomical shapes	Formwork, tiles
Fixing waste	Dropped, spoiled or discarded material during fixing	Bricks, roof tiles
Application and residue waste	Hardening of the excess materials in containers and cans	Paint, mortar, plaster
Waste caused by other trades	Damages occurs by succeeding trades	Painted surfaces
Criminal waste	Theft and vandalism	Tiles, cement bags
Management waste	Lack of supervision or incorrect decisions of the management	Throwing away excess material
Waste due to wrong use	Wrong selection of material	Rejection of inferior quality marbles, tiles

3.3 Indirect waste

In this type of waste, the material does not get waste physically, but the payments for the material are wasted partly or wholly. The indirect waste consists of the following categories as shown in Table 2.

Table 2: Categories of indirect waste (Skoyles and Skoyles, 1987)

Category	**Reason**	**Example**
Substitution waste	Substitution of materials in work, which will incur losses to either contractor or client	Use of facing bricks for common bricks
Production waste	Contractor does not receive any payments for the work he has carried out	Use of excess plastering to rectify the uneven surfaces of brick walls
Negligence waste	Site errors because of the condemned work or use of additional material	Over excavation of foundation, resulting in the use of additional concrete
Operational waste	Unavailability of proper quantities in the contract document / the material that are left in the site	Formwork

In addition to the above classifications, Ekanayake and Ofori (2000) have classified the sources of waste under four major categories as Operational waste (errors by trade persons or labourers, accidents due to negligence, damage to work done caused by subsequent trades, use of incorrect material, required quantity unclear due to improper planning, equipment malfunctioning, inclement weather), Design waste (lack of attention paid to dimensional co-ordination, changes made to the design while construction is in progress, designer's inexperience in method and sequence of construction, lack of attendance paid to standard sizes available on the market, designer's unfamiliarity with alternative products, complexity, errors ands incomplete contract documents, selection of low quality products), Material handling (Damages during transportation, inappropriate storage, materials supplied in loose form, use of whatever material which are closed to working place, unfriendly attitude of project team and labourers, theft) and Procurement waste (Ordering errors, lack of possibilities to order small quantities, purchased products that do not comply with specification).

4. RESEARCH METHODOLOGY

As waste barricades the efficiency, effectiveness, value, and profitability of construction activities, there is a need to identify the origins or the causes of waste and control it within reasonable limits. Thus, it is vital to identify the root causes of waste to implement successful waste management strategies. Accordingly, the aim of the research is to identify the significance of waste causes/origins, towards the generation of waste. To achieve this aim the following objectives are formulated;

Identify the significance of waste causes

Identify the most significant source of waste towards the generation of waste

Identify the relationship between the source of waste and the capacity of contractors

A structured questionnaire survey was carried out to evaluate the significance of causes of waste towards the generation of construction material waste. Based on the classifications of Ekanayake and Ofori (2000) and Skoyles and Skoyles (1987), main sources of material waste were divided into four categories as Operational, Design, Material handling, and Procurement. Further, their sub elements (causes/ origins of waste) were identified accordingly as shown in Table . The questionnaire was prepared using the Likert scale where the respondents were asked to identify the significance of causes towards the generation of waste within a scale ranging from 1 to 5 {very low significant (1), low significant (2), significant (3), high significant (4), very high significant (5)}. The significance of the cause of waste to the correspondent source was calculated by considering the mean of each cause of waste within the main source of waste. Mean was computed as shown below.

$$M = \frac{\sum_{i=1}^{n} Sp_i \times Sf_i}{TR}$$

M = Mean of the waste origin.

Sp_i = Point given for significant level.

Sf_i = Frequency of significant level.

TR = Total response.

Further, the significance of the main sources of waste towards the generation of construction waste was calculated by considering the mean of the mean sample (Grand Mean) which is computed as;

$$M_M = \frac{\sum M}{N}$$

M_M = Mean of the sample means.
M = Mean of the each sample.
N = Number of samples.

In addition to the identification of the significance of causes towards the generation of construction waste, the research analysed the relationship between the waste sources and the "capacity of contractors". In the Sri Lankan construction industry, contractors are categorised into number of Grades depending on their financial capacity (turnover, current assets), technical capacity (human resource, plant and equipment, work experience) and merit and demerit points (use of quality management systems, awards received for construction excellencies). The grades of contractors varies from M1 (highest capacity) to M9 (Lowest capacity). For this research, questionnaires were issued from M1 to M6 contractors within the Colombo metropolitan area. The sample of the questionnaire survey is shown in Table 3.

Table 3: Sample of the questionnaire survey

Grade	**M1**	**M2**	**M3**	**M4**	**M5**	**M6**
Number of questionnaires issued	25	20	20	15	17	20
Number of Respondents	25	19	16	14	15	17
% Response	100	95	80	93	88	85

5. DATA ANALYSIS AND DISCUSSION

5.1 Significance of the causes and sources of waste toward the generation of waste

According to Table 4, it can be seen that poor workmanship, insufficient communication between the design and construction teams, inadequate supervision, damages caused by succeeding trades have the highest influences for the generation of construction waste under the "Operational waste" category. The reasons behind *poor workmanship* can be considered as allocation of inexperience labourers and lack of skilled labourers. Labour migration has become a serious issue in the Sri Lankan construction industry which resulted in skilled labour shortage. Low degree of supervision on subcontracted work, unmanageable scope of work per supervisors and inappropriate material issuing systems can be pointed out as the reasons for the generation of waste due to *inadequate supervision*. Poor planning decisions, errors in scheduling of work, lack of knowledge about the construction process has increased the waste due to *damages by subsequent trades*.

Under the "Design waste" category, design changes during the construction period, lack of attention paid to dimensional coordination, and lack of information in the drawings are the most significant causes. Poor understanding of clients' needs during the design stage and lack of involvement of the contractors to develop practical design solutions have ultimately resulted in *design changes during the construction stage*. Lack of awareness about the standard sizes of materials available in the market, design of irregular shaped buildings can be considered as the root causes for the waste due to *lack of dimensional coordination*. Further, time pressure on the design team to complete the drawings has resulted in producing incomplete drawings which intern increase waste due to *incomplete drawings*.

Table 4: Significance of causes of waste

Source	Causes of waste	Mean
Operational waste	Poor workmanship	4.11
	Poor communication between designer and builder or within the organization	3.91
	Inadequate supervision	3.52
	Damages caused by succeeding trades	3.50
	Required quantity unclear due to improper planning	2.71
	Bad weather condition	2.66
	Use of incorrect material, thus requiring replacement	2.56
	Dropping and spoiling of material during fixing	2.07
	Malfunctioning of equipment	2.01
	Site accidents	1.80
Design waste	Design changes during the construction period	4.52
	Lack of attention paid to dimensional coordination	4.30
	Lack of information in the drawings	4.01
	Incomplete and errors in contract documents	3.50
	Designers unfamiliarity with alternative products	3.25
	Selection of inferior quality materials and products.	2.55
	Lack of attendance paid to standard sizes available in the market	2.46
	Complexity of the drawings	2.07
Material handling waste	Inappropriate storage facilities.	3.63
	Damages during transportation.	3.22
	Material supplied in loose forms	2.45
	Unfriendly attitudes of project team and labourers	2.07
	Theft and vandalism	1.50
Procurement waste	Mismatch of material purchased with specifications	3.42
	Ordering errors	2.65
	Lack of possibility to order small quantity	2.44

Inappropriate storage facilities and damages during the transportation are the significant factors for the generation of waste due to "Material handling". Limited space allocations in material stores, improper arranging and stacking of materials, storing the bulk material in open ground can be considered as reasons to generate waste due to inadequate storing facilities. Waste due to transportation manly arises due to the use of equipment with poor condition.

Communication errors, non availability of materials in the market can be pointed out as the reasons for the generation of waste due to mismatch of purchased materials with the specifications under the category of “Procurement waste”.

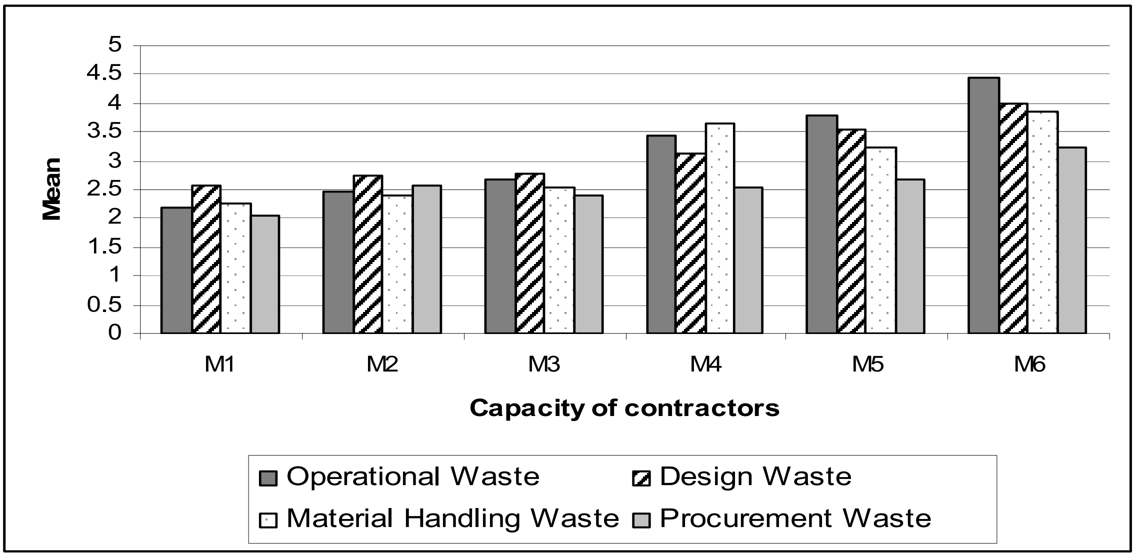
Within the four main types of waste sources, Design waste has the highest impact on the generation of waste followed by the Operational waste (Table 5). This fact shows the inadequate attention for the waste management practices during the design stage of the construction work.

Table 5: Significance of sources of waste

Source of waste	Mean
Design waste	3.33
Operational waste	2.88
Procurement waste	2.84
Material handling waste	2.57

5.2 Relationship between the sources of waste and the capacity of contractors

Figure 1: Relationship between the capacity of contractors and the waste sources



The relationship between the source of waste and the capacity of contractors is shown in Figure 1. It can be clearly seen that the influence from the waste sources are less with the higher capacity contractors. This may be due to the availability of skilled workforce and management staff, proper programming of construction activities, appropriate storage facilities, use of proper tools and equipment for material handling etc. by the contractors with higher capacity.

6. CONCLUSION

The generation of material waste has become a problem in the Sri Lankan construction industry as it is beyond the acceptable limits. Thus, attention has been paid on developing and implementing better waste management plans. Identification of the root causes of material waste is essential to develop effective waste management plans.

The main causes for the generation of waste in the Sri Lankan construction industry were identified as design changes during the construction stage, lack of attention paid for the dimensional coordination and poor workmanship. Further, Design waste was evident as the most significant waste source among the operational, procurement and material handling waste sources. The above facts indicate the inadequate waste management practices during the design stage of construction work. Therefore, this emphasise the importance of initiating waste management plans and practices during the design stage rather than limiting them to the construction stage. Accordingly, better briefing processes to identify the clients requirements, paying more attention on building morphology and dimensional coordination of materials and products, getting the expertise knowledge of contractors to enhance the buildability of projects can be pointed out as important aspects that have to be considered during the design stage. Retaining the skilled workforce via providing better facilities, training and education, development of attitudes of the construction workforce towards the waste minimisation practices, and providing appropriate storage facilities can be identified as factors which will help to minimise the generation of waste during the construction stage.

Further the study revealed that the impact from the waste sources is high for the low capacity contractors due to lack of resources such as skilled workforce, storage facilities, material handling methods etc.

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THE BARRIERS AND POSSIBLE SOLUTION TO ACHIEVE SUSTAINABLE DEVELOPMENT

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Abstract: The increasing spectrum of environmental and social challenges instigated by the failure of development strategies, the continuous proliferation of unsustainable patterns of production and consumption coupled with the anticipated level of population stimulated the pursuit of a new path. Sustainable development has emerged as a possible remedy. Despite increasing efforts to marry the social and environmental challenges with economic growth, progress remains remote. Against this background, the paper aims to investigate the root cause of the current poor progress in terms of the practical application of the concept. The paper reinforces the drawbacks of the current societal conflict resolution mechanism: market and political arenas. As a possible solution, it suggest the urgent need for a shift to the third arena, which facilitates integration of public debates, scientific evidence and policy, and extensive use of innovative tools such as precautionary principle to ensure a high-quality decision-making process.

Keywords: challenges, development, progress, solutions, sustainability.

1. INTRODUCTION

Sustainable development emerged as a possible means of integrating social, environmental and economic growth so that the needs of the present generations can be met without jeopardising the possibility of the future generation from meeting their own needs. The concept of sustainable development is a classic example of the evolution of a new world order. A concept which "has passed through all the predictable stages: from an ideological side-show, an interesting trend met with equal measures of enthusiasm, scepticism and uncertainty to an agenda on which we might have differences of opinion, but one which we cannot deny, and one which individuals, companies and institutions increasingly adopt as their own…. Typically, it begins as an almost unnoticeable trend that gradually takes shape and finally develops into a fundamental global condition" (Nordic, 2002 pp 8). Figure 1 shows the dramatic increase of international media interest in sustainability while Figure 3 shows the timeline of both global and UK efforts to achieve sustainable development

Despite increasing high profile global conferences and events aimed at promoting sustainable development, its uptake in terms of practical application is conspicuously low (NFSD, 2002; Dyllick and Hockerts, 2002). This paper explores the reason behind this and reviews a large body of knowledge to develop a topology of challenges and a timeline of various attempts to promote sustainable development. It also examines barriers to sustainability and suggested a possible way forward.

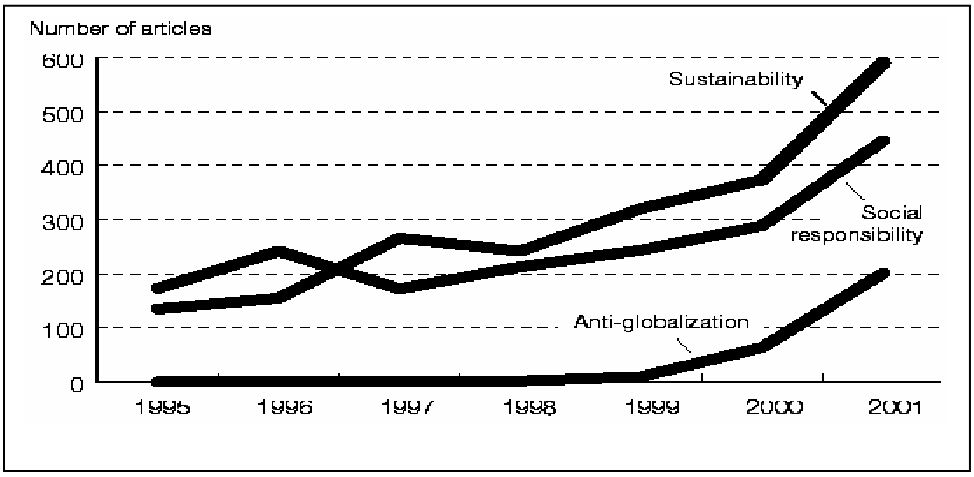


Figure 1: Key words in 12 leading international media 1995-2001 (Nordic, 2002)

2. THE NEED FOR SUSTAINABLE DEVELOPMENT

Sustainability describes the ideal society- a better quality of life for everyone now and for generations to come (see Brundtland, 1987; DETR, 1999). The relevant literature is abound with the spectrum of sustainability challenges (IPCC, 1996; UNDP 1999; 2000). The evolution of sustainable development has been driven by demographic and environmental concern, value creation and increased industrial activity.

Demography, poverty and economic concern

The current world population is about 6 billion, an increase by 140 per cent over the last fifty years. By 2050, it is projected to be 9 billion (UN, 2002). Of the current six billion, fifty per cent have to survive on less than two dollars per day (Leisinger and Schmitt, 2002), one-fifth have no access to health care, one-sixth have no access to safe water to drink, and over 40 per cent lack access to sanitation and modern energy services (DTI, 2004).

Demography, poverty, urbanisation and quality of life

Geographically the earth is ageing. Demographically, most of the nations are becoming younger (Fussler and James, 1996) although in the most developed countries, life expectancy is rising while birth rate is declining. The implications of this are: slowdown in the rate of economic growth, unsustainability of pension schemes and public health facilities. In the EU, regional imbalances remain a major concern as 1 in 6 Europeans live in poverty.

Value creation, industrial activity and environmental degradation

The increasing depletion of natural resources and environmental degradation underscore the urgent need to decouple economic growth from environmental degradation. Major environmental problems such as CO_2 emissions, deterioration in air and water quality, depletion of forest, and solid waste generation are caused by industrial activity. As a result, some have demanded 90 per cent dematerialization of the economic processes to achieve a ‘factor 10’ improvement (Schmidt-Bleek, 1994).

Unequal distribution of wealth

Inequalities within and between countries are greater than anything experienced before (UNDP, 2000), where 80 per cent of the world income is received by 20 per cent of the world's population (Leisinger and Schmitt, 2002). The ill-conceived globalisation through strategic alliances; the ever-increasing economic power of the World Trade Organisation exacerbate these gaps (UNDP, 1999). Aside from the moral and ethical considerations associated with social inequalities, there are many practical issues. Inequality reduces efficiency and productivity of the poor thereby causing low economic growth and undermining social cohesion. Social exclusion promotes violence, crime, drugs, family breakdown, dependence on state benefits and so on. Extreme inequality threatens the whole economy as a large proportion of the society loose connectivity with the assets and organisations that produce the wealth (Dimbleby *et al*, 2000). According to Gates (1999 pp8) *"Two-tier societies and two-tier marketplaces are not the fertile soil in which robust democracies take root"*.

Other contemporary challenges and impact on the built environment

The occurrences of new diseases, especially the growing impact of the AIDS epidemic, the effect of climate change and urban growth on the built environment are examples of other contemporary challenges. Future changes in the built environment will have to meet the challenges created by climate change and urban growth. Statistics indicate (Figure 2) that the population of cities will increase three-fold to over six billion by 2050.

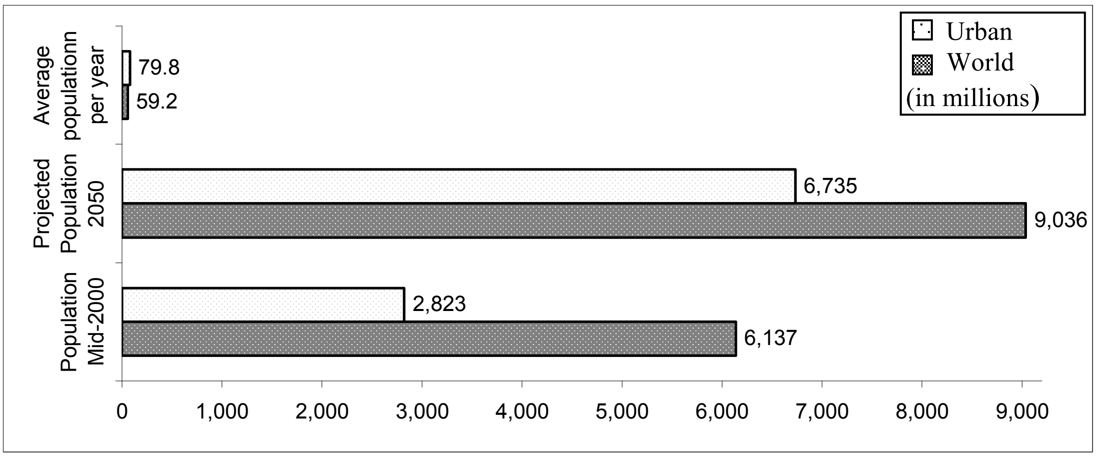


Figure 2: Population Trends[1]

[1] *Ccollated: http://www.prb.org/Content/NavigationMenu/Other_reports/2000-2002/2001 World Population Data Sheet.htm#highlights)*

The environmental and social changes addressed have been with us for much of the last century, but the pressures are intensified as society now faces additional environmental and social stresses (Roome, 1998). Dealing with them will require considerable invention and innovation. Sustainable development is presently the only answer available (Enmarch-Williams, 1996; Blair, 2005).

3. THE SEED OF SUSTAINABLE DEVELOPMENT

Literature review indicates that the concept of sustainable development is not new. The historical decline, the content and structure of many traditional views and religion beliefs and body of knowledge are the crucial tenet of the contemporary concept of sustainable development–*'living in harmony with nature and within society'* (Adetunji *et al*, 2003). The narrow concern of the adverse impact of our economic model in the late 1960s (Carson, 1962; Erhlich, 1968) has blossom into a wider debate on a major reform of this model in the early 1970s (Meadows, 1972; Schumacher, 1973).

The International Union for the Conservation of Nature (IUCN) in collaboration with the World Wildlife Fund for Nature and The United Nations Environment Program (UNEP) formulated the World Conservation Strategy in 1980. This strategy aimed to integrate the environment and development concerns into a single concept of conservation (Tryzna, 1995) and provided a focal point for an earlier diffuse idea and underpinned the concept of sustainability (Khosla, 1995). Holmberg (1994) argued that though the IUCN could claim credit for introducing the term 'sustainable development' for the first time. The World Commission on Environment and Development (WCED), through the Brundtland Report (1987), brought the concept to the political arena. Figure 3 shows the timeline of both global and UK Government attempts to promote sustainable development.

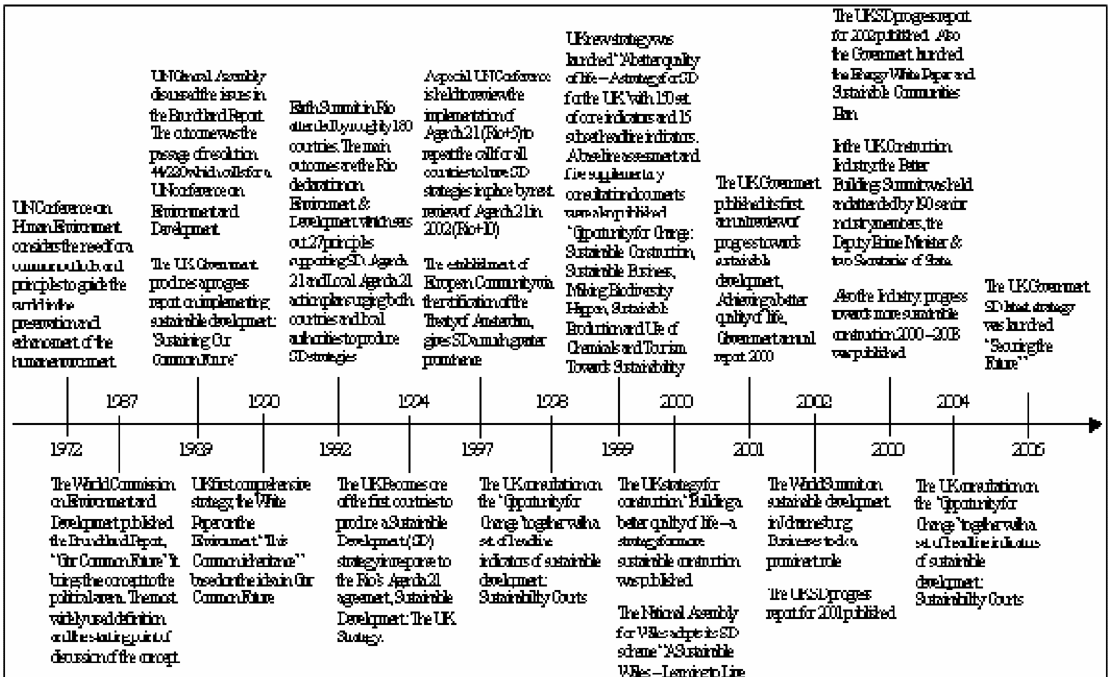


Figure 3: The timeline for sustainable development

3.1 Sustainable Development - Knowledge Versus Progress

During the last four decades there has been a proliferation of political activities to promote sustainable development. However, despite the increasing efforts to marry social and environmental challenges with economic growth, the outcomes of various reviews consistently suggest that success is mixed and progress remains remote (Annan, 2001). The conclusion of the global analysis of the progress made so far indicated *"little evidence of a massive shift in attitudes and actions on the part of all major players upon which the realisation of a sustainable development process depends. Individual, political and entrepreneurial inertia as well as tactical behaviour continues to delay a halt of environmental destruction and resource mismanagement"* (NFSD, 2002 pp2). In the UK, the recent authoritative review of progress since 1999 concluded 'Shows Promise, But must try harder (SDC, 2004). Against this backdrop, through extensive literature review and deductive reasoning, the paper explores the root cause of the current poor progress and suggested possible solutions.

4. BARRIERS TO ACHIEVING SUSTAINABLE DEVELOPMENT

4.1 Historical Disparity Between the two Parts of the Concept

A good appreciation of changes in thinking regarding the conceptualisation of sustainable development is a prerequisite to understanding the challenges of its practical application (Elliot et al., 1994). The origin of the concept of sustainable development lies in two distinct disciplines of development and environment, which were separated until 1960s. As understanding of the challenges and achievements of both disciplines changed, they came closer with the realisation that environment and development were interdependent and mutually reinforcing issues. The changing perceptions of both epistemologies and their emergence are possible reasons for the poor progress of the practical application of sustainable development.

Changing perceptions of development

In the 1960s, a positive causal relationship between development and economic growth was assumed and economic growth was measured through Gross National Product (GNP). It was generally assumed that the problem of the South could be quickly solved through financial aid, technology and expertise transfer (Elliot et al., 1994; and Radclift, 1987). In the 1970s, some progress was indicated by GNP. However, the increased poverty, population growth and inequality provided renewed challenges to economic development. As a result, the focus was widened to include 'Even distribution of income' and 'Population control'. These are perceived as fundamental parts of any development strategy, hence such phrases as 'Growth with Equity' and 'Redistribution with Growth'. The understanding of development took a new dimension in the 1980s and was perceived as a multi-dimensional concept encapsulating widespread improvements in the social, as well as, the material well-being of all in the society. It was recognised that there was no single model for achieving development and that investment in all sectors (for example, agriculture, industry and so on) was required. For development to be sustainable; it must encompass not only economic and social factor, but also those related to population, natural resources and resulting impacts on the environment (Radclift, 1987).

Changing perceptions of the environment

Environmental conservation took off in the 1960s when coherent bodies of work were published (Carston, 1962; Erlich, 1968). The multiple effects of unsustainable patterns of production and consumption of the developed world started to emerge. Concern was intensified due to population growth, increasing demand on natural resources in the developing world and its threats on global environmental quality. However, the notion of environmental conservation gained little or no support from the developing countries for various reasons (Radclift, 1987):

- resources were perceived as infinite;
- environmental degradation is inevitable consequence of industrial development;
- scepticism of the motives behind proposal to limit their development;
- strong belief that development can only be achieved through industrialisation; and
- environmental problems are solely caused by the industrial world hence they should deal with.

Emergence of environment and development

The major political dilemma of the Brundtland is the integration of social and environmental decline with the desire for economic development in the South and economic growth in the North (Adetunji, 2003). This historical disparity is the cause of current divergence of views and perspectives, values and beliefs and, experience and insights as evidence in the various global political negotiations on environmental targets.

4.2 Lack of Clarity and Contradictions of the Concept

The relevant literature provides different definitions for sustainable development and there is still much confusion and conflict about the meaning of the concept. Sustainability is an integrative and crosscutting concept, characterised by deep-rooted contradictions of incompatible goals (Dovers and Handmer, 1993). This systemic dysfunction is rooted in the often irreconcilable two parts of the concept- 'sustainability' and 'development'. The combination of these two words resulted in multi-dimensional variables and sub-variables rather than the sum of two concepts put together (Samson, 1995). Dovers and Handmer (1993) identified eight contradictions as follows:

- **Cause versus cure:** technological and cultural paradox.
- **Humility versus arrogance:** uncertainty of decision making despite increased information regarding global environmental crisis.
- **Intergenerational versus intragenerational equity:** redistribution of resources is ecologically defined but politically impossible trade off.
- **Economic growth versus ecological limits:** 'sustainable' and 'development' is an oxymoron.
- **Individual versus collective interests:** the reconciliation of the two distinctive views. The western culture is epitomised by individual sovereignty, protected through the political frameworks, while sustainability is a collective problem instigated through the sum of the individual preferences.
- **Diversity versus purpose:** potential conflict between diversity of democracy and purpose action.
- **Adaptability versus resistance:** differing kind of resilience in the face of change.
- **Optimisation versus spare capacity:** optimisation is anti-sustainability.

Table 1: Summary of comments on conceptual irregularities

Commentators	Comments
Brandon, 2000; Cecchini, 2000	Vague, ambiguous and ill defined
Meadowcroft, 1999; Oldeman, 1995; O'Riordan Voisey, 1998; Hill and Bowen, 1997; Gatto, 1995	Fuzzy concept and open to a wide range of interpretations
Dovers and Handmer 993; Mullaney and Pinfield, 1996;	Incompatible and incomplete
Pearce, 1989; Daly, 1996	Motherhood and apple pie, a breeding ground for disagreement
Kirby, 1995	Anthropogenic- centred on human welfare excluding other creatures

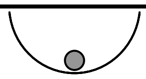
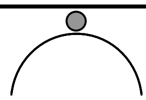
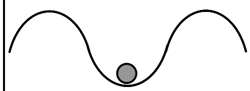
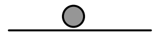
4.3 Time Required for Cultural Change and Lack of Political Will

The pursuit of sustainable development requires a concomitant reform in constellation of social and political forces at the global, national and local levels. Of course this is a cumulative and lengthy process, which requires cultural change. Several voluntary agreements have been reached, particularly during and post Rio Summit, but the political will to enforce them has often been misplaced (Blair, 2005). The regional agreement on sulphur dioxide and a global agreement on ozone-depleting chemicals such as chlorofluorocarbons led to a general optimism that the world is heading towards the right direction and inspired the conventions on climate, biodiversity and the forests. However, the outcomes of the negotiation on these three issues indicate misplaced optimism (Dresner *et al.,* 2002).

4.4 Differing Views and Conflicts of Interest Among Major Players

The differing views and conflict of interest among major players on the ability of the environment to endure human impact are the major reasons for inadequalte policy. This has raised concerns on the effectiveness of the current democratic decision-making and consensus-seeking mechanism to the achievement of sustainable development. Drawing from the work of Thompson (1990), Rayner (1991) and Samson (1995), the conceptual debates on the effect of the global development and environmental change can be characterised using the analogy of four competing views of environment, which represent a mixture of physical and perceived reality (Samson, *et al.,* 1995). As depicted in Table 2, the illustration comprises four topologies of environmental views, demonstrated by a bowl situated in a landscape to represent ideal-typical positions.

Table 2: Summary of the four competing viewpoints

Views of nature	I. Environment is robust	II. Environment is fragile	III. Environment is robust within limits	IV. Environment is chaotic
Visua-lisation				
Comment	Environment is extremely robust and very forgiving of human impact regardless of what is done to the landscape, the ball will always return to equilibrium at the bottom of the basin (Simon 1981).	Environment is extremely unforgiving and fragile to the extent that a trivial knock on the landscape will cause its collapse (Goldsmith, 1993; Devall and Sessions, 1985.	Environment is resilient and forgiving within identifiable boundary, which must not be surpassed or the ball can be knocked over the edge. (Brundtland Report and national/ local strategies)	Environment is random, chaotic unpredictable. Defies any sort of mitigation, control or management. A ball on an flat plane.
Views	**Individualist:** Environmental crises are positive challenges with bundles of new opportunities for human ingenuity.	**Egalitarian:** Global environmental changes are reflection of the multiple negative humans impacts and these will eventually lead to irreversible collapse of the planet	**Hierarchist:** Ecological degradation and natural resources requires carefully management through accurate scientific understanding of ecological limits to avoid global catastrophe	**Fatalist:** Environment is lottery driven cornucopia with sheer luck.
Institution / shared	Business and industry	Deep ecologist	Political institution / Government	Proponents do not often enunciate view.
Solution	Free market and green technology. The invisible hand steer the market in the right direction and the Gov't should have a laissez-faire attitude.	Substitution of anthropocentric hierarchies with bio-centric egalitarianism; living in harmony with environment	Internalisation of externalities; standards and operating procedures; scientific research	Doing nothing is the best solution
Example *(*Tolba et al., 1992, pp 2)	Recovery in Cental American from over use by early settlements to original state of dense tropical jungle.	The problem of desertification and urbanisation.	Kano a large city in north Nigeria has withstood intermittent droughts over many centuries. Forest fires, release essential nutrients contributing to rapid regeneration'	

Each interprets the concept based on his/her own background, personal orientation to justify their own chosen strategy or action, and all opposing views are rouge information, misguided and deliberate attempts to impede economic growth. This calls to mind the South-North and America-Europe divide on forest and climate change negotiations and accounts for the poor progress since Rio Summit. The American negotiate from the premise that 'environment is robust' while the European 'environment is robust within limits'. There is an entrenched dichotomy between individualist (business and industry), egalitarian (deep ecologist) and hierarchies (political institutions), each of which has been observed to display its own distinctive form of rationality that legalises its operation. These become more interesting when the unpredictability and ever-changing faces of nature comes into play, occasionally fitting each of these views, thus alternately testifying the legitimacy of these multiple views, as can be seen from the example provided in Table 2.

5. DISCUSSION AND POSSIBLE WAY FORWARD

The discussion so far suggests that the conventional 'market' and 'political' regulatory arenas are narrow in scope in marrying development with multiple views of environmental capability. There is a disparity between democratic decision-making, consensus-seeking and long-term planning concerning sustainable development (Schomberg et al, 2002). For instance, the review of literature concerning climate change negotiations indicates that negotiations by most national representatives are mainly based on political feasibility rather than environmental acceptability. The reason being, (i) the increasing concentration of power to the few multi-national corporations through globalisation and (ii) probable maximisation of re-election prospect of national governments especially when environmental competes with economic objectives. Many political leaders have a strong inducement to negotiate for, or even reject, the lowest possible level of environmental measures that are achievable with no major economic repercussions and can be presented to the public as a success. The Bush-administration rejection of the Kyoto agreement and disinclination to any reduction of CO_2-emissions is an example (Dresner, 2002).

In view of these, like many authors (Birkeland, 1996; Keijzers 2002; Schomberg*,* 2002), the paper reinforces the need for the so-called third arena of the societal conflict resolution (depicted in Table 3) based on the global ethics of co-responsibility and new deliberative procedures to accommodate conflicting interest and limitations of market and political regulatory mechanisms. The third arena with decision-making process based on debate, mediation and transition management as opposed to the current process of vote and negotiation. The following elements form the main components of the third arena (Schomberg *et al,* 2002):

- **Increase in public debates** at all levels to provide an interface between system and subsystems – politics, law, science and the political decision-making process.
- **Technology assessment** procedures must be established to complement general public debate and to provide an interface between a particular subsystem and the political decision-making process
- **Constitutional change** or structural political change to accommodate the new forms of public debate and the development of transpersonal science and technology assessment processes.
- **Science for sustainability** is a complex system surrounded by scientific uncertainty and ignorance. There is a case for a new type of tool to facilitate smooth science-policy interface. A new decision-making tool for policy makers to assess the quality of the information rather than the truth within each scientific statement. Governance, precautionary principle, and sustainability should be inherently connected to each other to ensure a high-quality policy process.
- **Normative (deliberative) design** based on foresight/back-casting the establishment of normative targets, as a point of departure will help to find a common ground between scientific and policy level. Deliberative procedures such as the application of the precautionary principle help to find consensus on such targets.
- **System innovation** offers a route for achieving sustainability benefits. This requires a 'transition management' with the key elements of formulation of transitional goals and the use of process management based on a philosophy of

learning – by – doing and doing – by – learning, to resolve the long-term goals of sustainability and short-term ambition of the private and public sectors.

- **Visionary Enterprises**: the companies of tomorrow are the one that start integrating long term planning in its core business as evidence of the growing numbers of green consumers. Hence all organisation must develop a visible long term plans.

Table 3: Dimensions of societal conflict resolution (adapted by Schomberg, 2002 pp 20)

Dimensions	Interests	Standards	Processes	Arena
Individuals	Wants/Preferences	Efficiency	Trade	Market
Individuals/ Society	Rights	Social Justice/Equity	Vote/Negotiate	Politics/stakeholder agreements
Individuals/ Society/ Environment	**Needs/ Responsibility**	**Ethics of Responsibility- Precautionary Principle/ Pursuit of sustainability**	**Debate/ Mediate/ Transition management**	**Long term Planning concerning sustainable development/International negotiations**

6. CONCLUSION

Sustainable development like any other evolutionary concept has a long history. The spectrum of challenges and their deep-rooted interconnectivity are the justification for the pursuit of sustainable development. Despite increasing effort to marry the social and environmental challenges with economic growth, progress remains remote. The key main barriers to progress are (i) historical disparity between the two parts of the concept; (ii) lack of clarity and contradictions of the concept; (iii) time required for cultural change and lack of political will; (iv) differing views and conflict of interest among major players; and (v) inadequacy of the current societal conflict resolution mechanism (market and political arenas). To achieve the ultimate goal of sustainability, this paper reinforces the urgent need for a shift to the third arena, which facilitates a smooth integration of public needs (through public debates and capacity building), scientific evidence and policy, and extensive use of innovative tools such as precautionary principle (preventative measure, even without scientific certainty of major human or environment impairment) to ensure a high-quality decision-making process.

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MAPPING KNOWLEDGE FOR A SUSTAINABLE URBAN ENVIRONMENT – TYPES AND BENEFITS

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Abstract: In order for organisations to effectively exploit their knowledge assets, it is important that they effectively identify where knowledge resides. This is at the heart of "knowledge mapping". Knowledge mapping aims to track the acquisition and loss of information and knowledge. It explores personal and group competencies and illustrates how knowledge flows throughout an organisation or 'network'. This paper reports some of the findings from an Engineering and Physical Sciences Research Council (EPSRC) funded project entitled "Knowledge mapping and bringing about change for the sustainable urban environment". This research project investigated the different types of knowledge mapping techniques to bring about change from a sustainable urban environment (SUE) perspective. In this paper, discussions are provided on the different types of knowledge mapping that exist and the challenges associated with their implementation. The paper also provides recommendations with regards to strengths, benefits and evaluation of the suitability of knowledge mapping techniques in different contexts. It is concluded that if chosen and used effectively, knowledge mapping is useful for decision makers working in the area of sustainability. Such benefits include: improved ability to locate knowledge in processes, policies, people, and repositories; and improved awareness of organisational cultural issues, reward systems, knowledge sharing and value, legal process and protection (patents, trade secrets, trade marks) associated with knowledge exploitation in organisations. The full exploitation of knowledge mapping techniques is also dependent on a variety of factors the main purpose of their use.

Key words: Decision making, knowledge mapping, sustainable urban environment

1. INTRODUCTION

Many industries are facing pressure to increase the sustainability of their practice (Parkin, 2000). This pressure, in many cases, imply significant change of an industry's understanding of the demands of society and of its clients, as well as its own corporate social responsibility, and can entail major changes in its work practices. Sustainability issues inherently cut across many boundaries; and are trans-disciplinary and trans-organisational.

This brings to the fore issues of how individuals, groups and organisations make knowledgeable interpretations for sustainability within organisations and professional structures and, in industries based on multi-firm and multi-professional projects, across these boundaries. The above discourse would suggest that the vagaries of different industrial sectors are likely to impact on how knowledge for sustainability is created, transferred and applied. Egbu and Suresh (2005) defined sustainable urban environment (SUE) as "a complex integrated urban system (a mix of natural elements and the built environment) with an ability to absorb changes to key sustainable urban development variables (environmental, economic and social), while answering the needs of the present and future urban users (business and citizens)".

Knowledge in the field of sustainability is also subject to ideological pressures that can be at odds with what makes both business and ecological sense. Under these pressures, from many sources at many different levels of power, decision-making can be either paralysed or pushed into unsatisfactory directions.

The challenge of knowledge management is to understand how to create practical solutions to support individuals and groups as they generate or acquire this multi-faceted knowledge so as to suit the particular requirements of their application context (Van Beveren 2002, Armistead 1999, Alexander et al 1991, Storey and Barnett 2000, Despres and Chauvel 1999, and Coulson-Thomas 1997). Organisations must also grow the capability to share knowledge between specialists and across internal and external boundaries (Quintas 2002).

In a recent research Buckley and Carter (2002) examined the process of knowledge sharing, intra-organisational governance of knowledge, knowledge frontiers within and between multinationals and concluded that both application strategies (use of a given portfolio of knowledge) and discovery strategies (new combinations of knowledge) are important goals of knowledge governance structure. Meeting these challenges would produce great leverage, since it would release more of the untapped value in existing knowledge and will make its communication across a spectrum of uses a more realistic proposition. This is also at the heart of using knowledge more creatively and facilitating knowledge based innovations.

The ability to generate new technological knowledge is now viewed to be linked to a specific learning capability which draws from diverse knowledge bases and is able to activate a systemic recombination process (Antonelli, 1999). The principal purpose and clearest benefit of a knowledge map is to show people in an organisation or within a network/supply chain where to go when they need expertise. A knowledge map can also serve as an inventory. It is a 'picture' of what exists in an organisation or a 'network' of where it is located. It therefore can be used as a tool to evaluate the corporate knowledge stock (e.g. knowledge for sustainability) revealing strengths to be exploited and gaps that need to be filled (Davenport and Prusak, 1998). Knowledge maps are excellent ways to capture and share explicit knowledge in organisational context.

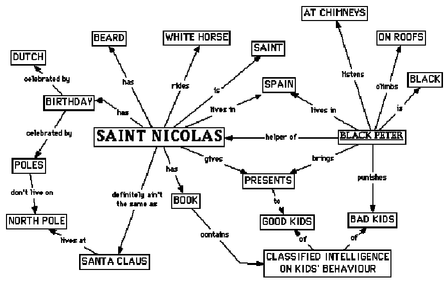
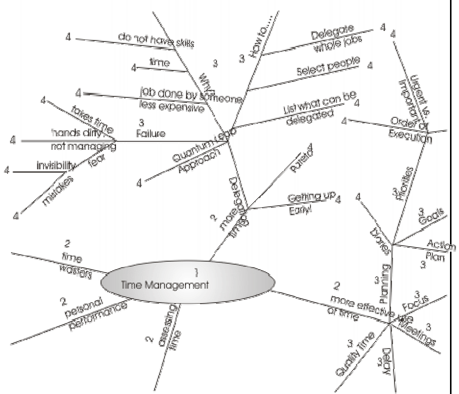
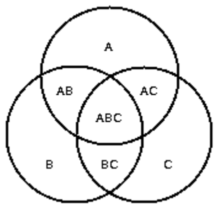
In order for organisations to effectively exploit their knowledge assets, it is important that they effectively identify where knowledge resides. Organisational knowledge also has to be co-ordinated. Knowledge mapping aims to track the acquisition and loss of information and knowledge. It explores personal and group competencies and proficiencies and illustrates or maps how knowledge flows throughout an organisation or 'network'. Knowledge mapping is being experimented within education (O'Donell, 1993), business (Huff, 1998) and healthcare (Birbaum and Somers, 1998).

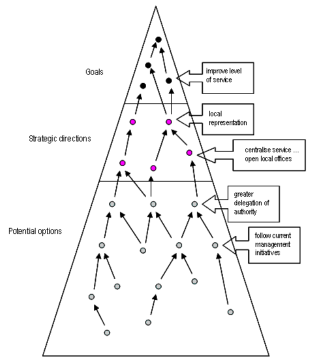
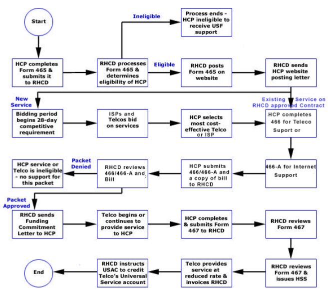
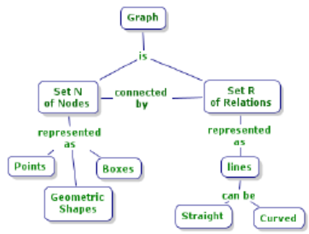
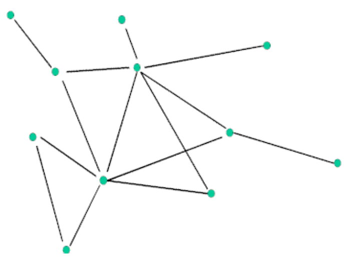
Knowledge mapping in a sustainable urban environment context is in its infancy and has the potential to address a number of challenges that organisations are currently facing (Suresh and Egbu, 2004). This paper reports some of the findings from an Engineering and Physical Sciences Research Council (EPSRC) funded project entitled "Knowledge mapping and bringing about change for the sustainable urban environment". This research project investigated, inter-alia, the different types of knowledge mapping techniques to bring about change from a sustainable urban environment (SUE) perspective. This paper also discusses the challenges associated with their use and implementation.

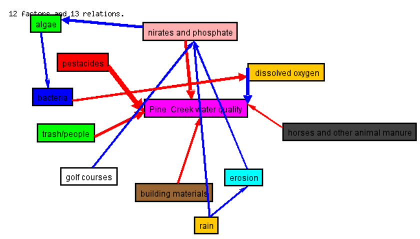
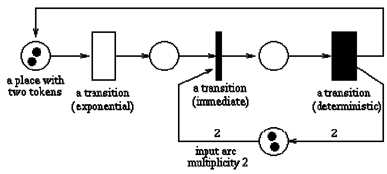
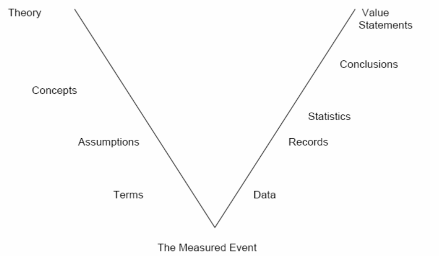
2. TYPES OF KNOWLEDGE MAPPING TECHNIQUES

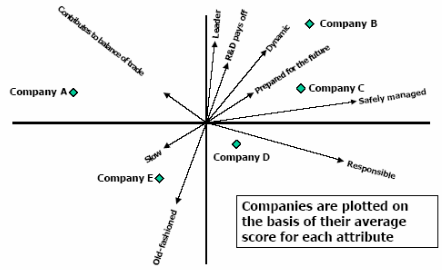
A thorough literature review leads to the identification of **seventeen** knowledge mapping techniques (**Table 1**).

Table 1: Types of knowledge mapping techniques

Description	**Application**	**Schematic presentation**
Concept map Node-link structure in which nodes denote concepts and links show the relationship between these concepts	Express a particular person's knowledge about a given topic in a specific context; explore prior knowledge and misconceptions; problem-solving tool, shorthand form for organising and sequencing ideas	
Mind Map /idea map Begin with one central theme or concept and radiate hierarchically outwards as sub-concepts/additional ideas emerge	Note-taking technique; a way to capture and reflect the processes in the brain; used for training scheme manual	
Concept circle diagram Labelled circles which may be inclusive, exclusive, and/or overlapping to show the relationship between concepts	Show the existing and desired relationship between concepts, organisations, departments etc.; organise ideas into categories	
Semantic map Similar to mind, idea and concept maps; 6 different types: definitial, assertional, implicational, executable, learning and hybrid networks	Used for artificial intelligence and machine translations but also previously used in philosophy and languages	(see concept map)

Cognitive map Mapping of thoughts a person has about a particular situation or problem of interest; from concept mapping to word webbing	Refer to the mental models that people uses to perceive, contextualise, simplify, and make sense of otherwise complex systems	
Process map Blocks of activities or tasks sequenced in a logical way to achieve a specific goal/ objectives include factors like timescale, resources etc.	Define the sequence of tasks which link the actions of people within & across functions in order to achieve a specific goal	
Social mess map / Cross boundary causality map Problems are situated in a tangled mess of causal factors that cross the boundaries of stakeholders, processes, industries and social arenas	Summarise a particular group's understanding of the problems, causes, influences and relevant data about the mess	
Conceptual map Graphical means to compose concepts and conceptual relations	Used as a communication language between individual and computer systems	
Knowledge flow map High-level knowledge models in a transparent graphical form	Used to map and measure relationships and flows between people, groups, organisations and information/ knowledge processing entities	

Causal map Structure of people's causal assertions and generation of consequence following those assertions	To explore beliefs of individual or groups in order to establish cause & effect relationships; 'what-if scenarios'	
Ontology Working model of entities and interactions either generically, or in some particular domain of knowledge or practice; 3 types: domain-oriented, task-oriented and generic	Tool in searching all of the available information in a given field	
Petri net Abstract, formal model of information flow; consists of places, transitions and directed arcs; 2 types: stochastic and generalised stochastic	In search for natural, simple, powerful methods for describing and analysing the flow of information and control in systems	
Cluster Vee diagram Road map showing a route from prior knowledge to new and future knowledge	It has been developed to help students studying science make explicit essential elements to constructing scientific knowledge	
Thesauri Set of concepts in which concept is characterised by hierarchical, synonymous, horizontal, and other relevant relations	Used in retrieval system and modern information (e.g. Web, bibliographic records etc.)	
Visual thinking network Meta-cognitive and knowledge representation strategy that encourages the user to integrate multiple ways of thinking that inform concept formation	A technique by which the user can represent, organise and revise their meaning-making of knowledge by grouping and linking symbolic and pictorial visualisations into a coherent whole	

Topic map Electronic versions of back-of-book indices		
Perceptual map Simply way of taking complicated results from research surveys and presenting them on a clear and informative map	Standard way to visually summarise the dimensions that customers use to perceive and judge products and identify how competitive products are placed on those dimensions	

3. CHALLENGES IN KNOWLEDGE MAPPING IN SUE CONTEXT

In creating graphical representation of an organisation's knowledge asset, some of the major challenges that would be encountered are the handling of the dynamic aspect of the organisation's environment and the dynamic character of the knowledge base itself. Some knowledge loses its value over time, other knowledge may be replaced with superior knowledge, and some knowledge may simply be forgotten. This calls for a dynamic approach to knowledge mapping. Sustainability, as a dynamic process, supports continuous changes in economy, society, environment, technology, culture and value etc., namely developments. However, under the context of sustainability, development does not automatically equate to growth infinitely or stagnation, but developments evolve in a way that adapts to changes and improves the connection between economy, environment and society, rather than fixing one area while causing problems in another.

Therefore representing the knowledge processes to bring about change in sustainable urban environment would be a challenge. This is because most knowledge mapping techniques are static in nature and they can only symbolise one concept at a specific time. Sustainable urban environment has parallel factors or concepts on which its delivery is dependant. Some of these factors are man-made and some are natural and most knowledge mapping techniques may not be able to consider these factors in parallel time while mapping the original concept unless knowledge is represented with the help of artificial intelligence.

Also, mapping of knowledge between different users with different perspectives and purpose is a key challenge because of the possibility of miscommunication in maps between map-makers and map-users who might not share the same language, or do not see eye to eye. This is because knowledge maps are abstract, they capture representations and these representations, to be useful, must be shared and understood. The only way to successfully increase the probability of knowledge map communication is to ensure that the map-makers and the map-users share the same symbols or representations or the ''legend'' which accompanies the knowledge map is sufficiently clear, simple and useful. This integration has always proved very difficult to achieve in practice (Seeman and Cohen, 1997).

4. BENEFITS OF KNOWLEDGE MAPS IN SUE CONTEXT

To a large extent, organisations will only reap benefits from mapping their knowledge depending on the strategies they have in place. Such strategies should be geared towards ensuring that the knowledge map encourages sharing of information and identifies areas of expertise. This will ensure that bridges of co-operation are built to increase productivity.

Essentially, knowledge map encourages the re-use of ideas and processes. It also prevents the re-invention of the wheel. Knowledge maps improve the ability of organisations to locate knowledge in processes, relationships, policies, people, repositories and context. Knowledge maps can help in the recognition of barriers to the flow of sustainable knowledge within and across organisations. Hunt (2003) also suggests that knowledge map may provide a possible answer to the challenges of how to locate new forms of useful knowledge, and the flow of knowledge within and across the organisations, including new directions for training employees, stimulating and facilitating knowledge sharing, and establishing useful links with external stakeholders.

Knowledge maps can quickly connect experts with each other or help novices identify experts promptly. As a consequence, knowledge maps can speed up the knowledge seeking process and facilitate systematic knowledge development since they connect insights with tasks and problems. Knowledge maps also assist in communicating the results of restructuring, re-engineering and organisational changes to those involved.

Other benefits of knowledge map are:

1. It helps in finding critical information quickly and highlights islands of expertise,
2. It provides an inventory and evaluation of intellectual and intangible assets,
3. It improves awareness of organisational cultural issues, reward systems, knowledge sharing and value,
4. It provides legal process and protection (patents, trade secrets, trademarks) associated with knowledge exploitation in organisations,
5. It improves decision making and problem solving by providing applicable information,
6. It provides insights into corporate knowledge, and,
7. It increases the ease of access to all in the organisation.

5. RECOMMENDATIONS AND CONCLUSIONS

Knowledge mapping techniques can be applied successfully in order to facilitate the change in sustainable urban environment (SUE) by mapping best practices and identify the gaps in process of sustaining the urban environment. Knowledge mapping forms a key technique for knowledge management initiatives, since key competitive decisions can be taken based on the resulting transparent overviews of knowledge maps.

When creating knowledge maps within the context of SUE, the following two factors needs considered:

- During the development of knowledge maps, a three dimensional approach is required which maps the knowledge within the economic, social and environmental context.

- Most knowledge maps tend to include technical knowledge for processes and skills but it is recommended that knowledge maps should also include the 'generic processes and skills' which are required to facilitate the change in sustainable urban environment.

It is also recommended that within the context of SUE, we may have to come up with an innovative way in terms of representation of knowledge maps. Sustainability is a socio political process and to represent the knowledge within this context, we can not wholly rely on computer based representation of the knowledge. Human factor is essential to representing the knowledge within the SUE context. One of innovative way in capturing the socio-political tacit knowledge is to establish a community of practice for sustainability knowledge sharing and perhaps representations.

Knowledge mapping tools have the ability to effectively identify and coordinate organisational knowledge. Knowledge mapping tools also aim to track the acquisition and loss of information and knowledge. It maps how knowledge flows throughout an organisation or 'network'. This paper has shown the different types of knowledge mapping techniques that could bring about change from a sustainable urban environment perspective. The most important challenge associated with the use and implementation of knowledge mapping tools is the need for a dynamic approach to knowledge mapping. This is due to the dynamic characteristics of sustainability and knowledge itself.

Presently, most knowledge mapping tools are static and might require the help of artificial intelligence to make it dynamic. But all is not lost as strategic implementation of knowledge mapping tools within a sustainability urban environment is very useful for decision makers working in the area of sustainability. Some of the benefits of knowledge maps are improved ability to locate knowledge in processes, people, repositories and context; and improved awareness of islands of expertise and evaluation of intellectual and intangible assets, improved decision making and problem solving by providing applicable information, and effective knowledge sharing associated with knowledge exploitation in organisations. The full exploitation of knowledge mapping techniques is also dependent on a variety of factors and the main purpose of their use. While knowledge mapping for sustainability urban environment has been deemed important this has been relatively under studied by researchers. Research in this area has the potential to contribute to an improved understanding of how to continue to exploit knowledge mapping for improved sustainability urban environment performance.

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THE EFFECT OF FLOODS AND FLOODPLAIN DESIGNATION ON VALUE OF PROPERTY; AN ANALYSIS OF PAST STUDIES

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Abstract: The frequency of severe flood incidents in the UK and worldwide is increasing resulting in heightened interest in the implications of flooding on floodplain residents and the wider community. Short-term impacts include severe disruption to normal business, damage to buildings and increasing flood insurance claims. For property owners, the long-term cost of a flood can include loss of property value because potential purchasers are deterred by the risk of repeat flooding. Property can also suffer reduction in equity, without having a history of flood damage, due to location in a designated high-risk area. This paper examines the evidence from previous studies in the UK, US, Canada, Australia and New Zealand to determine the range of measured flood effects and detect any broad patterns. The magnitude of estimated impacts varies widely across studies, partly because both flood events and floodplain designation have been considered, partly due to the quantity and quality of data available but also due to the highly local nature of floods and the risk awareness of house purchasers under different disclosure regimes. Lessons are drawn from the methodologies, including data collection and analysis problems to inform a proposed study of flood impacts in the UK.

Keywords: Flood, price, property, review.

1. INTRODUCTION

Flooding is an increasing phenomenon, not just in the UK but worldwide, see for example Munich Re (2004), Halligan (2004). The increase has been blamed on climate change, global warming and the melting of the polar ice caps although experts disagree on the extent and speed of this change (Office of Science and Technology, 2004). Additional factors in the UK are the natural erosion of the coastline and the slow tilt of the country towards the South East. The increasing urbanisation of the world means that the activities of mankind have increased the amount of properties at risk of flooding whether or not the climate is in a permanent shift (Clark, 2002). Properties continue to be built on the floodplain and there is some evidence that the actions of governments in building flood defences has increased the tendency for floodplain development (Boase, 2005). In addition to this, in the UK, the value of property at risk has increased as homeowners have increased investment in their homes in carpets, fitted kitchens and other fixtures which cannot be easily removed in anticipation of flooding.

Recent events in the UK, particularly the floods of Autumn 2000, Boscastle in 2004 and Carlisle in 2005, have focused the media and public mind on the impact of flooding on homeowners and businesses in the centre of vulnerable conurbations. There have been many newspaper articles covering the immediate aftermath of storms and floods and much speculation about the impact on insurance and house prices, for example Hughes (2000), Halligan (2004) and Thompson (2005). In a first attempt to assess the real effect of flood disasters and flood awareness on property value the existing evidence in the literature is analysed. It emerges that there is a body of literature that examines the effect of living on a floodplain, concentrated largely in the United States where flood insurance is compulsory for floodplain residents. There is some work in Canada, Australia and New Zealand and two lone studies in the UK. This paper summarises that literature and attempts to draw from it some insights into the possibilities and difficulties in generating models of flood effects on house prices. This will feed into an ongoing study into the impacts of flooding on residential house prices in the UK.

2. LITERATURE REVIEW

The findings from studies from the UK, US, Canada Australia and New Zealand are grouped below by country. When interpreting the results from the research to date, and particularly its relevance to the UK it must be borne in mind that different disclosure regimes exist across the world and this seems to be partially reflected in different observed impacts. Potential purchasers may become aware of flood risk status at various stages of the buying process. At one extreme personal experience, or high media coverage, may ensure that all buyers are aware of local flood issues. At the other extreme sits the normal situation in the UK where there will be ad-hoc discovery of flood risk.

2.1 UK Findings

The UK studies (Building Flood Research Group (BFRG), 2004; Eves 2004) are both based upon surveys of valuation professionals, thus the prices examined are assessed prices and depend heavily on the experience of surveyors. Both authors are reluctant to fix upon an absolute figure for discount of flooded or floodplain property because of the wide variation in responses. For example BFRG (2004) found the median discount to be 12-15% but the responses indicated a wide range of opinions among valuers even when working in the same market. It is also concluded that there is no consensus on the length of recovery, the median value is 3-4 years. There is consensus in that flooded properties may stay on the market longer than other similar properties, and that a slight discount for floodplain properties not previously flooded may be expected. This study illustrates both the difficulty of the problem and the need for some guidance for valuers on the matter. High insurance premiums on previously flooded properties are identified as a possible driver for price discounting. Another aspect stressed by Eves (2004) in particular is the positive value placed on riverside location, which acts in direct opposition to the risk of flood.

2.2 Australian Findings

Eves (2002) studied the effects of flooding on the housing market in Sydney. It was concluded that in periods of flooding there is a discounting effect for flood-prone property, peaking at about 16%. As the gap between floods increases this discounting ebbs away and flood-prone property catches up with its flood-free equivalent. Lambert and Cordery (1997) studied floods in Sydney and in Nyngan. In Sydney they observed some small and temporary impacts. In Nyngan, where the whole town was deluged, and where again the main effects were temporary, prices were depressed for about 6 months following the flood. There was some suggestion that a slight divergence in long-term growth between Nyngan and the control community could have been caused by memories of the flood. An examination of repeat sales of houses sold immediately following the flood at a depressed price and then resold shortly afterwards shows the action of opportunist entrepreneurs making gains well above expected returns, presumably after some investment in reinstatement. Faith in the long-term recovery in prices seems to be widespread and borne out in reality.

2.3 New Zealand Findings

Montz (1992) studied the effect of events in three New Zealand communities. No precise estimates of impacts are presented, however, the conclusions are that all flood effects are temporary. In Pearoa a temporary dip was observed, in Te Aroha the whole community, not just those properties flooded, experienced decline and in Thames while there was no effect for a first flood, a second flood affected the whole market. Four years after the flood in Te Aroha the flooded properties had recovered more than the non-flooded and in Thames the non-flooded properties seemed to suffer more discount from the second flood than the flooded properties. In a further study of two of these communities Montz (1993) demonstrated that subsequent disclosure of flood risk via planning constraints had no effect on the value of properties.

2.4 US Studies

In the US as mentioned above, there is great interest in the designation of floodplains because in some areas of the country, where credit is required, flood insurance is compulsory and is subsidized by government. A summary of results from studies undertaken in the US is presented in table 1. The studies vary between testing properties actually flooded and properties designated at risk of flooding. This can be a very important distinction. Actual inundation might be expected to heighten the concern of potential buyers, if they are made aware of it. Designation on the other hand may carry with it obligations on the future resident and may not correlate well with actual flood risk. In many cases the accuracy of categorisation is poor. For example in Houston, Texas (Skantz and Strickland, 1987) a flood occurred in 1979 and of the 33 studied properties that were actually flooded only 10 were in the 100-year floodplain. The research also differs in whether it tests for the temporary effect of specific events or looks at the long-term static effect of floodplain.

Results worth highlighting include a study by Tobin and Montz (1994) in Wilkes Barre, Pennsylvania that found a positive effect of flood in that the prices of flooded properties were higher after the flood, relative to non-flooded properties. This is similar to the effects that Montz (1992) discovered in New Zealand. The authors propose that this may be due to investment in the damaged houses resulting in improved quality in the flooded sub market. In Wilkes Barre it could also be attributed to the lack of alternative property. The Skantz and Strickland (1987) study observed no direct impact following a flood but saw, albeit weak evidence, that later insurance increases triggered a depression in house prices.

Table 1: Summary of findings from US flooding studies

YR	AUTHORS	PLACE	FLOODPLAIN EFFECT
2004	Troy and Romm	California	-4.2%
2003	Bin and Polasky	Pitt County North Carolina	-8.3% post flood -3.7% pre flood
2001	Harrison et al	Alachua County, Florida	-2.9%
2001	Shultz and Fridgen	Fargo/Moorhead NorthDakota/Minnesota	-9%
1994	Tobin and Montz	Des Plaines, Illinois	No effect
1994	Tobin and Montz	Linda and Olivehurst California	-30% >10ft flood -10% 18" flood
1994	Tobin and Montz	Wilkes Barre, Pennsylvania	Positive effect.
1991	Speyrer and Ragas	New Orleans, Urban Suburban	-6.3% -4.2%
1990	Bialaszewski and Newsome	Homeworld Alabama	no effect floodplain location
1989	Shilling et al	Baton Rouge, Louisiana	-8% floodplain location
1989	Donnelly	La Crosse, Wisconsin	-12% floodplain
1987	Skantz and Strickland	Houston, Texas	No effect. Effect of insurance rate increase
1987	Macdonald et al	Monroe Louisiana	-8.5%
1979	Zimmerman	New Jersey	No effect
1976	Shabman and Damianos	Alexandria, Virginia	-22%

2.5 Canadian Findings

The Canadian experience is somewhat different; floodplain regulation is weaker than in the US and is aimed at controlling development on the floodplain. Disclosure is not widespread and so perhaps it is not surprising that of seven studies quoted by Schaeffer (1990) only one found any significant discount. The Schaeffer (1990) study itself, based on a very small sample, produces confusing and inconsistent results. Three different methodologies are applied and the outcomes are dependent on the methodology. One approach yields no significant effects while the others show marginal price depression due to floodplain. The effect of subsequent designation is seen, against expectation, to raise the prices of designated property. A survey of homeowners by Babcock and Mitchell (1980) seems to show that even in high-risk areas, and with homeowners, who had suffered flooding in the past, perception of risk is low and very few had purchased flood insurance. This was reflected in the house price data where no significant impacts were detected.

3. ANALYSIS OF METHODOLOGIES

Many of the studies summarised above are based on a hedonic model of house prices. Where sufficient data is available this appears to be the preferred method (MacDonald, 1987; Shilling et al, 1989; Donnelly, 1989; Harrison, 2001; Bin, 2003; Troy and

Romm, 2004; and others). Hedonic models are based on a utility function, breaking price down into a function of a set of preferences for various aspects of the heterogeneous commodity of housing. Aspects considered might be physical properties of the house, such as the number of bedrooms, or locational variables such as proximity to local amenities or transportation. The result is a regression model of some form where the influence of each factor is estimated with least squares.

Variations on the hedonic or regression model include alternative methods of dealing with locational variation for example Speyrer and Ragas (1991) who used spline variables in the regression to model location and by Troy and Romm (2004) who used layering, that is taking information on locational attributes at a more aggregate level than the pricing information. An extension of the regression method was used by Skantz and Smersh (1987), adapting events analysis from the financial sector. Predictions are made from the estimated model and the residuals examined over time. This method shows where deviations from the equilibrium model occur in time and then this can be linked to events in the market, in their case a huge increase in insurance cost. An interesting adjustment to the hedonic methodology was employed by Shabman and Damianos (1976). In attempting to model the flooded sub-division, the explanatory power of the model was low. Using the model developed on the non-flooded control area, predicted values were compared to actual transaction prices in the affected zone. This same method was subsequently employed by Schaeffer (1990).

Other studies (Tobin and Montz, 1994; Eves, 2002) look at raw sales figures over time. Means are compared before and after events. The variability of house sales, mix effects, seasonality and other market events may confuse the picture when looking at raw sales data but this may be a useful methodology either as a first step or where specific flood events are examined on well understood sub-markets or where good information on location and mix variables is not available.

Repeat sales was used by Montz (1992) and others. In this method the problems of differences between properties is removed by considering the differences between serial sales of the same property. This method is most useful in analysing prices before and after a flooding event or where growth rates are different between flooded and non-flooded sub groups. In those markets where frequent flooding or floodplain regulation has resulted in permanent capitalisation into property price, repeat sales would not capture the effect. Finally the UK examples are based on surveys of expert opinion and Babcock and Mitchell (1980) also use surveys to test perceptions of homeowners and real estate valuers.

4. LESSONS DRAWN FROM THE LITERATURE

The above examples of work examining the influence of flooding on property value illustrate some of the issues that will face the proposed research in the UK. Below is a summary of the lessons that can be utilised in any future work

4.1 Data Requirements

Firstly, and most obviously is the availability of data. It is clear that to build models such as those quoted above, highly detailed data on individual properties is necessary.

Data is needed on house prices, property details and locational variables. Information on the flooding incident is also desirable, including which houses were flooded and to what depth. As mentioned above, relying on floodplain designation as a proxy for properties flooded may be risky and result in underestimating the effects of flooding. In using designation to look at capitalisation of flood risk in the absence of flood it is important to establish the profile of the designation and whether the official designation correlates with the populations perception of that risk. The burden of collecting such data and the necessity that houses have to change hands during the study period has resulted in small sample sizes for many analyses. Availability of data has in many cases determined the methodology used and so data collection is of primary importance in such housing research.

4.2 Explanatory Variables

In the US models the variables commonly included are: Size of heated accommodation, size of unheated accommodation, size of plot, presence of air conditioning, fireplace, garage, number of bathrooms, number of bedrooms, age and date of sale. Some studies (Bin and Polasky, 2003; Troy and Romm, 2004 and others) also include locational variables, distance to airport, rivers, major roads or specific estate variables. Troy and Romm (2004) also include socio-economic variables by census tract. In general, size, age and number of bathrooms are strong explanatory variables. In the UK one would anticipate that some of these would be less relevant such as air conditioning and other additional locational variables may be needed. A review of UK housing studies, not related to flooding will help to identify the most important variables for the UK.

4.3 Time Period

This will very much depend on the sort of research intended. If a particular event is to be analysed, sufficient observations before and after the flood must be taken, and time must be allowed for the market to return to equilibrium. Lambley and Cordery (1997) reported recovery in under a year. Tobin and Montz (1995) however, in revisiting Linda and Olivehurst eleven years after their first study, suggest that for the homes flooded to the greatest depth recovery may take longer than ten years. The long-term impact of the flood was exacerbated by the presence of properties that were not renovated quickly after the 1986 flood. It would seem that the maximum possible time period must be examined. If, on the other hand, a static hedonic model is constructed, then, ideally, the shortest time period should be used which provides sufficient data points. The choice of a period of relative stability is desirable, not too close to any disruptive events. In most markets a fairly long time period will be necessary in order to obtain sufficient observations, the researcher must then deal with the effects of inflation during that time.

4.4 Dealing with market Inflation

In most of the models above either discounting (Bin and Polasky, 2003), or a time trend variable were added (Skantz and Strickland, 1987). Time trend variables in linear models have the defect that they can only generate a steadily increasing (or decreasing) market; in real examples this is not very likely. Speyrer and Ragas (1991) used dummy variables for each year because they identified a non-monotonic trend in house prices. Use of discounting raises the problem of which discounting factor to use. Regional house price indices are not always available and constructing a local index specifically for the study increases the data demand or leads to bias if too small a sample is used. Comparison against a control group was used by Montz (1993) and Shabman (1976) however careful choice of this control group is necessary.

4.5 Number of Properties

Given the difficulty in obtaining data, it is unlikely that any study of a flooding incident would collect too much data. In the UK where most flooding incidents affect relatively small numbers of properties, lack of data could be a real issue. Previous research has been carried out on samples ranging from just under one hundred (Bialaszewski and Newsome, 1990) to many thousands (Troy and Romm, 2004). Typically if designation is studied then more observations are available than if an actual flood is examined. Given the high variability of house price data and the large number of variables necessary to account for all influencing factors, the larger the dataset the better. The smaller the sample the more likely it is that omitted influential variables will bias the estimate of the impact of flooding. Of course the collection of data is expensive in terms of time and money and this should be balanced against the increased reliability of the results. If a predictive model is required then an even larger set is needed in order to allow for testing of the model on a held back sample.

4.6 Functional Form

Where a regression model is utilised, many authors discuss the use of different functional forms. The theory does not predict a particular relationship and so the choice is an empirical one, often based on best fit. Linear and Log/linear are the most common selection. Where more than one form has been tried, the overall conclusions have not differed between models (Shilling et al, 1989). It is probable that other considerations such as collinearity have a greater bearing on the outcome of the model. Bin and Polasky (1993) use a log transform for distance related variables based on the experience of other housing studies. Unless there are theoretical reasons to choose alternative forms or unless data exploration clearly demonstrates a specific non-linear relationship, a linear model should be preferred with testing of residuals to determine if it is adequate. Troy and Romm (2004) used a semi logarithmic model after examination of residuals from a linear estimation.

4.7 Partitioning the Data

Datasets may need to be divided in the time dimension or into sub markets as building one model of the whole market may not be an effective strategy resulting in poor estimation and reducing explanatory power. Firstly consider the case where a flood or new legislation imparts new information on risk to the market. The house buyers' perception of the relative desirability of properties in and out of the floodplain will change after the event. Harrison et al (2001) built three models, one before and one after the implementation of the National Flood Insurance Reform act in 1994 and one over the whole time period. They found that the price discount due to floodplain location doubled after the implementation, while estimates of other factors remained fairly robust across the time periods. The third model, utilising the whole time period and including a dummy for post implementation discount gave an even higher estimate post reform discount, however, this is no longer significant. Their results demonstrate the danger of using a global model, in this case detecting no significant effect from the legislation. Research should begin, if possible, by estimating pre and post flood and testing whether the models are significantly different. An alternative to using different models would be to use a model that allows for time varying effects.

Secondly consider the case where there are different markets for floodplain and non-floodplain property. This could be due to differences in type of property. In New Zealand Montz (1993) found that houses in the flood plain differed, in terms of average physical attributes, from those outside it and therefore compared trends within sub markets. Differences could also occur in the type of buyer, they might be poorly informed individuals, cash buyers or buyers who are in the market for “development” or “investment” property. Troy and Romm (2004) for example found that hazard disclosure had a significantly greater impact on Hispanic neighbourhoods of California than non-Hispanic communities. Research should consider likely sub markets to ensure that smoothing across sub markets does not affect significance testing but also to generate a deeper understanding of the underlying process. MacDonald et al (1987) split their dataset to check the homogeneity of their test neighbourhood. They observed higher impacts in one neighbourhood that consisted of higher priced properties.

4.8 Collinearity

If the independent variables used in a predictive model are correlated to one another then they are described as collinear. This is a common problem in housing studies where, for example, lot size will be strongly related to house size. Collinearity results in biased estimates of the partial regression coefficients; they cannot then be used for robust prediction. Most authors in this literature search have ignored or sidestepped the problem, simply selecting the variables with the most explanatory power. Presumably the assumption is that there will not be much correlation between flood variables and the rest. Troy and Romm (2004) touch on the issue. Their model included a Hispanic/disclosure interaction term that demonstrated that the strength of the effect of disclosure varied with the percent of Hispanic residents. Hispanic concentration was highly correlated with floodplain location, they posit due to financing arrangements. Bialaszewki and Newsome (1990) tested whether multicollinearity had affected their results using stepwise regression and by examining the correlation between other independent variables and the flood variable. They concluded that it had not changed the outcome. Collinearity can be dealt with by a number of methods such as principal components analysis or residualisation, see Donnelly (1989) for an application of residualition.

5. CONCLUSIONS

The outcome of published analyses into the effect of flooding on property prices has produced a wide range of estimates. This is in part due to differing definitions of flood effect and also to the proximity of a flood event. The consensus is that the impact of a flood event declines over time as people forget about it and permanent capitalisation of flood risk into price is largely due to regulated disclosure of flood designation. This implies that in modelling the long-term effect of flood it is vital to choose stable time periods or to use the shortest possible time period. Alternatively models could recognise the temporally adaptive nature of the market and not force flood response to be constant over time.

The measured effect of flooding is also highly dependent on local issues such as frequency of flooding and availability of alternative housing. Some studies observed that there was no depreciation due to flooding. One counter-intuitive result is observed in which flooded houses increased in value relative to non-flooded. This could be explained by the impact of reinstatement resulting in betterment. It seems unrealistic to expect all UK flood risk zones to demonstrate the same pattern. Equally it does not seem possible to say a priori, from the literature, exactly which factors will come into play in a given flooding scenario. For the UK the development of local models is a logical first step. A build up of experience may make national generalisations possible in the longer term.

In the published research some form of hedonic modelling is the preferred methodology where sufficient data is available. Data availability often dictates methodology. Repeat sales analysis is a methodology that allows for testing of flood events and reduces the requirements for explanatory variables. Great care needs to be taken in defining test and control groups as lack of precision could lead to erroneous results. Sub markets need to be considered, certain property types or neighbourhoods may be more vulnerable to the effects of floods than others.

In the UK detailed data on property transactions is not so readily available as in other markets. UK studies have used surveys to canvass expert opinion and from this research availability of insurance is identified as a possible mechanism for disclosure of flood risk. The UK work also highlights a river view as a positive driver for house price. This would be a severe nuisance factor for a study concentrating on riverside properties. An examination of the general UK housing literature would help to identify key explanatory variables specifically relevant within the UK housing market.

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TIME PERCEPTION IN RELATION TO ARCHITECTURAL SPACE

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Abstract: Time and space are the essential and perpetual themes of architecture. Perception of time influences the built environment with its requirements in our everyday lives. This study underlines that the way of understanding and constructing time alters in parallel to the mechanical and then digital understanding of time. In order to limit the study, clock tower and mobile phone are given as symbolic examples for each period respectively. The effects of time perception are explored in order to clarify the requirements of contemporary "Artificial Intelligence Age" and the new era. Cosmic, public and personal time constructions are specified so as to shed light on the transformation of architectural space. In order to dwell on the changing dynamics of time and its perception, this research is an intention to reveal the substantial importance and direct influence of time perception, to give an insight for architects and designers to grasp the everyday influence of time and temporality.

Keywords: Architectural Design, Architectural Space, Time Perception.

1. INTRODUCTION

The rapid transformation of our environment is affected by our lifestyles and also influences our everyday lives. We can feel this through the transformation in our built environment as well as in every part of our lives. It is obvious that the way of living changes with new technologies, with new scientific inventions, economic developments, cultural transformation, and thus with the perception of time. The habits of life, patterns of thought and values are all altering with these dynamics. Architecture is also in the cycle of life and it is rebuilt to reconstruct the quality after major transformations, which has become a function of time in today's city.

This paper concerns the relationships between the physical form of the urban environment and time perception and it is rather an informative study for designers' improved understanding of time and temporality. It is considered that, different societies may have diverse concerns about time. In this study, time will be cited as a social construct and will be considered more social than natural. Therefore, measurable time, being the standpoint of modernization process, will form the structure of this paper. Personal use of invented objects or contemporary condition of miniaturization will be given an additional emphasis, in order to discuss the subject in relation to the social meaning of time.

In this study, the transformations that entered our lives with the clock tower are exemplified, in the sense of a rupture in the perception of time, to clarify the alteration from natural time to mechanical. Then the alterations in our perceptions, which appeared with the introduction of the mobile phone, are demonstrated hoping to shed light on the transformations in our everyday lives.

1.1 Aim of the Study

Unlike the Modern and Premodern ages, today we are experiencing the digital understanding of time. Therefore, the object of this study has been to describe the condition of the city of the 21st century from the perspective of time, for the consideration of further works of architects and designers.

1.2 Method of the Study

In the present paper, time perception is classified as cosmic, mechanical and digital. Still, cosmic time is not the substantial focus and measurable time is underlined in relation with technological developments. To understand and to conceive the modern notion of time, modern time perception is discussed with its indicator mechanical clock considering natural and digital time perceptions. Then, the indicators are discussed with their reflections on spatial perception and on socio-cultural and urban structures, to gain further insight about this dynamic relationship.

Other than natural occasions, clock towers, pavement clocks, watches, press, radio, television, and today mobile phones can be counted among the mechanical and digital devices that were assigned the obligation to notify time and to communicate. To clarify the changing time perception, and to conceive a collective time perception with the regularization of time, two examples of indicators of time are chosen; clock tower being the first instrument of defining and measuring the abstract time for a society; and mobile phone, being one of the contemporary instruments of delimiting time to a single individual. These two indicators of time are also selected for having radically different spatial returns and having the characteristics of starting the alienation process from nature and transforming the social connotation of time.

To illuminate the transformation of space, the examples are chosen from the field of commerce, which is one of the functional factors that have conditioned the sizes and plans of cities and their physical existences. These two examples, which take place in public spaces, are given to make possible the argument of daily movements of the crowds and attraction zones of cities for the public use. Although many examples could be given to exemplify the subject, clock tower – market place / bazaar and mobile phone – shopping mall couples are given as symbolic examples in this study just to determine the limits. Market place / Bazaar is situated in the town center with the clock tower and shopping malls are the contemporary spaces of public domain. These two examples show contrasts in their spatial and cultural usage.

Clock Tower is one of the indicators of time. This device is mostly attached to the city square, in which daily activities take place. In the spaces like bazaar, coffee-house and worship spaces, clock towers help the identical understanding of time. These dynamic public spaces of daily activities have the power of spreading its own energy. Here, clock tower helps to structure the communication between public and private spaces and to order the physical flowing (Cengizkan, 1999, 97).

Mobile phone is another indicator of time in our day. This device has allowed continuous and free communication for more than last ten years. Today mobile phones are not only tools for communication, but also kinds of technological computer. With several properties of a clock, alarm, schedule, organizer, calculator, camera and many others, they also have the obligations of declaring and even establishing time. For providing continuous and free communication from space, it is possible to state that mobile phone removes the boundaries between public and private space, so that the notion of space disperses. In the temporality, time perception and space construction of 21st century, shopping malls can be referred to as "compact city centers". Replacing the ancient city square, shopping malls became important attraction and interaction zones in the city.

Current study, targets to be a research of reflections onto the transformations and alterations of social, cultural and economical changes in contemporary architectural and urban spaces as well as in human psychology, from clock tower to mobile phone. Therefore it is a research of the themes of time perception and space construction.

2. ABSTRACT TIME PERCEPTION AND THE MECHANICAL CLOCK

Time can be defined as the system of those relations which any event has to any other as past, present, or future; or indefinite continuous duration regarded as that in which events succeed one another; or a particular period considered as distinct from other periods (The New Grolier Webster International Dictionary of the English Language, 1973).

According to Gurevich, social time differs not only among different cultures and societies, but also within each socio-cultural system as a function of its internal structure. There is not one single 'monolithic' time in every society; instead, there exists a whole series of social rhythm governed by the laws of different processes and by the nature of various human groups (Gurevich in Gardet, 1976). The progress of a society and its culture is shaped within the structure of social consciousness. Time perception, being one of the main components of this structure, shows the fundamental trends in a society.

In pre-modern cultures, there was no need to connect the events with time nor to date them; time was usually linked with place. Telling the time without any reference to any social or spatial markers was nearly impossible. But in large and powerful states, in order to share the common sense of time between the individuals, the necessity for determining and organizing time increased.

Mechanical watch is evaluated as the main reason or the base of modern idea of time, almost in every scientific work. It has taken over an ordering role in organizing the social practical with a new cycle. With the invention of the mechanical clock, time perception was altered from cosmic to modern. All technical tools and machines were added to the opportunities of nature before the mechanical clock; nevertheless, this invention either worked with nature's occasions or joined them. By working absolutely in self-regulation without nature, it organized an unusual lifestyle with its own cycle. Therefore, the invention of the mechanical clock caused a separation from space with the virtual understanding of time. With universally accepted, equal intervals of hour and its smaller units, space also became representational, in its own three dimensional reality. This distinction is considered to start the process of modern time and modern space – time concepts. Hence, mechanical time determined the boundaries of Modern and Premodern ages (Tanyeli in Davidson, 1998).

As McLuhan mentions, the natural needs of man came to arrange themselves to the clock rather than to the organic needs.

As a piece of technology, the clock is a machine that produces uniform seconds, minutes and hours on an assembly-line pattern. Processed in this uniform way, time is separated from the rhythms of human experience. The mechanical clock, in short, helps to create the image of a numerically quantified and mechanically powered universe… Time measured not by the uniqueness of private experience but by abstract uniform units gradually pervades all sense life (McLuhan, 1964, 146).

In relation to that, Elias states that we certainly use mechanical clock to measure something. However, the thing we measure is not that abstract 'time', but something concrete; the so-called, 'the length of a workday', or 'the period of moon eclipse', or 'the speed of a runner in a 100-meter race' (Elias, 2000, 16). Becoming 'as regular as clock-work' (Mumford, 1934, 16), the increasing tempo of civilization required a greater power and in line, power accelerated the tempo. Unlike the irregular regimentation of time in the past, this tempo started to structure the entire World.

Mass production can be considered to be a reason for this process. Specifically, the wide use of cheap watches, which were first produced in Switzerland in the eighteen-fifties served for proliferation (Mumford, 1934, 197). For their individual use, watches are excluded from the focus of the present paper as far as modern time concept is exemplified with clock tower for measuring the abstract time for a society. Still, this modern construction of time had its own spatial patterns, which will be discussed in the next chapter.

3. SPATIAL REFLECTIONS OF TIME

With the ongoing developments in science and technology not only the socio cultural values of societies but also the time and space perceptions changed and transformed. These developments in technology of communication, electronics, industry and nuclear, formed the bases for both opportunities and problems. Values, which shape and order life styles, altered immediately. Architectural culture is also in a process of transformation with all these transforming dynamics. In the rapid period of transformation, reflections to architecture can be mentioned as the demolition of the old and the construction of the new. This took place in such an enormous amount that, a collapse in cultural, historical and social structure was observed. Therefore, the altering time perception is seen influential in transforming and defining the structures of cities, the built environment and the building types by imposing changes on the everyday life.

Public spaces that are created by societies in time reflect the public and private values. As Madanipour mentions, in pre-modern urban settings, public spaces such as urban squares and market places played the role of arenas for public communication and these were places where the social interaction of people took place. The squares which were fronted by town halls, religious buildings and together with commerce became natural meeting grounds for the masses (Madanipour, 1996).

Being an indicator of time, clock tower took the obligations of declaring and establishing time, from the bell towers of churches or minarets of mosques of that period. Clock tower was usually situated at the city center, at such a distance that its bell could be heard from the periphery and structuring the space with its visual and auditorial character (Cengizkan, 1999, 97). It had a mission of announcing the time to the public, not to a single individual like the mobile phone does today. Bazaar / market place took place in relation to the clock tower. Both were in the center of daily movements, where the individuals meet. Announcing the time to regularize it for the society, clock tower had a property of being delimited by place and structuring the space. The bazaar, which took place in this structure, had a light, temporary spatiality.

With the new possibilities of technology and new materials, new kinds of buildings were introduced: airports, hotels, exhibition halls, shopping malls and etc. surrounded the cities. As middle class and working class have mostly moved to the suburbs, their way of living and use of public space changed. Shopping centers have replaced downtown as a setting for communal life and disseminated as the new center of city. These new kind of public spaces are constructed usually out of the city, with their own temporality and architecture. Constructed on the idea of the automobilized life, shopping malls are built in their hugeness and various colors, which can be realized from a far distance and be recognized at momentary experiences. Therefore, the style of contact started to be ordered by the speed of car.

Swift communication and simultaneity that were introduced with such technological improvements can be assumed weakening the characteristics of societies and transforming the space. Mobile phone played a key role in this process of rapid communication. It is appropriate to illustrate it for annihilating the public space with its personal use. In our age, people also use mobile phones, to grasp time. Naturally, unlike the clock tower, mobile phone declares time to a single individual only. In contrast with the clock tower, mobile phone has a spatial aspect independent from place, and thus dispersing the sense of place.

4. URBAN TRANSFORMATION IN RELATION TO TIME

With the ongoing developments, technology enters human affairs with the change of pace or pattern. The variations and speed, which appear firstly with mechanical and then digital understanding of time, create artificial needs and new kinds of specializations in private and public life. These inventions accelerate and enlarge the scale of previous human functions and create totally new kinds of cities with new kinds of work and leisure (McLuhan, 1964, 8). The new spatial and social organizations influenced our relations with cities as well. Elements of the past and the present are placed simultaneously in today's city. As Rajchman mentions, 'There are many cities at the same time and other cities in the city every time' (Rajchman in Davidson, 1998, 163). With the changing economy, ideology, technology, scientific inventions, therefore transportation, communication, mass culture and activities; it is obvious to observe the altering urban forms, public spaces, building types and façades, materials, techniques, applications and interpretation of building programs of today's cities.

In this chapter, urban transformation and developments in building processes will be discussed in relation to Artificial Intelligence Age, in which time is perceived more personal than social.

4.1. Transportation – Communication – Mass Culture

Transport and transmission played key roles in transforming the urban space in the sense of time perception. In the nineteenth century, the development of railway transportation accelerated the birth of the suburb. The railway caused a rupture from the city center but the new settlements were ordered towards the railway and massed around the stations.

These alterations in and with technology of transport in the city center caused a transformation in the urban form. While previously urban objects and space were formed by everyday life and through human praxis, the style of contact started to be organized with the order of car speed. Just for the mobilized life, the facades facing the roads were turned to new boundaries, which were formed and meant to be signs. As Virilio mentions, the speed of the city increases through automobile traffic and also through telecommunications (Virilio, in Armitage, 2001, 63). Just like the automobile increasing the capacity and the ability of movement of human beings, vehicles redefined the human capacity and allowed a freedom on space. This caused growth of not only the cities, but also the problems of urban life. The identity of a city has close ties to its inhabitants' experiences. But in limited time, perceptions and also experiences are insufficient. Therefore the identity of receiving-perceiving person and variety of evaluations are required to be integrated into the field of architecture even in the simultaneous city of the 21st century.

4.2. Public Space

As it is always suggested, the recent public space is essentially taking new forms. The expansion in the number and types of public spaces seen today, including new commercial spaces, displays how our ways of living continue to shape the design and management of places. Built on an area of nearly a city citadel, shopping malls not only contain shopping activity, but also many other activities which take place in a city centre (coffees, restaurants, hairdressers, cinema complexes, drycleaners, and so on). Therefore, they act like a city centre and become a focus of attraction.

While the town square of the medieval towns formed a public space, the public uses of these malls are still discussed. With their hugeness, shopping malls formed super blocks, competing the city centre. Therefore, road networks in cities are meant to ease the vehicular movement to reach these super blocks, covering the whole city. In time, the bigness of these malls tends to determine the scale of new spaces, without a designed unity.

4.3. Building Types and Facades

As the transport to these new types of buildings is with automobiles in general, it is mostly possible to reach them from the parking lot or the garage. Therefore, façades are not that important anymore; they are simplified just for the building's view from the motorcar and not ornamented as it was done before.

As Virilio emphasizes, in contrast to the previous periods, a building today is not built to last forever throughout these ongoing differences in place perception. In this process of gaining speed, the lifespan of buildings has also shortened due to their early ageing and swift corrosion. As its lifespan is now limited to fifty or hundred years, it has become something of a movement in time, a three-dimensional image that will disappear in time (Virilio, in Armitage, 2001, 58). Therefore, even the facades of buildings are evaluated as time-based images.

4.4. Building Programs

As discussed formerly, with the transforming dynamics, both the building types and space concepts changed. With the altering building types, according to contemporary needs of human beings, also the function of many buildings transformed. Many of these buildings, such as factories, terminals, stations, etc. are reused with various functions. Most of the flats and houses in the city center are left for different sorts of labor, for better standards of living in suburbs. Consequently, it may be appropriate to say that it is not valid to define a fixed program for the frozen time of any building.

4.5. Materials

Mainly with the developments in computer technology, modern societies are more globalized today. Architectural culture is not apart from these tendencies. Design and building processes are more collective than they were in any time. Architects and designers from different countries can work on a common project and any materials from any place of the world can be used in the building process. Locality of the materials is not significant anymore. All the materials, workers, and the project sites can be chosen from different points of the world. Building forms are spread on all over the world and details are ready at hand for any use in any time.

4.6. Flexibility

With the industrial inventions and scientific discoveries, great transformations in social life emerged. Working hours were also modified and enlarged with these transformations. As Lyotard mentions, with the digital form of the machines, it is possible to synthesize the data anywhere and anytime. Therefore, the data also became independent of place and time, reachable at a spatial and temporal expanse (Lyotard, 1991, 50). Virilio mentions this process as the 'Third Revolution', in the realm of speed (Virilio, in Armitage, 2000):

1. Transportation with the invention of the steam engine, the combustion engine, the electrical motor, the jet engine and the rocket.
2. The revolution of transmission, which can still be observed now in electronics, beginning with Marconi; radio and television.
3. The transplantation revolution, which is closely related to the miniaturization of objects.

According to him, with railways, motorways, bridges and large factories, technology is spread over the territory, but in this process of 'Third Revolution', it enters the innards of the human body (Virilio, in Armitage, 2000, 49). Living theory of relativity through mobile phones, through 'live' programs on TV, through the telecommunications media, through Virtual Reality, through cyber space, through video-conferencing, through supersonic, air travel and so on; he mentions that we have become deterritorialized by the shortening of distances in terms of time (Virilio, in Armitage, 2000, 27). Telecommunications, in dissolving the 'here' and 'now', serve both to break down distance, the 'physical distance', and to create 'psychological distance'. In the realm of mobility and emancipation (Virilio, in Armitage, 2000, 39), with the wide use of Internet, the screen has become the space of interaction.

In this process of evolution, time and space lose their importance. The activities of man may take place at any time and in any place gradually. Also the activities of the societies started to be more digital than physical. The banks, libraries, commercial managements, and many others, have taken place with all their information in the virtual environment of Internet that allows a kind of space for any time. The sense of reality is blurred with the blurring identity, personality or physical characters of the users. In this process of alterations in social and built environment, transformation of time and its perception from public to personal can be mentioned influential.

5. CONCLUSION

The concept of time is interrelated with other concepts like: experience, motion, human actions and consciousness and also space. That is why it is attempted to integrate the element of time into the understanding of designers and architects, in respect of analyzing the social processes involved in the making of space and place.

The perceived, lived and experienced world has gained a new feature with the developments of knowledge and communication technologies. From the years that mechanical clock was invented the speed has increased and time perception has altered throughout new eras. With the effects of technological inventions, time perception, and related with that, the socio-cultural structures of societies change, as well as the spatial properties.

While the transformation of perception of time formed new spaces, some problems also emerged. Alienation to nature and disregarding human practices are some of the mentioned problems. This study stresses that these altering dynamics break down the 'physical' distance, but create 'psychological' or 'mental' distance. The answers of the questions 'in which way people perceive, what do they feel, what are the particular needs and expectations of every individual' are not the focus of this paper. But it is obvious that, there is not a universal or an average human and also there is not a single public interest. The needs and expectations of every time period are not the same. Building types, forms, facades, the amount and type of open spaces, the types of public spaces can be based on the clarified lifestyle, culture, demographic characteristics and economic circumstances of the population in time.

The focus is that architectural spaces and objects to be 'qualified', is just the obligation of architects and builders. In any case, they should be aware of the dynamics which force the society and the city for a transformation, more than any one else. Increasing the quality of lives of societies by offering well-designed spaces is the essential requirement of architecture and the design world. Since everything in the world is under construction, actors in the design world, as the supposed genius members of the innovative and creative team, should consistently be searching for spaces which qualify for new times and new philosophies, without neglecting the human experience and the context. Throughout the process of minimizing 'physical' distance, unlike the virtual space, built environment – concrete space – should be designed and produced in relation to 'psychological' expanse.

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THE ENVIRONMENTAL PERFORMANCE OF CLASSROOMS: A CASE STUDY FROM EL-MINYA GOVERNORATE, EGYPT

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Abstract: The provision of primary schools in Egypt is one of the demanding issues facing the Egyptian government since the earthquake of 1992. In the aftermath of the quake the government has designed a substantial number of primary schools around the country in an attempt to replace schools lost in the disaster. This paper presents the results of an investigation into the environmental performance of classrooms inside eighteen government schools from the El-Minya Governorate. Interviews were conducted with the pupils and the staff of the schools. The authors of the present paper believe that the environmental performance of these classrooms could be better addressed than at present. Accordingly, this investigation was essentially to establish the roots of the problems and to identify approaches for further investigation. One problem is that schools of typical design have been built in varying climatic regions of the country. The results suggest that the majority of pupils and teachers in all case studies suffer from thermal and visual discomfort during much of the academic year inside the classrooms.

Keywords: Egypt, Environmental performance, Schools

1. INTRODUCTION

This paper presents the findings of a pilot study which is part of an extend research project running at Dundee School of Architecture investigating the environmental performance of government schools in Egypt. The main aim of this pilot study was to identify environmental problems inside classrooms of government primary schools. This study focused on problem identification. Proposal for addressing the environmental problems found will be the focus of the next part of the research; it is not covered here. Schools investigated in this work are those designed and built by the Egyptian General Authority of Educational Buildings (GAEB) after the earthquake of 1992. Eighteen case studies from El-Minya Governorate were surveyed. A total number of 108 classroom occupants were interviewed to assess their subjective response.

2. BACKGROUND

2.1 Location of the study

Egypt occupies the Northern corner of Africa. It is bounded by the Mediterranean Sea from the North, the Red Sea from the East, Libya from the West and Sudan from the South as shown in Figure 1. The total area of the land is just over one million Km2, only 4% of this area is inhabited. Egypt is divided into 26 administrative units called ‘Governorates’; each is divided into several towns. Each town includes one city and several villages. Egypt lie in the dry equatorial region except its northern areas which lies in the moderate warm region with a climate similar to that of the Mediterranean. On average the climate is warm and dry in summer and moderate with limited rain fall that increases at the coast in the winter. The climate in Egypt is influenced by several factors including its geographical location, topography, general system of atmospheric pressure and the water surfaces surrounding it. The country is divided into seven climatic design regions; the largest is the desert region. El-Minya Governorate is indicated on the map.

Figure 1: Egypt boarders and El-Minya Governorate location

All the case studies are located in El-Minya Governorate, which lies in the heart of Egypt and is bounded by Bani-Suef Governorate from the north, the Eastern Desert from the east, the Western Desert from the west and Assuit Governorate from the south (Figure 1). Its total area is 56,587 Km2 and consists of nine towns, each has a centre called city. Each town is divided into several administrative sectors; each includes a number of villages and has its council. The total number of villages in the governorate is 346 (IDSC; 1999).

2.2 Primary schools in Egypt

Figure 2 illustrates the growth of public school numbers in Egypt. It can be seen from this figure that the number of schools has jumped twice since the 1950s. The first time was at the end of 1952 when the Revolution brought about - at that time what was considered - a host of achievements that included an increase in the number of schools

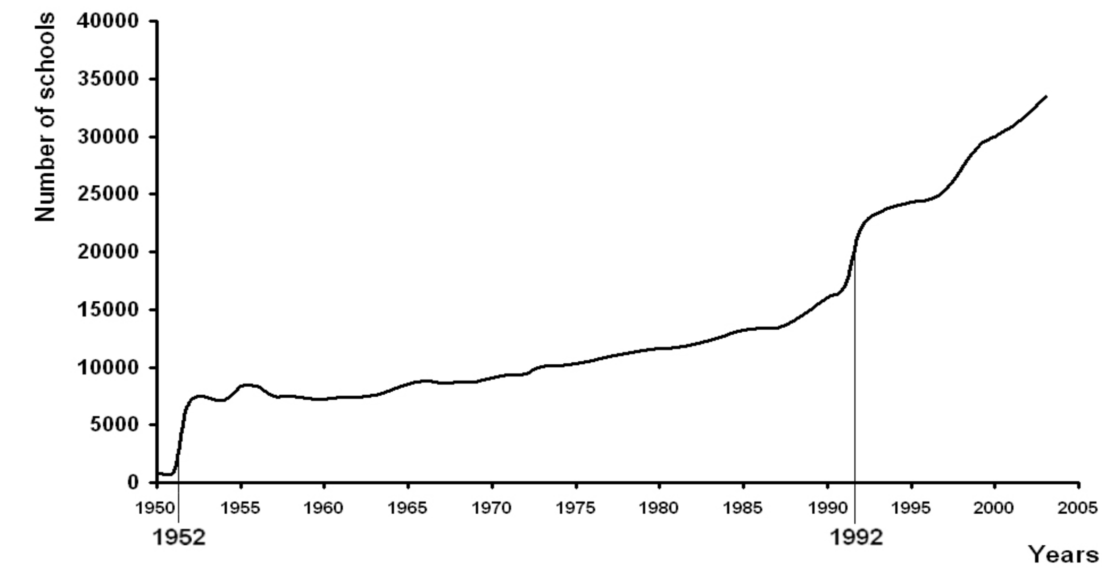

Figure 2: Schools number in Egypt from the year 1951 to 2005, after the Egyptian Ministry of Education (Ministry of Education; 2005)

(IDSC; 2005). The second was after the 1992; the government had to build many schools to replace those destroyed by the major earthquake of that year (GAEB; 1994).

2.3 Research problem

In 1992 Egypt was hit by an earthquake that registered 4.7 on the Richter scale and was followed shortly by an aftershock measuring 3.8 (Farag; 2002). This disaster affected 3964 buildings including a considerable number of schools increasing the demand for primary schools which was already high pre 1992.

Another factor that contributed to the increase in this demand was the changes that took place in the education system. Primary education in Egypt has traditionally had six levels. In the academic year 1988/1989 this was reduced to five levels (Fergany; 1994), but in 2004/2005 the sixth level was reintroduced. In 1999 the policy was to build bigger primary schools to cope with the increased numbers of pupils expected by the academic year 2004/2005. Until the academic year 2004/2005 this problem was not solved completely; 14% of the primary schools in Egypt did not have enough classrooms to accommodate the pupils in the sixth level who started school at 1999. Accordingly pupils had to use the classrooms of nearby preparatory schools (Ebrahim; 2004). This greatly affected the educational process.

The government established the Egyptian General Authority of Educational Buildings (GAEB) to be responsible for designing, building and maintaining new schools around the country to deal with the new demands before and after the earthquake. The authority designed several prototypes for all the education stages including primary schools. The number of classrooms in each prototype varied from six classes to forty three classes per school (GAEB; 2004).

The problem at the heart of the present research is that the same basic school designs were repeated all over the country without taking into consideration the varying effects of climate on the environmental behaviour of such schools. In previous work Gado (Gado; 2001) proved that the implementation of this design policy using the same design in different parts of Egypt in the housing sector produced climatically problematic dwellings. It is expected that the same will be true for the school buildings. Investigating this problem is very important. The majority of children up to the age of twelve in Egypt spend from 15% to 22% of their time in mainstream schooling.

2.4 Previous work

Many attempts had been made in the past to approach government schools in Egypt. However, the majority of these researches approached this issue from social, educational, economical or theoretical points of view and very few looked into their environmental design. Toulan (Toulan; 1982, Toulan; 1989) focused on the conceptual design of primary schools. Abdalla (Abdalla; 1994) studied the impact of new educational tools on both conceptual design and human dimensions. Shalabi (Shalabi; 1996) and El-Mola (El-Mola; 1999) investigated the integration of the educational process with the architectural design process. El-Nashar (El-Nashar; 1998) studied the physical setup of the educational spaces and its impact on children's behaviour. Noufal (Noufal; 1998) studied factors affecting schools built in overcrowded districts of Cairo. El-Hefnawy (El-Hefnawy; 2002) investigated health and safety issues in educational buildings especially in primary and preparatory schools (fundamental schools). The Housing Building and Urban Planning Research Centre (HBUPRC) under the supervision of Ministry of Education conducted a research aiming to formulate guidelines for designing fundamental schools in Egypt (HBURC; 1987). The study looked into the quality of educational spaces, their occupants' responses and their environmental performance. A survey was conducted that included twenty fundamental schools in Greater Cairo and a questionnaire was distributed to teachers the head teachers. The most recent research that was found (IERS; 1992) during this review looked into the conceptual design of fundamental schools, landscape design, materiality, and solar shading.

From previous notes, it can be seen that only a few studies have touched on the environmental performance of primary schools in Egypt. The majority of work has been oriented towards other aspects of primary schools design. This gap in the body of knowledge was identified and is being approached in this extended research project.

3. RESEARCH METHODOLOGY

Egypt is divided into seven climatic design regions the largest is the desert region. The climate of El-Minya Governorate represents the typical climate of this region. Accordingly it was decided to choose all the cases studies from this governorate.

3.1 Case studies

The study chose to investigate primary schools as these represents just over 44% of all the governmental schools in Egypt (Education; 2005). In this work three prototypes designed by GAEB were investigated; the six classes prototype (T6), the twelve classes prototype (T12) and the eighteen classes prototype (T18). These three prototypes represent 80% of the primary schools built after the earthquake of 1992 (GAEB; 2004). A total number of eighteen primary schools were used in the survey; five T6, seven T12, and six T18 schools. These case studies are located in seven different towns of El-Minya Governorate. Out of the eighteen schools twelve were built in rural contexts (villages) and six were built in urban areas (city).

3.2 Method of data collection

The present study has used semi-structured interviews to collect data from the occupants of the case studies. This method of data collection is very flexible, suitable for gathering information and people's opinions and motivations (Drever; 1995). More importantly it guaranteed a higher response rate when compared to questionnaires distributed by post. A mixture of closed and open ended questions was used in the interviews. The open ended questions explored the occupants' subjective response to the buildings; while the closed ended questions were used to allow the application of statistical analysis on the results later on in future work. A total number of one hundred and eight occupants were interviewed, 29% of whom were females. Six occupants were chosen randomly from each school, three pupils and three teachers from each.

The aim of the interview with the pupils was to collect data related to their state of comfort inside the classrooms. This work was concerned with thermal, visual and acoustic performance of the classrooms. The interview with the teachers and head teachers aimed to collect data from them regarding both the classrooms and their office rooms. Only the results relating to the classrooms are presented in this paper.

The following three closed ended questions were asked in the interviews:

Q1: Do you feel warm during summer and cold during winter inside the classroom?
Q2: Do you experience any kind of visual discomfort?
Q3: Do you have problem hearing the speaker regardless your location in the classroom?

The interviewees had to choose one answer for each question; either yes, no or not sure. Any difficult expression such as 'visual discomfort' was explained prior to the interviews. The results are presented in the following section.

4. RESULTS AND DISCUSSION

On analyzing the data collected from the interviews it has been found that the majority of occupants of all case studies are not thermally or visually comfortable for most of the academic year. Figure 3 presents this data. 78% of the occupants involved in the interviews were thermally uncomfortable, 58% of them were visually uncomfortable however only 21% reported that the acoustics of the classroom is poor.

83% of the occupants inside T6, 74% inside T12 and 82.35% inside T18 were thermally uncomfortable for most of the time. This could be due to the use of large (2.5m x 1.4m) unshaded south facing single glazed windows. This led to almost half of

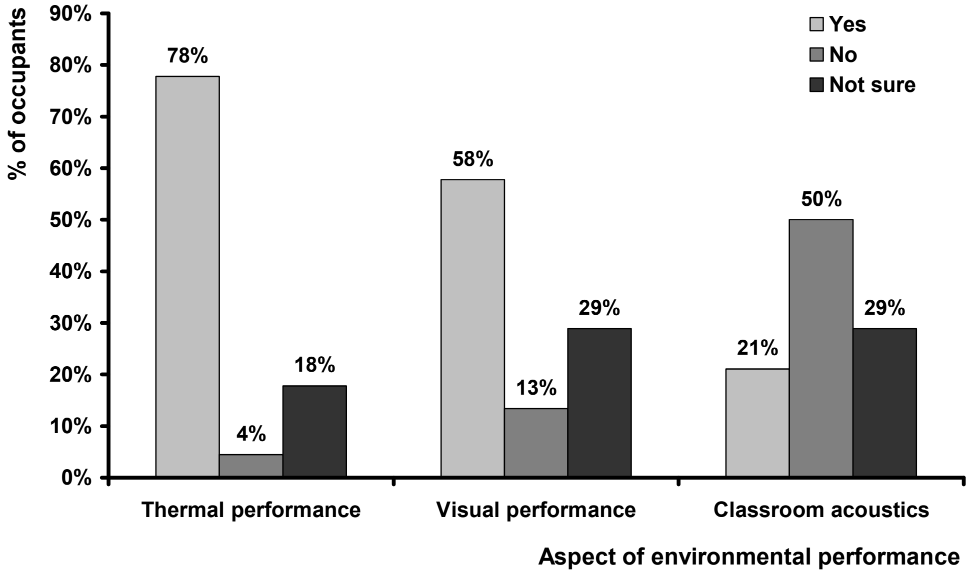

Figure 3: Percentages of occupants feeling discomfort, neutral and who could not answer

the children inside the classroom receiving direct solar radiation on their bodies most of the time as shown in the example in Figure 5.

This together with air temperatures that range between 35^{o}c and 42^{o}c in summer will lead to thermal discomfort or even sunstroke in severe cases. The children reacted to this by moving around the classroom, disturbing the educational process and crowding into shaded areas of the room, which made their thermal discomfort worse. In other cases the children and teachers reacted to this situation by sticking sheets of paper on the windows or by painting the windows using dark opaque emulsion as shown in Figure 6 and Figure 7. This led to a severe drop in natural light levels and led to the use of artificial lighting during the day.

Figure 5: Direct solar radiation on the children

Figure 6: The use of artificial lighting systems during the day

61% of the occupants inside T6 reported that they experience visual discomfort and cannot clearly see the blackboard as shown in Figure 8. 63% of T12 occupants and 47% of T18 occupants reported the same. This is due to the presence of many sources of glare inside the visual field of the children such as; reflections on the blackboard and high levels of light on the working surfaces. This led the occupants to close the windows most of the time leading to stuffy and smelly classrooms due to low levels of air change. It also led as mentioned earlier to low natural light levels and thus artificial lights were being used during the day.

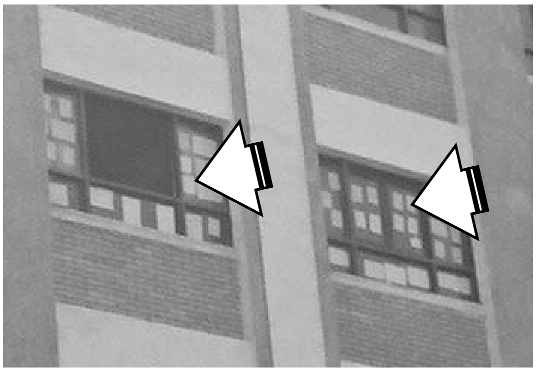

Figure 7: Transformation done by the occupants

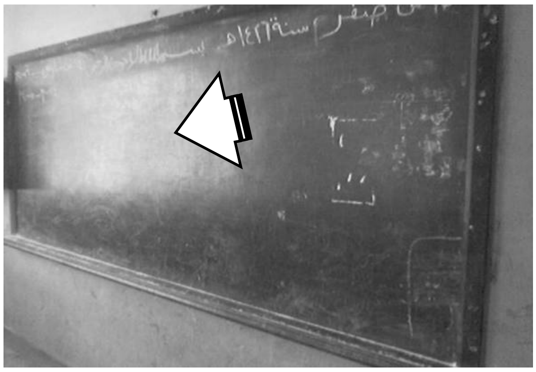

Figure 8: The reflections on the blackboard

As for the acoustic performance it was found that 48% of T6 occupants reported that the acoustics inside the classrooms were poor as they could not normally hear the speaker regardless of their location inside the room. However, only 11% of T12 occupants and 12% of T18 occupants reported the same. This could be due to the large number of pupils inside the same classroom that can reach from 60 to 70 pupils as shown in Figure 9. Another reason could be the high levels of noise coming from external sources especially in overcrowded areas (Figure 10). This can explain why the highest percentage of dissatisfaction was noted in T6 schools since four out of five T6 cases were located in urban contexts while 10 out of the 13 T12 and T18 schools were located in rural contexts where sources of noise are minimal.

Figure 9: Overcrowded classroom

Figure 10: A school in a highly populated area

5. CONCLUSIONS

An interview with 108 occupants inside eighteen government primary schools in El-Minya Governorate was conducted. Three conclusions can be drawn from this work:

1. The majority of the occupants are thermally uncomfortable for most of the time
2. The majority of the occupants are visually uncomfortable for most of the time
3. Less than 25% of the occupants reported that the classrooms acoustics are poor

6. FURTHER WORK

This work will be further developed. A questionnaire will be used to collect data from a larger number of occupants in larger number of case studies. This is important to further confirm the results of this pilot study and identify the most significant environmental problem inside the government primary schools. This will help directing future work in this project. In addition, a number of cases will be monitored during the hottest and the coldest months of the academic year; May and January respectively. This objective measure will confirm the subjective opinion of the occupants. Several passive measures will then be tested using computer modeling in an attempt to enhance the environmental performance of the classrooms. Monitored data will be used to validate the simulations.

7. ACKNOWLEDGMENTS

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BUILDING PERFORMANCE AND SUSTAINABILITY: THE INTEGRATION OF BUILDING ENERGY AND ENVIRONMENTAL SIMULATION TOOLS IN ARCHITECTURAL DESIGN - DEMONSTRATED THROUGH A CASE STUDY OF NEW HOUSING DESIGN

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Abstract: Sustainable building is a global issue and its life cycle influences the life cycles of the planet significantly. In order to accomplish sustainable building design which could contribute to reducing pollution and improving the environment, building simulation and analysis tools are necessary; especially at the earliest stages of design. This paper discusses the importance of sustainable design and development, and explains how building energy and environmental assessment techniques could be used in a rational and innovative manner for building sustainability and design support tools. Moreover, it provides an example case study and discusses the benefits of using such developed strategies for sustainable development to predict the dynamic response and performance of buildings and to assess and compare the effects of different design options.

Keywords: Building Environmental Design, Building Simulation Tools, Integration and Environmental Modelling, Sustainability.

1. INTRODUCTION

The environmental strain caused by global urbanisation is one of the many compelling reasons why architects, engineers and developers must explore sustainable design and development, and it is about building with sensitivity to local and global environmental concerns [Architectural Design, 2001]. Therefore, it is important to say that the integration of buildings energy and environment simulation tools in architectural design could support sustainable design and development and accordingly contribute to reducing pollution and improving the environment.

The computerised building energy performance simulation is a powerful implement for the virtual toolboxes of architects, engineers and developers. It provides valuable information that helps designers make better decisions about the characteristics of building envelopes, glazing, lighting, and HVAC systems [Waltz, J. P., et al, 2000]. By using building simulation, designers and developers can provide more value to the building operators who must eventually pay the utility bills, and can be protected by basing decisions on more specific and opulently detailed information.
The aim of this paper is to review the basics of building simulation and demonstrate a case study - simulation model analysis to support the integration of building simulation tools. By observing these guidelines, designers and developers can improve their

chances of producing simulation results that are accurate and relevant, and therefore significantly improve building energy performance.

To make effective use of building simulation, it is vital that designers and developers adopt some common-sense practices, such as listed below:

- Incorporate building simulation into the earliest design phases,
- Maintain vigilance to avoid mistakes, and
- Do not use simulation when it cannot answer the design questions at hand.

2. BASICS OF BUILDING SIMULATION

Building designers and developers can implement the following to make the best use of building simulation:

- Start early, by incorporating building simulation into the earliest design phases;
- Keep it simple, by adding no more detail to a simulation model than is necessary to answer the design questions you are considering;
- Refine as you go, so that the simulation model evolves with the design; and
- Maintain vigilance, to avoid mistakes.

By following these basics, common-sense guidelines, the designers can considerably improve the accuracy and relevance of building simulation. Even a simple energy model can be used to effectively guide major decisions early in the design process. Although building simulation can add substantial value to a building design, it may not be right for every design project. Sometimes, the time and cost of developing a good model exceeds the benefits that it may potentially provide. While there are no hard and fast rules for determining whether or not to use simulation, here is a list of circumstances that are typical signals to refrain from using building simulation:

- When the design process has proceeded so far that it is highly unlikely that anything can be changed.
- When a project is so small that the cost of running a simulation cannot be justified.
- When the design questions that need to be answered are out-side of the realm of what typical simulation programs can evaluate.
- When the designer needs detailed design information, not just energy results.

In general, it is recommended that designers don't simply reach for building simulation whenever there is a design question at hand. Instead, carefully consider whether building simulation software can answer that question and whether or not the benefits of using simulation are likely to exceed the costs [Malkawi, A. M. and Augenbroe, G., 2004]. The choice of which tool to use should be based on the designer level of familiarity with building simulation, the kind of questions wished to be answered with the model, and the required level of detail. If this the first attempt at developing a model, it is probably best to stick with one of the simpler, user-friendly tools. This then will allow the designer to focus on its program inputs and not on program syntax. As an example, when to evaluate specific technologies, such as daylighting controls, it is recommended to select a program that has such capabilities.

Much of the potential for error in building simulation comes from the user's lack of familiarity with a particular program. A user who is proficient with a simple tool will usually get better results than a novice user running a highly sophisticated program. If the design questions to be answered require a simulation package that the user is not proficient in, it is recommended to retain a consultant who has those skills. While collaborating with a consultant, there may be a necessity to make arrangements which will allow the user to gain experience with the software package, but still take advantage of the consultant's safety net of expertise.

3. CASE STUDY – SIMULATION MODEL ANALYSIS

A theoretical case study is given to demonstrate how building energy and environmental simulation tools have been integrated in the early stages of design. The building simulation tools used for this simulation model analysis are ECOTEC and IES Virtual Environment. There are four different house types investigated as shown in Figure 1. This case study describes a simulation exercise and analysis work on domestic buildings, and outlines the results of advanced computer simulations aimed specifically at optimising the natural lighting and ventilation of the house.

- Radiance to establish the natural lighting quality and to optimise the size and location of windows and ECOTEC to act as a platform for Radiance and to analyse the heating loads.
- A Computational Fluid dynamics (CFD) package, IES VE, to determine the natural airflows in magnitude and direction for a range of window openings and the impact of an artificial ventilation system on the flows.

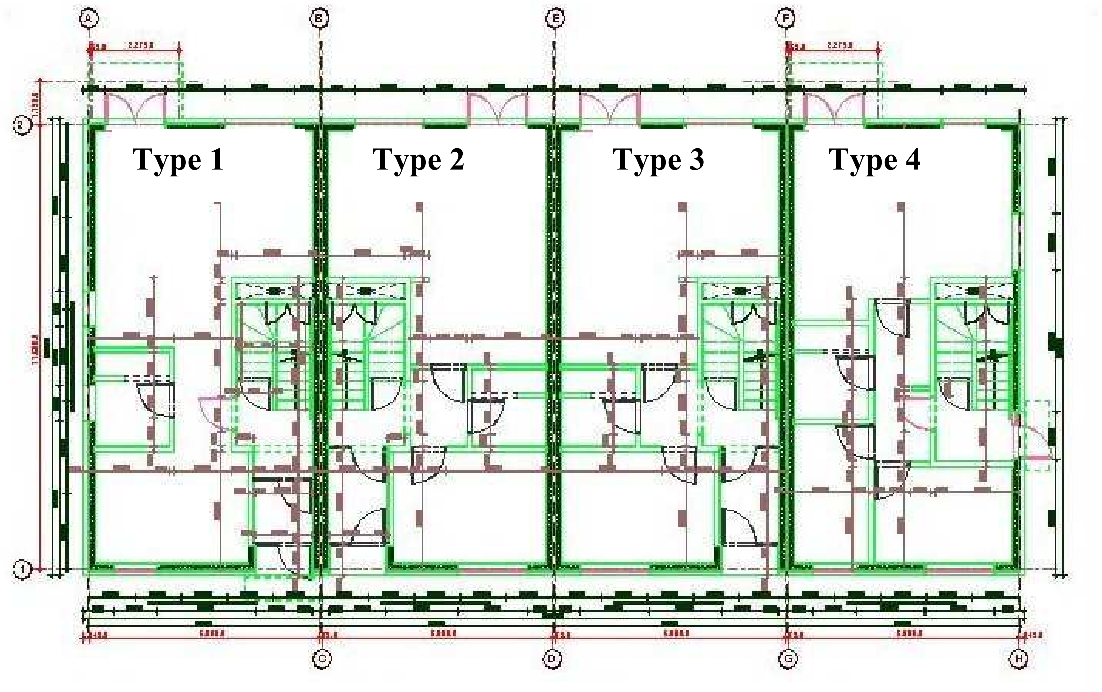

Figure 1: The four House Types investigated

3.1 Lighting Simulations

The quality of daylight is very important and it is generally recognised that a Daylight Factor (DF – the relationship between the amount of natural light available at a location within a building compared to the amount available at the same time outside the building) of 2% is appropriate for the room to be perceived as being 'naturally lit' (THERMIE, 1994).

The initial simulations carried out were aimed at establishing the DF in the houses from the drawings supplied by the designer. The simulations shown were taken from an analysis carried out in December and shown in Figures 2.

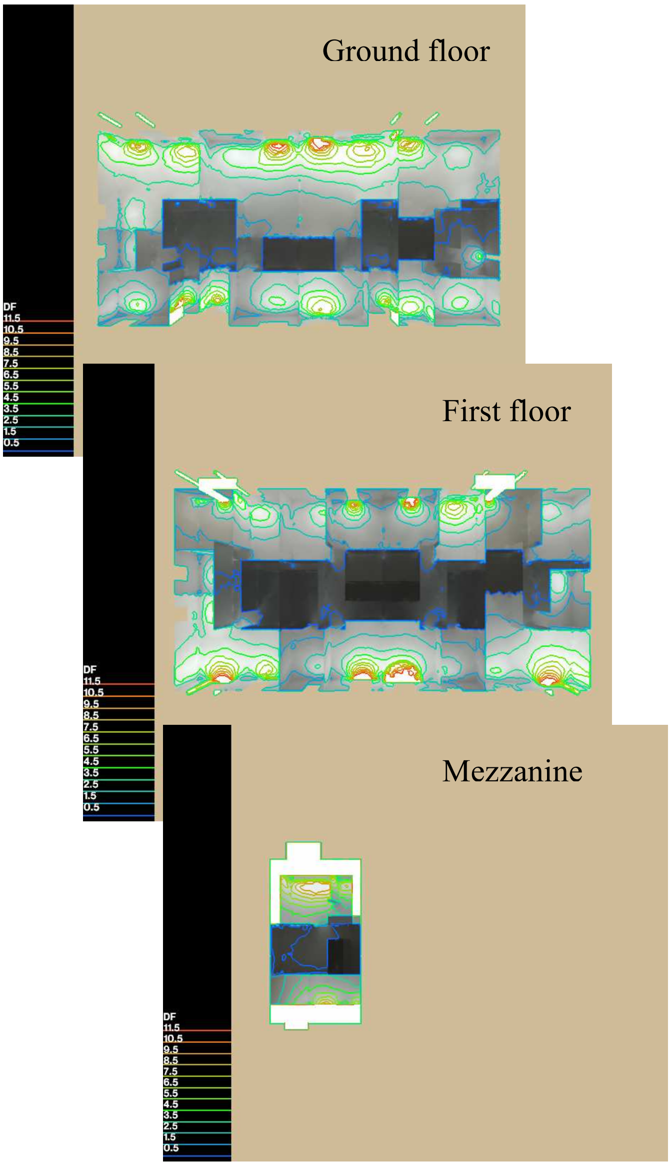

Figure 2: DF Simulations on all Floors

These results clearly show that the DFs on the surfaces within the main rooms are above 2% indicating that the rooms will appear well lit. In the toilets and other internal spaces with no direct access to natural light from the windows the levels will be below the 2% value.

As the above simulations show there appears to be good daylight penetration to the main spaces, however it is also important to establish the daylight factors on the working plane (0.8 m from ground) and to compare the average room daylight factor against British Standard (BS 8206-2) requirements.

EcoHomes - the homes version of BREEAM (BRE Environmental Assessment Method) covers houses and can be applied to both new and renovated homes. This BRE developed assessment method balances environmental performance with the need for a high quality of life and a safe and healthy internal environment. The issues assessed are grouped into seven categories: energy; water; pollution; materials; transport; ecology and land use; health and well-being.

In the EcoHomes assessment (BRE, 2005), there is a requirement for daylight calculations to be carried out. To be regarded as being adequately day lit the main rooms should have average daylight factors as shown in Table 1. For the four house types the average daylight factor was calculated according to BS 8206-2 and the results shown in Table 2.

Table 1: Average Daylight Factors

Room Type	Daylight Factor %
Living room	1.5
Kitchen	2
Dining room	1.5
Bedroom	1

Table 2: Average Daylight Factors calculated

House and Room	Average Daylight Factor %
Type 1	
Ground Floor Kitchen/ living	7.78
Bedroom	3.49
First Floor Bedroom 1	9.38
Bedroom 2	3.16
Mezzanine Bedroom	10.11
Living	7.19
Type 2	
Ground Floor Living	5.37
Kitchen/ Living	6.16
First Floor Bedroom 1	2.61
Bedroom 2	8.36
Bedroom 3	3.16
Bedroom 4	6.01
Type 3	
Ground Floor Kitchen	6.83
Living	6.16
First Floor Bedroom 1	2.61
Bedroom 2	8.36
Bedroom 3	3.16
Bedroom 4	6.01
Type 4	
Ground Floor Bedroom 1	3.49
Kitchen/ Living	6.58
Bedroom 2	3.17
First Floor Kitchen/ living	7.68
Bedroom 1	8.54
Bedroom 2	2.47

From these calculations it is clear that in all cases adequate daylight is provided to then main rooms in all dwellings. This is further demonstrated in the Radiance simulations shown in Figures 3a - c below.

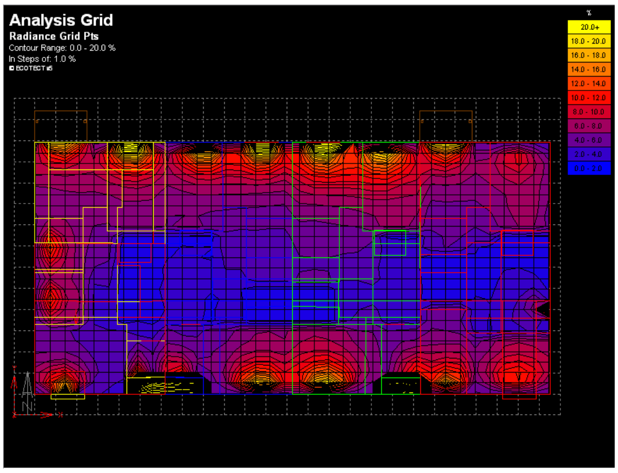

Figure 3a: Ground Floor Daylight Contours on Working Plane

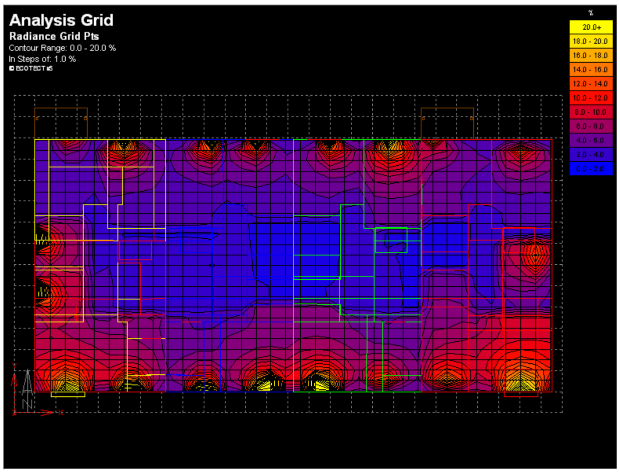

Figure 3b: First Floor Daylight Contours on Working Plane

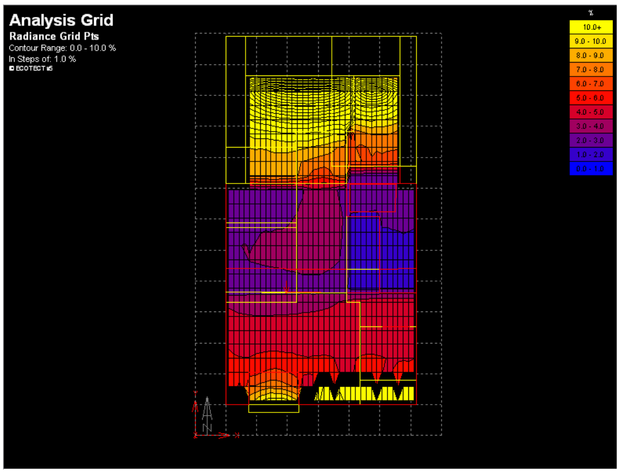

Figure 3c: Mezzanine Floor Daylight Contours on Working Plane

3.2 Design Modifications

3.2.1 <u>Enlarging the Window on the Ground Floor of House Type 1:</u>

As can be seen from Figure 3a, the distribution of daylight over the room appears to be poor and therefore to improve the quality a modification to the window was considered. By increasing the size of the window (1.8 m high by 1.5 m wide) a significant improvement in the quality of light entering the house was obtained. Figures 4a - e show the results for four periods during the year.

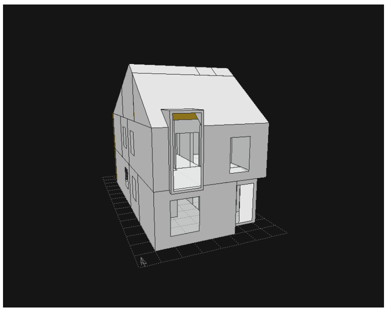

Figure 4a: The House Type 1

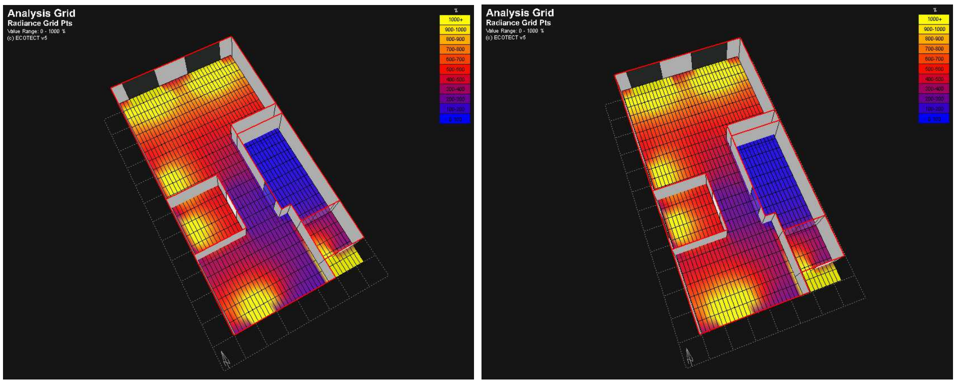

Figure 4b: March before modification after modification

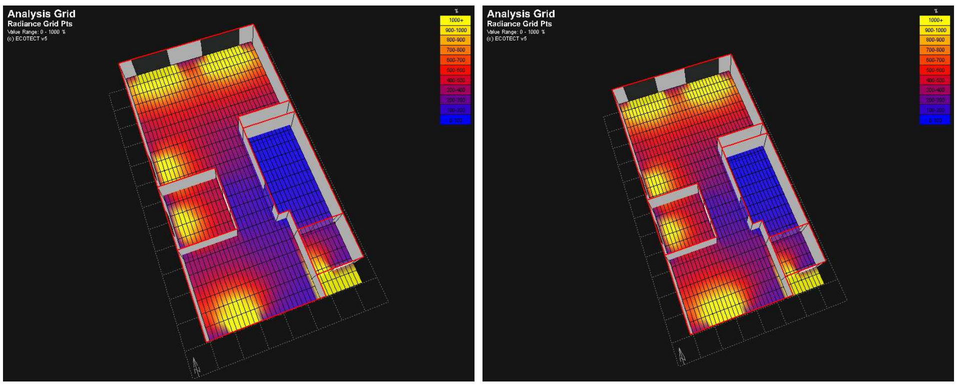

Figure 4c: December before modification after modification

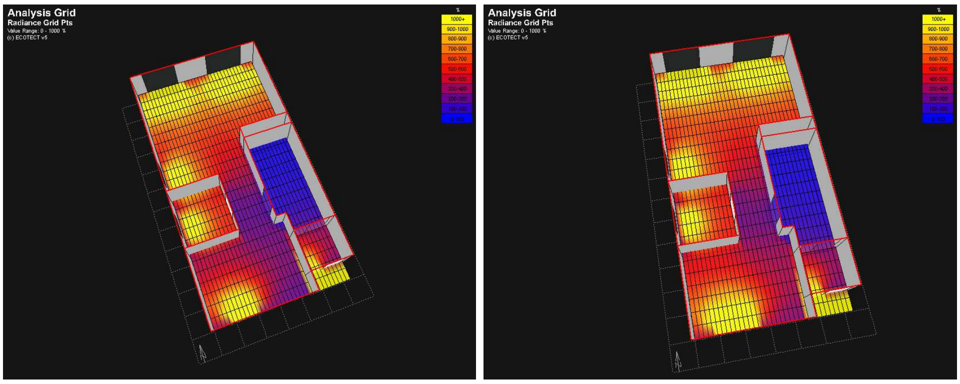

Figure 4d: June before modification after modification

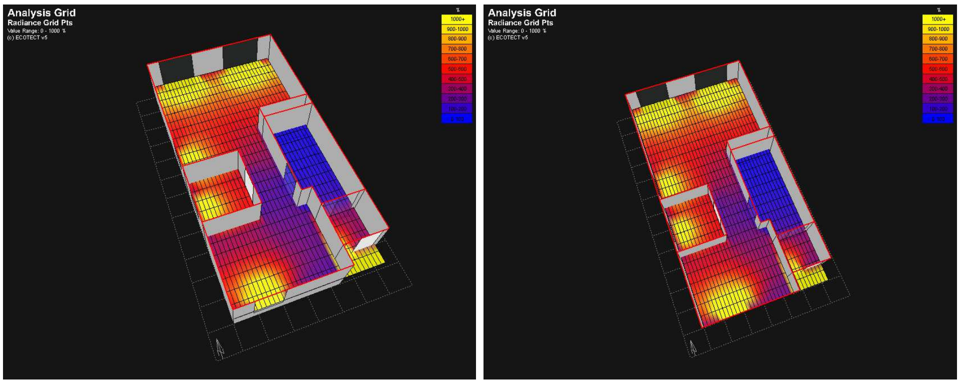

Figure 4e: September before modification after modification

3.2.2 <u>Adding a Roof Light above the third Floor Mezzanine of House Type 1:</u>

From the initial simulations (see Figure 3c) it was shown that the light levels on the mezzanine were low. A roof light (2.0 m wide by 2.0 m high) was positioned in the roof. The results of this analysis are shown in Figure 5a - e for four periods during the year.

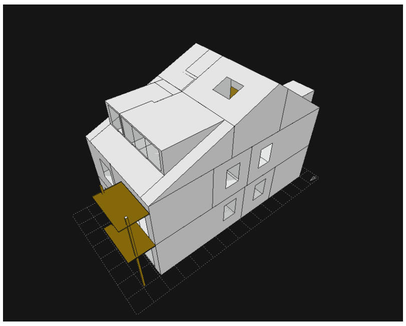

Figure 5a: Location of Roof Light on North

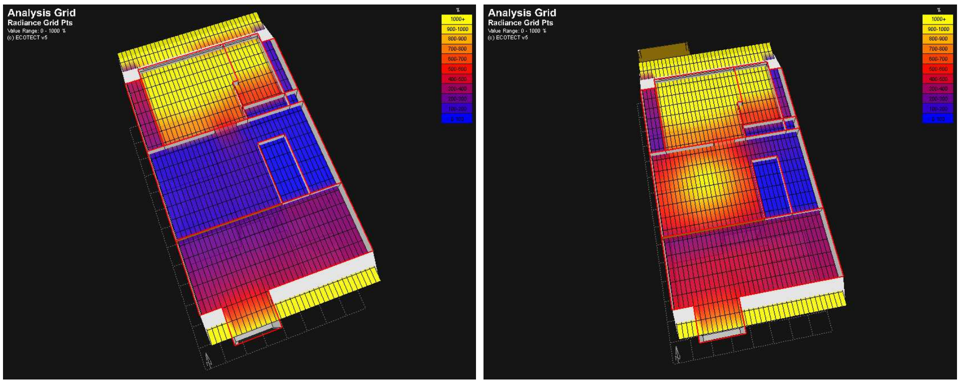

Figure 5b: March no roof light with roof light

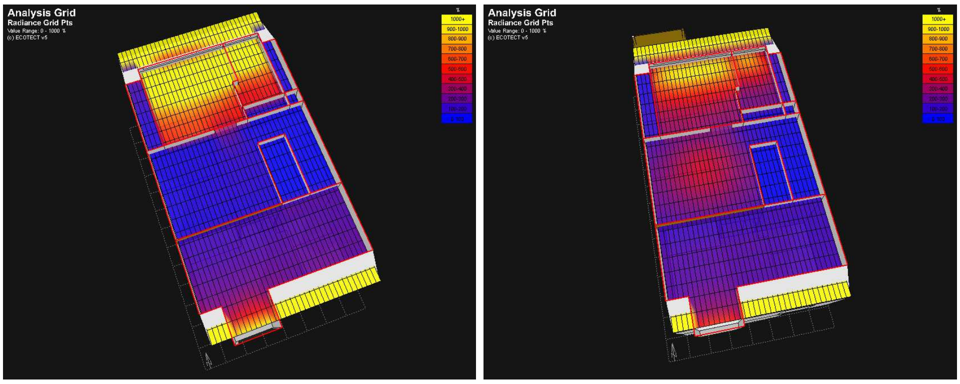

Figure 5c: December no roof light with roof light

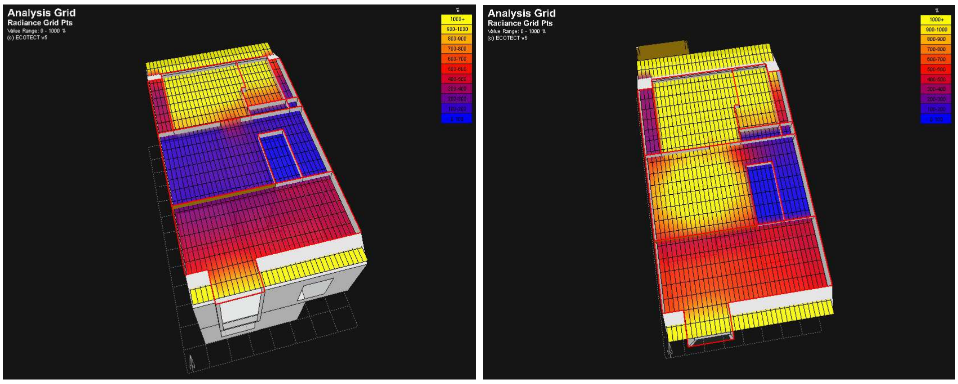

Figure 5d: June no roof light with roof light

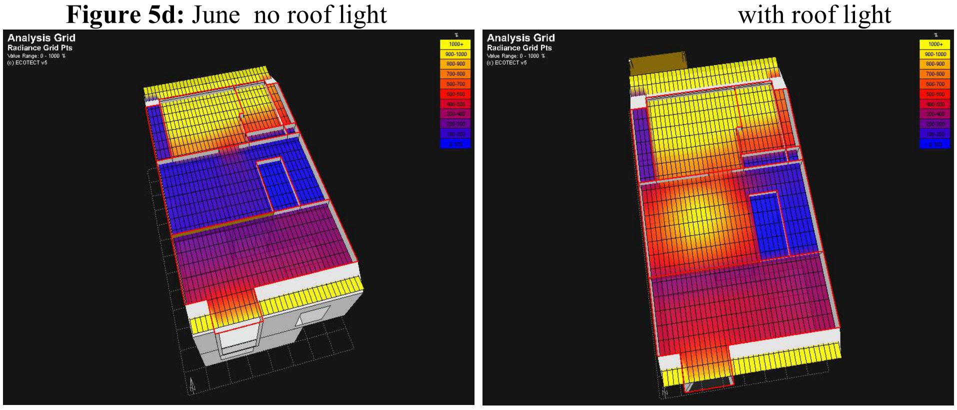

Figure 5e: September no roof light with roof light

It is clear from this study that by adding a roof light that a very significant improvement in the amount of natural light on the mezzanine was obtained. It is therefore recommended that a roof light be added to the design.

3.3 Sunlight Penetration

Another aspect of the design of these houses is the sunlight penetration into the house. A full analysis has been carried out over the whole day for the four main months in the year (March, June, September and December) with a view to obtaining the extent to which the sun reaches the inner core. Also to shade the rooms in hot periods, simulations of two different shading devices were carried out. The first being the addition of an external shade (protruding 1.0 m from the window and tapering to the sides), the second being the addition of blinds.
A snapshot of the simulations for 10:00 am is shown in Figures 6a - e for the sunlight penetration and Figures 7a - h for the addition of shading devices.

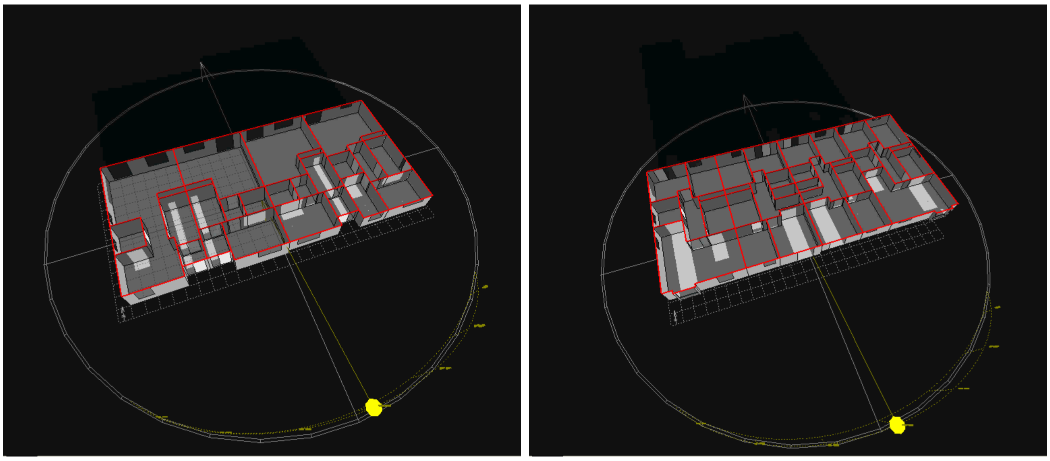

Figure 6a: Ground floor December First floor December

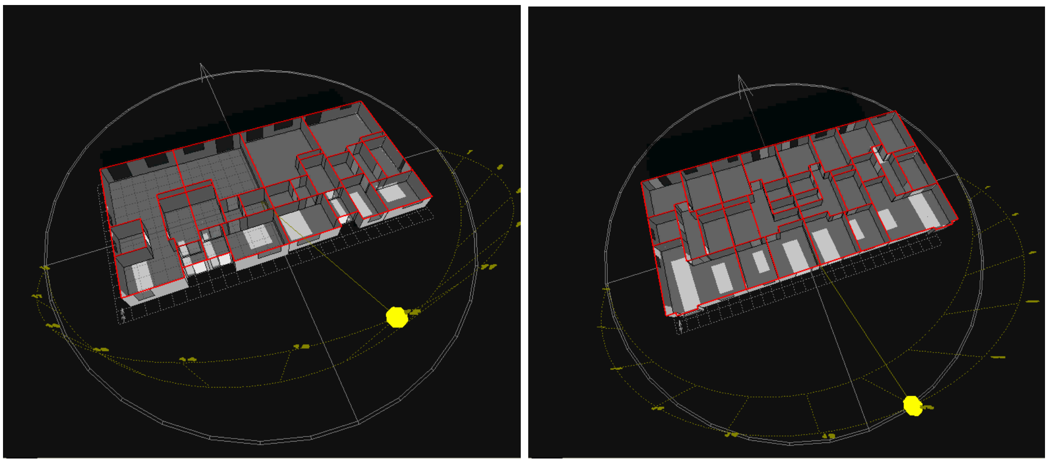

Figure 6b: Ground floor March First floor March

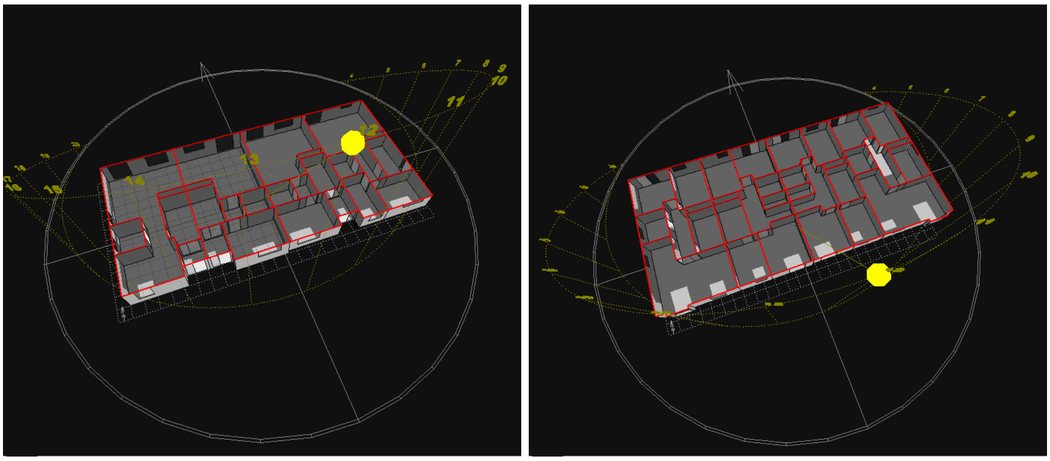

Figure 6c: Ground floor June First floor June

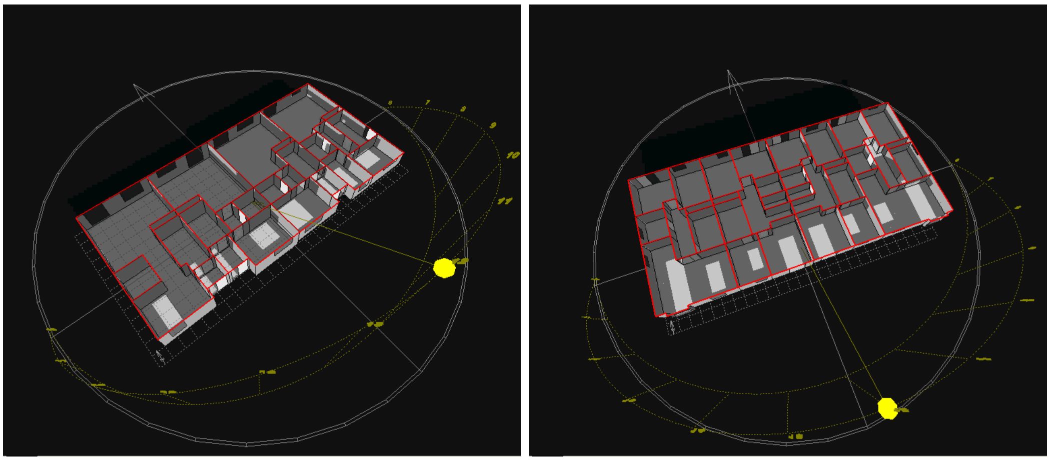

Figure 6d: Ground floor September First floor September

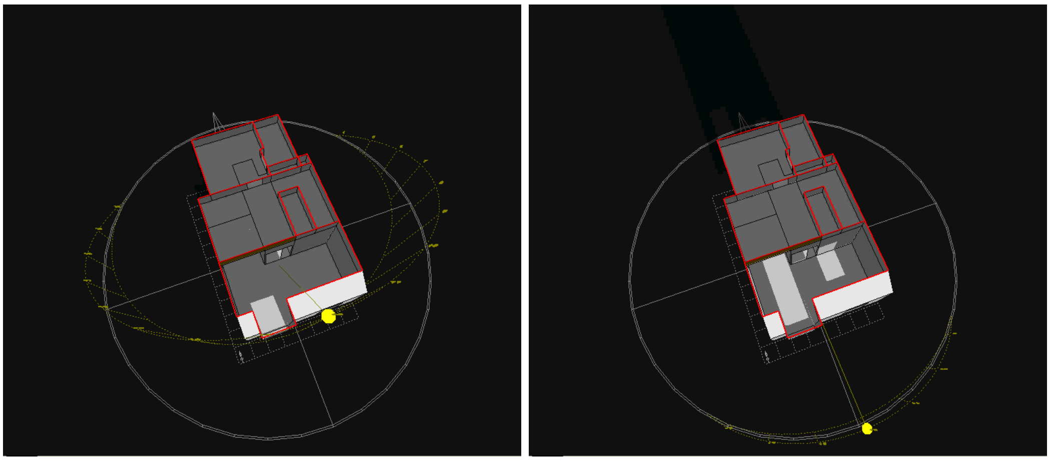

Figure 6e: Mez June Mez December

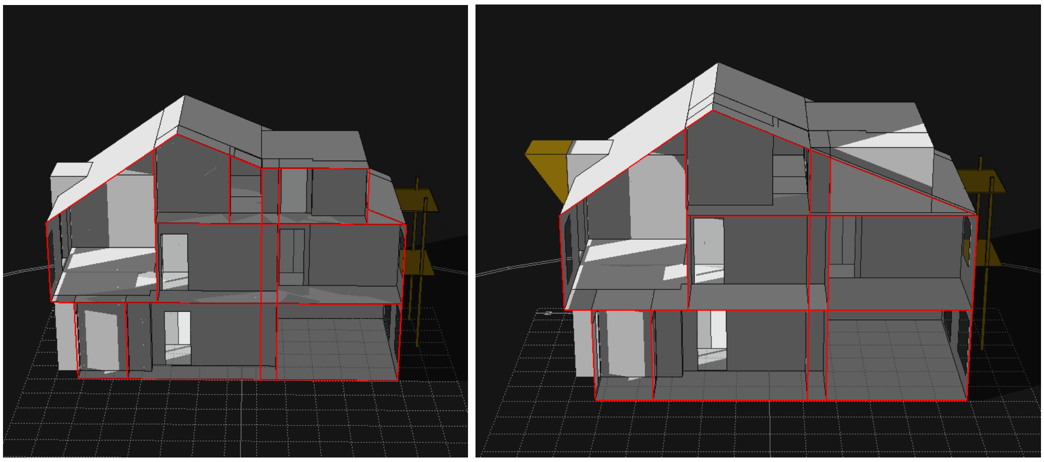

Figure 7a: December no shading December with shading

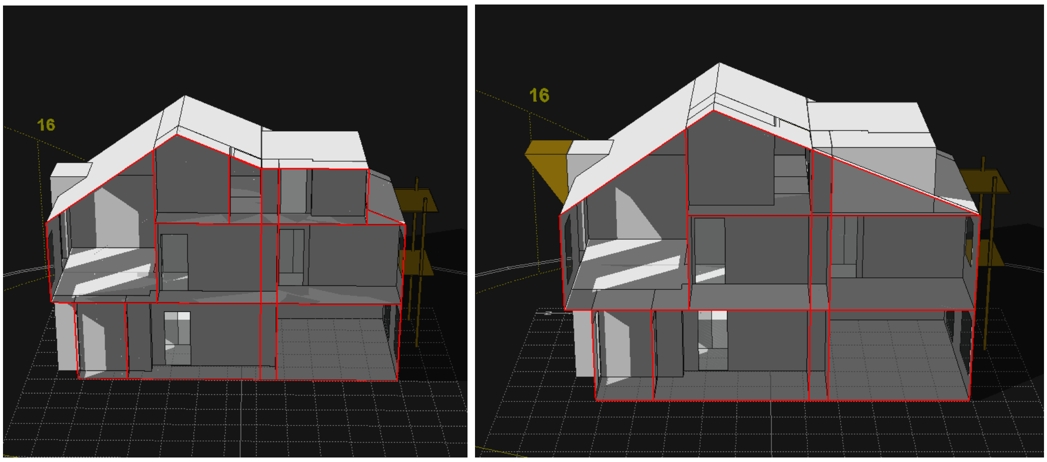

Figure 7b: March no shading March with shading

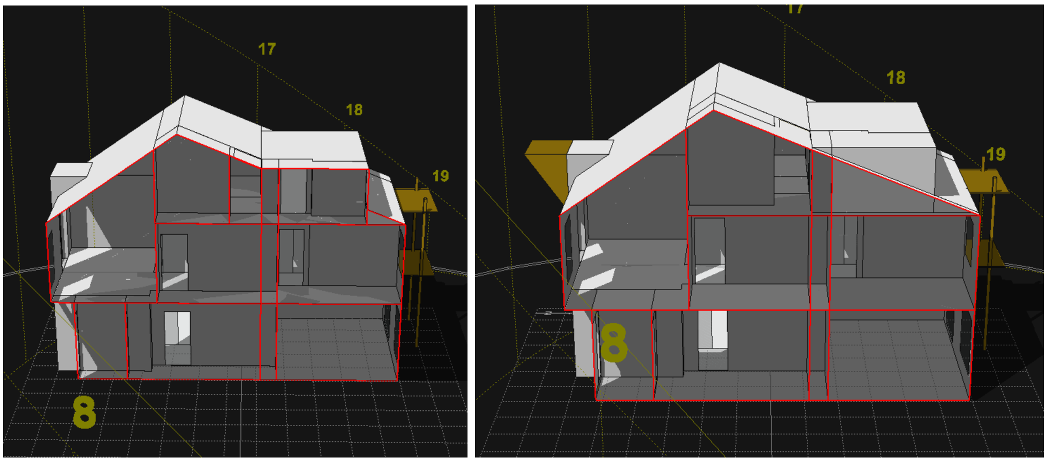

Figure 7c: June no shading June with shading

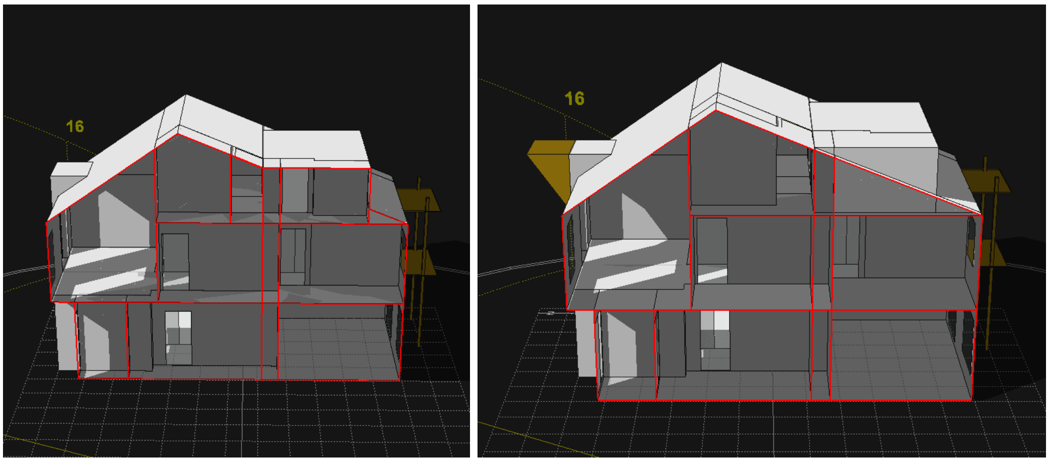

Figure 7d: September no shading September with shading

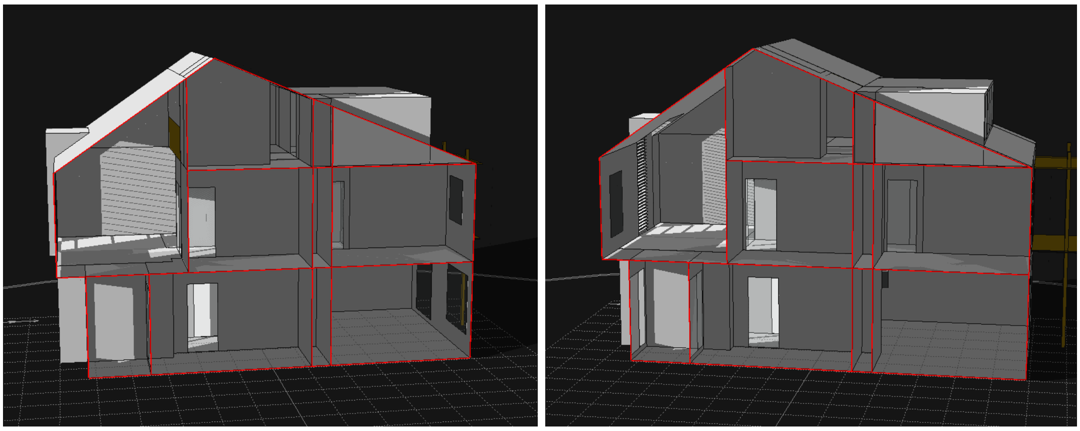

Figure 7e: December 200 mm gap between louver December with 100 mm gap

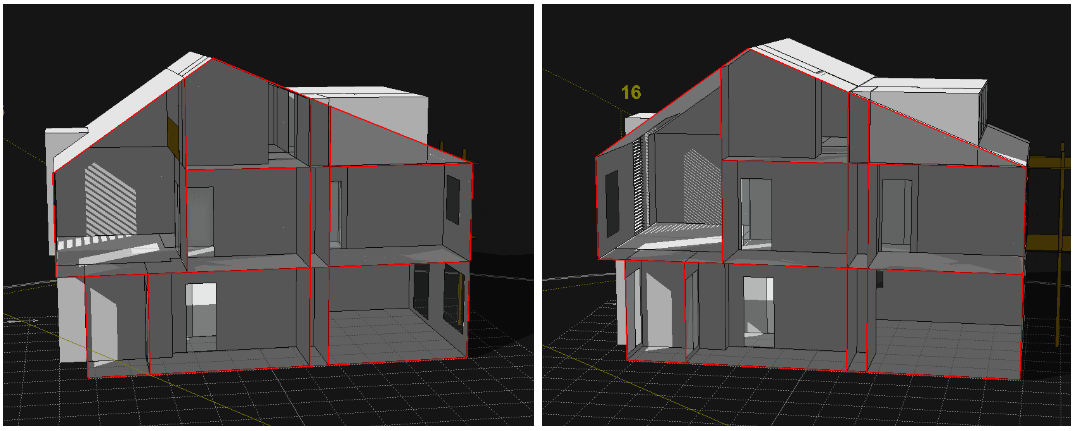

Figure 7f: March 200 mm gap between louver March with 100 mm gap

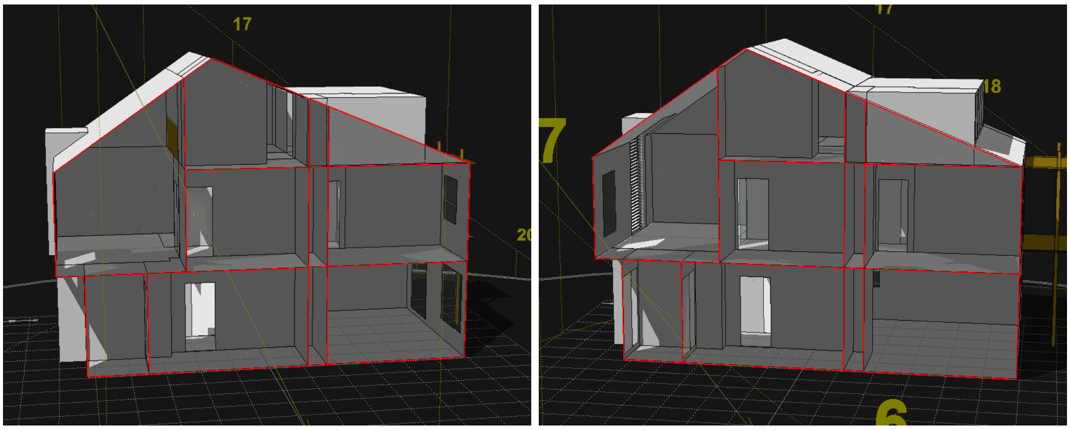

Figure 7g: June 200 mm gap between louver June with 100 mm gap

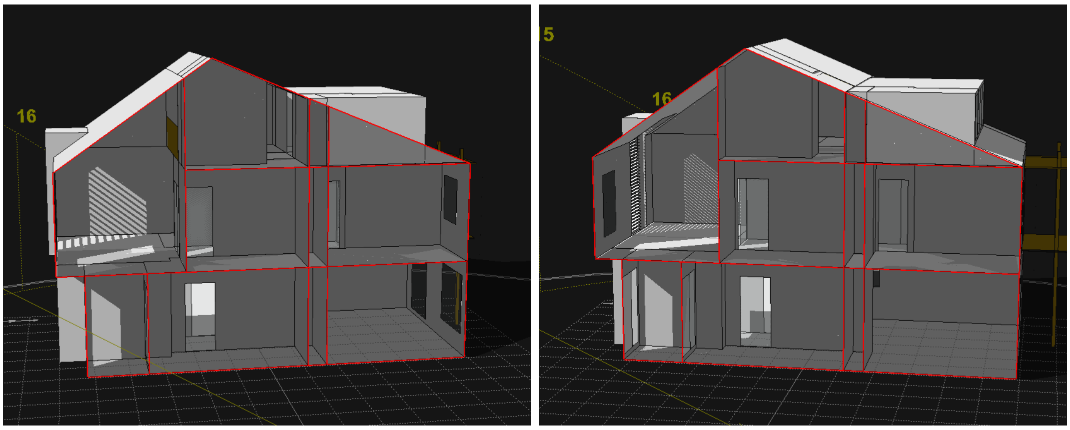

Figure 7h: September 200 mm gap between louver September with 100 mm gap

3.4 Thermal Analysis

The Ecotect software was used as the platform for the lighting simulation and it is capable of carrying out a thermal analysis for the house Type 1 that was animated for a range of operating modes. Figure 8 and Table 3 show the predicted energy loads on a monthly basis for this house type with a two period occupancy and an air change rate of 0.5 per hour. The results clearly show that the house will have a very low energy requirement.

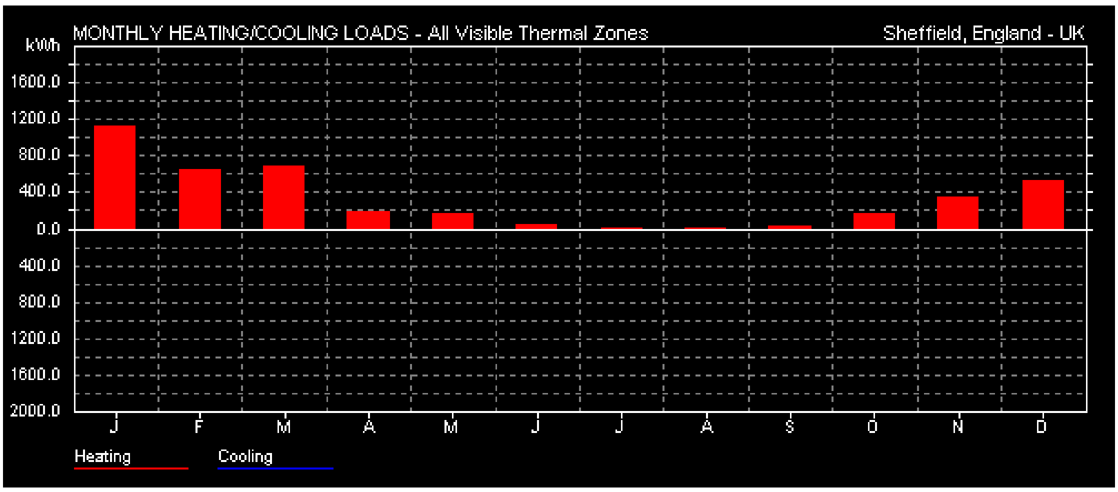

Figure 8: Predicted Energy Loads for the Type 1 House

Table 3: The projected Monthly Heating/Cooling Loads

Monthly Heating/Cooling Loads		
Max Heating: 5.44 kW at 07:00 on 12th January Max Cooling: 0.00kW - No Cooling		
Month	**Heating Load (kWh)**	**Cooling Load (kWh)**
Jan	1116.47	0.00
Feb	649.7	0.00
Mar	686.22	0.00
Apr	186.06	0.00
May	173.37	0.00
Jun	54.35	0.00
Jul	1.54	0.00
Aug	9.01	0.00
Sep	34.62	0.00
Oct	165.3	0.00
Nov	355.63	0.00
Dec	529.78	0.00
Total	**3962.05**	**0.00**
Per m²	**21.32**	**0.00**
Floor Area: 185.84 m²		

3.5 Further Analysis and Results on Energy Usage

The Ecotect programme was set up according to the following schedule and annual heating demand and costs for obtained. Inside air temperatures were set to maximum 22 °C minimum 18 °C. This means that when the outside temperature is above the minimum the heating system is switched off and when the heating is on it will switch off when the mean inside temperature reaches 22 °C.

Operating period	Mode A - set to switch on at 06:00 am and off at 23:00 pm Mode B – set to switch on at 06:00 am and off at 09:00 am Mode C – set to switch on at 16:00 pm and off at 23:00 pm Mode D – Mode B + Mode C		
Ventilation rate	a range was used	-	0.25 ac/hr 0.5 ac/hr 1.0 ac/hr 2.5 ac/hr
Gas cost			1.8 p/kWhr

The results of this analysis have been translated into the following bar-charts (see Figures 9 and 10), which show quite clearly that depending on how the house is used there will be a large range in the amount of energy used.
Note: A, B, C and D refer to the heating operational mode.

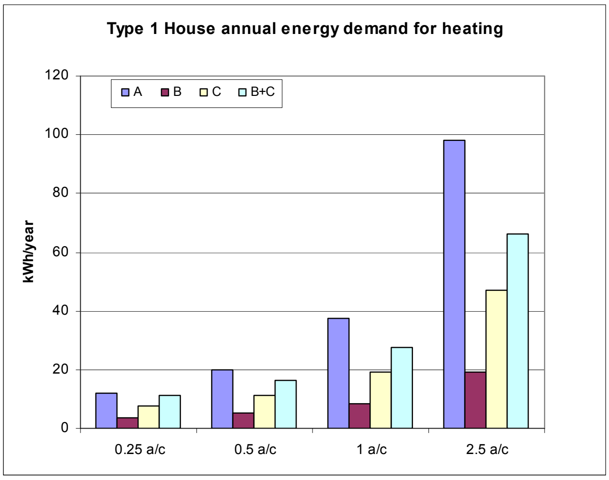

Figure 9: Predicted Annual Heating Demand

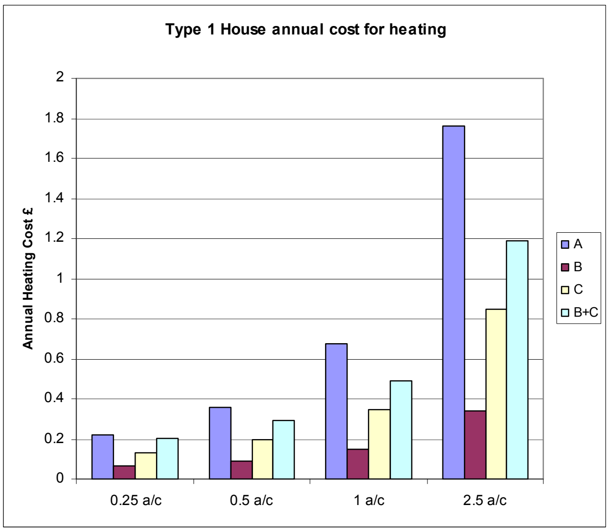

Figure 10: Predicted Heating Costs

3.6 CFD Airflow Analysis

CFD airflow simulations were carried out, using IES MicroFlo CFD tool, both inside and outside of the house types, providing the designer with software to understand the likely air flow and heat transfer processes occurring within and around house spaces given specified boundary conditions, which may include the effects of climate, internal energy sources and HVAC systems.

When developing a design, designers pay attention on integrating the natural ventilation system with the architecture by placement of fenestration systems, providing a building with a unique architectural expression, lower energy costs, improved thermal comfort and occupant satisfaction by supplying fresh air and a strong psychological connection to the outdoors.

The main reason for carrying out this analysis was to investigate whether or not appropriate natural ventilation can be provided and also to avoid stagnant areas. The initial analysis was to determine appropriate air flows, while a series of CFD animations were produced which then demonstrate how the air flows through the exterior and interior of the dwellings.

Externally, the velocity components, pressure, temperature, etc. around the house spaces are available throughout the domain around the house in each season of a year. Figure 11 shows the complex nature of the flow grid used. The interior air flow simulates the natural airflow pattern in magnitude and direction for a range of openings, and the impact of an artificial ventilation system on the flows. The results of this simulation can display the velocity vector and velocity contour throughout the model on the X/Y/Z-grid as well as in axonometric view. Representative examples of simulations carried out are shown here by way of illustration:

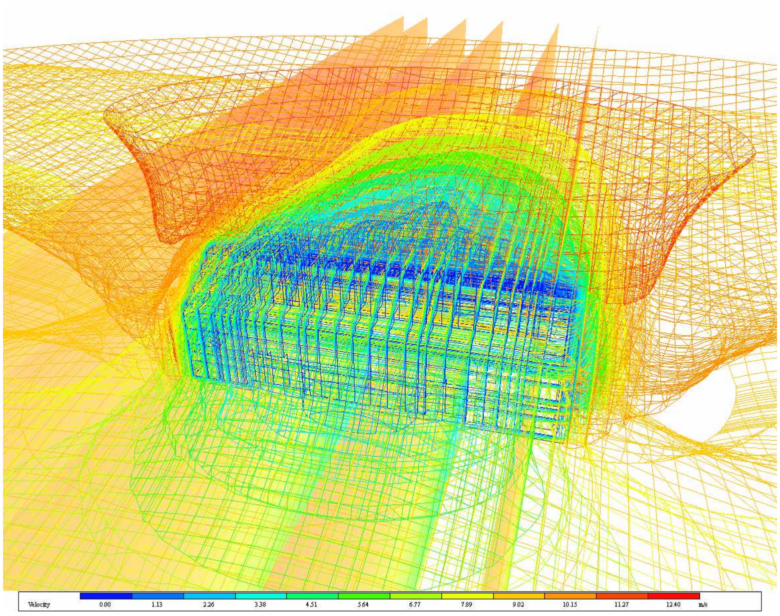

Figure 11: The external air flow grid, slices of filled velocity vector and pressure surfaces

Figure 12 shows that the air flows across the first floor of Type 2 house when the windows are open are quite adequate. There is a concentration of flow in the corridor but there are no stagnation areas, which can indicate all over air movement within the dwelling. This is important in warm summer months when air flows help to maintain thermal comfort within the dwelling.

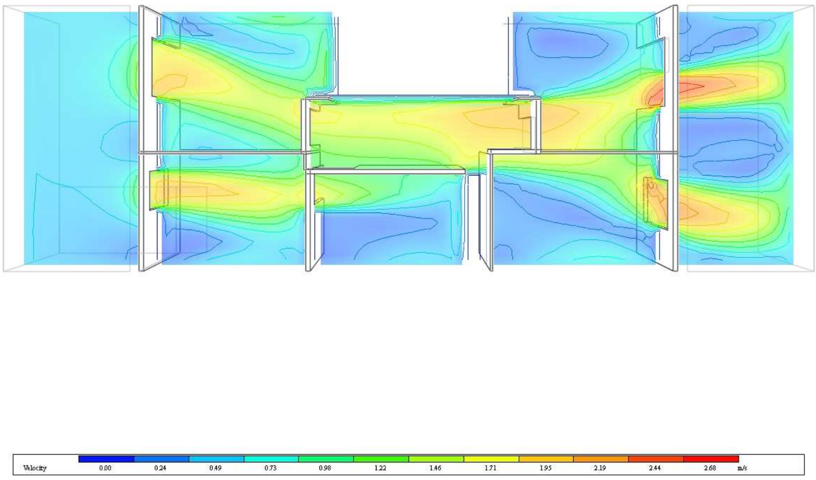

Figure 12: Air flows across Type 2 house at 1.8m from floor surface

Figure 13 shows how the air flows over the mezzanine level of Type 1 house and clearly demonstrates that adequate flows are produced.

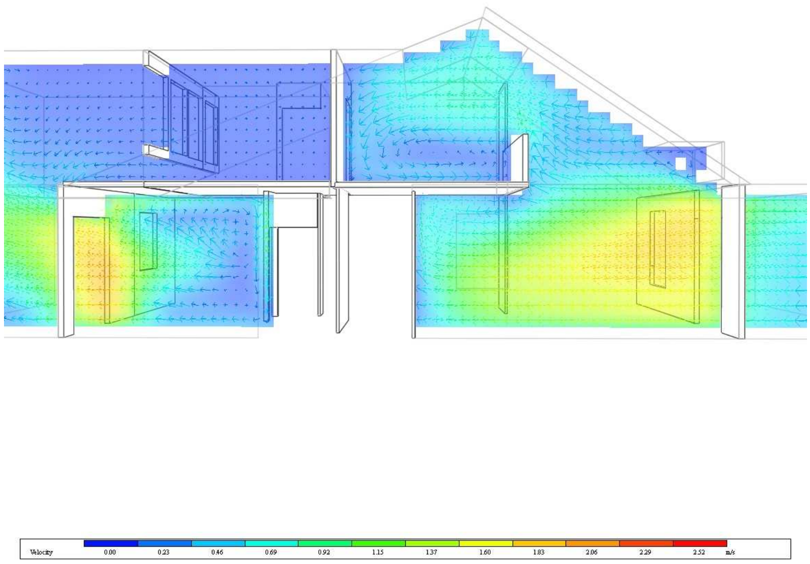

Figure 13: Air flows across the mezzanine level of Type 1 house

Figure 14 shows how the air from a central air supply mechanical ventilation system is distributed throughout the dwelling. This simulation was carried out to investigate if the mechanical background ventilation provided by a system such as Nuaire would be adequate to ensure that 'fresh' air could reach all parts of the dwelling. The results indicate that this would be the case.

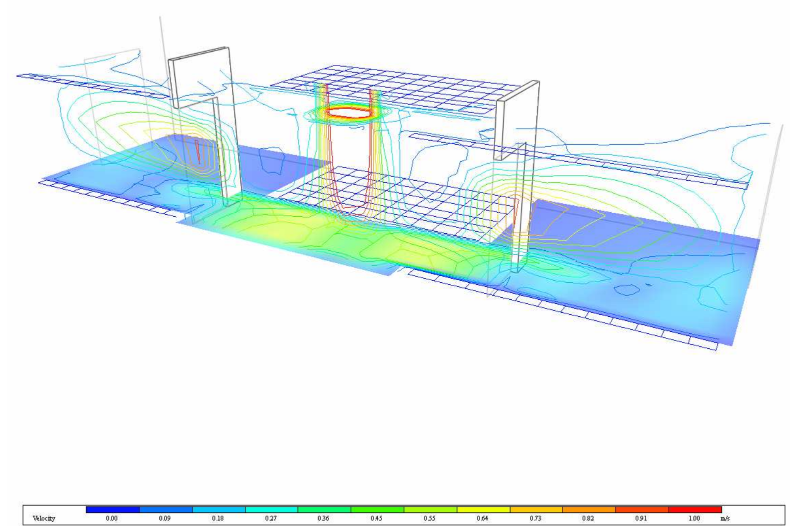

Figure 14: Air flows due to the introduction of a supply (single point) mechanical air supply system

4. CONCLUSIONS

This paper has demonstrated that by the integrated use of a range of computer packages, a better overall understanding of the impacts of lighting, heating and ventilation on the overall performance can be obtained. Also this overall understanding has resulted in modifications to the design which further inputs the performance as outlined below:

4.1 Lighting

From the analysis work carried out it is suggested that:

- The window on the ground floor of house Type 1 is enlarged to allow more light to penetrate the room.
- Type 1 house would benefit from the addition of a roof light over the Mezzanine area which will greatly enhance the quality of the light entering that space.
- The daylight factors calculated all give levels above the recommended minimum for the kitchens, living areas and bedrooms.
- The internal zones benefit from having glass doors or no doors in terms of light penetration.

4.2 Heating Load

Heating load estimates are quite simple processes to carry out within the Ecotect software. The results indicate that the house will have a design load in the region of 3 to 5kW (depending on house type), which is low for this size of dwelling.

Without an understanding of how the occupants will use the house, particularly with respect to window opening patterns making exact assumptions regarding the amount of energy used for heating is a little difficult. However, as the house types will be very well sealed with little or no infiltration, the 0.25 air changes per hour result as the maximum attainable can be assumed. This gives a heating cost approaching £40.00 per year which is overoptimistic as windows will be opened. Experience indicates that figures between 0.5 and 1 air change are more likely, giving heating costs in the region of £50.00 to £100.00 per year. It is to be noted that increasing the air change rate from 1 will have a very significant effect on the heating costs. If it is decided to install a heating system which includes a mechanical air supply then it is imperative (to keep running costs down) that some form of heat recovery system is incorporated in the design.

4.3 Air Movement

In warm periods it is essential that the house types can be adequately ventilated as a means of ensuring thermal comfort. The IES VE CFD analysis demonstrated that with the windows open there would be adequate air flows across the internal spaces. It was also noted that the air did circulate to the corners which will prevent stagnation.

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APPLICATION OF CRYO – POWER ULTRASOUND FOR THE RECOVERY OF OIL POLLUTION CHEMICALS

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Abstract: A low temperature power ultrasound oil and oil slurry treatment system has been designed and constructed. Preliminary evaluation of the equipment is reported. A model organic pollutant (anthracene) has been used to investigate the potential of the equipment. The theories and hypotheses under investigation include distinction between true ultrasonic degradation of an organic chemical species as opposed to thermal degradation. Secondly the chemical breakdown products and reformation products form an important feature of the work. This relates to hazard and risk presented by any such emerging chemical at the treated pollutant site. Anthracene is one of the polyaromatic hydrocarbons considered cancerous in nature. However the present investigation using HPLC analysis indicates possible reformation products such as the isomer of anthracene i.e. phenanthrene. Also other products produced in the treatment system, and of concern are still under investigation e.g. cyano derivatives, phenols and dienes. This low temperature study performed in acetonitrile carrier solvent reveals only some of the emerging products i.e. those that exhibit fluorescence spectra. The work is also conducted using an electrochemical approach in conjunction with power ultrasound, though data is not yet available from this operational feature of the equipment..

Keywords: oil pollution, low temperature, ultrasonic treatment.

1. INTRODUCTION

In the late 1970s it was still possible to find crude oil on the beaches of Jersey, largest island in the Channel Islands. Jersey is geographically located about 100 miles south west of southern England. The crude oil on pristine beaches was buried approximately 30 cm below the sand at the high tide level. Where had this crude oil come from and why had it not been totally removed from the beach for reprocessing?

A particular oil pollution incident was detected on Portelet beach, Jersey (Figure 1(a)) and was thought to be remnants of the oil slick from the Torrey Canyon oil tanker disaster (Scilly News 1967). Portelet beach is crescent shaped, about 300 metres in length and located at the base of a very steep cliff with no access road available (Figure 1(b)).

An approach to cleaning up oil contaminated sites and reclaiming chemicals using power ultrasound is examined. It is a primary function of this research that any method developed using ultrasonic cavitation collapse at low temperatures will be cost effective, efficient and incorporate sustainability through the premise of recycling chemicals. Thus some of the costs of environmental remediation of the polluted sites will be offset against the profit gained from the sale of chemicals obtained from the sites. This in effect means that the pollution pays for its own treatment, in part; at the same time chemicals already resourced from the environment (ie the individual constituents of oil) are liberated and reused. Thus the concept of "Profit from Waste" is fulfilled on both economic and sustainability grounds.

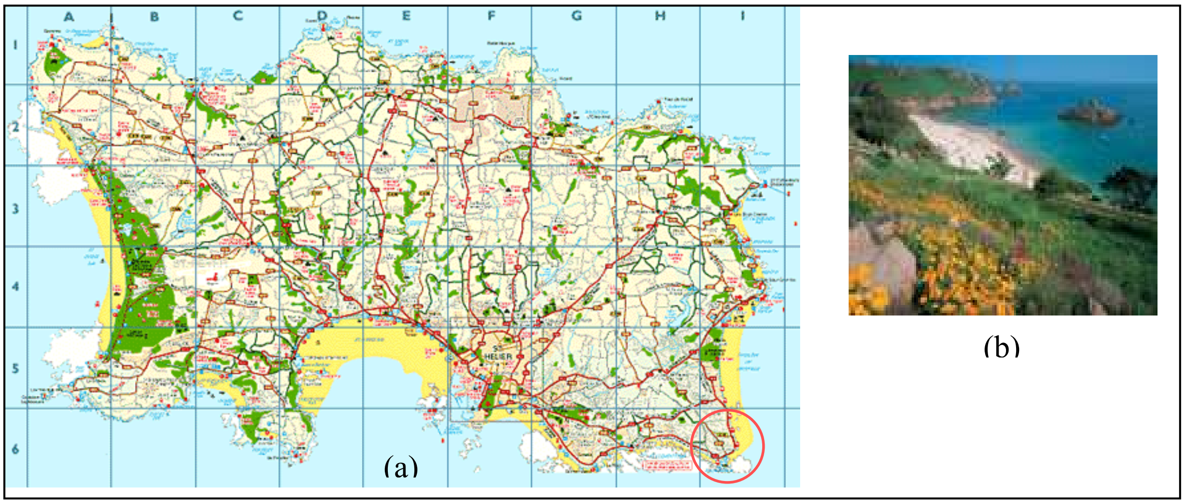


Figure 1: (a) Map of the Isle of Jersey with the oil contaminated area (red circle) and (b) inset the

Portelet Bay beauty spot and wild life habitat, a typical casualty of oil spill contamination.

Current oil removal technology incorporates a barrage defence in combination with chemical detergents to treat / remove oil from contaminated sources, but these methods can have serious consequences for the environment (Green Nature 2003).The present research attempts to discover if it is possible to develop a low temperature ultrasonic technique to retrieve and treat polyaromatic hydrocarbons (PAHs) and hydrocarbons (HC) that have been accidentally or in some cases deliberately released into the environment

The effectiveness of low temperature sono methods are being tested using laboratory experimental conditions to treat waste oil by substituting PAHs and HC as the reactant species. Recovered products can then be used as the raw materials for other processes. If this can be achieved then the costs of the environmental remediation of the polluted sites may become viable. It is also important that any successful methods developed can be scaled up to sufficient size and integrated at "onsite" oil contamination locations with minimal cost. Thus this will be a high efficiency process reducing the overall environmental impact caused by the oil release.

Another aspect of the research, forming an integral and necessary feature is the fundamental study and recording of sono cavitation events and their influence on reaction pathways, while the bulk media is at low temperature i.e. ~ 0 ^{o}C. This part of the research is of particular importance and the control of temperature is critical when using applied ultrasound in order to show if the reactions are thermal or sonolytic or are influenced by some other mechanism. It is this fundamental study of reactions and the provision of hypotheses and chemical mechanisms, their confirmation and understanding that will form the basis of the second phase of the research.

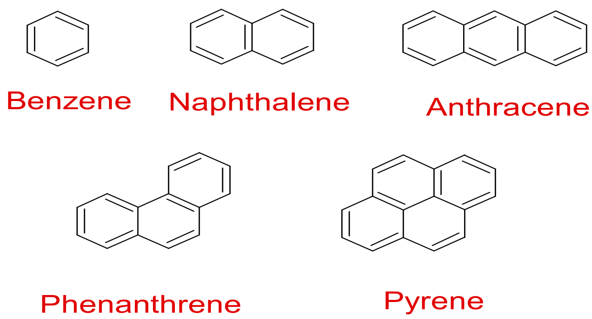
1.1 Health and Safety Considerations.

Anthracene is listed as "group 3 compound unclassified as to its carcinogenity to humans" in literature published by ATSDR (1999) and IARC (2002). Anthracene does however pose health risks and these are documented in many hazardous chemical fact sheets (IARC 2002). Anthracene is the second of the homologous series of the common PAHs with naphthalene first and phenanthrene third.

1.2 Health Effects Associated with PAHs.

The hazards that these pollutants pose to health can be significant, many PAHs for instance can be carcinogenic and can cause health defects to various organs of the body (MSDS 2002). For example, breathing very high levels of benzene vapour (C6 H6) can cause death, while high levels can cause drowsiness, dizziness, rapid heart rate, headaches, tremors, confusion, and unconsciousness (physchem 2002). The EPA has set the maximum permissible level of benzene in drinking water at 0.005mg/l while the OSHA has set a permissible exposure limit for benzene at 1ppm air in the workplace during an 8 hour shift (physchem 2002). The threshold limit value (TLV) for benzene recommended by MSDS is 10 ppm (physchem 2002). EPAQS recommends air quality standard for PAH 0.25ng/m3 as the annual average (physchem 2002). Structures of PAH are derived from the benzene molecule (Figure 2).

Figure 2: Chemical Structure of the first four common PAHs (Louden M.C. 2002.) Note. Benzene is not a PAH but is the basic structure from which all other PAH compounds are formed.



2.0 THE SCIENCE OF SONOCHEMISTRY

2.1 Utilising Ultrasound in Chemistry

Ultrasound can be used to speed up the rate of chemical reactions and can also be used to alter chemical reactions by various pathways. When utilising ultrasound in chemical experiments heat is generated from cavitation collapse which leads to a rise in reactant temperature that can lead to erroneous conclusions.

2.2 Reaction Rates.

The common consensus is that for every 10° C in reactant temperature rise the reaction rate may double, this fact leads to uncertainty when the analyses of results using ultrasound are compiled. Are the results due to wholly ultrasonic induced mechanisms or has a rise in reaction temperature effecting the outcomes.

An example of the reaction rate increase using ultrasound is the Ullmann coupling reaction which requires the use of 10 fold excess copper powder and heating for 48 hours. Using power ultrasound produces similar results using 4 fold copper powder for 1.5 hours were obtained (Mason T.J.,Peters D.2002).

2.3 Estimates of Energy Released at Bubble Collapse.

The energy released at bubble collapse (~5000 K, 150 to 10,000 atmospheres in approximately 3 microns) been estimated to be ~3 /10000 of an Erg which is about ~100 x 10 ^{6} electron volts (Apfel R..E. 1994)

2.4 Cavitation Bubble Inception.

The chemical and mechanical effects of ultrasound are caused by the formation of cavitation bubbles from the rarefaction (low pressure) period of the sound wave. [Figure 3] During this period the liquid is pulled apart at points where impurities are present forming cavities or voids in the liquid. These are termed the nucleation sites, also called weak spots in the fluid (Figure 3 (Suslick K.S. 1988)).

2.5 Cavitation reaction zones

There are three principle zones in which reactions can take place, the forces within these zones vary in intensity from extreme in site 1 through to medium in site 3, and this results in chemical reaction taking place under different conditions. The three zones have been diagrammatically presented in Figure 4.

2.6 Radicals.

The formation of free radicals is one method by which ultrasound can be used to accelerate the reaction rate. Free radicals are atoms or a group of atoms that have unpaired valance electrons (Free radicals 2001). Free radicals are very reactive due the fact that they have free valancy, a very important property that can be utilised in chemistry particularly for the enhancement of chemical reactions.

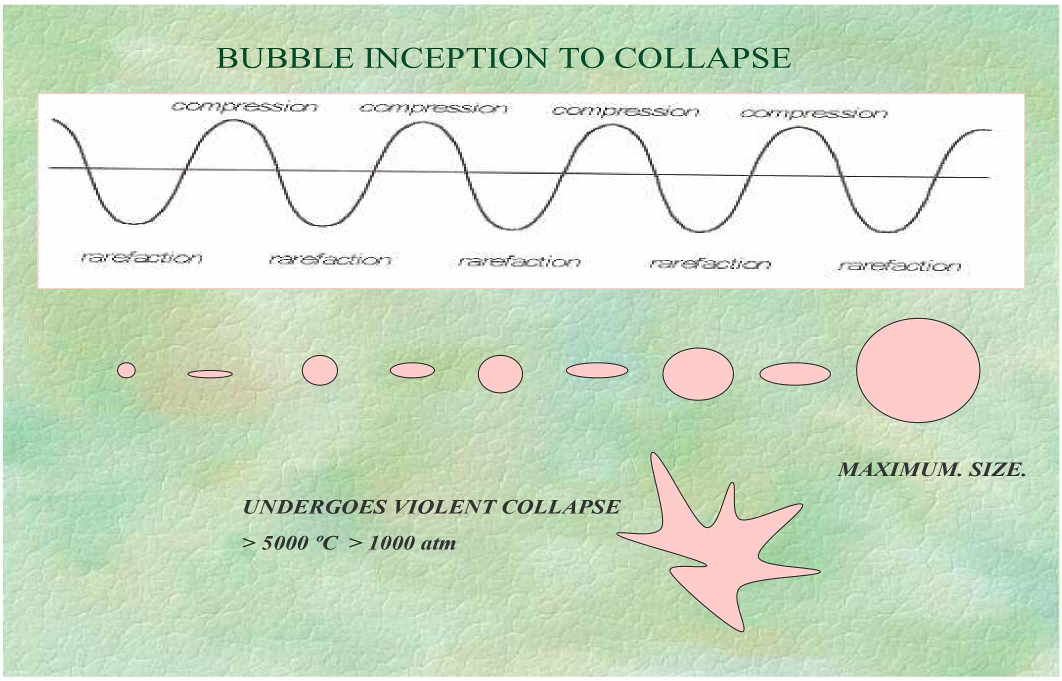


Figure 3: Cavitation Bubble Inception. The sine wave figure represents the change of events that cumulates in the collapse of the bubble, the values attained at bubble collapse are given in the texts (Louden M.C. 2002).

The release of shock waves and the effect of micro - streaming together with the transition from high to low velocities away from the bubble can cause intensive shear stress inside the liquids. For a 5 µm diameter cavity at 1 MHz a velocity of 5.5x 10^5 s^{-1} and a shear stress of 550 Nm ^{2} are quoted (Mason T.J., Peters D. 2002)

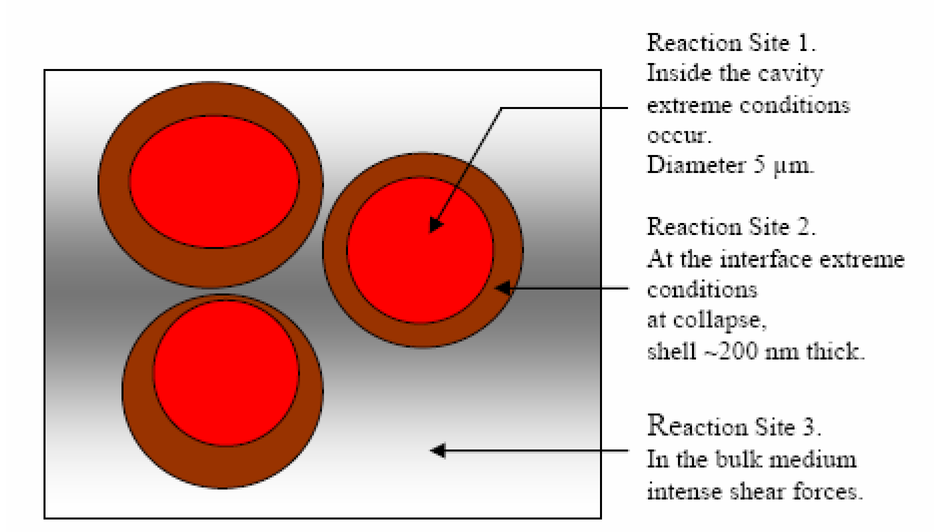


Figure 4: Cavitation Reaction Zones.

2.7 Other Ultrasound Effects.

Ultrasound can have other mechanical effects on the reaction, these include increasing the surface area of the reactants, acceleration of dissolution, renewing the surface of a catalyst or the reactant materials. By contrast chemical effects from cavitation induced from ultrasound will not occur,

1 In a solid.
2 There are no dissolved impurities in the system.
3 When the sound intensity is less than the cavitation threshold.
4 When the reactant is not volatile enough to enter the cavitation bubble during bubble nucleation.

The cavitational activity is directly proportional to the number density of the particles in the fluid medium, if only small amounts of cavitation bubbles are formed then only small amounts of activity will be available for the enhancement of chemical reaction. Higher cavitational activity can lead to greater reaction rates within the chemical system being sonicated with products being produced faster, and in greater quantity.

2.8 Cavitation Theory.

In order to understand the physics of what is happening within the cavitation bubbles produced from ultrasound two distinct theories have evolved.

1 The hot spot theory.
2 The electrical theory.

2.9 The Hot Spot Theory.

The hot spot theory states that during cavitational collapse localised hot spots are formed within the incompressible fluid. These hot spots can reach temperatures in excess of 5000 K and 150 to 10,000 atmospheres. Nathalie Kardos and Jean-Louis Luche quote temperatures of 5000 K and pressures up to 1200 bar and fast cooling < 10^{10} K / s; these data compare favourable with the data quoted by other researchers Figure 3.
(Mason T.J., 1999, Suslick K.S., 1988, Kardos N., Luche L., 2001)

2.10 The Electrical Theory.

The electrical theory states that an electrical charge is formed on the surface of the cavitation bubble producing very large electrical field gradients across the bubble that can provide the energy to cause bond breakage within the chemical system being sonicated. The hot stop theory is the more accepted of the two theories. (Suslick K.S. 1988)

2.11. Stable and Transient Cavitation.

Chemical effects due to ultrasound are associated with the collapse of the cavitational bubbles both stable and transient within the system. Stable cavities oscillate for several acoustic cycles before collapsing or never collapse at all. Stable cavities are relatively long-lived produce low temperatures and pressures on collapse but have sufficient long-term effects. Stable bubbles contain mainly gas with some vapour and are produced by intensities 5 Watts per square cm and oscillate often non – linearly about some equilibrium size for many acoustic cycles. Transient cavities exist for only a few acoustic cycles and then collapse, transient cavities are therefore only short lived but produce high temperatures and pressures on collapse (Figure 3).

Transient cavities produce radicals and sono-luminescence. Transient cavities are thought to be voids or partially filled bubbles, are created by intensities > 10 Watts per square cm and undergo violent collapse. The time for bubble has been calculated at about 10^{-6} seconds, since bubble collapse occurs within a very short timescale the process is assumed to be adiabatic (Kardos N., Luche L., 2001).

3.0 PRE - EXPERIMENTAL LABORATORY WORK

3.1 Temperature Control.

At the outset of this research the control of temperatures generated within the sonocative processes was considered to be one of basic requirements in order that qualitative and quantitative results were obtained. Also it is important to show that the reactions are truly sono electric or sono electro regulated or enhanced and that the effects are not just thermal.

Weissler discovered in 1953 that the sonochemical process is temperature dependant, ultrasound inducted cavitation reduces as the temperature increases. (Mason T.J. 1999)

Yasui and co workers also discussed the fact that the sono chemical effect is reduced as the temperature of the reaction is increased. These findings are extremely important for this research since a significant effort has been to designing and manufacturing a reliable temperature control system. (Yasui K., Tuziuti T., Lida Y., 2003)

3.2 Solubility and Concentrations of Reactants.

As anthracene is not readily soluble in water and other solvents such as Acetonitrile were used as the carrier medium. The anthracene sample to be sonicated was prepared using 100 mg stock anthracene, made up to 1litre with acetonitrile, this solution was stored in a glass flask complete with stopper within a dark compartment. The formation of cyano derivatives from the acetonitrile was a possibility as was the formation of chemical sub species, e.g. phenols and dienes was taken into account during experiments

3.3 Modifications to the Kerry Ultrasonic Bath. and design, construction of innovative cooling system.

The ultrasonic bath was adapted to accommodate a glass tube 11cm long and 6 cm diameter. Figure 5 shows this part of the apparatus (called the reactor core) which is mounted centrally and sealed at the bottom in the ultrasonic bath, the reactor core is surrounded with 1 litre of coolant, which is a combination of commercial antifreeze and water. The cooling system was adapted, improved over an approximate nine month period utilising innovative technology until a satisfactory system was finally developed. The completed cooling system is shown in figure 5

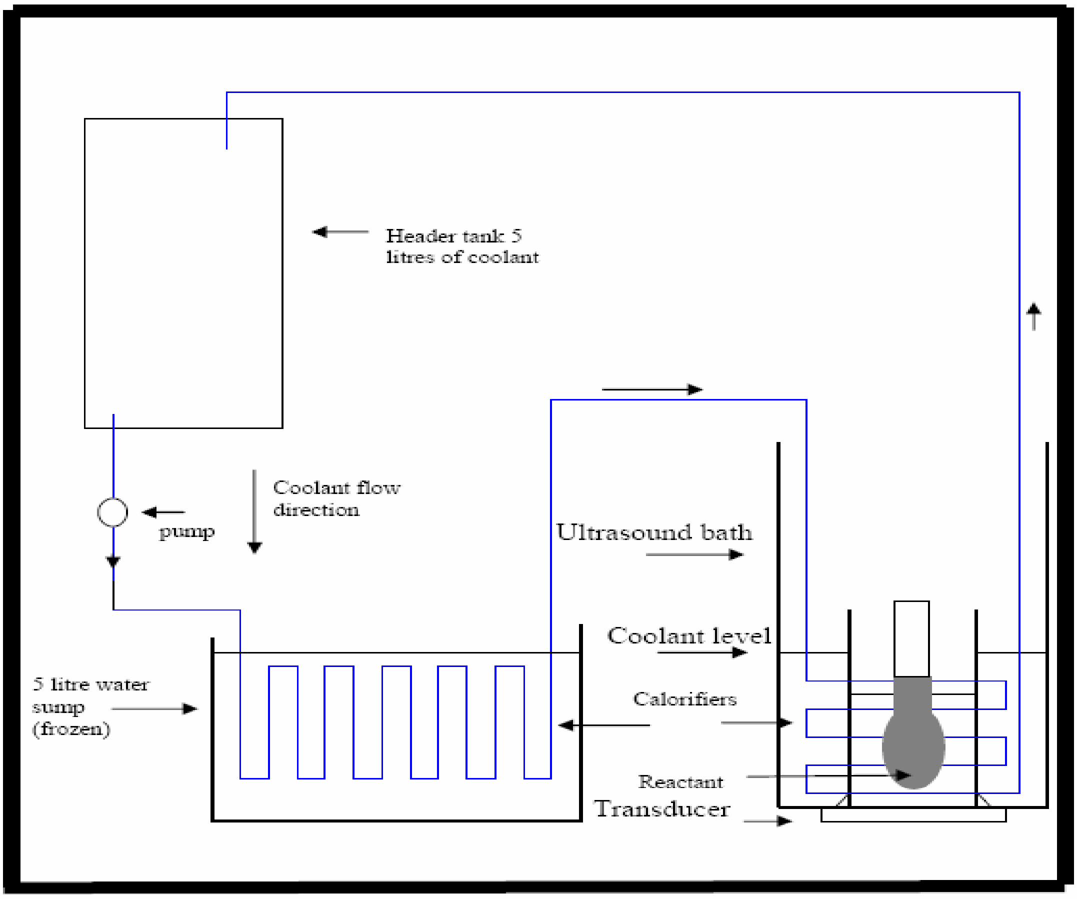


Figure 5: Location of components within in cryo system.

Copper pipe (8mm) with coolant containing antifreeze is pumped from the header tank to through the internal calorifier located in the frozen sump to maintain constant low temperature. A second calorifier is connected to encompass and cool the modified reaction chamber in the ultrasound bath, coolant is then returned to the header tank to complete the system. It is impossible for cross contamination to effect the reactants using this system The components and layout of this system provided a practical and safe method of controlling the heat generated when experiments where be conducted. The system has been run under test for long periods without any apparent faults.

In order to test the effectiveness of the cooling system the equipment was switched on and left to run overnight in order to attain low temperature in the region ~ - 5° C. For initial sono low temperature experiments it was considered that temperatures below freezing would constitute a favourable start condition. The system was capable of controlling temperatures within various ranges dictated from experiments constraints. Experiments were carried with varying time lengths with temperatures being closely monitored, many experiments were carried out to determine the time that produced best results, but always within realistic temperature limits.

3.4 Experiment chemical pollutants.

Anthracene, the selected PAH was chosen since its potential health effects are considered negligible or very low and was prepared in concentrations ranging from 1ppm to 100 ppm in acetonitrile and used in the experiments. Anthracene and water are not readily miscible and produced a cloudy aqueous solution, this fact precluded the use of water as the carrier solvent. Acetonitrile was chosen as the carrier solvent anthracene and acetonitrile produced a transparent solution. Higher concentrations of anthracene were preferred since it was considered that only small changes would be observed Experiments were conducted at time intervals from 0 minutes to 140 minutes with samples taken for analysis at 15 minute intervals using HPLC analysis with fluorescence detection. The results were printed in table and graph formats and held for future reference and comparison.

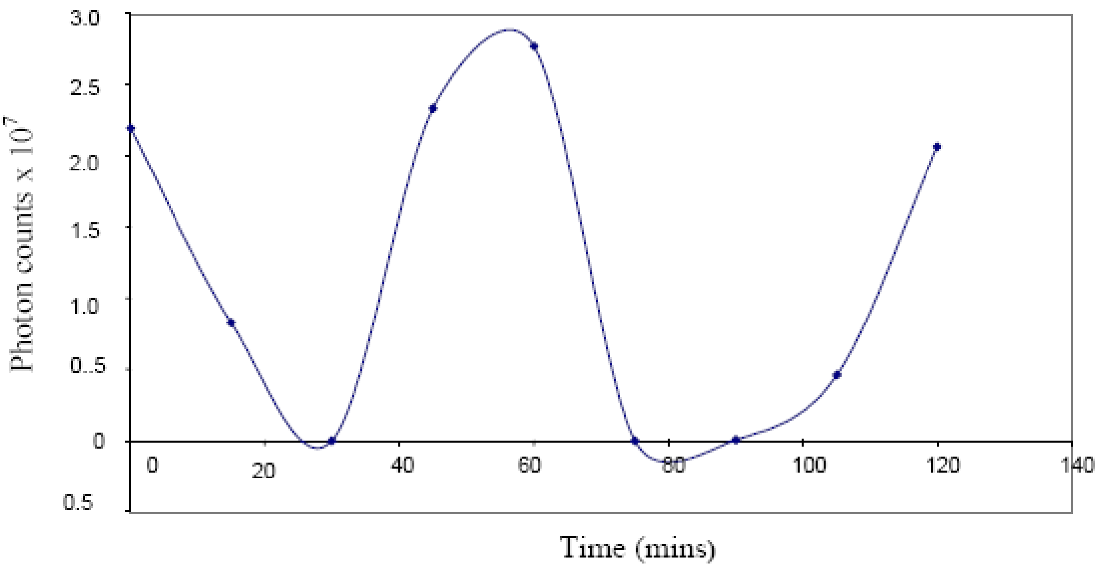


Figure 6. Time (mins) verses Photon Counts Phenanthrene production from Anthracene using ultrasound (troughs represent degradation and peaks represent reformation).

4.0. CONCLUSIONS

When using the sono system in the low temperature mode ~ 0° C to 10 ° C the results did show that the anthracene was being chemically altered to form other chemical species.

The species detected were, naphthalene, phenanthrene, pyrene, with anthracene also seen in the results. These PAHs species were seen in all results and at all temperatures regardless of the original concentration of reactants, with time the only parameter. Naphthalene ($C_{10}H_8$) was detected at 3.5 minutes, phenanthrene ($C_{14}H_{10}$) at 6.3 minutes , pyrene ($C_{16}H_{10}$) at 8.9 minutes, anthracene ($C_{14}H_{10}$) was the first to detected with retention time of 2.9 mins. Anthracene was being degraded into other compounds using sono chemistry within the applied temperature range.

Isomeration was seen when anthracene was degraded to form phenanthrene and then phenanthrene reformed to anthracene, in this case the formation and reformation of these two compounds was back to back, (figure 6).

Using equipment designed and constructed in early research, methane gas (CH_4) was detected in small quantities within the temperature range 30° C to 45° C.

The formation of the lower aliphatic compounds such as methane was considered to be an important prime reformation product, since the gas can be used as a fuel source without further treatment.

Further experiments using the low temperature equipment may have the possibility to increase the yield of PAHs and HC compounds to a point were the low temperature system becomes sustainable.

Other compounds not yet investigated could also be formed during low temperature reactions and will require further ongoing investigation.

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EXPERIMENTAL INVESTIGATION INTO THE BUOYANCY DRIVEN CONVECTION IN PASSIVE SOLAR HEATING FACADES

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Abstract – Emphasis has recently been focused on the reduction of energy use in the heating and cooling of building interiors. This has resulted in increased interest into passive solar air heating systems (such as Trombe walls) and passive ventilation techniques (such as solar chimneys). Such Solar Façade elements have now been in use for several decades and all rely on a solar-induced buoyancy-driven convection mechanism to produce the required airflows. The heat and mass transfer mechanics of both of these systems is not completely understood, which has made predicting the performance of these systems difficult to forecast.

This paper will detail the latest experimental research into heat and mass transfer in buoyancy driven airflows into the influence of system height and aspect ratio. Two test rigs, resembling the essential features of a passive solar air heater are utilised. The test rigs have a system height 1m and 0.5m allowing the influence of system height on the airflow to be determined. Measurements are made of the air, plate and cover temperatures, the air velocities and the heat fluxes. The results from these two systems are compared with previous work from other researchers and the effect of the height of the channel (and the height to depth aspect ratio) is discussed.

Keywords: Passive Solar, Natural Convection, Heating and Ventilation

1. INTRODUCTION

Passive solar systems are playing an increasing role in reducing the mechanical cooling and heating loads of modern buildings. Solar façades rely on buoyancy driven (natural) convection to induce airflow. A Trombe Wall (figure 1) comprises a massive thermal wall (for example, made of concrete) with a black surface, which absorbs the incident solar radiation. As the surface (the 'absorber plate') heats up, this in turn heats the air in the channel between it and the cover, inducing the heated air to circulate into the room behind it. Some sources have reported up to 65% of a building heating requirements being met by a Trombe Wall (Wigginton *and Harris, 2002; Luminosu, 2003)*.

By opening vents at the top of the Trombe wall, the system can operate in 'ventilation mode', creating a solar chimney. The Double-Skin Façade is essentially a pair of glass "skins" separated by an air corridor. *Hirunlabh et al (1998)* achieved an air extract air rate of up to 0.02kg/s, equivalent to 2.2 air changes per hour, for a small house in a tropical climate. *Afonso et al (1999)* reported achieving a 22% level of ventilation requirements in a Portuguese climate using solar chimneys.

Solar chimneys were also extensively utilised in the BRE Environmental building in Garston. This building also used night-time cooling, computer controlled louvre to optimise light levels, ground source heat pumps and a PV array (Wigginton *and Harris,* *2002)*. The combined effect of these systems was a reduction in total building energy use to 117 kWh/m^2, a 53% improvement on a normal office building and 30% better than best practice. However, overall the performance of the BRE building was a little disappointing as other buildings have achieved far greater reductions. Limerick County Hall, for example, used solar chimney effects, night time cooling and a double skinned façade glazed system is expected to achieve a 87% reduction in CO_2 emissions with a total energy use level of 76.4kWh/m^2.

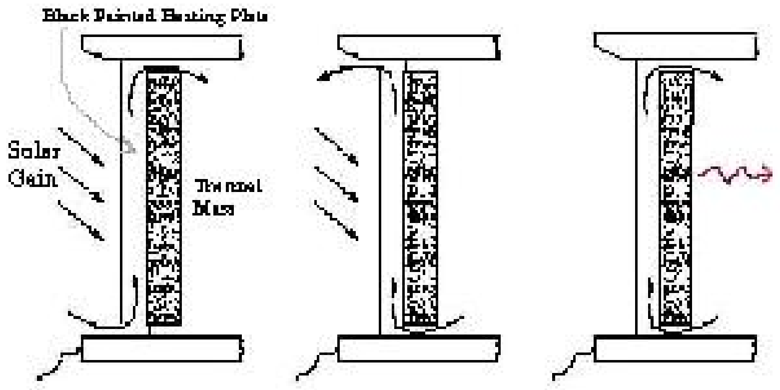

Figure 1: Trombe Wall

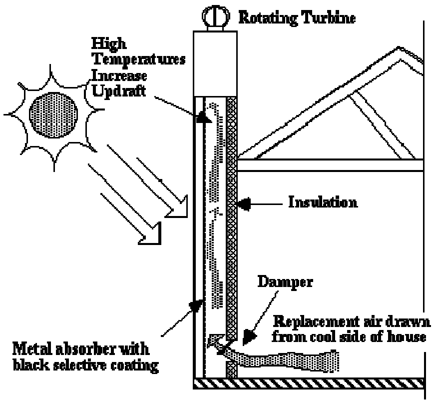

Figure 2: Solar Chimney

Increasing interest in photovoltaic (PV) facades suggests another application. The photovoltaic thermal façade (PVT) consists of a solar chimney type of arrangement which uses a PV array itself as an absorber plate. The convection of heat away from the PV array can be utilised to heat or ventilate the building, and the efficiency of array is also improved by the reduction in temperature. *Eicker et al (1999)* reported a 22% improvement in the performance of the PV arrays on the Mataro Public Library using this type of arrangement. Further, between 40% and 160% of ventilation needs and 12% of winter heating needs were provided by facade, in addition to 47,000 kWh per annum of electricity from the PV arrays.

Although much of the basic science of buoyancy-driven convection has been extensively studied, it is a very complex subject. Specific applications, such as solar façades, are not completely understood, and so their exact performance can seldom be predicted accurately. This lack of knowledge contributes to the poor take-up of this type of technology. In particular, the relationship between airflow, heat transfer, heat input, the precise geometry and other characteristics of such systems are not clearly understood, and therefore many passive solar air collector systems have been designed on an *ad-hoc* basis. This paper presents some results from a test rig designed to simulate the performance of a passive solar heating panel under controlled conditions, as part of an on-going series of experiments designed to define the characteristics of these systems

2. PREVIOUS RESEARCH

Several researchers have specifically investigated the issue of the heat transfer rates in thermosyphoning systems. For example, *Bouchair (1994)* and *Chen et al (2003)*, studied vertical channels as solar chimneys. Both also considered the influence of aspect ratio (channel depth to height), concluding that these influence heat transfer, system efficiency and air mass flow rates. *Chen* reported that the temperature profile along the channel height was influenced by the aspect ratio, and that airflow rates continued to increase as the channel depth increased. He did not find an optimum channel depth, despite observing a backflow for channel depths greater than 300mm. He also noted a decline in temperatures above a certain vertical height in the channel, depending on the aspect ratio and channel depth. This suggests that there is a link between these factors and maximum temperature, and therefore thermal efficiency. *Bouchair* reported an increase in the airflow rate up to a channel depth of about 300mm (corresponding to an aspect ratio of 0.1 for his test rig), after which backflow can occur, resulting in a decline in performance.

During a numerical analysis of buoyancy driven flow *Fedorov and Viskanta (1997)* noted that the velocity profile was continually developing up the channel height. These results closely match those of experimental work performed by *Miyamoto et al (1986)*. Other researchers suggest that height may be important, independent of aspect ratio. For example, *Afonso and Oliveira (2000)* determined that efficiency is a function of height for solar chimneys, and *Ong (2003)* suggested that mass flow rate is a function of both channel height and depth. Although *Balacco (2002)* considered different channel heights analytically, most experimental investigations to date have been based on a single channel height, and therefore little experimental evidence exists for the influence of channel height (as opposed to aspect ratio) on the system performance.

The present study follows very closely the experimental procedure used by *Habeb (2003)* and *Habeb et al (2004)* so that results can be directly compared. Habeb had however only considered a single system height (of 1.025m's) and only aspect ratios up to 0.107. The present study would expand this to include a 0.51m test rig, cover a greater range of aspect ratio's and advance the study of transient behaviour as well as applying more enhanced dimensionless analysis to the results from both sets of tests. This paper reports some preliminary results, comparing the performance of these two test rigs. *La Pica et al (1993)* also used a similar test rig, 2.6m high, However, significantly his test rig had a silvered cover specifically to reduce radiation heat losses, so direct comparisons are not necessarily valid.

Most investigations focus on steady-state conditions, and only a few experimental studies have referred to transient conditions. The controlled nature of the experimental work reported here allowed transient data to be captured reliably, and this is also presented in this paper.

3. EXPERIMENTAL TEST RIG AND PROCEDURE

The experimental test rig was designed to resemble the essential features of a passive solar air heater (see figure 3). It comprised a vertical channel, open top and bottom (but with no inlet or outlet ducting) and closed at the sides. A controlled heat input was via an electrical heating mat behind the aluminium absorber plate, which was painted matt black. The cover was a sheet of transparent Perspex. Heat losses from the back of the channel were minimised by 100mm of rockwool insulation behind the heating mat.

Temperatures were measured using fine (0.2mm) thermocouples, and airflow with a temperature-compensated hot-bead anemometer, calibrated down to 0.15 m/s. All data was recorded using a multi-channel data logger. Experiments were conducted on the 0.5m test rig at channel depths of 20, 40, 60, 80, 100 and 150mm (corresponding to aspect ratios of 0.04, 0.08, 0.12, 0.16, 0.20, and 0.29 respectively) with heat inputs of 200, 400, 600, 800 and 915 W/m^2 (a total of 30 tests). The test procedure involved setting the channel to the required depth and switching on the power. A uniform heat flux (UHF) was thus applied, and the transient temperatures through the test rig and air velocity through the channel were recorded at 2-minute intervals. When steady-state conditions were established, after about 4-5 hours of heating, smoke tests were performed for a visual check on the airflow patterns, and air velocity profiles across the channel were measured. The power was then switched off and the transient cooling behaviour recorded, until the air temperature returned to ambient conditions.

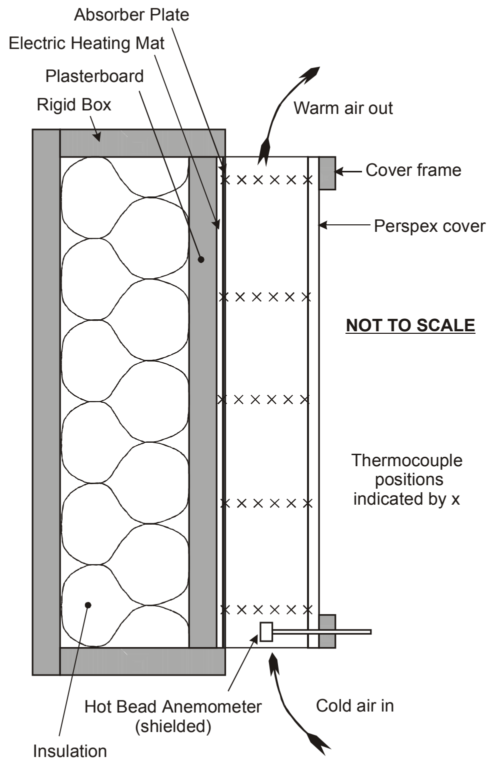

Figure 3: Test Rig schematic

3.1 Temperature and Velocity Profiles

The horizontal and vertical steady-state temperature and velocity profiles were of a similar form to those reported by *Habeb (2003)*. Temperatures increased along the height of the test rig, as can be expected, but started to decrease from a point about two-thirds of the height. This has been observed by several previous researchers, but the cause of this effect is open to interpretation.

Temperatures across the channel depth showed a fairly flat profile in the airstream, with the temperatures of the (heated) plate and the (unheated) cover both higher than the air temperature. Therefore the heat transfer by radiation to the cover is greater than the heat transfer by convection to the air.

The velocity profile at the bottom of the channel was found to be flat, showing that the flow was essentially undeveloped. At the top, the velocity close to the heated plate was higher than in the middle of the channel. A second peak close to the cover is also observed. This is noticeable particularly at high heat inputs (1000 W/m^2) and deeper channels (100mm, aspect ratio 0.1). This was also observed in the 1.0m experiments.

The main difference between observations from the 1.0m test rig and the current investigation was that, with a shorter test rig but similar channel depths (*i.e.*, greater depth-to-height aspect ratios), flows tended to be more unstable. Although the test rig was shielded as far as possible from the rest of the laboratory, the air flows were more prone to disturbance by external influences, such as draughts and other stray air currents in the room. Flow visualisation tests using smoke indicated that some recirculation took place within the channel at high aspect ratios, but no backflow occurred (i.e., no air exited at the bottom of the channel).

3.2 Mass Flow Rate and Thermal Efficiency

Air flow rate is a key performance indicator for the system working in ventilation (solar chimney) mode. The mass flow rate, *m* in kg/s per metre width of the collector, is given by:

$$m = \rho v s \qquad (1)$$

Figure 4 shows air mass flow rate against channel depth *s* for different heat inputs Where ρ is the air density, and *v* is the air bulk velocity. In general, the air flow rate increases with channel depth (could be expected, due to reduced friction forces) and with increasing heat input (also expected, due to higher temperatures and buoyancy effects). However, at low heat inputs, the airflow appears to decrease as the channel depth increases. *Habeb's* results also suggest a similar trend. This lends some support to the suggestion by *Bouchair (1994)* that there is an optimum channel depth for air flow through a solar chimney, and further, that the optimum depth increases as the heat input increases. The thermal efficiency of the system is defined as:

$$\eta = Q_{gain}/Q_{in} \qquad (2)$$

Where η is the thermal efficiency, Q_{gain} is the heat gain and Q_{in} the heat input. The heat gain, Q_{gain}, can be determined by:

$$Q_{gain} = m\, c\, (T_{out} - T_{in})/H \qquad (3)$$

Where c is the specific heat capacity of air, H is the height, Tout & Tin the outlet and inlet temperatures. Figure 5 shows efficiency as a function of heat input. There is no clear dependence of efficiency on channel depth, but efficiency is clearly a function of heat input. The figure shows an obvious distinction between the 1.0m test data and those from the 0.5m tests, hence implying that channel height has an influence on the thermal efficiency.

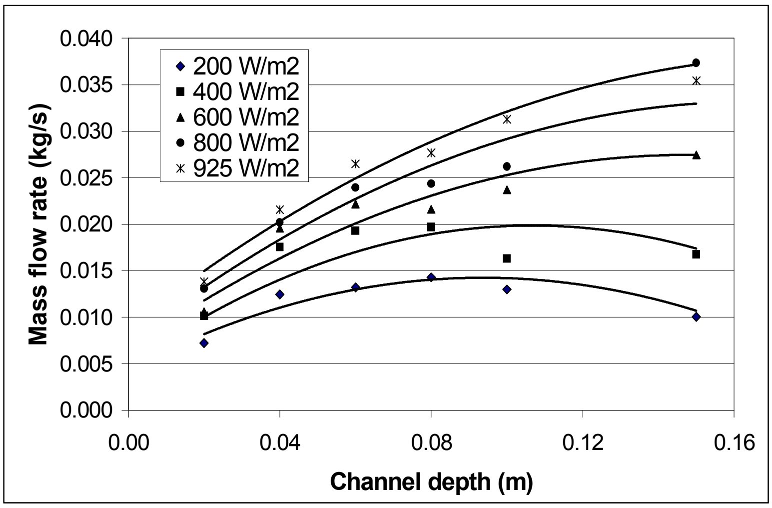

Figure 4: Flow rate against channel depth

3.3 Heat Transfer Coefficient

An overall heat transfer coefficient *h* can be defined as:

$$h = Q_{gain} / (T_{mp} - T_{mc}) \qquad (4)$$

Note that this is an overall heat transfer coefficient, based on the temperature of the plate and the air in the channel, but by implication it also includes heat gained by the air from the cover. Figure 6 shows the heat transfer coefficient h as a function of heat input. This shows trends similar to those of efficiency against heat input (figure 5).

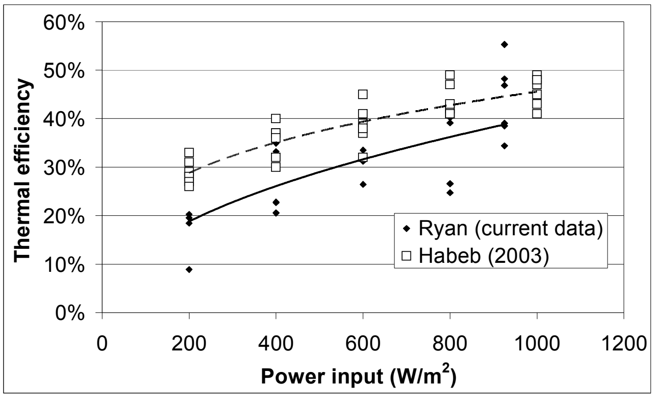

Figure 5: Thermal efficiency against power input

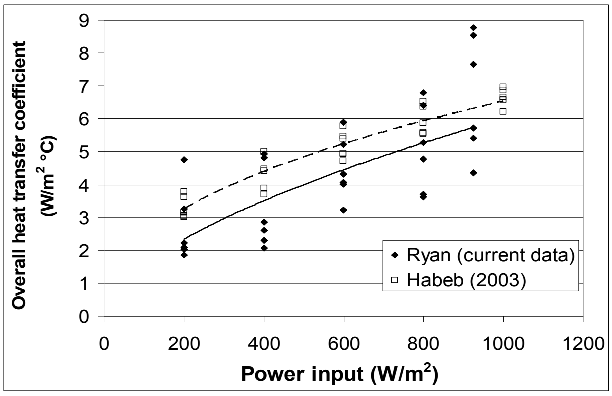

Figure 6: Heat transfer coefficient against power input

4. DIMENSIONLESS CORRELATIONS

Dimensionless correlations were sought to establish relationships between the independent variables and the performance indicators. The following dimensionless numbers were used, each representing a characteristic of the system:

4.1 Rayleigh number Ra**

The Rayleigh number Ra is often used when assessing the performance of buoyancy-driven convection, and many workers use a modified Rayleigh number Ra*. This is the product of Rayleigh and Nusselt numbers, and is based on the heat convected to the air stream from the hot surface. In the current investigation, the effect of the heat input to the system is sought, and therefore a Rayleigh number based on the heat input is used, termed Ra** to distinguish it from other variations:

$$Ra^{**} = \frac{\rho^2 g \beta Q_{in} H^4}{k \mu^2} . Pr \qquad (5)$$

Effectively:

$$Ra^{**} = Ra^{*}/\eta \qquad (6)$$

4.2 Non-dimensional height H/H0

This represents the height independently of the aspect ratio. H_0 is a nominal 'standard' height, taken conveniently to be 1m. A set of correlations was performed, combining the experimental data from the current investigation with those of *Habeb*, to include the dimensionless height relationship. *La Pica's* data was excluded from this set of correlations, because the cover material was silvered during his experiments, which effectively adds another variable to the equation. The following relationships were obtained:

4.3 Thermal efficiency

$\eta = 3.39 \times 10^{-5}\ (\mathrm{Ra}^{**})^{0.32}\ (s/H)^{-0.0786}\ (H/H_0)^{-1.167}$ (7)

correlation coefficient $R^2 = 0.68$

This implies that:

$\eta \propto Q_{in}^{0.32}$ (8)

$\eta \propto s^{0.0786}$ (9)

$\eta \propto H^{0.192}$ (10)

Efficiency is a strong function of Q_{in} and a weak function of H

4.4 Nusselt number and heat transfer coefficient

$\mathrm{Nu}(H) = 1.29 \times 10^{-4}\ (\mathrm{Ra}^{**})^{0.483}\ (s/H)^{-0.166}\ (H/H_0)^{-1.027}$ (11)

correlation coefficient $R^2 = 0.92$

This implies that:

$h \propto Q_{in}^{0.483}$ (12)

$h \propto s^{-0.166}$ (13)

$h \propto H^{0.071}$ (14)

The heat transfer co-efficient is a function of heat input

4.5 Reynolds number and mass flow rate

$\mathrm{Re}(s) = 2.95 \times 10^{-2}\ (\mathrm{Ra}^{**})^{0.452}\ (s/H)^{0.652}\ (H/H_0)^{-0.617}$ (15)

correlation coefficient $R^2 = 0.94$

This implies that:

$m \propto Q_{in}^{0.452}$

$m \propto s^{0.652}$

$m \propto H^{0.539}$

Note that the exponents for *H* in equations (10), (14) and (18) can be deduced from the exponents for Ra**, *s*/*H* and *H*/*H*$_0$ in equations (10), (14) and (18). Mass flowrate is a function of all three, with "s" being an apparently stronger function than Q_{in}.

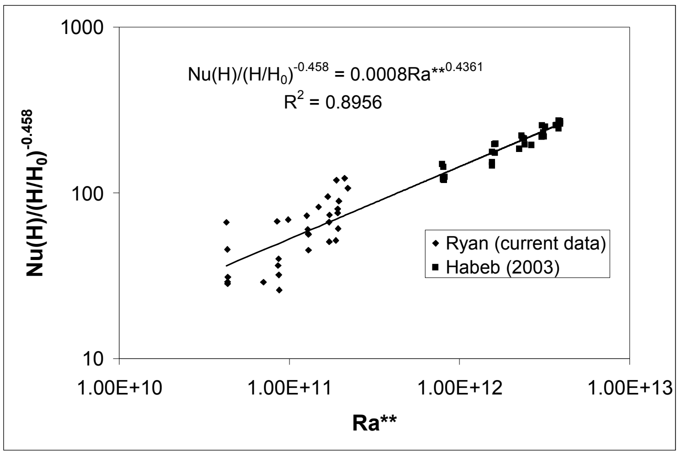

Figure 7: Graph for correlation equation (14) –current data (Ryan) and *Habeb's* data only.

5. TRANSIENT EFFECTS

For a passive solar collector the transient performance of the system is important. As the rate of heat input may not be continuous (clouds block out sunshine, sun blocked for part of the day by a neighbouring structure), the rate at which the system reaches steady state or drops out of steady state is important. Trombe Wall systems are designed to gradually built up a stock of residual heat during the day, within the rear thermal mass, which is then slowly released during the night. The current test rigs possess only a modest thermal mass, so they can perform only a limited degree of thermal storage.

5.1 Warm up Results

For the 1.0m test rig the time constants for the overall system are in the order of 90 – 180 minutes. For the channel air the typical time constants range from 130 to 80 minutes, and for the plate the time constants are shorter, 120 - 70 minutes. This means the plate reaches the steady state before the airflow. The cover is the slowest to reach steady state, taking up to to 180 minutes to reach steady state. The air velocity time constant (the time taken for the air velocity to settle at its steady state is much slower than any of the others, with values ranging from 150 to 120 minutes.

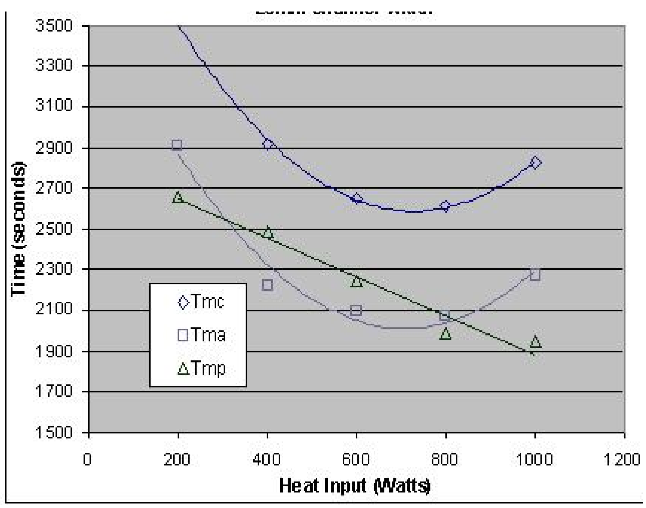

Figure 8: Transient performance during Heating phase for 20mm channel width

The results from the 0.5m test rig were processed using Sigmaplot in a similar manner. The time constants during the heating phase heating for the 0.5m tests are generally noted at being 15% to 8% lower than the time constants for the 1.0m tests, indicating that the 0.5m rig heats up faster than the 1.0 test rig. This may be related to its lower thermal mass. Even though the test rig lacks the normal dense thermal mass of a Trombe wall. A Heat flux meter mounted on the rear wall revealed a heat flow level, of the same intensity as observed during steady state, for 10 to 20 minutes after the power is switched off. This heat flow then declines rapidly over 30 minutes. This indicates that even a relatively minor thermal mass, will still provide some residual heat gain.

5.2 Cooling Results

Past experiments by authors such as Habeb did not make any record of the cooling rates of thermo-syhononing panels. Hence experiments were undertaken with the 1.0m high test rig to determine if these trends noted for the heating cycle carried over to the cooling cycle. It is found that the plate cools quickest, returning to steady state value (which is usually a degree or two above ambient) within a period of 130 – 90 minutes from power off. No clear trend can be observed linking these time constants to either the original rate of heat input or the channel width. This is with the exception of a trend of declining time constants for the air velocity with increasing heat input. However, the T ratio's for many of these readings were low (3-5), raising question about the accuracy of these calculations.

6. DISCUSSION

The current investigation was designed to assess the effect of system height on heat transfer and air flow, by comparing data from two test rigs which differed principally by their heights. For a system used as an air heater, it appears that height makes a small difference to the thermal efficiency. The results from the current tests suggest that, for a given height (*i.e.*, 0.5m in this case), the thermal efficiency is a weak inverse function of channel depth, *i.e.*, efficiency decreases slightly as channel depth increases. *Habeb's* data suggest that channel depth had no appreciable effect on efficiency. Both sets of data agree that the heat input has a positive effect of the system efficiency. This implies that a passive solar air heater would be more efficient in sunnier climates – the reverse of what would normally be required!

However, for a system used as a solar chimney, the system height does have a significant effect, as do the heat input and the channel depth. It should be noted that these correlations exclude the data from test with channel depths above 80mm, both for the 0.5m test rig and the 1.0m test rig. Above this figure, the flow rate showed signs of decreasing as the channel depth increased, which supports the observation by *Bouchair (1994)* and the suggestion that there is an optimal channel depth for a solar chimney. However, at present there are insufficient data to take this analysis any further. Although some of *La Pica's* data are useful for some comparisons, he used a silvered cover, specifically to reduce heat losses. Therefore his data are not directly comparable with those from the rest of the data used in these calculations.

The correlations presented in this paper were developed using the regression tools from the Analysis Tool Pack in Microsoft *Excel*. The calculations were also performed using other curve-fitting software (for example, *SigmaPlot*). The correlations did not match exactly, but were, nevertheless, close enough to give confidence in the overall correlations and conclusions. However, it does suggest that, even though the results are presented in this paper to 3 significant figures, perhaps, in general, they should be presented to only 2 significant figures.

There is a clear link between the rate of heat input and the time taken by the different elements of a collector to reach steady state. Time constants decrease with increasing heat input. A reduction in system height from 1.0m to 0.5m's results in an decrease in time constants by 15%, when compared via channel depths and up to 35% when contrasted using aspect ratios. There is no correlation between heat input nor the maximum temperature reached and the rate at which the system cools down.

7. CONCLUSIONS

Tests were performed on a vertical heated channel, which represents the essential workings of a passive solar air heater. In this way, the effect of system height could be determined. Using only data from tests with channel depths up to 80mm, the principal results are as follows:

- For a system working as a solar air heater, the efficiency of the system depends principally on the heat input:

$$\eta \propto Q_{\mathrm{in}}^{0.32} \qquad (11)$$

- Efficiency is a weak function of both channel depth and channel height.

- For a system operating as a solar chimney, where mass flow rate is the principal requirement, heat input, channel depth and height are important:

$$m \propto Q_{\mathrm{in}}^{0.452} \qquad (16)$$

$$m \propto s^{0.652} \qquad (17)$$

$$m \propto H^{0.539} \qquad (18)$$

However, it is noted that other workers suggest that there is an optimum channel depth, above which flow rate starts to decrease with increasing channel depth. There are indications from the current investigation that support this suggestion, but there is insufficient data to take this analysis further.

In terms of future activities, this study is being continued, and a test rig 2.0m high is being constructed. This will give more data on the effects of height on the key performance parameters of this type of system.

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Nomenclature

a, b & c	regression coefficient's
c	specific heat capacity of air (J/kg °C)
H	height of the channel (m)
H_0	reference height (taken as 1m)
g	acceleration due to gravity (= 9.81 m/s^2)
h	overall heat transfer coefficient (W/m^2 °C)
k	thermal conductivity of air (W/m °C)
m	air mass flow rate (kg/s)
Nu(H)	Nusselt number based on height = $h.H/k$
Q_{in}	heat input (W/m^2)
Q_{gain}	heat gain by the air in the channel (W/m^2)
R^2	correlation coefficient
Ra*	modified Rayleigh Number $= \dfrac{\rho^2 g\beta Q_{in} H^4}{k\mu^2}$
Ra**	modified Rayleigh number based on heat input = Ra*/η (see equation 6)
Re	Reynolds number = $\rho v.s/\mu$
Pr	Prandtl number
s	channel depth (m)
T_{in}	inlet air temperature (°C)
T_{mc}	mean temperature of the air in the channel (°C)
T_{mp}	mean temperature of the heated plate (°C)
T_{out}	outlet air temperature (°C)
v	air bulk velocity (m/s)
β	temperature coefficient (1/K)
η	thermal efficiency
μ	dynamic viscosity (kg/m s)
ρ	density (kg/m^3)

AN INVESTIGATION INTO THE USE OF SLATE WASTE AGGREGATE IN CONCRETE

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Abstract: In keeping with its approach to sustainable development, it is UK Government policy to encourage greater use of industrial waste products as an alternative to primary aggregates in concrete. This conserves natural resources and reduces the space needed for landfill disposal.
Slate has been worked in Britain for at least 400 years, providing roofing and building materials, but also generating vast quantities of waste. A recent survey in the UK showed that the overall ratio of waste production to finished products is about 10 to 1. Consequently, the volume of slate waste stockpiles are significant, between 400-500 million tonnes, with 6 million tonnes generated each year, located largely in North

Wales, but with other sources in mid Wales.
Generally, slate waste aggregates are different from natural aggregates, so that concrete made with the use of them has specific properties. Concrete normally is made from a mixture of aggregate of good quality, e.g. gravel or limestone, and cement. As aggregates generally constitute about 70 to 80% by volume of Portland cement concretes, their properties such as size, grading, shape and surface texture, have marked influence on workability, strength and durability of concrete.

This paper reports upon literature review on the suitability of using slate waste as an alternative aggregate in concrete and discuses the main constraints that hinder its uses in concrete such as, flaky particle shape, risk of alkali-silica reaction and the presence of pyrites. Recommendations to improve its efficiency are presented. Also the importance of further research into the effect of slate waste aggregates inclusion on concrete failure mechanism are suggested for future works.

Keywords: aggregate, concrete, slate, waste

1. INTRODUCTION:

The current use of resources in the construction industry is very high (CIRIA, 1999), approximately 275 million tonnes of aggregates are used each year in the UK as raw materials for construction (WRAP, 2004), of this around 65 million tonnes are sourced from recycled or secondary resources. By 2012, if UK demand for aggregates increases by an expected 1% per cent per annum, an extra 20 million tonnes of aggregates will be needed each year (WRAP, 2002). The options are to satisfy this additional demand by extracting further primary aggregates, which are non-renewable resources that cannot be replaced within typical human timescales (Sarre, 1991), or follow a more sustainable route and continue to increase the use of recycled and secondary aggregates. As both the UK and European Union moves towards more sustainable development, it is clearly desirable if recycled and secondary materials could be utilized more extensively, as substitutes, natural materials could be conserved. This has significant environmental and economic cost advantages (in terms of waste minimisation as well as sustainability benefits (Collin, 1994). Significant quantities of secondary aggregates are available both as existing stockpiles and that generated annually by industrial process. The total annual production of slate waste is estimated to be 6 million tonnes. This is added to the estimated stockpile of about 500 million tonnes (King, 1997), which puts it second only to colliery spoil in terms of the amount of waste available (Lydon, 1975).

It should be made clear that any proposal to introduce a waste materials substitute as a building material must be based on a planned appraisal of the new materials. The by-product must fulfill the engineering requirements in terms of its physical properties and must not contain excessive amounts of deleterious components, which may lead to corrosion or instability of the concrete (Gutt, 1974).

The existing knowledge of the present utilisation of slate waste aggregates in concrete shows that the use of such aggregates is limited due to three main constraints. First the flaky particles shape of slate waste fails the flakiness requirement for natural aggregates in BS 882 (CIRIA, 1999). However, the most fundamental effect of flakiness is its effect on workability and mix design, especially water demand, and therefore indirectly on the quantity of cement required to achieve any required strength grade of concrete (BRE, 1993). Second the slate waste may to some extent be reactive with alkalis from cement (Butter et al, 2000), the reaction results in the formation of a gel which absorbs water, expands, and therefore exerts internal pressure which sometimes can be far in excess of that which concrete can sustain, thereby causing the formation of micro-cracks (Marzouk, 2003). Finally, the presence of pyrite in slate waste aggregates varies. Some forms of pyrites are considered potentially expansive, if included in structural concrete mixes (Butter et al, 2000).

This paper aims to summarise the constraints on the use of slate waste as aggregates in concrete due to specifications and to make recommendations to improve the aggregate properties.

2. DEFINITIONS:

Although the terms ‘recycled’ and ‘secondary’ are often used interchangeably, it is important to distinguish between recycled and secondary aggregates production, as different operations, locations, and environmental effects may be involved (ODPM). The following definitions for recycled and secondary aggregates are widely used:

Recycled aggregates: comprise crushed, graded inorganic particles processed from materials that have been previously used in construction e.g. crushed concrete and masonry (Price, 2002). Recycled aggregates can comprise; construction and demolition wastes, asphalt road planings and used railway ballast.

Secondary aggregates: usually by-products of other industrial processes not previously used in construction. They can be further sub-divided into manufactured and natural, depending on their source. Examples of manufactured secondary aggregates are pulverized fuel ash (PFA) and metallurgical slags, while natural secondary aggregates include china clay sand and slate waste (AggRegain).

Increased environmental awareness has led to pressure to use recycled and secondary materials rather than classifying them as waste. Waste is produced when a product or material is considered by the owner to have no further use and is discarded, although it could be viewed as a 'resource' in the wrong place, waiting to be used (Price, 2002).

3. HISTORICAL BACKGROUND

The history of the use of slate in construction buildings is known to go back nearly two thousand years. The Romans used it in building their fort of Segontium, near Caernarvon in North Wales (Lindsay, 1974); they clearly appreciated its versatility and used it for roofing and flooring and even as a lining material for the channel of the hypocaust.

North Wales has always been by far the largest producing area of slate although it is quarried in Mid-Wales, Cornwall, Devon, Cumbria and the Highlands of Scotland (Sherwood, 1995). Slate quarrying reached its peak in the 19th century when the development of the canal and then rail networks meant that slates could be transported cheaply from the slate-producing areas to all parts of the country for use as roofing material. From the turn of the century slate quarrying fell into rapid decline as tiles once again became the cheapest method of roofing. During the last ten years there has been an increase in production but this is still at a very low level compared with Victorian times (Sherwood, 1994).

The geological origins of slate from argillaceous sedimentary deposits, or sometimes from volcanic ashes that have been metamorphosed have give a rock that exhibits characteristic 'slatey' cleavage (Crockett, 1975). However, only the rock suitable for splitting is acceptable because the main end use is for roofing. This factor together with the losses incurred during cutting and splitting of large blocks of good slate leads to high proportion of waste at all stage; nearly 90 per cent of the quarried output accumulates in mountains of loose tipped waste such as those at Blaenau Ffestiniog (Gutt, 1974).

4. CHARACTERISATION OF SLATE WASTE:

Slate is a metamorphosed mudstone with well-developed cleavage and parallel alignment of mineral constituents (DoE, 1991). The most important constituents of slates are shown in Table 1. Illite may also be present, together with minerals such as calcite, dolomite, pyrite, feldspar, graphite and other carbonaceous matter, as well as small quantities of other minerals (Crockett, 1975).

Table 1: The most important mineral constituents of slate (Watson, 1980)

	% by weight
Sericite mica	38-40
Quartz	31-45
Chlorite	6-18
Haematite	3-6
Rutile	1-1.5

The characteristics of different slates depend on the nature of the original sediments and the modification of their mineralogical constituents, as well as the formation of new ones, during metamorphism (Watson, 1980). Mill waste, mainly the ends of slate blocks and the chippings from the dressing of the slate, consists mainly of slate itself, but rocks such as cherts which are sometimes interbedded with the slate and igneous rocks may also be found in it (Sherwood, 1994).

Although most common slates are derived from argillaceous sediments, there are some which have been formed from accumulations of fine-grained volcanic ash and dust (Watson, 1980).

Chemical Composition:

A typical chemical analysis of slate waste from different quarries is given in Table 2. The waste is chemically inert (Sherwood, 1995) and the principle minerals that it contains are relatively stable. However, some examples can contain significant quantities of calcite and pyrite which are both subject to attack, particularly in industrial areas (Watson, 1980); also it is possible that the slate waste contains quantities of finely divided silica and mica which will to some extent be reactive with alkalis from cement (Butter et al, 2000). This possibility is being discussed as part of this study.

Table 2: A typical chemical analysis of slate waste from different quarries (Crockett, 1975; Charmbury, 2004; Gutt, 1974)

	(Crockett, 1975)	(Charmbury, 2004)		(Gutt, 1974)
	Typical	Penrhyn	Ffestiniog	Scottish quarries
	% by weight			
SiO_2	45-65	58.38	54.10	54.7
Al_2O_3	11-25	19.58	22.29	18.1
FeO	0.5-7	-	-	5.4
Na_2O	1-4	0.12	0.78	1.5
K_2O	1-6	0.35	4.20	2.8
MgO	2-7	2.43	1.54	3.9
TiO_2	1-2	0.68	1.11	1.0
Fe_2O_3	-	11.27	9.91	1.7
Mn_2O_3	-	-	-	0.1
MnO	-	0.21	0.35	-
CaO	-	1.52	0.45	1.7
SO_3	-	<0.01	0.10	0.4
CO2	-	0.50	-	-
F	-	-	-	0.02
P_2O_5	-	-	-	0.15
Sulphide S (other than pyretic)	-	-	-	0.13
Pyritic and Organic	-	-	-	0.4
Loss on ignition	-	3.77	4.95	6.7
Not determined	-	1.19	0.22	1.3

Physical Properties:

The properties of different slates vary rather widely depending on their source. Perhaps one of the most significant properties of slate is its cleavage. The way in which slate has been formed generally gives it low porosity this means that many slates are highly resistant to weathering (Watson, 1980).

A summary of the physical properties of Welsh slate waste is given in Table 3 (Sherwood, 1994). The waste materials from slate production comprise various sized fragments (Dhir et al,1996). The slate waste, provided that it can be crushed to satisfy the relevant grading requirements will satisfy most other requirements with regards to factors such as plasticity, particle strength and durability (Sherwood, 1994).

Table 3: A summary of the physical properties of Welsh slate waste (Sherwood, 1994)

	Source*					
	A	B	C	D	E	F
Property						
Water Absorption(%)	0.2	0.3	0.3	0.3	0.2	0.3
Flakiness Index	93	100	100	100	93	98
Elongation Index	23	29	34	34	23	27
Aggregate Crushing Value (kN)	25	29	26	30	24	23
Ten Percent Fines Value (dry) (kN)	160	130	140	120	170	160
Ten Percent Fines Value (soaked) (kN)	110	90	80	70	110	100
Aggregate Impact Value	27	29	29	33	28	28
Relative Densities: Oven-dry Saturated Surface Dry Apparent	 2.80 2.82 2.84	 2.76 2.78 2.80	 2.75 2.77 2.79	 2.80 2.82 2.84	 2.80 2.82 2.84	 2.80 2.81 2.83
$MgSO_4$ Soundness	99	98	98	98	99	98
Plasticity Index	0	0	0	0	0	0
Slake Durability Index (%)	96	94	95	94	96	96
Sulphate content (g.SO_3/litre)	0.01	0.01	0.01	0.01	0.01	0.01

*Sources of slate waste aggregate:
A-Penrhyn B- Ffestiniog C-Llechwedd
D-Croes-Y-Ddu-Afon E- Aberllefni F- Burlington

5. USES IN CONCRETE:

The literature contains references to various possibilities of using slate in concrete. It can be used as a concrete admixture from slate powders, as a dense aggregate from crushed slate and as a lightweight aggregate from expanded slate, the latter being beyond the scope of this study.

1. Slate powder as a concrete admixture:

Slate powder has been considered as a partial replacement for cement in conventional concrete (Watson, 1980). In 1976, Watson et al determined the compressive strength of concrete specimens in which fine slate powder had been blended with ordinary Portland cement using 0, 10 and 20% slate in dry mix. They concluded that the slate powder does seem to be primarily that of an inert filler. Also, there is a possibility of cost reduction, and perhaps increased workability. On the other hand in 2000, Butter et al found that the addition of slate dust reduced the cost of concrete made with alternative aggregates, which in general demanded relatively high cement contents to obtain the workability and compaction required for good quality concrete.

2. Crushed slate as dense aggregate in concrete:

A number of publications have referred to the possibility of using slate as a dense aggregate in concrete.
In 1966, McGhee et al pointed out that the platey and often elongated shape associated with the slate particles is considered to be unconducive to good workability and may have an adverse effect upon strength and durability. They concluded that production of workable mixes could be made to produce concrete conforming to specifications and the materials appeared to provide adequate compressive strength, good flexural strength and excellent freeze-thaw resistance. Their work has suggested that some other properties, including aspects of durability and long-term behavior, appear to be satisfactory for the particular slate that they investigated.

Another investigation was carried out in connection with the construction of a haul road in North Wales. The slate was crushed to a grading similar to one given in a United Kingdom specification for cement-bound granular material for sub-base and road base construction. The flakey, elongated nature of the slate particles led to the addition of sand to achieve reasonable compaction and a selected pulverized fuel ash (PFA) was used as a pozzolan, which increased the volume of cementitious paste. The initial work anticipated that the aggregate was randomly oriented and the finish obtained on the test cubes was found to be very good when PFA was added (Watson, 1980).

The case of a dam in southwest England in which the slate waste was used in conjunction with china clay sand as an aggregate for concrete is quoted in BS 6543, section 18.4. To obtain some workability the aggregate to cement ratio was reduced and a plasticiser was used. Building Research Establishment (BRE) visited this dam recently and the concrete was found to be in excellent condition.

After visiting sixteen slate quarries in 2000, Butter et al pointed out that the variability of the slate was greater than had been anticipated. The quality of material varied from good to poor rock hardness and in the quantity of pyrites present. It has been demonstrated that slate waste from some sources can be processed to create an aggregate which, in carefully designed mixes, will produce concrete with strengths comparable to normal aggregates. Nevertheless, it was found that there was a risk of alkali-silica reaction in the presence of high quantities of alkali in mortar samples.

6. CONSTRAINTS TO WIDER USES:

Although slate waste can be used as an aggregate in concrete, its use is limited due to three main constraints:

Particle shape

The relation between concrete composition and its mechanical properties has long been a matter of research interest (Ozturan et al, 1997; Davis et al, 1989; Davis et al, 1992). Aggregates generally constitute about 70 to 80% by volume of Portland cement concretes (Mindess et al, 1981). Due to the large volume fraction it occupies in concrete, aggregates exert a major influence on volume stability and durability. The properties such as size, grading, shape and surface texture have marked influence on workability and strength of concrete. The flaky nature and the smooth surface texture of slate particles (Mears, 1975) may cause problems in workability and strength of concrete. First, aggregates having more angularity contain more voids than rounded ones and hence demand more water to produce workable concrete. This will have an indirect effect on the quantity of cement required to achieve any required strength grade of concrete (Shergold, 1953; Kaplan, 1958; Murdock, 1960). Secondly, aggregate surface texture is one of the most important factors affecting bond strength; rough surfaces usually have a higher bond than smooth surfaces (Kaplan, 1959).

Slate waste aggregate fails the flakiness requirement in BS 882 (CIRIA, 1999), which requires the value not exceeding 50 for uncrushed rock and not exceeding 40 for crushed rock or crushed gravel. The flakiness index is the percentage of flaky particles in aggregates retained on the 6.3 mm and larger sieves, and is tested according to BS 812:Section 105. The flaky shape of slate waste can exclude its general use in concrete apart from specially designed mixes (CIRIA, 1999).

Constraints surrounding flakiness can, however, be overcome. In 2000, Butter et al utilized a crushing process to improve the shape of the slate to make it acceptable in concrete mixes. The results were promising; the shape of the aggregate improved, and this was verified by the reduction in the flakiness index. The same process was used by Mears: grid rollers, which break the longer needle-shaped pieces of slate into small pieces, were used to overcome the problems in compaction. On the other hand, in the example of haul road in North Wales (Watson, 1980), it was found that the addition of sand and a selected pulverized fuel ash (PFA) led to the achievement of better compaction. While other researchers concluded that using extra cement with a plasticizer (BS: 6543, 1985) or the partial replacement of Portland cement by slate powder (Watson et al, 1976) were necessary to increase workability.

Alkali-silica reaction

Aggregates for concrete should be sufficiently hard and strong for the grade of concrete required, should not react adversely with the cement nor contain impurities that do so and should remain reasonably stable when subjected to change in moisture content (BS 6543, 1985). There is a risk of alkali-silica reaction (ASR) in the presence of high quantities of alkali in mortar sample (Butter et al, 2000), as the slate waste aggregate may contain quantities of finely divided silica and mica. The reaction is known to cause cracking and expansion of concrete structures (TR. 22). ASR is an internal chemical reaction between alkaline components in the cement and certain active mineral constituents in some aggregates. The alkaline components, such as sodium and potassium that are derived from cement, as well as other constituents, cause the dissolution of the siliceous components of the aggregate resulting in the formation of a non-deforming gel. As the gel continues to absorb moisture, the micro-cracks widen (Marzouk, 2003). On the surface, the cracks appear in the form of map work cracking. Extensive research on field structures has indicated that crack widths can range from 0.1 to 10 mm in extreme cases (Neville, 1995; Swamy, 1994).

BS 8110:part 1:1997 defines some requirements for ASR but the main source document is Concrete Society Technical Report Number 30. The most frequent method of specification relates to the limitation or immobilization of alkali, but occasionally non-reactive aggregate combinations are required and these may be assessed by the concrete prism test according to BS 812-123:1999 or petrographic examination. In the UK the most common method for minimizing the risk of cracking due to ASR is to specify a maximum alkali cement of 3kg/m3 for the concrete. This figure includes alkalis from the Portland cement and from other sources. Additionally, where PFA and ground granulated blast furnace (GGBS) is being used, it has been recommended that the effective alkali content of these materials be taken to be one-sixth and one-half respectively of their total alkali contents (TR. 22).

A number of approaches to avoid the deteriorative effects of use of alkali-reactive aggregate were proposed by many researchers. In 2004, Mather revealed that many aggregates that have some degree of reactivity will be innocuous when used with low-alkali cement. If an alkali-silica reactive aggregate must be used with cement that is not low-alkali, damage can be avoided or minimized by using adequate amounts of a suitable pozzolan or slag. Additionally, in 2000, Butter et al demonstrated that the presence of PFA would lower the risk of ASR. It was further found that the use of slate dust, produced during the crushing of the aggregate, as a partial cement replacement, was able to minimize the risk of the reaction while, in 2003, Alexander recommended that 50% replacement of cement with corex slag was specified to prevent ASR damage.

3. Presence of pyrite

From the research results so far, it is clear that the presence of pyrite should not itself be a cause for the rejection of an aggregate and not all forms of pyrite are unstable. Minor amounts of pyrite do not generally cause any serious problems though they can lead to surface staining of the concrete. However, a fuller investigation will be necessary if the amount of pyrite in the aggregate is large or especially if it occurs as finely disseminated material in cleavage planes. Such form of pyrite can oxidize causing expansion and a number of adverse consequential effects, including sulphate and acid attack on the cement matrix of the concrete (DoE, 1991).

7. CONCLUSIONS

To sum up, there have been instances in which slate has actually been used as the dense aggregate in concrete. It was generally found that these aggregates have high resistant to weathering and low porosity. The principle minerals that it contains are relatively stable and inert. Additionally, it has been shown that concrete of about 30 MN/m2 compressive strength at 28-days can be produced from mixes that have adequate workability characteristics for practical use.

Although the use of slate waste aggregate in concrete is limited due to many constraints, with careful mix design it can still be used. The experimental investigations show that the workability of slate waste aggregate concrete may be significantly improved by using a crushing process to improve the shape of the slate particles. Also, using extra cement with a plasticizer or using slate powder as a partial replacement to Portland cement can increase workability. On the other hand, in order to minimise the risk of ASR, low-alkali cement should be used. If cement that is not low-alkali must be used, it has been found that the presence of PFA or the use of slate dust or the use of corex slag were able to minimise the risk of the reaction.

Generally, lack of widespread reliable data on aggregate substitutes can hinder its use. To design consistent, durable slate waste aggregate concrete, more testing is required to account for variations in the aggregate properties. Concrete is a composite, and its properties depend on the properties of its component and the interaction among them. In the composite many characteristics of the aggregate affect properties in fresh concrete, which later will modify the behavior of hardened concrete. The shape and texture of the coarse aggregates change the workability, inducing differences in consolidation; similarly, any difference in fluidity of the matrix will result in a significant change in bond strength. As a result, the analysis of the effect of any particular characteristic of the aggregate in concrete is more complex as aspects of fresh or hardened concrete are superposed, making it difficult to compare the effect of an isolated variable given the superposition with others.

There is general agreement about the importance of the matrix-aggregate bond. It is known that the transition zones (interfaces) are the weakest link of the composite material, playing a very important role in the process of concrete failure, as crack growth usually starts at the matrix-aggregate interfaces. The critical interfaces are generally those between coarse aggregate and mortar. Crack propagation usually starts at the interfaces, and the cracks grow through the matrix. Coarse aggregates arrest crack growth, producing meandering and branching of cracks and some particles are fractured. This mechanism depends greatly on the characteristics of the aggregates, especially surface texture and shape, and on the strength differences between aggregates and matrix. Thus the type of coarse aggregate is one of the most important variables affecting the behavior of concrete.

In light of the above, a concrete mixes made of slate waste aggregate will be produced taking into consideration the existing knowledge to overcome those problems associated with workability and ASR. The effect of slate waste aggregates inclusion on concrete failure mechanism, including tensile and compressive strength, stiffness, energy of fracture and crack pattern will be tested. A comparison between these results and the results from natural aggregate mixes will be made.

Finally, The composition of slates from different sources varies considerably and some contain minerals, for example pyrite among others, which can cause problems in concrete. As a result of this, it is most important to note that, before any particular source of slate waste is actually used for producing concrete, a proper evaluation must be carried out to ensure that the particular material in question has no detrimental effect upon any aspect of the performance of the concrete under service conditions.

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PROJECT PRICE FORECASTING AND THE EVALUATION OF HOUSING ASSOCIATION PROJECTS FOR SUSTAINABLE BENEFIT

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Abstract: Clients aim to get the maximum benefit from their construction projects. Many factors impact upon the realization of such benefits including the setting of reliable project budget estimates. Increasingly project budgets need to consider issues related to sustainability if they are to provide meaningful strategic advice for clients to use in reaching their business decisions. This paper is drawn from a developing PhD study in this topic area and considers relevant literature taken from the research strands identified above so as to make the case for the development of a model that encompasses the main issues related to sustainability, and cost planning. It is posited that such a model would be a useful decision aid or tool for practitioners to use in the delivery of added value services to their clients. The paper concludes by setting out an approach to the research and an agenda for future action in this topic area.

Keywords: Budgeting, Project Price Forecasting, Sustainability, Evaluation.

1. INTRODUCTION

Clients of the UK construction industry face risks caused by the poor performance of the industry in general and the delivery of their projects over budget in particular. The causes of these on going problems are the uncertainties in the feasibility stage of projects when project investment decisions are made. Such poor performance can be expected to be exacerbated by the government's policy of including sustainability features in its future publicly funded projects.

The evaluation of the feasibility stage of construction projects is still of crucial importance in the construction industry unlike projects in other industries such as manufacturing (Aouad *et al*.1998). Over the past two decades, all involved in the construction industry have become increasingly aware of the importance of early stage project price advice on potential design decisions. It is acknowledged that decisions made during the design stage of projects can have a significant impact upon the future running and maintenance costs of buildings (Elhag and Bussabaine 2001). Flanagan and Tate (1997) assert that typically the available information about a project at this stage relates to an initial brief that identifies the functional use of the project, the floor area required, an indication of its desired quality, space requirement, site location and planning constraints, the histogram of average building price and the access to indices for adjusting price level. Yet clients often decide whether or not to go ahead with their projects at this early stage on the basis of the design team's project price forecast. It is clear that the decisions made at this stage always take account of the limited nature of the information upon which they are based. As a result the decisions are always subject to risk and uncertainty. Recent government policy on the introduction of sustainability as another project criterion for their publicly funded housing projects has added to the difficulties practitioners face in providing a value for money early stage project evaluation service to their clients.

This paper starts with a consideration of literature related to prior work on the processes involved in project price forecasting and the principles of sustainable construction practice. The paper then identifies the differing sustainable benefit evaluation approaches currently advocated, namely (i) cost benefit analysis (CBA), (ii) analytical hierarchy process (AHP) and (iii) stochastic modeling. The paper concludes with a statement of the research problem still to be resolved and a consideration of the approaches available for its resolution.

2. LITERATURE REVIEW

The literature review will cover three main strands: project price forecasting, the principles of sustainable construction and the potential project evaluation mechanisms for sustainability, namely cost benefit analysis (CBA), analytical hierarchy process (AHP), and stochastic modeling.

2.1 Project price forecasting process

Fortune and Cox (2005) claimed that in order to develop an understanding of how building project price forecasting advice can have its quality enhanced, it was necessary to consider the process itself. Research conducted by Sarshar *et al.* (2000) developed a generic process protocol for use in the construction industry. The process protocol is a mechanism that facilitates the arrangement and classification of all the processes that are involved in the design and construction of a project. It can be thought of as an information route-map of how the processes related to construction projects ought to work so as to produce a more efficient, effective and economical way of undertaking the design and construction of projects. It has been claimed that tangible benefits can be realised in this process through wastage reduction, shortening the duration of projects and improving communication methods and channels (Aouad *et al.*1998). The process protocol identified the main phases of activity that need to be addressed in the delivery of a client's project but as yet its many sub-phases remain to be fully detailed. The generic process protocol considers the whole lifecycle of the construction project whilst integrating its participants under a common framework. The process protocol is divided into a series of sub phases defined as: pre project, preconstruction, construction and post construction. Within each of these major phases there are sub phases that can be operated at the same time to make the process more efficient in smaller scale projects. One such sub-phase of the process protocol is the pre-design phase. At this initial stage of the project the adopted process is unpredictable because the process has not yet been specified in detail and adopted in practice; such processes can change as the brief or clients needs progresses. It has been claimed that performance at this sub-phase depends on the capabilities of the individuals, rather than that of the organisation (Sarshar *et al*. 2000).

Fortune and Cox (2005) argued that at each stage of the process there was a need for feedback and professional judgement to be exercised. Their model (see Fig.1) indicated that the formulation phase of the process can be further sub-divided into iterative stages of project investigation, model selection and application.

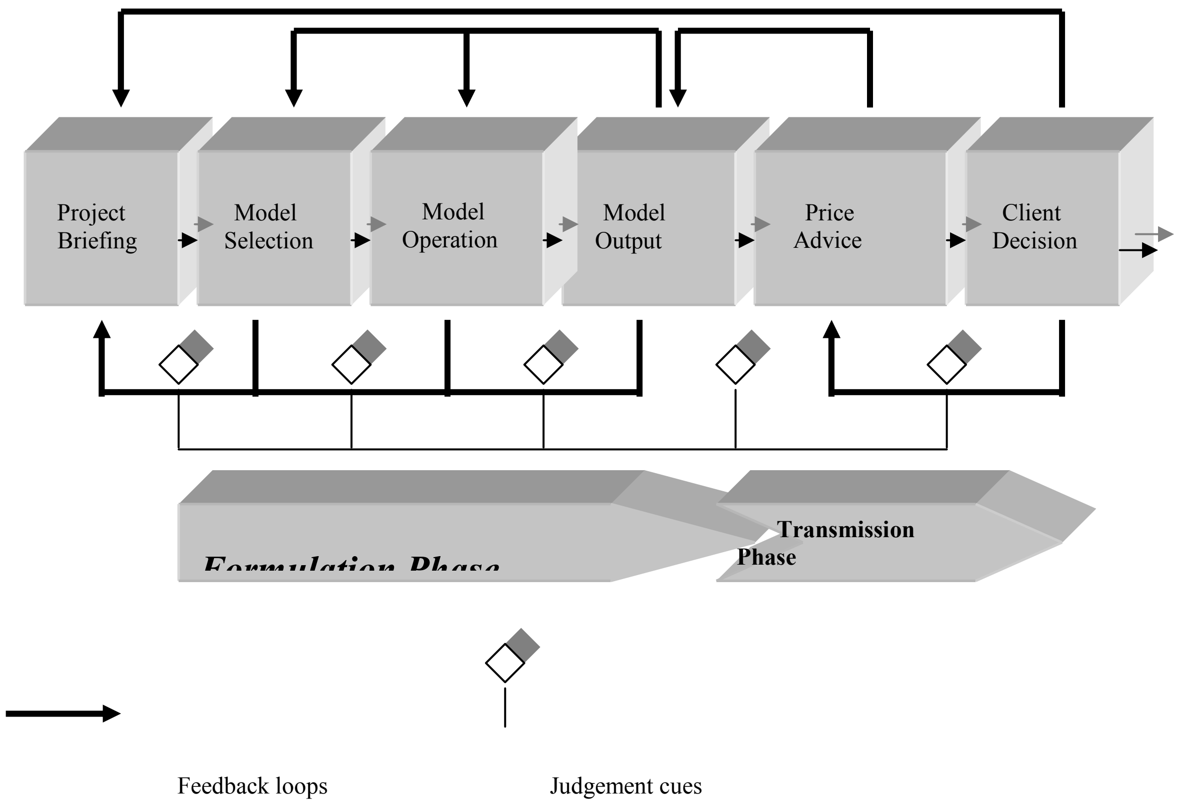

Figure 1: Model of building project price advice process (Fortune and Cox 2005)

At the feasibility stage there is uncertainty and as a result evidence suggests that practitioners are unable to forecast the reliable price of the project to the client and this can often be significant for the well being of project stakeholders especially if the project is publicly funded by the government. An empirical study of Fortune and Lees (1996) established that construction professionals involved in the formulation of strategic project price advice for clients have a propensity to make systematic errors of judgement. The result of that study also showed that judgement could be considered as being either a positive or a negative influence on the quality of advice provided. In particular, the following errors were found to be common place: sample size error, base rate error, logic error, ease of recall, regression to the mean, conjunction fallacy, insufficient anchor adjustment, conjunctive and disjunctive, and overconfidence. The follow-up research of Fortune and Lees (2001) confirmed that practitioners have a significant propensity to commit errors. This propensity could have an impact on the quality of advice provided to clients.

Project price estimating is a crucial phase for a successful construction project and the impact of unreliable cost estimating on construction businesses are significant (Akintoye 2000). Successive large scale surveys of current practice have established the ‘state of the art’ in terms of building project price forecasting techniques in-use, (Fortune and Cox 2005). It is clear that practitioners are adhering to the tried and trusted techniques that make use of manual deterministic approaches that are focused on the assessment of anticipated capital costs. There is some evidence that life cycle cost models are finding some use but they are far from being widely adopted. Fortune and Cox (2005), in their latest snapshot of current practices, indicate that there is only minimal use of project price forecasting models that seek to evaluate the sustainable impacts of proposed project designs. Increasingly in government funded housing association projects there is an expectation that the housing associations professional advisors will undertake an evaluation of the sustainable benefits of the project prior to its formal commissioning. The evaluation of sustainable benefits are expected to consider the impact of the project in relation to the social, economical and environmental benefits that the project will bring to the local community in which the proposed project is to be situated. The evidence of recent survey data of practice related to this area of service delivery reveals that there is a gap or knowledge shortfall in sustainable project evaluation practice and the sustainable cost models were found to be not in widespread use Fortune and Cox (2005). This gap is central to the thrust of this proposed PhD study.

2.2 Sustainable Construction:

Sustainability is an approach that has been determined as a development that delivers basic environmental, social and economic services to a community without threatening the viability of natural, built and social systems upon which the delivery of those systems depends (International Council for Local Environmental Intiatives.1996)

In the construction industry, sustainability is becoming increasingly important as the global environmental and social conditions are in decline. In addition, western society in general accepts that everything is governed purely by the financial costs and profits. Society wants better facilities for health, education and to preserve the environment in which it lives. According to UNCHS (1996) sustainable construction addresses the responsibility of construction industry in attaining sustainable development which is described as making efficient use of resources within the carrying capacity of ecosystems, and provide people with equal opportunity for a healthy, safe and productive life in harmony with nature and their cultural heritage, and spiritual values, which ensures economic and social development and environmental protection. Implementing sustainability issues starts at the strategic and concept stage of a project where the technical and economic feasibility of alternatives will be compared in order to select the best possible project. Sustainability decisions made at the beginning of a project life cycle have a far greater influence than those made at later stages since design and construction decisions will influence the continuing operating costs and, in many cases, revenues over the building projects' lifetime (Bowsell and Walker 2004).

On the economic impact of the sustainability the client should consider issues related to the substitution of natural for man-made capital as much as possible within the project (Fortune and Weight 2003).This commitment would cause the project manager to seek to ensure that the project contributed to the demand for environmentally friendly goods and services in the local economy and as a result utilised as far as possible suppliers and sub-contractors supply chains that adopted environmentally friendly practices.

Yet the construction industry has a significant social responsibility to minimise the damage its projects do to the social environment as it provides the means for many of the basic human needs: shelter, health care, education, service and social interaction. During the construction process, all the companies who are involved in the project should give assurance to their members of staff to keep them safe, skilled and well valued. Now this assurance is spreading to the neighbourhoods who live around the construction sites and who will use the completed products. The scope for taking social issues into account during procurement is more limited than the scope for environmental issues because, by virtue of their nature, they are less likely to be clearly related to the subject of the contract. And there will be more efficient and effective means of achieving social outcomes than through the procurement process. However, there will be cases where social issues can logically be taken into account. The sustainable project would be a way to make a contribution towards poverty in a particular area. The manager of this kind of project may seek to utilise local labour and local firms of sub-contractors as resources on the project as much as possible (Fortune and Weight 2003). How relevant social issues can be appropriately reflected in public procurement is being actively debated. As with all public expenditure, any cost premium incurred through the inclusion of requirements of a social nature must be critically tested for need, affordability and cost-effectiveness to ensure that they can be justified in public expenditure terms. Risk assessment of the social impacts of procurement will help establish the key social impacts from procurement, notably suppliers' compliance with social legislation that presently only focuses on health and safety (Boswell and Walker 2004).

Carter's (2005) work with Housing Association project delivery teams confirmed that a gap exists between policy and practice in the delivery of sustainable construction projects. Carter's partly grounded theory of sustainable procurement practice identified the following issues as being key matters that need to be agreed by the project stakeholders when considering a sustainable housing project, namely, design quality, energy efficiency, site selection, funding, transport, supply chain, and recycling. The results of this RICS funded work revealed a departure from the policy interpretation of sustainable development in practice by project stakeholders associated with the procurement of Housing Association projects in Scotland. The difference was found to be ingrained in the housing association development sector. Organisations with their own sustainable development policy documents have had them developed on the premise of equal weighting to social, economic and environmental aspects of sustainability, yet their detailed perception of sustainability shows an emphasis on social and environmental factors by the practitioners charged with project delivery. However, the research of Ding (2005), which was based on general construction projects in Australia developed an assessment model that sought to incorporate environmental and social issues into the decision-making process on an objective basis at an early stage of development. However, their proposed sustainability index model is based on four criteria (financial return, energy consumption, external benefits, and environmental impact) and depends on a weighting mechanism to establish if a solution is sustainable. This model conflicts with Carter's model in terms of its detailed features and overarching features that are incorporated within it. The conflicting nature of their findings call for a further investigation to be undertaken that looks to identify the overarching features of sustainability that are required in H.A. new build sustainable projects.

2.3 Project evaluation approaches for sustainability:

The literature reviewed generated alternative approaches to the evaluation of sustainability impacts within proposed building projects. Each are now taken in turn,

2.3.1 Stochastic Modelling:

Shen and Wang (2001) developed an alternative quantitative model for assessing the feasibility of a construction project involved in contributing to sustainable development. This model incorporates three major dimensions, namely, economic, environmental, and social development. The model is proposed for application at project feasibility stage when investment decisions need to be made. This research sought to establish the sustainable development value (SDV) of a potential construction project. The major principles of SDV are the economic development (E), the social development (S), and the environmental development (En).Therefore, Shen and Wang (2001) established an analytical expression to indicate the relation between SDV and the indicators E, S and En shown as follows:

$$SDV = f(E, S, En)$$

However, the implementation of a construction project will have various impacts to E, S, and En at different stages in different formats of presence during the whole development process of a construction project. Therefore, when the sustainability of a construction project is examined, time must also be specified. Shen and Wang (2001) incorporated this feature in the following expression,

$$SDV = f(E\ (t), S\ (t), En\ (t))$$

A project with a positive total value of SDV can be considered feasible or adequate in line with the principles of sustainable development.

This mathematical solution for the evaluation of sustainability in proposed building projects maybe attractive in terms of its quantitative basis but it has been found in practice that many features of social and economic well being derived from sustainable construction projects cannot be easily quantified. In addition the model remains hypothetical and requires application and testing in the real world before its usefulness can be properly ascertained.

2.3.2 Analytical Hierarchy Process:

It is generally accepted that decision-making for sustainable housing projects is a very complex issue. There are many design alternatives which differ according to the cost or the sustainable benefits of the project. Determining the priority for each alternative is not easy because a large number of factors are suspected of playing a role as these factors do not only involve financial implications. In these circumstances it is necessary for practitioners to use decision support tools to make the best choice. The quantitative factors of sustainability in construction projects may be measured in incomparable units such as the health of the people in the project. Huizingh *and* Vrolijk (1995) said that the use of AHP is not restricted to a particular business function, so AHP can be used in the evaluation of sustainable projects. There are many choices of design available to the sustainable project in the feasibility stage and so to select one particular alternative from a set of known options by using AHP, nine phases should be considered. These phases will start by listing the alternatives and all the proposed information about the project, and then define threshold levels and the minimum requirements which an alternative has to fulfil. Then the alternatives which do not meet these requirements are dismissed. The fourth phase is to define criteria that will be used to judge the alternatives after the alternatives and the criteria have been defined, the manager develops a decision hierarchy. This hierarchy consists of at least three levels, a goal, criteria and alternatives. Then the decision maker evaluates all alternatives pair wise for each criterion, for each criterion, every possible combination of two alternatives is judged in this way, and then the pair wise comparisons are represented in a matrix, and to fill the matrix, driving the remaining pair wise comparisons from the judgements of the manager (the comparisons are mirrored on the diagonal. The use of this technique has potential for the evaluation of real choices in terms of sustainable designs for potential projects but by itself it will not provide an overall project assessment or an evaluation between differing options.

2.3.3 Cost benefit analysis:

Cost benefit analysis (CBA) is another method which can be used to support the selection of the sustainability features of a proposed project. CBA features are the assessment of costs (initial and recurring) and the comparison of benefits and costs. To compare the alternatives, benefits and costs must themselves be comparable which means they need to be measured in the same units, over same period of time. To estimate benefits, first, it is necessary to identify the benefits for both the customers and the organization that provides the service(s) to the customers. After the benefits are identified, it is necessary to establish performance measures for each of the identified benefits. The final step is to estimate the value of the benefits. If a benefit cannot reasonably be assigned a monetary value, then it should be valued using a more subjective, qualitative rating system (which assigns relative numerical values for the competing alternatives). All benefits for the full system life cycle for each competing alternative must be included (Watkins 2003).

After the costs and benefits for each year of the system life cycle have been estimated they are then converted to a common unit of measurement which is used to properly compare the competing alternatives. That is accomplished by discounting future financial values, which transforms future benefits and costs to their present value. For example, the valuation of the benefit of cleaner air could be established by finding out how much less people paid for housing in more polluted areas which otherwise was identical in characteristics and location to housing in less polluted areas. Generally the value of cleaner air to people as revealed by the hard market choices seems to be less than their not literal valuation of clean air. Some measurements of benefits require the valuation of human life. It is sometimes necessary in CBA to evaluate the benefit of saving human lives. There is considerable antipathy in the general public to the idea of placing a financial value on human life as society wants better facilities for health, education and environment. So the existing price mechanism which is purely set on profitability and perfectly copes with the situations where financial costs and returns are the only considerations can be seen to be not suitable to estimate the cost. Economists recognize that it is impossible to fund every project which promises to save a human life and that some rational basis is needed to select which projects are approved and which are turned down. These choices can be used to estimate the personal cost people place on increased risk and thus the value to them of reduced risk. This computation is equivalent to placing an economic value on the expected number of lives saved.

When the costs and benefits for each competing alternative have been discounted, it is necessary to compare and rank the discounted net value (discounted benefit minus discounted cost) of the competing alternatives. When the alternative with the lowest discounted cost provides the highest discounted benefits, it can be seen to be clearly the best alternative. Most cases may not be that simple and other techniques must be used to determine the best alternative. The work of Ding (2005) argued that CBA is used to show whether the total benefits of a project exceed the total costs in order to determine a preferred option. But monetary value, when applied to environmental assets, is difficult, if not impossible, to ascertain. Completely replacing a monetary market approach with non-monetary techniques has limitations. The non-monetary approach ignores the financial matters in the evaluation framework. This may contradict the ultimate principle of a development, as financial return is fundamental to all projects because a project may be environmentally sound but very expensive to build. Therefore, environmental issues and financial considerations should accompany each other as parts of the evaluation framework when making decisions. The outcome of the CBA model using this approach alone can be subject to value laden errors that, if used incorrectly, could lead to a less sustainable solution being adopted.

3. THE STATEMENT OF THE PROBLEM:

Given the nature of the literature reviewed above it can be seen that the research is to identify how the sustainable social housing projects can be evaluated at pre-construction stage. To solve the problem the research aims to develop a decision aid to allow practitioners to aid clients make effective value for money (VFM) decisions. Each of the evaluation tools reviewed above contains useful features that could be of benefit to practitioners operating in the real world. This research seeks to develop a decision aid that can combine the best features of the identified models, which are seminal to this study. Such a model would be an effective tool that could work with existing building project price forecasting tools to deliver real benefit to practitioners and their clients at the pre-design stage of project development.

Given the nature of the research problem identified above it is apparent that this research will need to utilise a mixed methodological approach. Such an approach will reflect the nature of the problems being investigated. The initial stage of the study will seek to build on Carter's (2005) CONSUS model of sustainable procurement practice by seeking to confirm the significance of each of its sustainability features with a significant sample of stakeholder organisations associated with housing association projects. Then the work will need to embrace qualitative methods to explore the sensitivity of the features identified in the quantitative phase to change and manipulation so as to develop a model that can be tested in real time case studies. It is acknowledged that access to real time data may well be problematical and the active co-operation of the RICS and its corporate members in the provision of suitable data is currently being sought.

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EXPLORING THE RELATIONSHIP BETWEEN PERSONALITY AND MOTIVATION WITHIN THE STRATEGIC EMPLOYEE RESOURCING FRAMEWORK (SERF)

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Abstract: Employee and team motivation are central aspects of Strategic Human Resource Management (SHRM). Motivation is necessary for the achievement of organisational integration, employee commitment, flexibility and quality of work, which SHRM advocates as essential to effective organisational performance. Strategic Employee Resourcing Framework (SERF) is a vehicle for facilitating employee and team motivation in the construction industry through integrated employee resourcing activities. This framework supports effective managerial decision-making that takes into account (often competing) organisational strategic priorities, operational project requirements and individual employee needs and preferences. The aim of personality theories is to identify and explain the ways in which individuals differ from one to another. In the context of SERF personality theories contribute toward understanding the individual employee needs and preferences and how these influence their performance. Currently there is little evidence about considerations of personality in employee and team motivation in the context of the construction industry. This paper introduces a current research project that seeks to begin to address this gap between motivation and personality within the SERF. A literature review discussing the current position in terms of employee and team motivation and personality theories is followed by an outline of the research aim and objectives. The paper concludes with considerations of the potential contribution to knowledge and the practical implications of the research.

Keywords: Construction Industry, Motivation, Personality, Strategic Employee Resourcing Framework (SERF), Strategic Human Resource Management (SHRM)

1. INTRODUCTION

Based on recent research in the area of Strategic Human Resource Management (SHRM) in the construction industry, a Strategic Employee Resourcing Framework (SERF) has been proposed (Raidén, 2004). The SERF consists of five interrelated and mutually reinforcing SHRM activities: team deployment; human resource planning; training and development; performance/career management; and employee involvement, which together take account of organisational strategic priorities; operational project requirements and individual employee needs and preferences (ibid). These SHRM activities share a common influence: their relationship with employee motivation. Both the SERF and motivation theories emphasise the differing needs individuals have. However, Osteraker (1999) highlights that theories of motivation have received extensive criticism due to their insufficient ability to take into consideration the uniqueness of the employees and how this affects the needs they have. Central to the study of individuality is personality. According to idiographic theoretical approaches to personality, personality is unique to every individual. This uniqueness needs to be taken into account in the work place and be aligned with organisational and team goals (Mullins, 2004; Raidén, 2004). This paper presents an early proposal for a research project that seeks to begin to address this gap between motivation and personality within the SERF model. The project proposal is introduced through a mental map suggested by Wallace and Poulson (2003). This map provides tools for thinking for the development and evaluation of literature and intellectual projects. Accordingly, the structure and components of the mental map are introduced at first. This is followed by an outline of the research project using the mental map. Discussion on the usefulness of this model precedes the conclusions, which consider the potential contribution to knowledge and the practical implications of the research project.

2. THE MENTAL MAP

Wallace and Poulson's (2003) mental map consists of a complex set of different types of knowledge, literature and projects; tools for thinking and outcomes. Table 1 presents the mental map as matrix, where the y-axis rows refer to the broad areas of [1] knowledge, [2] literature and [3] projects. On the x-axis columns progress from [a] different types (of knowledge, literature and projects) through the [b] tools for thinking to the [c] outcomes for each broad area (knowledge, literature and projects).

Table 1: The Mental Map (after Wallace and Poulson, 2003)

<table>
<tr><th></th><th>[a] Types</th><th>[b] Tools for thinking</th><th>[c] Outcomes</th></tr>
<tr><td>[1] Knowledge</td><td>▪ Theoretical
▪ Research
▪ Practice</td><td rowspan="3">▪ Concepts
▪ Perspectives
▪ Metaphors
▪ Theories/ Models
▪ Assumptions/ Ideologies</td><td>▪ Arguments (Hypotheses/ Generalisations)</td></tr>
<tr><td>[2] Literature</td><td>▪ Theoretical
▪ Research
▪ Practice
▪ Policy</td><td>▪ Theoretical knowledge
▪ Research knowledge
▪ Practice knowledge</td></tr>
<tr><td>[3] Projects</td><td>▪ Knowledge for understanding
▪ Knowledge for critical evaluation
▪ Knowledge for action
▪ Instrumentalism
▪ Reflexive action</td><td>▪ Theoretical, research and/ or practice knowledge
▪ Theoretical, research, practice and/ or policy literature</td></tr>
</table>

2.1 Tools for thinking

Central to the mental map are the tools for thinking (Table 1 column [b]). The definitions for each of the tools depend on how the researcher, reader and/ or writer comprehends the relationship between the tools (Wallace and Poulson, 2003: 11). Nevertheless, Wallace and Poulson (2003: 11) provide some generic definitions, which firstly explain concepts as the "*terms which [are] used for classifying, interpreting, describing, explaining and evaluating aspects of the social world*". Secondly, they indicate that perspectives are formed when a set of concepts is combined as a screen in order to view events in the social world. Thirdly, metaphors are used when a researcher, reader and/ or writer is viewing a thing through the image of something else. Fourthly, a design that bundles a small number of concepts with the aim of illustrating their relationship to each other is called a model. A model is also incorporated as part of a broader theory: *"Theories are widely viewed as a coherent system of connected concepts, sometimes lying within one or more perspectives. They may be used to interpret, explain or, more normatively, to prescribe what should be done to improve an aspect of the social world"* (Wallace and Poulson, 2003: 13). Finally, any interpretation of the social world rests on a certain assumption(s). Assumptions are based on granted beliefs about an aspect of the social world (ibid). Similarly, the term ideology embraces the beliefs, opinions and attitudes about an aspect of the social world (ibid: 14).

2.2 The different types of knowledge and associated outcomes

As illustrated in Table 1 (row [1], column [a]) there are three kinds of knowledge: theoretical knowledge, research knowledge and practice knowledge. Theoretical knowledge refers to a discussion based on theoretical interpretations of a coherent system of connected concepts (as suggested by the definition of a theory above), which develops through claims about the social world. When the claims are supported by empirical evidence and investigation, research knowledge is produced. Practice knowledge relates to outcomes that are achieved via taking action in the social world (Wallace and Poulson, 2003: 18). The tools for thinking (concepts, perspectives, metaphors, theories and models, and assumptions and ideologies) apply to all three different types of knowledge. In essence, the tools help process and produce different kinds of knowledge.

Arguments form the outcomes of the different types of knowledge (Table 1: row [1], column [c]). They are an essential element in critical analysis in that they support the conclusions which have been drawn about an aspect of the social world (Wallace and Poulson, 2003: 14). Conclusions derive from claims about knowledge. There are two dimensions of variation among knowledge claims; the first is hypotheses and the other generalisations (ibid). The first, hypotheses, refer to proposed explanations for a phenomenon. The second, generalisations, refer to reasoning from detailed facts to general principles.

2.3 The different types of literature and projects and associated outcomes

In terms of literature, Wallace and Poulson (2003) differentiate between four types: theoretical literature, research literature, practice literature and policy literature (Table 1: row [2], column [a]). Theoretical literature contributes to development of theory, research literature examines empirical data to produce research knowledge, practice literature is aimed at informing practitioners (both practice knowledge), and policy literature seeks to influence formulation of policy. These connect to the types of knowledge in their tendency to emphasise claims to different kinds of knowledge (ibid: 20).

The third part of the mental map outlines five sorts of intellectual project for studying phenomena: knowledge for understanding, knowledge for critical evaluation, knowledge for action, instrumentalism and reflexive action (Table 1: row [3], column [a]). Following Wallace and Poulson (2003: 23) the word 'project' is used to encompass any enquiry. The different types of projects reflect the way in which an enquiry has been conducted. Each project takes in different types of literature (theoretical, research, practice and/ or policy literature). The outcomes of the different types of projects construct different types of knowledge (theoretical, research and/ or practice knowledge) which writers then use to produce different types of literature (theoretical, research, practice and/ or policy literature) (Table 1: row [3], column [c]). Thus, should the mental map be viewed as a circle, the loop is complete, as follows:

1. The knowledge for understanding develops theoretical and research knowledge in order to understand but not to improve an aspect of the social world
2. Knowledge for critical evaluation starts from a negative standpoint and attempts, through the development of the theoretical and research knowledge, to criticise, to argue for its rejection and to advocate improvements
3. Knowledge for action starts from a positive standpoint and attempts to develop theoretical and research knowledge with practical application with the aim to inform improvements
4. Instrumentalism also starts from a positive standpoint but with the attempt to impart practice knowledge in order to improve practice
5. Reflexive action starts from a self-critical action developing practice knowledge (Wallace and Poulson, 2003: 23).

Overall, the elements of the mental map (different types of knowledge, literature and projects; tools for thinking and outcomes) are aimed at helping researchers involved with intellectual projects, and readers engaged with literature in general, to develop skills in critical analysis when developing and carrying out projects. They are also intended to aid such individuals and groups in communicating their intentions, methodologies and outcomes via literature outputs. As alluded to above, this paper uses the mental map to introduce an early proposal for a doctoral study and to test the usefulness of the model.

3. A MENTAL MAP FOR EXPLORING THE RELATIONSHIP BETWEEN PERSONALITY AND MOTIVATION WITHIN SERF

3.1 Rationale for the study – background knowledge and anticipated outcomes

The proposed research project explores the role of personality in motivation and its relationship with the motivational elements of SHRM within the SERF model (team deployment, human resource planning, training and development, performance/career management and employee involvement). The need for investigating the role personality plays in employee motivation, and the importance it should therefore receive within the SERF model, builds from the recent interest for adopting SHRM-style people management practices in the construction industry (Druker and White, 1995; Maloney, 1997; Dainty *et al*, 2000; Loosemore *et al*, 2003; Raidén, 2004; DTI, 2005). The complex environment within which construction organisations operate, combined with the economic fluctuations which influence the industry's workloads, presents a considerable challenge for effective people management (Druker and White, 1995; Raidén *et al*, 2004). The short-term timescales force quick decisions on fundamental aspects of organisational working life and operations. Traditionally, managers from a craft or engineering background naturally attempted to achieve "the best" technical/ financial business outcome and took appropriate steps to implement that fit (De Feis, 1987). Many construction managers still operate in this fashion, focusing on the achievement of financial, programme and quality outcomes over other project performance criteria (Dainty *et al*, 2003). Thus, much of the current project allocation decision-making tends to be ad hoc and based on the implicit knowledge of senior managers (Raidén *et al*, 2004). The skills and knowledge requirements of the project dominate the decision-making, at the expense of individual needs and aspirations. Employee resourcing decision-making is at an imbalance, which leads to employee dissatisfaction, staff turnover and consequently a recurrent demand to recruit.

The aforementioned rationale focuses on *practice knowledge*, suggesting an argument (outcome of the knowledge) that the potential outcomes of the research should help the industry, and organisations within it, to improve their approach to people management. This is clearly in line with the applied nature of cross-disciplinary research.

The current position of *theoretical knowledge* further supports the need for the research. This derives from the following claims. The development of motivational programs was directed by personality theories in the early 1900s (Wiley, 1997). In spite of this strong connection between the two subjects, theories of motivation receive recurrent criticism on their insufficient ability to take under consideration employees' uniqueness (Osteraker, 1999). Some theorists, such as Maslow, McClelland and Adams, attempted to include elements related to personality characteristics. For example, Maslow stated that employees achieve the highest level of motivation through self-actualization (Cloninger, 2004). Yet, he fails to explain how personality as a whole affects motivation.

This brief position statement highlights severe weaknesses in current theory. Thus, the proposed study is strategically placed to contribute to the development of theoretical knowledge in addition to the practice knowledge. In particular, publications produced to communicate the outcomes of the research are anticipated to provide context specific, in-depth accounts of the relationship between motivation and personality within the SERF (this is supported by the research methodology, see section 3.3 below).

Finally, to close the gap in *research knowledge*, the project rationale stems from the conflicting results of recent empirical studies. These outcomes have opened up a debate, which would clearly benefit from an added input. In short, Furnham *et al* (2002), for example, argue that personality does not have a strong influence on employees' levels of job satisfaction. In contrast, Nikolaou's (2003) investigation suggests that there is a relationship between personality and job satisfaction. However, Furnham *et al*'s (2005) later cross-cultural research established a strong relationship between some personality traits and work values. Further, context specific research considering personality in the construction industry is scarce. Thus the outcomes of the proposed research have potential for valuable input into the existing body of research knowledge.

3.2 Theoretical, research, practice and policy literature

The above establishes the proposed study as applied and cross-disciplinary on the basis that all three kinds of knowledge (practice, theoretical and research knowledge) are used to build the rationale for the project. This assertion dictates that all four types of literature (theoretical, research, practice and policy literature) should be considered. Due to the early stage of the project, focus here is placed on theoretical and research literature on SHRM, motivation, SERF and personality, since these types of literature form the foundations for this project (Wallace and Poulson, 2003: 17). The practice and policy literatures will be examined as an integral part of further development of the study together with a more thorough in-depth examination of the theoretical and research literatures.

SHRM, motivation and the SERF

Over the past decade the SHRM paradigm has developed as an effective and profitable approach to people management. It is a widely accepted and adopted approach to personnel recruitment, retention and performance improvement within many public and private sector organisations (Baker, 1999). However, despite the labour-intensive, "people oriented" nature of the construction industry (Druker and White, 1995: 80) little attention has been paid to SHRM within the sector (Loosemore *et al*, 2003; Raidén, 2004). Some have suggested a need for construction organisations to move toward SHRM-style people management practices (Druker and White, 1995; Maloney, 1997; Dainty *et al*, 2000; Raidén, 2004), but few have considered how to implement this change effectively (Loosemore *et al*, 2003).

It was identified above that motivation is a central element of SHRM. Stewart (2003: 8) supports this with an assertion that the key to organizational success is motivated employees. Motivation theories tend to explain what motivates employees (content theories) or how they might be motivated (process theories). In the context of the construction industry the importance of employee motivation is often highlighted through the need for qualified workers (Yankov and Kleiner, 2001); increased scarcity of skilled employees and managers (MacKenzie *et al*, 2000) and the complex, dynamic and uncertain nature of the industry (Smithers and Walker, 2000). This is directly linked to the industry performance improvement agenda, via the hypothesis that stimulated and trained employees can improve their performance and consequently the industry's productivity (Yankov and Kleiner, 2001; DTI, 2005), but with little empirical evidence. Indeed, although motivation forms a central element of SHRM, and the DTI's (2005) Respect for People Agenda calls for industry wide performance improvement on people issues, literature searches within the leading journals produce insufficient results to demonstrate matching research activity.

The SERF is a model designed to take into account the (often competing) organisational strategic priorities, operational project requirements and individual employee needs and preferences in managerial decision-making in a way that facilitates employee motivation and the achievement of organisational/ team goals simultaneously (Raidén, 2004). Through effective management of the five activities (team deployment; human resource planning; training and development; performance/career management; and employee involvement) in an integrated way, the aim is to encourage construction organisations to initiate and develop practices associated with the SHRM-style people management, away from the traditional 'personnel' focused approach (ibid). Although employee involvement forms one of the five core components of the SERF, little is known of the type of role personality should play within the framework and the importance it should therefore receive.

Personality Theories

Personality theories seek to identify and explain the ways in which individuals differ from one to another (Cloninger, 2004). Four main approaches have emerged: nomothetic approaches, idiographic approaches, cognitive approaches and psychoanalytic approaches. The main interest of nomothetic approaches is to collect data from groups and apply this to developing an understanding of individuals (Mullins, 2004). Focus is on personality types and traits. These compare one person with another (Carlson, 1971), which makes understanding a person as a whole difficult and fails to recognize personality as a combination of many aspects. In contrast to the nomothetic approaches, idiographic theories study individuals one at a time rejecting explicit comparisons, although implicit comparison may be unavoidable (Cloninger, 2004). Idiographic theories suggest that personality is influenced by the environment and thus development of personality is an interaction of parameters. The cognitive approaches study mental processes and their effect on behaviour. Similarly to idiographic theories, they suggest that personality is formed through interaction with the environment. The central focus of the psychoanalytic approach is the level of consciousness. Freud (classical psychoanalysis) and Jung (analytical psychology) developed the core foundations in this area: people are not aware of the most important determinants of their behaviour (Cloninger, 2004).

In summary, it is clear that this initial brief points to multiple areas of literature that may be anticipated to contribute to the development of the research. A more comprehensive examination of relevant literature will be undertaken as part of the doctoral study.

3.3 Projects – the 'how' in the mental map for exploring the relationship between personality and motivation within the SERF

The third element in Wallace and Poulson's (2003) mental map differentiates between five sorts of projects: knowledge for understanding, knowledge for critical evaluation, knowledge for action, instrumentalism and reflexive action (Table 1: row [3], column [a]). On the basis of the above (sections 3.1 – 3.2), the third approach, knowledge for action, is that anticipated as most suitable for the proposed research. This type of project starts from a positive standpoint with the view to develop theoretical and research knowledge with practical application (Wallace and Poulson, 2003: 23).

Currently the research aim (to investigate the role of personality in managing individual and team motivation utilising the SERF model) is supported by three literature related objectives: (i) to identify what aspects of personality should be considered in employee motivation; (ii) to identify what aspects of personality should be considered in team motivation; and (iii) to explore what is the relationship between personality and the motivational aspects of SHRM in SERF (team deployment, human resource planning, training and development, performance/career management and employee involvement). The development of the research methodology will build on these to incorporate the empirical investigation. This will follow from the idiographic approaches to personality, which focuses on developing an understanding of the uniqueness of individuals and the development of the self concept. This suggests a qualitative approach as the most appropriate method (Mullins, 2004; Cloninger, 2004). Much of the recent psychological research is also qualitative and includes detailed interview information, case studies and sometimes observational studies (Goodwin, 2002). Additionally, researches in SHRM support qualitative research methods and in particular in-depth interviews, case studies and questionnaires (see for example Dainty et al, 2000; Raidén, 2004; Sheehan, 2005). Hence, semi-structured interviews and questionnaires with open-ended questions are anticipated to form appropriate methods of data collection. The semi-structured interview seems particularly suitable since it allows for in-depth questioning but also provides a degree of structure (Naoum, 2003). This encourages the interviewees to discuss motivation and personality from their frame of reference. It is accepted that the researcher will have an impact on the study situation. However, every effort will be made to compensate for any bias within the research design.

The proposed research sample consists of "knowledge workers". According to Manville and Ober (2003), the core of modern business is not real estate, machinery and building but an employee with intelligence, understanding, skills and experience; the "knowledge worker". Employees with knowledge, skills, experience and qualifications managed in a positive way can be a strong competitive advantage for the company. Knowledge workers within construction firms often consist of the managerial and professional employees (Raidén, 2004). It is these groups that have experienced the SHRM-type individualisation of the employment relationship in construction organisations.

In summary, the proposed research is formulated on three kinds of knowledge: theoretical, research and practice knowledge. Similarly the anticipated outcomes reflect all three kinds of knowledge. Currently literature is drawn mainly from theoretical and research literature but it is expected that practice and policy literature will inform the study at a later stage. The project is planned in line with the principles of knowledge for understanding type of enquiry. In terms of the tools for thinking, the above discussion reveals that the main focus in the early development of ideas has been on concepts (SHRM), theories (motivation and personality) and models (the SERF). Perspectives or metaphors have not been employed; neither have strong assumptions or ideologies formed beyond suggestions for methodological approaches. The following section discusses the extent to which the mental map has been useful.

4. USEFULNESS OF THE MENTAL MAP

The description of Wallace and Poulson's (2003) mental map (section 2 above) stated that the tool is aimed at helping researchers involved with intellectual projects to develop skills in critical analysis and assist them in communicating their intentions, methodologies and outcomes via literature. In the light of the research proposal introduced above, it is confirmed that the map is a useful guide for illuminating concepts in the literature through a critical lens. However, more importantly the map was found helpful in developing clarified and comprehensible explanations for the early ideas. The mental map provided an essential introduction to 'learning to read critically' (Wallace and Poulson, 2003: 10). Through the tools for thinking it helped to establish a common language between different members of the research team and thus facilitated effective communication. The map made it also necessary to think about the research ideas holistically and in-depth. Heavy emphasis on the 'what' of the project was balanced with the 'how' and considerations for potential outcomes.

However, in writing this paper it became evident that an alternative order of arranging the three main areas in the mental map (Table 1: [1] knowledge, [2] literature and [3] projects) would be helpful in communicating research intentions, methodologies and outcomes. As a result, it is suggested that the first step focuses on literature. This provides the background to any study and is often the strongest point of justification for a project. Literature forms the main source of knowledge at early stages of academic enquiry. It helps in deciding on the approach for a project and also forms the foundations for the outcome(s) via critical discussion. An examination of the 'how' in terms of project type should follow the literature. Projects help explain the research path which will be/ was taken in achieving the outcome, knowledge, which therefore forms the final element. In summary, where Wallace and Poulson's (2003) [1] knowledge, [2] literature, [3] projects ordering may be useful as a generic guide to 'learning to read critically', an alternative literature, projects, knowledge format is suggested as more suitable for writing efforts. It is beyond the scope of this paper to suggest formats for visual representation of the model, however, the matrix (Table 1) was certainly useful here and it would perhaps be interesting to explore the 'circle' view mentioned above.

5. CONCLUSIONS

This paper has introduced a current research project that seeks to begin to address a gap in understanding the relationship between motivation and personality in the construction industry via the SERF model. This proposal derives from the assumption that motivated employees are an important asset in modern businesses. Several theories of motivation help to predict and manage employee performance; however, these theories fail to address personality. Wallace and Poulson's (2003) mental map was used to structure and refine the initial ideas. On the one hand, this was helpful in developing a critical approach to reading literature, formulating clarified and comprehensible explanations for the early ideas, facilitating effective communication within the research team and encouraging a holistic, in-depth approach. Heavy emphasis on the 'what' of the project was balanced with the 'how' and considerations for potential outcomes. On the other hand, an alternative ordering for the main areas was suggested: literature, project, knowledge (instead of knowledge, literature, project). Despite both the positive and alternative suggestions regarding the mental map it is important to remember that there is always the danger to limit researchers' innovations, interpretations and reflection should there be an attempt to fit all ideas into a model or a map. The next stages of the current project embark on detailed literature review and development of the methodology, which should pave the way toward the anticipated outcomes: contribution to understanding personality in motivation via theoretical, research and practice knowledge.

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FACTORS INFLUENCING ORGANISATIONAL CULTURE: A CONSTRUCTION PROJECT PERSPECTIVE

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Abstract: In seeking to improve the processes and outputs of organisations in the construction industry, culture is an important consideration. Organisations need to be able to assess and understand their own culture, how it develops, and the possible consequences of their particular orientations. To this end, this study interrogates literature on factors influencing culture, examining these factors from a construction project perspective to gain useful insights into the manner in which the culture of construction project organisations (CPO) develops. Reviewing organisational culture theory and theory on 'short life organisations,' the study identifies the main project-dependent determinants of the organisational culture as composition of CPOs, project characteristics, Project Managers and dominant groups, significant events, procurement approach, goals and objectives, location, and project-independent determinants as macro-culture, business environment, recruitment, training, and technology. These factors are discussed in detail. A conceptual framework for examining how organisational culture develops in CPOs emerges from this discussion and with it, a number of hypotheses that will be tested in this on-going research.

Keywords: construction project organisation, construction industry, organisational culture, short life organisation.

1. INTRODUCTION

In seeking to improve the processes and outputs of organisations in the construction industry, culture is an important consideration (Ankrah and Proverbs, 2004), and organisations need to be able to assess and understand their own culture and the possible consequences of their particular orientations. However, culture in the construction industry is an area that is characterised by a paucity of research, and is only now beginning to receive significant attention in a systematic manner. In a bid to promote research in this genre and as part of a wider study to investigate empirically, the impact of organisational culture on construction project performance, this paper investigates factors influencing the development of organisational culture in construction project organisations (CPOs). It interrogates the literature on organisational culture and attempts to relate the factors influencing organisational culture to the structure, profile and characteristics of the construction industry. In particular, the paper examines theory on 'short life organisations' (SLOs) to accommodate the perspective that CPOs are effectively, SLOs. In the context of this study, CPOs are regarded as organisations responsible for undertaking the construction of civil and building facilities, and delivering the completed construction product to the client. This encompasses the whole project supply chain.

2. ORGANISATIONAL CULTURE

Organisational culture can be anything to any number of people, and this is evidenced by the plethora of definitions available (e.g. Eldridge and Crombie 1975; Deal and Kennedy, 1982; Peters and Waterman, 1982; Schein, 1985; Graves, 1986; Kotter and Heskett, 1992; Thompson, 1993; Hampden-Turner, 1994; Hofstede, 1997; McNamara, 1999; Schneider, 2000; Mullins, 2005). There is however consensus on the fact that organisational culture comprises shared values and basic assumptions and that it is manifested in organisational 'practices'. These organisational practices comprise symbols, rituals, rules, behaviour norms, heroes, stories, language, routines and power structures among others (Hofstede, 1997; Mullins, 2005). It is a group phenomenon influenced by contextual factors. As explained by Schein (1985), it is developed through the organisation's attempts to solve its problems of internal integration and external adaptation. It is these contextual factors that make organisational cultures in different organisations peculiar, and they represent the reason for this investigation which seeks to provide useful insights into those contextual factors influencing the development of organisational culture within CPOs.

Within the construction industry itself, organisational culture is considered to be about the characteristics of the industry, approaches to construction, competence of craftsmen and people who work in the industry and the strategies, goals and values of the organisations within which they work (Abeysekera, 2002). This is consistent with views expressed in Ankrah *et al.* (2005b) to the effect that for the purposes of this research it is appropriate to concentrate on approaches to work or the 'practices' of construction organisations rather than on the core values or basic assumptions. As research evidence shows, there are more discernable differences in organisational practices than in the values or basic assumptions across organisations within any particular country (Hofstede *et al.*, 1990).

3. CONSTRUCTION PROJECT ORGANISATIONS

According to Harvey and Ashworth (1997), the construction industry is generally characterised by:

- Physically large and expensive products;
- Separation of design from construction (although new procurement arrangements are changing this);
- 'Powerful' clients;
- Extensive specialisation;
- Delivery of products at the clients premises;
- Bespoke designs, usually without prototype models or precedents to provide guidance; and
- Risk and uncertainty.

These characteristics necessitate the use of project-based and contractual arrangements for the procurement of construction products. The construction industry is thus generally very fragmented with an extensive list of specialisations and professions which all play important roles in the delivery of construction products to clients.

To deliver a construction product, a supply chain must be constituted bringing together the various specialisations, labour, capital and other resources required for the project. Given that organisations are generally groups of people cooperating and/or working together to achieve specific objectives which cannot be achieved by any single individual (Mullins, 2005), these construction supply chains can be viewed as organisations, and all the pre-requisites for effective functioning of an organisation apply, including an appropriate organisational culture that is congruent with the environment (Thompson, 1993). Given the project-based nature of such construction organisations, it is appropriate to refer to them as construction project organisations (CPOs).

Traditionally, this supply chain exists to deliver the client's product and once the project is complete, the supply chain breaks up and the constituent parts move on to become parts of other supply chains to work on other new projects. In other words, such supply chains are temporary and exist only for the duration of the project – from the award of the contract through construction on site to practical completion and the end of the defects liability period. The implication of this fact therefore, is that CPOs have a short lifespan, and with little or no history prior to a particular project, it begs the question of whether CPOs do indeed have a culture, and if they do, how this culture develops.

4. THE CULTURE OF CPOs

The absence of culture presupposes a randomness of behaviour within the CPO. However, the evidence suggests that this is not so. There are patterns of behaviour and a certain consistency and predictability in the way work on construction projects is undertaken and the nature of human relationships. It is as a result of this regularity of behaviour that the construction industry has acquired the various stereotypes with which it is associated such as being litigious (Rooke *et al*., 2004), antagonistic (Latham, 1994), under-performing (Egan, 1998), dangerous and dirty (Barthope *et al*., 2000), sexist and discriminatory (Dainty *et al*., 2002).

Construction remains a people's business and CPOs are human institutions. As long as it can be argued that organisational behaviour within these institutions is not random, it can also be argued that there are cultures that regulate behaviour (Hofstede, 1984). Evidence of such project culture is reported in Thomas *et al.*, (2002) who examined its impact on quality outcomes, and in Dainty *et al.*, (2002) who examined its impact on women on construction sites – referring to a "site culture." Moreover according to Deal and Kennedy (1982), every organisation has a culture, even if this culture is fragmented and difficult to read.

5. THE CULTURE OF CPOs – THE DETERMINANTS

Meudell and Gadd (1994) and Mullins (2005) describe organisations such as CPOs, which are created to run for short periods and to achieve specific goals, as "short life organisations" (SLOs). They question how such organisations develop their culture when there is little or no prior history, the organisation has specific short-term goals and objectives, and limited time for top management to exercise influence.

According to Meudell and Gadd (1994), this situation renders the traditional approaches for assessing the development of organisational culture inappropriate. From studies of typical SLOs, Meudell and Gadd (1994) found that rather than any other factors, the recruitment and training initiatives that were associated with SLOs were the overriding determinants of the organisational culture that developed, an idea echoed in Mullins (2005). An examination of how these factors operate within a construction project context will be helpful in determining whether they are on their own enough to determine the culture of a CPO, or there exist other moderating or mediating factors that need consideration.

5.1 CPOs and recruitment

The way and manner in which people are screened and selected for employment influences the sort of people who are recruited and become members of the organisation, and the values and behaviour they bring to the organisation. If these values and behaviour fit in with the organisation, then it leads to a perpetuation of the culture, otherwise it could lead to conflict and/or changes (Graves, 1986; Handy, 1993). The composition of the SLO will therefore be one of the most important determinants of culture.

The construction industry is characterised by a lack of formal hiring procedures at the operational level, and the hiring of complete gangs whose loyalty is to their boss rather than the CPO (Serpell and Rodriguez, 2002). Barthope *et al.* (2000) also identified the UK construction industry with casual employment where employees fail to identify themselves with the project and its successful completion. Such problems in the construction industry imply that there is difficulty in screening out those whose values and behaviours would not fit into the culture of the CPO. This is compounded by the fact that different parties are responsible for deciding who becomes part of the CPO at the operational level, with contractors employing subcontractors and suppliers who in turn contract other subcontractors and suppliers, and so on.

As a feature of the construction industry, this is a problem affecting all CPOs, and it indicates a greater likelihood of having a myriad of subcultures rather than a single pervasive culture. Within such an environment, training is a useful way of re-orienting project participants.

5.2 CPOs and training

As seen in Meudell and Gadd (1994), training initiatives are an important tool in cultivating a desired culture. Training initiatives can be used to transmit and embed in employees what is important and should be prioritised, what the goals and objectives of the organisation are, what the expected behaviour is, the relevant terminologies, what the various roles are and the extent of their responsibilities, and the communication networks. It can also be used to improve project leadership and management skills.

Generally within CPOs, such training initiatives are not likely to exist. What exists are a series of project meetings that run over the project life, which are used to discuss project progress, problems and related issues. This implies that the only training which the participants bring to the CPO is the formal (e.g. apprenticeships) and informal training (e.g. socialisation) that they have received in their own parent organisations. It has been shown elsewhere that differences in values and practices exist between the various parent organisations to which project participants belong (e.g. Maloney and Federle, 1990; Root, 2002; Rameezdeen and Gunarathna, 2003; and Ankrah and Langford, 2005), and this implies that different sub-cultures are likely to be found within the CPO, most probably differentiated along occupational lines. This is not inconsistent with organisational culture theory which recognises the existence of such organisational subcultures (e.g. Kotter and Heskett, 1992; Brown, 1998).

Going by the theory on SLOs, the two factors discussed above (i.e. recruitment strategy and training) should be adequate in explaining the cultural orientations likely to exist in CPOs. However, as seen in the discussion, the inadequacy of recruitment strategies and training initiatives only points to the lack of a homogenous culture within the CPO. These factors are useful in explaining the existent of various subcultures and communication networks, and cultures of litigation, antagonism and discrimination with which the industry is associated. They do not however adequately explain the structure of the project organisation, control and coordination mechanisms, reward systems, management philosophy, and other organisational processes that are influenced by organisational culture (see Thompson, 1993; Handy, 1993; Mullins, 2005). A more general approach to the development of organisational culture that goes beyond SLO theory is therefore required if adequate explanations are to found.

From the literature, there is a fair degree of consensus on the factors that generally influence the development of organisational culture (Table 1).

Table 1 Factors influencing organisational culture

	Graves (1986)	**Kotter and Heskett (1992)**	**Thompson (1993)**	**Handy (1985; 1993)**	**Hampden-Turner (1994)**	**Handy (1995)**	**Mullins (2005)**
People	•	•	•	•		•	•
The environment	•	•	•	•			•
Size		•		•		•	•
History, crises and successes		•	•	•			•
Technology and primary function	•	•		•			•
Goals and objectives			•	•			•
Leaders and ownership		•		•			•
Location		•					•
Recruitment policy	•						
Macro-culture					•		

Some of these factors can provide additional insight into the cultural development of CPOs. These factors are now discussed in detail to see the extent to which they are applicable in the context of a CPO.

5.3 The people within a CPO

According to Kotter and Heskett (1992), ideas or solutions that become embedded in a culture can originate from all members of the organisation. Moreover, the successful implementation of new work methods and practices are dependent on effective cooperation of staff and management. Mullins (2005) also talked about the match between organisational culture and employees' perception of the psychological contract, an argument supported by Handy (1985) who stressed that different cultures call for different psychological contracts. Culture is taught to new members not only through formal training initiatives, but also through socialisation and this way, various organisational members play a part in the grounding and perpetuation of the organisation's culture. From all these arguments, it can be concluded that the *composition of CPOs* is crucial to the culture.

The composition of the CPO can be differentiated along lines of gender, ethnicity, age profile and educational levels. Statistics from the CITB for 2002 estimated the UK construction workforce to be in the region of 2 million of which women make up only 9% and ethnic minorities make up only 2% (CITB, 2002). Pearce (2003) reported a fairly strong profile in terms of available skills with about 46% having an NVQ-equivalent level 3 or above. Since 1990, there has been a reduction in workers within the age range 16–29 years, indicating a decline in recruitment possibly attributable to the economic downturn of the 1990s. With a profile such as this, the culture of CPOs is skewed towards an exaggerated "macho" young white male behaviour (Barthorpe *et al.*, 2000; Serpell and Rodriguez, 2002) as characterised by the orientations shown in table 2. This is a situation that prevails widely across the construction industry. However, different behaviours are possible where local variations in employee profiles (such as number of female participants) exist. With particular regards to females, it has been noted that beyond reasons of social equality, women possess attitudes and attributes that new flexible organisations need (Handy, 1994 in Barthorpe *et al.*, 2000), and a more "female" culture in the construction industry has also been advocated for by Langford *et al.*, (1995 in Barthorpe *et al.*, 2000). Some of the desirable characteristics of the feminine culture in the workplace are identified by Hofstede (1997) as managers using intuition and striving for consensus, a stress on equality, solidarity, and quality of work life, and resolution of conflicts by compromise and negotiation. This seems to suggest that the greater the proportion of females, the greater the likelihood of developing an organisational culture that manifests these values, and the better the performance of the organisation is likely to be. This is an idea that can be put to the test in this research. Other such differences in *composition* may similarly lead to differences in the culture of CPOs.

5.4 The environment

This determinant of culture considers the stability or dynamism, and standardisation or diversity of the environment and also takes into account threats and dangers in the form of take-overs, mergers, nationalisation and economic recessions. In order to be effective, organisations must be responsive to these external environmental influences (Mullins, 2005). Significant changes in the environment may require changes in the culture to avoid a long-term deterioration of economic performance. It can be argued that this influencing factor is independent of the project and all CPOs are affected by the state of the economic or business environment.

5.5 Size

Increasing size leads to departmentalisation and/or "split-site" operations (Mullins, 2005). This is inevitably accompanied by communication and coordination difficulties, and necessitates the formalisation of mechanisms for communication, control and coordination, as well as the structure of the organisation. Decreasing size also has its impact. Handy (1985) describes size as being perhaps the single most important variable in determining the culture of an organisation.

CPOs also vary in size and this is in relation to project scale, type, complexity and clients served. This has an influence on the composition of the CPO, who manages the project, the duration of the project, as well as communication networks, organisation structure, and control and coordination mechanisms. It can thus be proposed that in an industry where each project is unique, the different *project characteristics* will lead to different cultural orientations.

5.6 History, crises and successes

Any organisation with significant history has a culture. This factor considers the reason and manner in which the organisation was formed, and the extent to which an organisation has had to be flexible, adaptable and sensitive. It also considers the merger history and managerial changes that have occurred in a firm (Handy, 1993). Crises, in the form of key events such as a merger, major re-organisation, new management, diversification into very different businesses or geographical expansion may bring in its wake, a change in culture (Kotter and Heskett, 1992; Mullins, 2005). On the other hand, continued success leads to the emergence of a culture that reflects the vision or strategy that led to the success. The age of an organisation is therefore an important consideration.

In the case of CPOs, history can be said to be limited, because of the project-oriented nature of the industry. However, to the extent that *significant events*, in the form of disputes and/or project management changes (e.g. Low and Shi, 2001) can occur even during the relatively short project durations, cultural changes can result. For instance, a culture of mistrust, antagonism and conflict can develop following a dispute on a construction project site. It can be proposed therefore that when *significant events* such as disputes or project management changes occur, changes in the culture and the way a project proceeds can subsequently occur.

In modern procurement of construction projects, it is becoming popular to have arrangements which allow for partnering (relational contracting, serial contracting or alliancing), implying that though CPOs still remain SLOs, there is arguably, some history that informs the culture that prevails in the CPO. It has been argued elsewhere that through partnering, expertise is developed and knowledge is accumulated and transmitted from project to project (e.g. Packham *et al.*, 2003). The same argument can be made for an approach to work, an acceptable way of behaviour, an attitude, or more appropriately, a culture which develops from project to project and becomes pervasive. This culture is often associated with a spirit of collaboration, open interaction, trust, commitment, mutual advantage, learning, innovation and productivity (Cook and Hancher, 1990; Crowley and Karim, 1995; Drexler and Larson 2000; Naoum, 2003), and this contrasts sharply with the traditional culture of antagonism, conflict and disputes. It can be seen from this that the *procurement approach* has an impact on the culture of the CPO, with different procurement approaches leading to the development of different organisational cultures.

5.7 Technology and primary function

The technological processes and methods of undertaking work are determined by the primary function of the organisation (Mullins, 2005). Although the type of technology does not necessarily lead to the development of one or other culture, it is clear that certain technologies appear to be more suitable for certain cultures (Handy, 1993). In the construction industry, the bespoke nature of projects implies that the primary function and associated technology may be dependent on project characteristics as already discussed. However generally speaking, construction technology is determined by the industry as a whole.

5.8 The leader/founder and ownership

This factor includes such issues as the founders' values, philosophy and dominance, nature of ownership, and extent to which the organisation has been centralised since its inception. Strong founders and strategic leaders are important in establishing organisational cultures that are both internally consistent and fit the environmental conditions (Kotter and Heskett, 1992). As mentioned before, ideas and solutions that become embedded in culture originate from various quarters within the organisation. However, more often than not, these ideas seem to be associated with leaders, particularly founders or other early leaders who articulate them as a vision, strategy or philosophy (Kotter and Heskett, 1992).

Within the context of a construction project, the concepts of relevance are Project Managers (PMs) and other dominant groups. Dominant groups may emerge from within the CPO, and where these are linked with particular occupations, the approach to work adopted by this occupation (their culture) may form the perspective from which this dominant group will seek to direct the approach to work on the construction project. Where for instance the dominant group takes health and safety seriously, the rest of the CPO will be more inclined to adopting a more health and safety conscious cultural orientation. It can thus be proposed that though they have limited time to exert influence on projects, *PMs* and *dominant groups* can influence different cultural orientations in the CPO usually linked to the respective occupations.

5.9 Goals and objectives

Differences in goals can be decisive in determining what the culture of an organization would be. Goals such as quality of product, good place of work, centre of employment, service to community, and growth influence different cultural orientations in organisations (Handy, 1985; Mullins, 2005). A charity with community service goals will not have the same culture as an airline with profit goals.

In the main, CPOs pursue a variety of project-related goals such as achieving adequate quality, minimising cost, health and safety, innovation etc. The prioritisation of these *goals* and *objectives* influences the organisational culture of the CPO, and CPOs set different priorities.

5.10 Macro cultures

Different macro cultures also have an influence on the development of organisational culture (Hampden-Turner, 1994; Abu Bakar, 1998) and this is because the organisation is a microcosm of society and bears similarities in some respects to society. Different nationalities prefer different organisational cultures (Handy, 1985).

The homogeneity that exists within the employee profile, with only 2% of the workforce being from the ethnic minorities (CITB, 2002), effectively rules out significant influence due to macro-cultural differences. Within the context of this study, where the focus is on the UK construction industry, the UK national culture will be the dominant macro-culture influencing individual behaviour. Using Hofstede's (1997) framework, the typical individual in a UK CPO will be expected to have a low power distance orientation, an individualist orientation, a masculine orientation and weak uncertainty avoidance. Table 2 summarises the key characteristics likely to prevail in the CPO as a result of these macro-cultural influences. Departure from these characteristics may be due to the influence of other determinants of culture.

5.11 Location

Geographical location can have an influence on the types of clients served and the staff employed by the organisation, as well as opportunities for development. The physical characteristics of the location such as a busy city centre or a rural area are important considerations. These can all have a significant influence on culture (Mullins, 2005).

Construction in the UK takes place all over the country, in various settings. Of some significance are the regional variations, which are well documented (e.g. Harvey and Ashworth, 1997). Such variations could potentially influence approaches to work. *Location* is therefore another relevant consideration.

Organisations generally have to live with the pressures of these countervailing forces (Handy, 1995). These pressures are felt differently by each organization and it is in reconciling these forces that the tone for jobs and cultures is set.

Table 2 Key charateristics due to UK macro-cultural influence (Adapted from Hofstede, 1997)

Cultural orientation	**Workplace behaviour/attitude**
Weak uncertainty avoidance	There should not be more rules than is absolutely necessary Time is a framework for orientation Hardworking only when needed, comfortable feeling when lazy Precision and punctuality have to be learned Tolerance of deviant and innovative ideas and behaviour Motivation by achievement and esteem or belongingness
Masculine	Live in order to work Managers expected to be decisive and assertive Stress on equity, competition among colleagues and performance Resolution of conflicts by fighting them out
Individualist	Employer-employee relationship is a contract supposed to be based on mutual advantage Hiring and promotion decisions are supposed to be based on skills and rules only Management is management of individuals Task prevails over relationship
Small power distance	More educated persons hold less authoritarian values than less educated persons Hierarchy in organisations means an inequality in roles, established for convenience Decentralisation is popular Narrow salary range between top and bottom of organisation Subordinates expected to be consulted Ideal boss is a resourceful democrat Privileges and status symbols are frowned upon

6. DISCUSSION

For the purposes of this research, it is possible to classify these determinants of culture in two ways; those that are *dependent* on the project and vary from CPO to CPO, and those that are *independent* of the project and are a characteristic of the construction industry and the environment at large, acting in the same way irrespective of the CPO under consideration. These are listed in table 3.

Table 3 Project-specific and project-independent determinants of culture

Project-dependent factors	Project-independent factors
Composition of CPO	Macro-culture
Project characteristics	Business environment
Project Manager & dominant groups	Recruitment strategies
Significant events	Training initiatives
Procurement approach	Technology & primary function
Goals and objectives	
Location	

In developing a framework that gives an understanding of how the culture of CPOs develop, this distinction is very useful as it makes it possible to distinguish between those contextual factors that are the same irrespective of the project under consideration, and which push all CPOs towards the specific cultural orientations, and those factors which vary from project to project and push CPOs in different cultural directions. It is thus possible to develop a conceptual model of the development of the organisational culture of CPOs (Figure 1) which takes into account these specific characteristics of construction projects.

Research into CPO culture requires the collection of data on all these various determinants of organisational culture. Generally, the contextual data associated with the project-independent factors are well documented and can be derived from the literature. Therefore, the contextual data that any subsequent survey needs to focus on principally are the project-dependent factors, which will be the most useful in explaining the cultural differences that exist between CPOs.

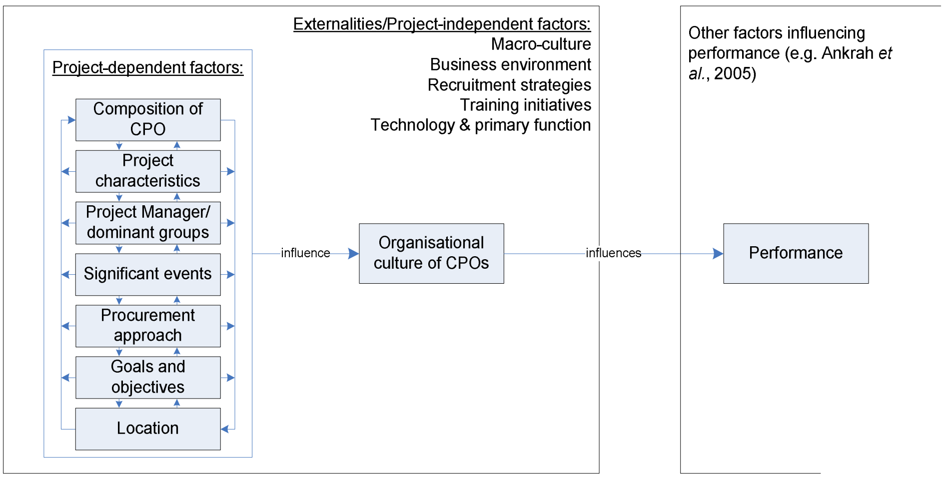

Figure 1 A conceptual model for analysing the development of the organisational culture of a CPO.

It is significant to note that all the factors identified as determinants of organisational culture are inter-related in fundamental ways (Brown, 1998). Leaders (Project Managers or dominant groups) for instance are influenced by the macro-cultures, and they in turn set the goals and objectives of the organisation.

7. IMPLICATIONS FOR ON-GOING RESEARCH

The foregoing discussion provides insight into the development of the organisational culture of CPOs. This is useful in the wider on-going research to examine the various ways in which the phenomenon of organisational culture impacts on project success or otherwise and the extent of its impact. It is useful to the extent that it permits the identification of the contextual factors that a questionnaire survey seeking to examine organisational culture, should focus on. Data on these contextual factors will provide evidence to support or question the existence of particular cultural orientations found to be present within CPOs. It will also be useful in categorising the data in terms of project composition and characteristics, dominant groups, occurrence or otherwise of significant events, procurement approach, prioritisation of goals and objectives, and location, and subsequently testing for significant differences in the categories. Hypotheses are very helpful in this regard, and from the framework above and the preceding discussions, some of the hypotheses that can be proposed are that:

H_1: There is no significant difference between the culture of CPOs irrespective of the composition of CPOs.
H_2: There is no significant difference between the cultures of CPOs irrespective of the characteristics of the projects on which they are engaged.
H_3: There is no significant difference between the cultures of CPOs irrespective of the professional/occupational group that dominates and drives the project.
H_4: There is no significant difference between the cultures of CPOs on projects irrespective of the occurrence or otherwise of significant events.
H_5: There is no significant difference between the culture of CPOs working on projects procured through partnering (or other) arrangements and those working on the more traditionally procured projects.
H_6: There is no significant difference between the cultures of CPOs irrespective of the prioritisation of goals and objectives.
H_7: There is no significant difference between the cultures of CPOs irrespective of where the project is located.

By carrying out appropriate tests on these hypotheses, it will be possible to test the two main hypotheses for this research project given as follows:

H_8: There is no significant difference between the organisational cultures of CPOs working on different construction projects within the UK.
H_9: There is no relationship between organisational culture and construction project performance in the UK.

8. CONCLUSION

Organisational culture in the construction industry is an area that is characterised by a paucity of research, and is only now beginning to receive significant attention in a systematic manner. In a bid to promote research in this genre and as part of a wider study to investigate empirically, the impact of organisational culture on construction project performance, this paper presents an investigation into the factors influencing the development of organisational culture in construction project organisations (CPOs).

Insights gained from the literature include the fact that CPOs need to be examined against the background that they are in actual fact 'short life organisations' (SLOs). Drawing from theory on SLOs and organisational culture, the study identifies the main determinants of the organisational culture within CPOs generally as project –specific factors including the composition of the CPO, size, leader and dominant group, history and crises, and procurement approach, and project-independent factors including the macro-culture, industry characteristics, people, business environment, and technology and primary function. Drawing from these findings, a conceptual framework for understanding the development of organisational culture in UK CPOs is proposed. Six hypotheses are also developed and proposed on the basis of these findings. Testing of these hypotheses will help in drawing conclusions on one of the main hypotheses of this research which is to the effect that the organisational culture of CPOs does not vary significantly irrespective of the project being undertaken.

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TOWARDS A NEW APPROACH FOR ASSESSING ORGANISATIONAL CULTURE IN CONSTRUCTION PROJECT ORGANISATIONS: OVERCOMING KEY METHODOLOGICAL CHALLENGES

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Abstract: It has become necessary to move away from the 'black box' approach of dealing with organisational culture in the construction industry, towards systematic research that provides useful insights into how its potential can be harnessed to improve performance and its adverse impacts mitigated. Based on this premise, this study presents the first phase of the development of an instrument for assessing organisational culture of construction project organisations (CPOs). From an examination of the methodological challenges, organisational culture is operationally defined as that unique configuration of solutions that CPOs and their members adopt in dealing with various organisational problems. These solutions are embodied in approaches to construction, human resource policies, and other strategies that CPOs adopt. In trying to assess this culture, the key is to identify fundamental organisational problems or dimensions of culture, and it is argued that in doing this the focus must be on 'practices' rather than on values. An approach for assessing organisational culture that combines qualitative and quantitative paradigms is proposed.

Keywords: construction project organisations (CPOs), dimensions, measuring organisational culture, methodological challenges, organisational culture.

1. INTRODUCTION

The phenomenon of organisational culture is real and has tangible impacts, and knowledge of this phenomenon is fundamental to understanding what goes on in organisations, how to run them and how to improve them (Schein, 1985). This implies that in seeking to improve the processes and outputs of organisations in the construction industry, culture is an important consideration and organisations need to be able to assess and understand their own culture and the possible consequences of their particular orientation. Assessing organisational culture, with particular reference to construction project organisations (CPOs), requires insight into the concepts, key principles and frameworks that underpin its evaluation, and how these relate to the construction industry. As part of a wider study to investigate empirically, the impact of organisational culture on contractor performance, this paper investigates the methodological challenges and other issues relating to the assessment of organisational culture and attempts to establish the key aspects that will be critical in assessing the organisational cultures of CPOs. It compares empirical approaches to the more popular qualitative approaches of assessing organisational culture, and reviews some of the existing approaches used in construction management research. Based on this review, the paper proposes an approach for the comprehensive assessment of the organisational culture of CPOs. In this study, CPOs are considered to be organisations responsible for undertaking the construction of civil and building facilities.

2. MEASURING ORGANISATIONAL CULTURE – THE METHODOLOGICAL CHALLENGES

Two fundamental questions immediately emerge when examining the possibility of measuring organisational culture. These are the questions of why it needs to be measured and if indeed it does need measurement, whether it can actually be measured.

With regards to why organisational culture needs to be measured, it has been argued that potentially, culture has the ability to influence various aspects of an organisation's processes and products (Ankrah and Proverbs, 2004). Organisations are communities of people with a mission, and each organisation has its own core culture, character, nature and identity. These basic characteristics are so fundamental and deep in hierarchy that they tend to be much more powerful than business processes, financial systems, business strategy, marketing plans, team behaviour and corporate governance (Schneider, 2000). Culture defines appropriate behaviour, motivates individuals and asserts solutions where there is ambiguity. It governs the way a company processes information, its internal relations and its values. It functions at all levels from the subconscious to the visible (Hampden-Turner, 1994). Organisational culture influences the success or otherwise of strategy, mergers, acquisitions and diversifications, integration of new technologies, meetings and communications in face-to-face relationships, and socialisation (Deal and Kennedy, 1982; Peters and Waterman, 1982; Graves, 1986; Thompson, 1993; Mullins, 2005). It accounts for the existence of inter-group comparison, competition and conflict, and the productivity of the organisation (Schein, 1985), and also helps explain why some companies are more successful than others (Smith, 2003). With particular reference to the construction industry, organisational culture has an influence on the propensity for litigation (Fenn *et al.*, 1997; Phua and Rowlinson, 2003), the degree of participation and openness, approaches to decision-making, the quality of communications and working relationships (Low and Shi, 2001; Skitmore *et al.*, 2004) the management philosophies and practices that contractors adopt for projects (Ngowi, 2000) and the attitudes and behaviours towards such aspects as health and safety (Cooper, 2000). As captured in Ankrah *et al.* (2005), it also influences strategy and approaches to construction in terms of the methods and technology applied in the construction process.

These influences can lead to positive or negative outcomes (Hampden-Turner, 1994; Handy, 1995), and to this extent some systematic form of assessment is required which enables the identification of those traits which either facilitate good performance or militate against it, particularly from a construction industry perspective. As will be seen from the literature, measurement provides a means by which this systematic assessment can be achieved.

Having established why measurement is necessary, it is important to consider how organisational culture can be measured or assessed in any systematic form. In respect of this question, Hampden-Turner (1994) argued that if necessary and within certain limits, organisational culture is measurable. This is reinforced by the literature on organisational culture which demonstrates precedents of various assessments of organisational culture. Examples of such tools and frameworks for the measurement of organisational culture are discussed in Schein (1985), Quinn (1988), Hofstede *et al.* (1990), Lui (1999), Ashkanasy *et al.* (2000), Cooke and Szumal (2000), and Delobbe *et al*. (2002) among others. Following these examples, this research proposes to measure the organisational culture of CPOs. However, for these measurements to be undertaken successfully, there are methodological challenges that need to be examined. These challenges may be enumerated as:

- Constituting a working definition of organisational culture that allows it to be conceptualised and operationalised;
- Incorporating a construction perspective in this definition;
- Determining the emphasis to place on values and 'practices';
- Identifying an appropriate research paradigm for the measurement process; and
- Developing empirical referents of the construct of organisational culture.

These challenges are reviewed below, drawing from the experiences of the other attempts to measure organisational culture as documented in the literature.

2.1 A Working Definition of Organisational Culture

There is general agreement that organisational culture, much like the generic concept of culture, is one of those terms that are difficult to express distinctly (Mullins, 2005), but everyone knows it when they sense it, similar to a feeling about someone's personality (McNamara, 1999; Mullins, 2005).

Organisational culture has been loosely defined as "how we do things around here to succeed" (Schneider, 2000). More formally, it has been defined as a pattern of shared basic assumptions that is learned by a group through solving its problems of external adaptation and internal integration, which having worked well enough, is considered valid and taught to new members as the correct way to perceive, think, and feel in relation to particular problems (Schein, 1985). McNamara (1999) argued that organisational culture is comprised of the assumptions, values, norms and tangible signs (artefacts) of organisational members and their behaviours, with new members of the organisation, consciously or unconsciously, soon coming to sense the particular culture of the organisation just as they would the personality of another person. Hofstede (1997) also defined it as the collective mental programming that distinguishes the members of one organisation from another. It is an organisation's way of behaving, identity, pattern of dynamic relationships, 'reality', or genetic code, and it has everything to do with implementation of management ideas and how success is actually achieved (Schneider, 2000). Eldridge and Crombie (1975) refer to the constant exercise of choice as being responsible for the individuality or cultural distinctiveness of organisations.

As can be seen from Schein's (1985) definition, organisational culture is rooted in the basic and universally shared problems (Schein, 1985; Hofstede, 2001), dilemmas (Trompenaars and Hampden-Turner, 1999) or contradictions (Quinn, 1988) which all groups or organisations have to deal with. It can be surmised from all this that *organisational culture* is that unique configuration of solutions – collectively evolved by organisational members – that an organisation and its members adopt in dealing with various organisational problems. The specific solutions chosen by an organisation represent “preferred” or “dominant” (Trompenaars and Hampden-Turner, 1999) behaviours and value orientations, and are the manifestation of the organisation’s culture. This definition makes it possible to systematically assess organisational culture because having identified fundamental problems that organisations contend with daily, ‘what is?’ questions can be asked of the solutions employed in dealing with those issues.

2.2 Incorporating the Construction Context

In the context of this research, one CPO can be distinguished from another by the specific solutions chosen to solve the same fundamental problems. Different CPOs choose different solutions. Abeysekera (2002) provides a useful perspective in which culture is perceived within the construction industry as comprising the characteristics of the industry, approaches to construction, competence of craftsmen and people who work in the industry, and the goals, values and strategies of the organisations they work in. Generally, it can be argued that the various solutions adopted by CPOs in dealing with their project delivery problems are embodied in these aspects identified by Abeysekera (2002) and this construction perspective must be rationalised into the organisational culture definition and the measurement framework to make it valid.

From the foregoing discussion, an investigation of organisational culture in CPOs involves looking at the solutions adopted, in terms of approaches to construction, human resource policies, and other strategies that CPOs adopt, for dealing with the fundamental problems all CPOs encounter.

2.3 Emphasising Values and/or Practices

In the definitions of organisational culture highlighted earlier, it could be seen that culture manifests itself in a variety of ways from the invisible and sometimes unconscious to very visible and tangible manifestations. Hofstede (1997) represented this by an onion diagram with the core represented by the values and underlying basic assumptions, and the outer skins consisting of rituals, heroes and symbols of the organisation (Hofstede, 1997), or artefacts, creations and behaviour norms (Schein, 1985), collectively referred to as ‘practices’. Generally, an investigation of organisational cultures involves examining these practices, and the values and underlying assumptions that inform these practices (Hampden-Turner, 1994). However, emphasis on values and practices vary across definitions and whichever one is emphasised more influences the problems investigated, the research questions asked, the methods applied, and the interpretation of the results (Bodley, 1994). For instance, whereas an emphasis on practices will lead to the pursuit of ‘what is?’ questions, an emphasis on values will lead to ‘what ought to be?’ questions.

In many past investigations, the emphasis has been on values and basic assumptions, and this emphasis has transcended investigations of culture at all levels from national levels down to individual levels. Although values are critical aspects of organisational culture, it has been empirically shown that organisations show more differences in their practices than in their values (Hofstede *et al*., 1990; Hofstede, 1997; van den Berg and Wilderom, 2004). As expressed by van den Berg and Wilderom (2004), organisational culture can be better defined by organisational practices, and as a result can be derived from existing practices within an organisation, department, or work unit. Smith (2000) also argued for this perspective by asserting that the conventional view of culture, which centred on notions of shared values and beliefs was inadequate, instead calling for a strongly operational perspective on organisational culture "as embodied in the organisation's structures, mechanisms and practices." These represent culture in action and are more credible reflections of the organisation's culture than statements of values and beliefs which may be out of step with culture as implemented (Smith, 2000).

The implication this has for defining organisational culture so that it can be operationalised and employed in a framework for assessing the culture of CPOs, is that rather than focusing so much on values, the emphasis must be on practices. This argument is consistent with the definition proposed previously in which organisational culture is seen as being embedded in the solutions employed by CPOs in dealing with fundamental problems. 'What is?' questions are therefore appropriate in this research context to identify and draw out the practices or solutions that CPOs evolve for dealing with their problems. The values and underlying assumptions that govern these practices or solutions can subsequently be extrapolated from these.

2.4 Choosing an Appropriate Paradigm

From a construction perspective, there have been various attempts to diagnose the culture of organisations in the hope of conveying some sense of the values, norms, basic assumptions, conventions, rules and practices to an internal or external audience. In research methodology terms, these assessments of culture may be classified under qualitative approaches (e.g. Serpell and Rodriguez, 2002) and quantitative approaches (e.g. Rameezdeen and Gunarathna, 2003). It has been noted that the choice of assessment approach is typically dependent on the background discipline of the assessors and why they are engaged in the assessment process (Cooper, 1998).

Qualitative methods have been the traditional approach adopted in classical anthropological studies of culture which have sought to describe as empathetically and as comprehensively as possible why and how members of the culture go about their business. They employ ethnomethodological methods which generally involve protracted periods of living within the group and gathering data from within by interacting with people in as natural a manner as possible and by observing the behaviour of the subjects unobtrusively (Columbia Encyclopedia, 2005), and where appropriate, by the analysis of documents. Schein (1985) prescribed one such method, referred to as "clinical iterative" interviewing, for assessing organisational cultures. From a construction industry perspective, there have been notable applications of such approaches using methods such as interviews (e.g. Serpell and Rodriguez, 2002), diaries (e.g. Dainty *et al.*, 2002) and participant observation (e.g. Rooke *et al.*, 2004).

Such ethnomethodological studies offer a very practical way of assessing organisational culture and allow in-depth analysis to be undertaken. They enable the researcher to capture very comprehensively, the 'language' and 'meanings' of the organisation with minimal bias on the outcome of the investigation. Such studies inevitably raise, as pointed out by Hofstede (1997), questions of reliability (would another observer have perceived the same phenomena?) especially as the point of reference is always the researcher's own culture, and questions of generalisability (how does this case help to understand other cases?). Whilst ethnomethodological approaches are useful in the discovery of values and underlying assumptions of people (the essence of culture), it has been shown that these values and underlying assumptions are insensitive to differences between organisations within the same national culture (Delobbe *et al*. 2002). Moreover such aspects, which frequently exist at an unconscious level, are difficult to quantify (Columbia Encyclopedia, 2005), and it has also been argued that what cannot be seen cannot be measured (Cooper, 1998). Although the methodology may be appropriate for the bespoke diagnosis of the culture of an individual organisation, it offers little help in comparative studies as the parameters vary from organisation to organisation. It also has the disadvantage of being very time intensive, making its application in research constrained by time considerations, impractical. Although anthropological researchers have favoured such qualitative methodologies in assessing culture, these shortcomings have led to the pursuit of more quantitative assessments of culture involving the use of questionnaire surveys.

Quantitative approaches rely on 'hard' data and Hofstede (1997) described such studies as "few and far between and not necessarily very convincing." Such studies have the advantage of reliability (independence of data from the researcher), and stability of the instrument over time, thus allowing the pursuit of longitudinal studies if necessary (Hofstede, 1997). The problem this poses is the extent to which culture constructs can be 'hardened' to provide empirical referents that can be measured. Examples exist of efforts that have been made to operationalise constructs of organisational culture to facilitate an empirical assessment with the aim of giving a describable sense of the culture of an organisation. Quantitative approaches permit data collection across a large number of organisations, and this facilitates cross-organisational analysis. Their usefulness in this direction therefore makes them worth considering when contemplating comparative studies. Examples of research adopting this approach within a construction context include Maloney and Federle (1990), Rameezdeen and Gunarathna (2003) and Ankrah and Langford (2005).

Just as in the case of the qualitative approaches, these quantitative approaches have limitations. It has been argued in many quarters that they are at best superficial, not giving enough depth to aid the understanding of the underlying assumptions that define culture. It is believed that most questionnaire measurements of culture have actually only provided an assessment of organisational climate as opposed to the actual organisational culture (Cooper, 1998; Hofstede, 2001). However, it is also possible to claim that the climate is a useful way of assessing culture which though less accurate and specific, is generalisable and does provide a useful description of a single organisation and an even more useful comparison with other organisations (Payne, 2000). Such quantitative studies, irrespective of the measuring approaches and instruments make culture discussible (Hale, 2000), and provide an opportunity to maximise the values of systematisation, repeatability and comparability.

To circumvent the limitations of either approach, it is also possible to synthesise the two approaches by starting with a qualitative orientation, followed by a quantitative verification (Hofstede *et al*., 1990) or *vice versa*. Hofstede *et al.*'s (1990) application of in-depth interviews and "paper-and-pencil" surveys, and a similar study reported in van den Berg and Wilderom (2004) are instructive, and provide examples of what can be achieved through a synthesis of qualitative and quantitative methodologies. Within construction management research, the evidence from literature suggests that such research on organisational culture, which incorporates both qualitative and quantitative elements, is lacking. Research in this vain is not only feasible, as seen in Hofstede *et al.*

(1990) and van den Berg and Wilderom (2004), but also necessary. This research will therefore employ both qualitative and quantitative methodologies to complement each other. This will effectively represent a departure from the norm.

2.5 'Hardening' the Constructs of Organisational Culture

Systematic and empirical assessments of the phenomenon of organisational culture must be underpinned by sound principles. To this end, it is important to recognise that culture, is an intangible concept observable only through its manifestations in verbal and behavioural forms, and such phenomena are typically described as constructs (Hofstede, 2001). An assessment of constructs of culture requires the identification of aspects important to culture just as an assessment of forces will consider such aspects as magnitude and direction (Hofstede, 2001). These aspects are referred to as dimensions of culture, and 'hardening' the construct of organisational culture involves the identification of these dimensions of organisational culture and developing empirical referents around these dimensions that can be measured. Various dimensions abound in the literature on organisational culture, and as can be seen from table 1, various researchers refer to different dimensions depending on what is considered important in the culture being studied, and whether the focus is on values or practices.

When dealing with a multitude of dimensions, typologies are employed as an alternative to provide a simplified means of assessing cultures. Typologies describe a number of ideal types of culture, each of them easy to imagine, against which the culture being assessed is compared (Hofstede, 2001). Typologies are used as metaphors and have mainly been utilised in studies of organisational culture for their ability to communicate easily a sense of what the culture is. Table 2 outlines various typologies employed by notable researchers. The application of typologies in cultural studies is problematic although they are easier to comprehend and communicate. The main flaw in their use is the inability of real cases to correspond with any single typology (Handy, 1995; Hofstede, 1997). The tendency then has been for researchers to associate organisations with the dominant typological orientation (e.g. Handy, 1995; Rameezdeen and Gurantha 2003). In actual fact, organisations have a hybrid of typologies (Handy, 1995; Schneider, 2000) and classification as one or other culture may be misleading. A general caveat in the use of typologies is the fact that they are metaphors and are meant to serve illustrative purposes only. Over-stretching meanings may lead to misrepresentation of organisational cultures.

Dimensions are therefore the preferable option in assessing organisational culture. However, as demonstrated by Hofstede (1984), a weakness in the use of these dimensions is the fact that they are subject to the influence of the researcher and tend to be value laden. This implies that dimensions developed in one national or industry context may not necessarily be appropriate in another setting. However, where appropriate dimensions can be identified, they represent the most realistic way of undertaking cross-cultural comparative studies. Typologies may be used to compliment these dimensions, but for this to be done, cases must be scored unambiguously using indexes and scales and sorted into clusters with similar scores. These clusters can then form the basis of the typologies (Hofstede, 1997).

Many of the dimensions already identified (see table 1) may be adapted and used in studies of the organisational culture of CPOs, but for reasons already pointed out, it can be argued that they offer limited help in a construction context. Another limitation has to do with the fact that most of these dimensions have evolved from research and diagnosis focusing on the shared values and basic assumptions of organisations (e.g. Schein, 1985). To obtain a more appropriate understanding of the organisational culture of CPOs, it is necessary to look beyond these existing dimensions, and to identify aspects that are particularly relevant in a construction context. This implies an opportunity to develop the precedents provided by the likes of Hofstede *et al.* (1990), but focusing this time on practices within CPOs. It is in such situations that qualitative approaches can be highly relevant and most useful.

3. TOWARDS A FRAMEWORK FOR ASSESSING ORGANISATIONAL CULTURE

Table 1 Dimensions of organisational culture

	Taylor & Bowers (1972)	Eldridge & Crombie (1975)	Deal & Kennedy (1982)	Schein (1985)	Quinn (1988)	Hall & Hall (1990)	Thompson (1993)	Handy (1993;1995)	Trompenaars (1994)	Hofstede (1997)	Trompenaars & Hampden-Turner (1999)	Sonnenfield (in McNamara, 1999)	Hofstede (2001)	Erez & Gati (2004)	Mullins (2005)
People															
Calibre of employees								✓				✓			
Dealing with uncertainty								✓		✓			✓		
Relation to authority or hierarchy										✓	✓		✓		
Power structures															✓
Concern, commitment & morale					✓		✓								
The primacy of human resources	✓														
Humanity's relationship to nature				✓											
Nature of reality & truth				✓											
Nature of human nature				✓											
Nature of human activity				✓											
Nature of human relationships				✓											
Individualism or groupism				✓				✓	✓				✓		
Characteristics of role relationships				✓											
Space orientation				✓											
Time orientation				✓		✓							✓		
Concepts of masculinity & femininity													✓		
Behaviour & rules for behaviour			✓				✓								✓
Integrity perception							✓								
Relationship between management & staff							✓								
Attitudes towards work & others									✓						
Processes and systems															
Degree of centralisation								✓							
Degree of formalisation								✓							
Selection & succession								✓				✓			
Control & coordination								✓							
Task organisation								✓							
People management							✓								
Management systems & philosophies							✓								
Discussion, participation & openness				✓	✓			✓							
Decision-making practices	✓						✓								
Decisiveness, direction & goal clarification			✓		✓										
Routine & rituals															✓
Team focus														✓	
Attention to detail														✓	
What management pays attention to & rewards or sanctions			✓					✓							
Motivational conditions	✓														
Structure		✓					✓								✓
Normative or pragmatic										✓					
Bureaucratic or unsystematic & patrimonial roles		✓													
Information management															
Measurement, documentation & information management					✓										
Information systems							✓								
Communication flow	✓														
Communication							✓								
Control															
Sources of power & influence								✓							
Continuity, stability & control					✓										
Parochial or professional										✓					
Open or closed system										✓					
Control systems															✓
Loose/tight or overt/suppressed control		✓								✓					

	Taylor & Bowers (1972)	Eldridge & Crombie (1975)	Deal & Kennedy (1982)	Schein (1985)	Quinn (1988)	Hall & Hall (1990)	Thompson (1993)	Handy (1993;1995)	Trompenaars (1994)	Hofstede (1997)	Trompenaars & Hampden-Turner (1999)	Sonnenfield (in McNamara, 1999)	Hofstede (2001)	Erez & Gati (2004)	Mullins (2005)
Control or influence of lower levels	✓														
Technology															
Technological readiness to change	✓						✓								
Technology		✓													
Business focus															
Growth, external support & resource acquisition					✓										
Profit/impact, productivity & accomplishment					✓										
Process or results orientation										✓					
Employee or job/task orientation										✓	✓				
Outcome orientation														✓	
Strategies							✓								
Target orientation							✓								
Risk-taking			✓											✓	
Client or market focus							✓								
Reaction of suppliers & customers							✓								
Learning and innovation															
Innovation							✓							✓	
Insight, innovation & adaptation					✓										
Speed & degree of feedback			✓												

By identifying the key challenges of measuring organisational culture and setting out how these can be overcome, the discussion so far demonstrates the potential that exists for the systematic assessment of culture. This potential can be seen in instruments for measuring culture such as Hofstede's Value Survey Module (VSM) (Hofstede, 1984) and the Quinn and Cameron 'Competing Values Framework' (CVF) (Quinn, 1988). Although there have been instances where these instruments have been used to assess the organisational culture of construction organisations (e.g. Maloney and Federle, 1990; Thomas et al., 2002; Root, 2002; Rameezdeen and Gunarathna, 2003; Lorenz and Marosszeky, 2004), it can be argued that they fall short of some of the requirements set out in the discussions above.

Table 2 Typologies of culture

Harrison (in Graves, 1986)	Quinn (1988)	Handy (1993; 1995)	Hofstede (1997)	Sonnenfield (in McNamara, 1999)	Trompenaars and Hampden-Turner (1999)	Schneider (2000)
Power	**Clan**	**Club**	**Families**	**Club**	**Family**	**Control**
Role	**Hierarchy**	**Role**	**Pyramids**	**Fortress**	**Eiffel tower**	**Collaboration**
Task	**Market**	**Task**	**Markets**	**Academy**	**Market**	**Competence**
Atomistic	**Adhocracy**	**Person**	**Machines**	**Baseball team**	**Adhocracy**	**Cultivation**

For instance, whereas Hofstede's VSM was developed within a national context and focused principally on values, Quinn and Cameron's CVF was a generic framework for assessing organisations and was initially developed as a means of assessing the effectiveness of organisations rather than the culture of organisations. Although these instruments utilise dimensions, neither instrument addresses fully the other requirements to be based on definitions of organisational culture that emphasise organisational practices and/or a construction context. It can thus be argued that research based on instruments such as these offer useful but limited insight into the organisational culture of construction organisations. Moreover, they have rarely been applied in a construction project context. As a result, to ensure a reliable and valid assessment of CPO culture, there is a need to develop a construction project-specific instrument that focuses on the key practices of CPOs. The development of such an instrument is rooted in having an appropriate approach for identifying a core set of dimensions around which this instrument can be developed. As a first step in this direction, this paper describes a fresh approach (within a construction context) to facilitate the identification of these key dimensions, showing how these will lead to the development of a CPO culture survey instrument.

This new approach proposes in-depth interviews to begin with, to capture as much as possible, the language and meanings of the industry, and to capture a sense of what organisational culture is perceived to be from a construction perspective. This is consistent with Hofstede (1997). These interviews are also to identify the fundamental problems CPOs have to deal with and potential aspects of organisational practices which mirror the culture of CPOs and may be operationalised as dimensions. This will be complemented by extensive surveys of literature examining the main problems of CPOs. Information obtained from this process will then be fed into the development of a questionnaire survey which will incorporate several conceptually related questions covering each of the various dimensions identified through the qualitative investigation. Delobbe et al. (2002) and Hofstede (2001) provide a comprehensive process for filtering these questions to identify the most useful questionnaire items for constructing indexes. This process involves the computation of coefficient alphas and item-to-total correlations, and principal components analyses. Following Hofstede (2001), an index will be constructed for each key dimension using the responses which show significant correlation. The results of these analyses will form the basis for the development of appropriate illustrative tools in the form of web charts, or typologies using appropriate metaphors where clusters in the data emerge. These illustrative tools will be used to communicate a sense of the various cultures CPOs adopt. An outline of this approach is shown in figure 1.

Key to this approach is the strong focus on the construction project context and on practices or preferred solutions for dealing with fundamental problems experienced by CPOs. Beyond describing and illustrating the organisational cultures of construction firms, an outcome of adopting this approach is that, it will be possible to identify the critical questions for inclusion in a survey instrument. When this is integrated with the formulae developed for computing the indexes, appropriate web charts and/or typologies, the output will be a self-administered organisational culture measuring instrument. Such an instrument will provide construction firms with a means of computing their organisational culture scores following an organisational survey, and to plot these scores on an appropriate chart, or represent it in an appropriate manner to communicate their organisation's culture.

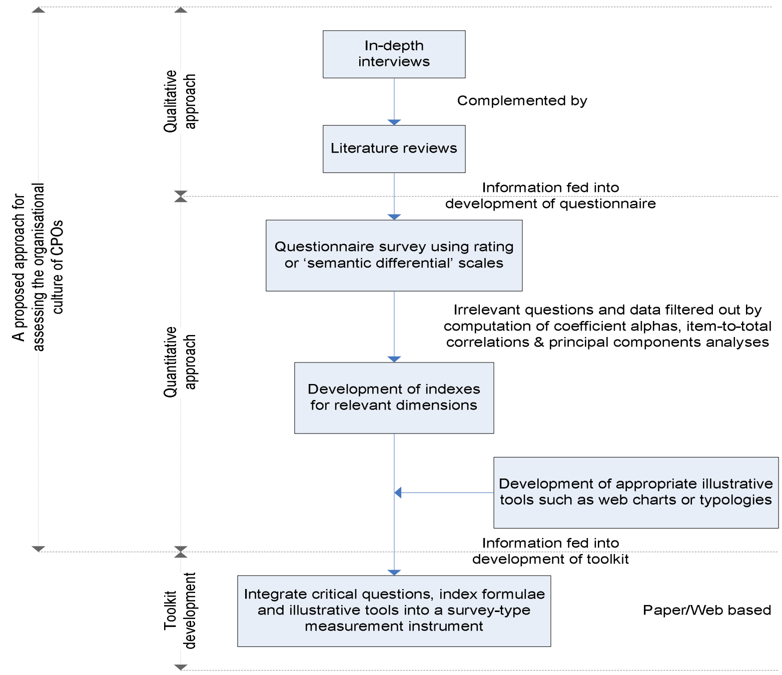

Figure 5 A proposed approach for assessing the organisational culture of construction firms

As far as research into organisational culture in the construction industry is concerned, applying this approach represents a departure from the traditional approaches applied by the likes of Maloney and Federle (1990), Root (2002) and Rameezdeen and Gunarathna (2003), in which existing frameworks such as Hofstede's VSM and Quinn and Cameron's CVF were transferred and applied directly, irrespective of whether their associated dimensions were relevant for the construction industry or not. It also departs from the arbitrary choice of dimensions as seen in Ankrah and Langford (2005), and from Serpell and Rodriguez's (2002) qualitative approach to assessing organisational culture in the construction industry.

4. CONCLUSION

Organisational culture is an important phenomenon that requires systematic investigation if it is to be harnessed effectively in the construction industry. However, there are methodological challenges that need to be overcome if such systematic investigations are to yield useful information. These challenges include developing an operational definition of organisational culture which takes account of the construction context and the need to emphasise organisational practices, and also identifying appropriate paradigms and developing empirical referents of the construct of organisational culture. Distilling various perspectives gives an operational definition of organisational culture as that unique configuration of solutions, collectively evolved, that CPOs and their members adopt in dealing with various organisational problems as embodied in approaches to construction, human resource policies, and other strategies that CPOs adopt.

Assessing this culture requires a synthesis of both qualitative and quantitative approaches. The quantitative approach requires the development of empirical referents of the construct that can be measured. This process of 'hardening' the constructs of culture is achieved through the identification of dimensions, and qualitative approaches are useful in this respect. In particular, Hofstede *et al.* (1990) and van den Berg and Wilderom (2004) provide examples of the potential that exists when various methodologies are applied. Following these precedents, this paper proposes a fresh approach within a construction context for assessing the organisational culture of CPOs. This approach synthesises both qualitative and quantitative approaches, commencing with in-depth interviews through to detailed statistical analyses of organisational practices as captured in questionnaire surveys. This systematic assessment of organisational culture will facilitate the investigation of the extent to which aspects of organisational culture influence the performance of construction projects. A further outcome of this synthesis of methodologies is the development of an instrument for assessing the organisational cultures of CPOs. Such an instrument is imperative if cultural differences among CPOs are to be identified in a systematic manner to facilitate comparisons, setting of benchmarks, and encouraging change.

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MANAGING THE CONSTRUCTION WORKER IN A KNOWLEDGE ENVIRONMENT

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Abstract: Valuable human and knowledge resources will be wasted unless organisations make better use of these prime resources. Construction knowledge workers and their tacit knowledge in particular is still considered to be relatively unexplored and proper understanding and management of this resource is of immense importance for better organisational performance. The paper stresses the importance of knowledge worker and tacit knowledge in construction and examines the contribution towards the company performance. Two dimensions in construction knowledge worker management are highlighted. This provides a valid basis to embrace the concept of knowledge worker and a knowledge culture at all levels within construction organisations.

Keywords: construction industry, human resource management, knowledge worker, tacit knowledge.

1. INTRODUCTION

As highlighted through number of government and academic reports (Latham, 1994; Egan, 1998, Fairclough, 2002), the construction industry is a sector of the economy which faces many challenges, especially in terms of performance. Yet, with the shift of businesses from an asset-centric to a knowledge-centric environment, it is increasingly being acknowledged that Knowledge Management (KM) can bring about the much needed innovation and improved performance the construction industry requires (Webb, 1998; Egbu et al, 1999, Carrillo et al, 2000; Kamara et al, 2003). Against this background of the knowledge economy, what people do with their knowledge, termed as tacit knowledge, is considered to be the real driver for the performance of the industry. Therefore, as a labour intensive industry, the construction worker and their tacit knowledge has become more relevant to sustaining business performance than traditional physical capital (Drucker, 1993; Scarbrough & Swan, 1999), and is considered as a critical factor in determining a construction organisation's ability to remain competitive.

The importance of the construction worker and their tacit knowledge is highlighted through the industry's reliance on skill and the capacity to bring different skills together effectively (Drucker & White, 1996). Accordingly, the concept of the knowledge worker has long been important to construction organisations (Green et al, 2004). Further, due to the intrinsic characteristics of the industry, construction employs an extremely diverse range of people from a wide range of occupational cultures and backgrounds, including unskilled people, managerial and professional positions, and carries the challenge in managing people effectively to ensure organisational success. Moreover, the construction industry has gained a reputation for the dominant culture of command and control which emphasise and correlate with the hard model of human resources management. In this context and in order for the construction industry to achieve best value, there is an emerging importance placed on effectively managing the knowledge worker and their tacit knowledge.

Accordingly, this paper aims to highlight the importance and the relevance of the concept of knowledge worker and their tacit knowledge in order to enhance the performance of construction organisations, through a critical and comprehensive literature review and synthesis. The paper is organised into five broad sections: the first section explores the knowledge intensive nature of the construction industry whilst the section two outlines the growing concept of knowledge worker in construction. In sections three and four the importance and the relevance of tacit knowledge in construction and its relationship to the performance are critically analysed respectively. Finally a case is made for the need to value and manage the knowledge workers and their knowledge in the construction industry,

2. CONSTRUCTION AS A KNOWLEDGE BASED INDUSTRY

There has been a surge of interest in managing knowledge during last few decades, leading to considerable changes in the business environment. Hence, knowledge management is now seen as the greatest value of creation for businesses, which has resulted in the move from an asset-centric to a knowledge-centric business environment. In the UK Government's Competitiveness White Paper, *Our competitive Future: Building the Knowledge Driven Economy*, a 'knowledge economy' was defined as one in which the generation and the exploitation of knowledge have come to play a predominant part in the creation of wealth (DTI, 1998). Against this background of knowledge economy, the subject of managing knowledge is increasingly being viewed as of critical importance for organisations wishing to retain competitive and achieve excellence in service delivery. It is argued (Robertson et al, 2001: Egbu & Robinson, 2005) that the construction industry, although known for its highly tangible products such as buildings and other structures, is increasingly now recognised as a provider of services, placing more emphasis on knowledge. Further, the UK Government's Competitiveness White Paper (DTI, 1998), refers to a more effective use and exploitation of all types of knowledge, particularly in the traditional construction industry in order to give the UK a competitive edge.

Construction is an industry which utilises a variety of separate firms in a temporary multidisciplinary organisation, to produce investment goods like buildings, roads, bridges etc, which are custom built to unique requirements. The industry is generally driven by single and unique projects, each creating and disbanding project teams made up of varying combinations of large and small firms from across the supply chain spectrum (Tatum, 1986; Carty, 1995; Halpin and Woodhead, 1998). The short-term temporary project based nature is considered as an intrinsic characteristic of construction and industry is considerably more fragmented than many other industries with a much greater concentration of small firms (Green et al, 2004). The industry is heterogeneous and diverse, consisting of different organisations, consultants, building materials and product producers, and professionals providing a range of services for client, customers and the wider community. The scale of small firm activity in the UK construction industry is considerable, with, in 2003, 98.2% of UK construction firms having 1-59 staff (Department of Trade and Industry, 2004: Table 3.1) and delivering some 45% of the industry’s workload (Department of Trade and Industry, 2004: Table 3.3) and accounting for 122,220 small and medium construction firms in 2003 (Green et al, 2004).

Despite the very high levels of service-input needed from these small and medium construction firms in the formation of construction products, too often, the industry is known for its products and not seen as an industry that provides services to its clients and customers. Nevertheless, the number of professional service firms within construction industry too has risen from 48,202 in 1995 to 52,490 in 1998 (CIB W55-W56, 2002) and the services offered by these professional service firms are characterised by being highly knowledge intensive in nature (Løwendahl, 2000) where knowledge has more importance than other inputs. Research conducted by Windrum et al (1997) and Den Hertog and Bilderbeek (1998) identified design, architecture, surveying and other construction services as knowledge intensive service sectors. This in a way evident the shift towards the knowledge economy in UK construction industry and there is significant agreement that the principle means by which this growing body of professional service firms creates value through the successful management of knowledge (Robertson et al, 2001). Further, the issues of knowledge production, transmission and transfer are considered to be important facets of the knowledge economy (Egbu & Robinson, 2005). Research carried out by Management of Knowledge and Innovation Research Unit (Egbu et al, 2003) has empirically established these aspects of the knowledge economy in construction industry. In this context, construction industry is perceived as a knowledge based value creating sector of the economy. Moreover, people are known to be the key to success in a knowledge economy, whom termed as knowledge workers. There are a wide range of professionals involved in construction industry, working as an inter-disciplinary team in delivering the construction products. In this context, the succeeding section explores in detail the construction worker in a knowledge environment.

3. KNOWLEDGE WORKER IN CONSTRUCTION INDUSTRY

People are recognised as possessing knowledge and know-how, having the ability to create knowledge and value, and collectively retaining organisational memory. What people do with their knowledge is the real driver for competitive advantage in the knowledge economy (Quintas, 2005). As highlighted by the UK Government’s Competitiveness White Paper (DTI, 1998), one of the two distinct tasks envisaged for organisations within the knowledge driven economy is to encourage and support employees in developing their skills and qualifications on a continuous basis. The UK construction industry employed 19,130 workers per £1 billion output (total of 1,599,000 workers) in 2003 (Green et al, 2004), hence considered to be one of the labour intensive sectors of the economy. Construction companies frequently claim that ‘people as their greatest asset’ (Carrillo et al, 2000) in a situation where literature on human resource management repeatedly emphasises the need to treat people as a key resource. People are an organisation’s most valuable asset and this is especially true in relatively low-tech, labour intensive industries such as construction (Green et al, 2004).

The rediscovery of the importance of employees’ knowledge coincided also with a popularisation of the idea of the ‘knowledge worker’. This is based on the notion that certain types of work are more knowledge intensive than others, and it is this knowledge intensive work that is growing within the economy (Quintas, 2005). The importance of the construction worker is highlighted by the fact that industry relies on skill and on the capacity to bring different skills together effectively (Drucker & White, 1996), thereby the concept of the knowledge worker has long been important to construction organisations (Green et al, 2004). In recent years, with the growth of the service sector, this emphasis placed on the construction knowledge worker has gradually increased. However, knowledge worker and their knowledge also represent the most difficult resource for organisations to manage. As an intrinsic characteristic of the industry, construction employs extremely diverse range of people from a wide range of occupational cultures and backgrounds, including people in unskilled, craft, managerial and professional positions, challenging to manage knowledge worker effectively to ensure organisational success. Further, much of this individual knowledge is unknown to others and unmapped and unrecorded. As Sheehan et al (2005) asserts in construction;

- Some 80% of the useful knowledge is tacit and cannot be written down
- The construction industry is characterised by a wealth of experiential knowledge, yet employees retire or leave the organisation, potentially taking tacit knowledge and a potential source of competitive advantage with them

As Rezgui (2001) cited, there are few key reasons that limit current approaches of KM in the construction industry. Among the key factors for these limitations are;

- Much construction knowledge, by necessity, resides in the minds of the individual working within the domain.
- The intent behind the decisions is often not recorded or documented.
- The individuals who have knowledge about the project are likely to left for another project at the end of the construction stage; hence their input is not captured.

All these three limitations indicate the direct correlation with the human factor in the construction industry and stress the importance of the concept of knowledge worker which has long been central to construction industry performance. Further, both Sheehan et al (2005) and Rezgui (2001) stress the point that much knowledge possessed by knowledge workers being tacit in nature particularly in construction industry. Accordingly, the following section outlines the nature of the tacit knowledge and its presence in construction as a knowledge based industry.

4. TACIT KNOWLEDGE IN CONSTRUCTION

Within the last few decades, there has been an increasing interest in the tacit dimension of knowledge, which is perhaps hardest to manage, as it cannot be formally communicated and is often embedded within human beings. As Herrgard (2000) suggests, tacit knowledge is obtained by internal individual processes like experience, reflection, internalisation or individual talents. Individuals are the primary repositories of tacit knowledge that due to its transparent characteristics is difficult to communicate and therefore cannot be managed and taught in the same manner as explicit knowledge. While highlighting the importance of tacit knowledge, Tiwana (2000) defines it as know-how that is stored in people's heads which is personal, acquired mainly through education, training and experience. In a similar sense, Saint-Onge (1996) describes tacit knowledge as an individual's intuition, beliefs, assumptions and values, formed as a result of experience. It is from these beliefs and assumptions, which make up an individual mindset that decisions are made and patterns of behaviour developed. Thereby, in working life one can easily find many examples of tacit knowledge such as intuition, rule-of-thumb, gut feeling and personal skills, all based on individual experiences. When synthesised, tacit knowledge could be classified into two dimensions knowingly the technical and the cognitive dimension (Herrgard, 2000, Hussi, 2004). The technical dimension encompasses information and expertise in relation to 'know-how' and the cognitive dimension consists of mental models, beliefs and values (Gore and Gore, 1999), in short conception of reality. As such, some forms of human knowledge can be communicated to others through language or symbols, however, the cognitive dimension of human knowledge cannot be communicated in language or symbol.

Within construction, the type of knowledge varies considerably, yet gains increase concern on tacit knowledge as a labour intensive industry. In the context of construction, examples of tacit knowledge include estimating and tendering skills acquired over time through hands-on experience of preparing bids, understanding the construction process, interaction with clients/ customers and project team members in the construction supply chain, as well as understanding tender markets (Egbu & Robinson, 2005). Specially, Engineers, Architects and other professionals within the construction industry are not in a position to 'cut and paste' best practice (Kamara et al, 2003) from the past due to the unique and the complex nature of the construction projects. They have to draw on the past to find solutions for the future. Tacit knowledge evolves from these shared practices and experience which need to be managed for the project and the organisational success. According to Wetherill et al (2002), knowledge in construction domain can be classified into three categories as illustrated in Table 1, which further highlights the emphasis placed on knowledge worker and tacit knowledge.

Table 1: Classification of Knowledge in construction domain (Wetherill et al, 2002)

Domain Knowledge	the information available to all companies and is partly stored in electronic data bases
Organisational Knowledge	company specific and intellectual capital of the firm which also comprises knowledge about the personal skills, project experiences of the employees
Project knowledge	which includes both project records and the recorded and unrecorded, memory of processes, problems and solutions

Above classification reflects the organisational hierarchy and when one moves from domain knowledge to project knowledge the concentration on knowledge too moves from explicit to tacit nature. By taking a different stance Stahle (1999) suggests organisations into three-dimensional system i.e. mechanistic, organic and dynamic nature, depending on the different challenges presented for management of knowledge. Mechanistic part deals more with explicit knowledge whilst organic nature helps the organisation to work flexibly with a people-centred orientation and involves the management of tacit knowledge. The dynamic nature facilitates continuous improvement and innovation. Wetherill et. al's classification reflects the organisational hierarchy and when one moves from domain knowledge to project knowledge the concentration on knowledge too moves from explicit to tacit nature, which further highlights the knowledge worker concept in construction. Stahle's suggestion indicates both the management and the production of the knowledge. In a similar sense Moodley et. al (2001) contends that the tacit knowledge is developed through the individual or project teams, while the explicit knowledge is created through process, procedures and other routines that can be codified. What ever the classification, tacit knowledge of the workers has been clearly highlighted in many research carried out in the construction industry. A research carried out within structural design firms (Al-Ghassani, 2003) showed that about 80% of knowledge used during concept design stage is tacit compared to about 20% of explicit knowledge. As such, managing tacit knowledge more effectively offers construction organisations a possible mechanism for improving their performance in times of greater competition. This stresses the importance of tacit knowledge in construction and succeeding section explores the possible relationship to performance when tacit knowledge is managed effectively.

5. STRATEGIC IMPORTANCE OF TACIT KNOWLEDGE

Researchers investigating on the sources of organisation's sustained superior performance have primarily and typically anchored their work in the Resource Based View (RBV) of the organisation (Barney, 1991; Wernerfelt, 1995; Peteraf, 1993). The RBV considers two assumptions in analysing sources of superior performance and competitive advantage. First, it assumes that firms within an industry may be heterogeneous with respect to the resources they control. Second, these resources may not be perfectly mobile across firms, and thus heterogeneity can be long lasting. One of the principle insights of this view is that not all resources are of equal importance or posses the potential to be a source of superior performance through resource heterogeneity and immobility. As Barney (1991) contended, it is the possession of key resources or strategic resources and its effective deployment in product-markets that render superior performance for organisations. To be a key resource or a strategic resource it should possess four attributes:

- It must be valuable: to exploit opportunities and/ or to neutralise threats in a firm's environment
- It must be rare: among a firm's current and potential competition
- It must be imperfectly imitable, and
- There can't be strategically equivalent substitutes for this resource that are valuable but either rare or imperfectly imitable.

These attributes of organisational resources can be thought of as empirical indicators of how heterogeneity and immobility a firm's resources are and thus how useful these are for generating superior performance through sustained competitive advantage. For many authors (Amit & Schoemaker, 1993; Grant, 1996; Krogh & Roos, 1996; Spender, 1996; Teece, 2000; Eisenhardt and Santos, 2000) knowledge, which possesses all these characteristics of a strategic asset, is the best and the only resource for achieving sustainable superior performance as postulates in the Knowledge Based View (KBV) of the firm. This perspective considers knowledge as the most strategically significant resource of the firm (Grant, 1996), and its proponents argue that heterogeneous knowledge bases and capabilities among firms are the main determinants of sustained competitive advantage and superior corporate performance (Decarolis and Deeds, 1999; Winter and Szulanski, 1999).

Yet, the increasing dynamism of the environment, with its frequent and rapid changes in technology, customer preferences, and competition, has led a number of researchers (e.g., Eisenhardt, 1989; D'Aveni, 1994) to question the sustainability of superior performance of any given strategic position, bundle of resources or set of moves. As Eisenhardt and Santos (2000) argued, in high-velocity environments, an extreme form of dynamic markets where even basic industry characteristics such as boundaries, competitors and customers are in flux, no specific advantages are sustainable. Therefore, the dynamic capabilities approach argues that competitive advantage is dependent on particular organisational and managerial processes, termed 'dynamic capabilities', which are defined as the firm's ability to integrate, build and reconfigure internal and external competencies to address rapidly changing environments (Teece et al, 1997).

Based on this understanding of organisations and dynamic environment, Grant (1996) proposed a knowledge-based theory of strategy. As Grant (1996) asserts, the source of competitive advantage in dynamic environments is not knowledge that is proprietary to the organisation, because the value of such knowledge erodes quickly due to obsolescence and imitation. Rather, sustained superior performance is determined by non-proprietary knowledge in the form of tacit individual knowledge. Tacit knowledge can form the basis of competitive advantage because it is both unique and relatively immobile. The distinction between tacit and explicit knowledge has proven to be particularly important in this dominant view, which identifies tacit knowledge as the most significant strategic resource of firms. Yet, because that knowledge is possessed by individuals and not the organisation, a critical element of sustained competitive advantage is the ability to integrate the specialised and tacit knowledge of individuals. As such, this highlights the importance of tacit knowledge towards organisational performance when integrated and managed properly. Having established the importance of the knowledge worker, tacit knowledge and it relationship to the performance, following section discusses further the management of knowledge worker and tacit knowledge.

6. DISCUSSION

KM is increasingly recognised as an integrated concept relating to the 'active management of intellectual assets, either in the form of explicit knowledge held in artefacts or as tacit knowledge possessed by individuals or communities' (Snowden, 1997). Nevertheless, as Harman and Brelade (2000) contended, KM to be effective, must encapsulate the idea that it is through the acquisition of knowledge by individuals and their willingness to apply their knowledge for the benefit of the organisation that competitive advantage is achieved. Davenport (1998) further highlights this issue by asserting "the most dramatic improvements in KM capability in the next ten years will be human and managerial". Invariably, the management of tacit knowledge is intrinsically linked to the management of people (Egbu et al., 2001) and to the processes that facilitate knowledge generation, distribution and sharing between related individuals and workgroups. This stresses two aspects or dimensions in tacit knowledge management i.e. the management of people or the knowledge workers with the right human resource policies and to ensure knowledge supportive and conducive environment or culture within the organisation.

As already discussed, a knowledge worker has traditionally been seen as a highly skilled, highly paid specialist. An increase number of individuals do work which is knowledge based and the concept of knowledge worker needs to embrace these individuals who can be found at the all levels within organisations (Harman and Brelade, 2000). A major aspect of managing tacit knowledge in a knowledge-based economy is giving to knowledge worker the power that arises from the ability to solve the critical contingencies facing the organisation. It means that knowledge worker will increasingly be able to determine that they are managed in ways acceptable to them. As suggested by Tyson (1995), for managers this will involve a paradigm shift to see themselves as facilitators rather than controllers. This highlights the necessity of managing knowledge worker with flexible, employee centred approaches based on consensual models (Harman and Brelade, 2000). Yet, Construction as an industry which has a reputation for its dominant culture of command and controls consistently emphasises and correlates with the hard model of human resource management. Also the culture of subcontracting and self employment marginalises the importance of people management and thereby reflects and reinforces the dominant industry receipt of hard human resource management. Soft human resource management policies based on empowerment and commitment are much more prevalent within organisations orientated towards creativity (Green et al, 2004). This is true when it comes to the professional service firms within the construction industry, who compete successfully internationally by investing heavily in knowledge based services. As such it is an urgent matter for the construction industry to move towards the softer approach based teamwork from hard model of human resource management to enhance the collective efforts.

The ignorance of the knowledge worker within the construction context has contributed to a great extent for the under performance of the industry as lamented by many authors. As Egan (1998) asserted;

"*….much of construction does not yet recognise that its people are its greatest asset and treat them as such. Too much talent is simply wasted, particularly through failure to recognise the significant contribution …… We understand the difficulties posed by the fragmented structure of the industry, but construction cannot afford not to get the best from the people ……*" (para 17: 14).

As contended by Nesan & Holt (1999), the issue of the critical role that employees play in fostering an effective construction business (appropriately referred to as the "people" factor) has often been overlooked. According to Cooke-Davies (2001: 185), "*it is people who deliver the projects and not processes and systems*", which gains increased validity in the context of construction, as a labour intensive industry.

As the second dimension, the KM environment needs to reinforce the acquisition, use and sharing of individual tacit knowledge. Therefore, significant effort should be directed towards exploiting non-IT techniques such as communities of practice to facilitate person-to-person and person-to-organisation interactions (Robinson et al, 2001). Communities of practice within which individuals share common work experiences and problem agendas provide a social context within which knowledge may be created and effectively shared. Several authors (for Eg, Augier and Vendelo, 1999; Koskinen, 2003), have repeatedly highlighted the importance of interaction, integration and involvement of knowledge workers through social networking within an organisation. Social interaction of employees cultivates a knowledge sharing culture based on shared interest, thus encouraging continuous knowledge generation through the evolution of a community of practice. Within the community of practice, tacit knowledge may be shared in non-codified forms (Brown & Duguid, 1998). According to Koskinen (2003), in such kind of knowledge environment manager could support the acquisition and sharing of knowledge and expertise by;

- Encouraging individuals to use their knowledge and expertise
- Facilitating innovation and creativity and encourage new ideas
- Representing the interests of the individual/ team to the organisation

This will involve an understanding of individuals and teams and a willingness to be open to new ideas and personal development. As such managing tacit knowledge in a knowledge environment, corporately through human resource policies and procedures will be judged by its ability to encourage and enable knowledge workers to apply their knowledge for the benefit of the organisation.

7. CONCLUSION

The advent of knowledge based economy requires a broader understanding of knowledge management and the concept of a knowledge worker. The construction is a knowledge based industry, where knowledge has become the driving force to bring critical competitive advantage. For the construction industry to perform successfully with the challenges of the knowledge economy it has to embrace the concept of knowledge worker and a knowledge culture at all levels within organisations. The paper stressed the importance of knowledge worker and tacit knowledge in construction, examined the contribution towards the company performance and the management of knowledge worker. This provides a valid basis for more empirical studies centred on knowledge worker and their tacit knowledge in the construction industry.

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SNAGGING WITHIN NEW HOMES IN THE UK: AN ANALYSIS BETWEEN ENGLAND AND SCOTLAND

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Abstract: The process of buying a new house often ends in tears for the buyer. The buyer suffering stress as a result of the number of snags encountered on what should have been their pride and joy. The matter is exacerbated by builders who often take a recalcitrant view on how to alleviate the situation. This recalcitrance being founded on the dearth of legislation to protect the house buyer. This paper discusses 'snagging' in the overall house buying process and evaluates the number of snags being discovered on new houses which have been 'signed-off' as being suitable for the buyer to move in to. The range and nature of the snags discovered on a geographical basis is considered in some detail. In order to ensure quality in new houses it is imperative that the house builder knows exactly how snags occur (the composite effect of defects, errors and omissions) and the impact on the finished product i.e. the new home. House builders will continue to neglect a real approach to quality (as defined by the buyer) and therefore snagging will remain a perennial feature of the house building process. The figures and analysis from this research represent the most accurate statistics on snagging levels found in new homes in the UK.

Keywords: House Building, Information, Snagging, Workmanship

1. INTRODUCTION

The last decade has witnessed a constant clamour from both clients and government for improvements in the quality of the finished product delivered by the house building sector of the UK construction industry. UK government ambitions to improve the quality of new homes have prompted a number of house builders to consider the implementation of quality initiatives such as Total Quality Management (TQM) and ISO 9000 (Sommerville, 1994). The import of these quality initiatives is at best questionable and their adoption does not appear to be a guarantee of an improvement in the quality of the finished article (Sommerville et al., 2004).

The volume of research specifically related to quality in new-build housing is remarkably scant given the size of the industry. The research that is there focuses predominantly on regulatory defects i.e. contraventions to either building regulations or the warranty providers' standards. No in-depth research has been carried out on "snagging", although the importance of snagging is shown by the fact that the last three Housing Forum/MORI customer satisfaction surveys carried out in 2000, 2001 and 2003 report an increasing number of new home purchasers as being unhappy with the quality of their new home, the recorded levels of satisfaction showing a downward trend.

The aim of this research was to examine the differences in snagging levels found within new homes within the UK on a geographical basis. The importance of the snagging process from the builder, the home buyer, the regulatory inspector and the independent inspector point of view is discussed which reveals how each party within the snagging process rates each particular aspect of the actual snagging items. Initial analysis of snagging data from 1696 new homes built by 271 UK house builders demonstrates the levels of snagging a home buyer could expect to find when purchasing a new home. It is clear that the snagging problem has worsened in 2005 with particular concern being placed upon new homes built within Scotland.

2. SNAGGING IN NEW HOMES

Snagging has almost become enshrined within the house building cultural paradigm as an accepted feature of the overall house building process. It has assumed a degree of acceptability, even though it is an unwelcome feature of modern house building. The term is widely applied within the UK construction industry: extraction of definitions of the term from within a range of built environment literature includes: rework, non-conformance, repairs, quality failures, quality deviations and defects (Love 2002). A definition of snagging that may be more acceptable across the broader spectrum of house builders is the identification and rectification of errors, defects and omissions within a new house.

Love and Li (2000) see rework as being “the unnecessary effort of re-doing a process or activity incorrectly implemented the first time”. The process of ‘snagging’ has been defined (by independent UK body Inspector Home) as “the act of checking a new home for difficulties with the quality of finish and workmanship”. These definitions concur with Ong (1997), who suggests that by its very nature the composite house building process often leads to minor defects being found in the finished article.

A number of factors that influence the quality of a construction product can be attributed to the design of the project and more importantly poor workmanship (Love and Sohal, 2003). Snagging involves the rectifying of mistakes and ineffective work (poor workmanship). For contractors and home buyers, snagging works cause unnecessary distress and conflict especially when they appear after practical completion has been awarded.

Within the UK, It is clear that the buyer plays decisive roles in selecting the house builder and the actual house itself, along with the finance provider. With conclusion of missives to purchase, the control of quality on the new house moves from what may be perceived as the buyer’s realm to the builder and mortgage lenders. Although in reality, the quality expectations were never that of the buyer. The quality standards are set and managed by the builder – in some cases even the inspection of the house for habitation approvals is significantly controlled by the builder. The home buyer has no control over the quality of the finished product. The mortgage lender seeks assurance that the house will be ‘fit for purpose’ and this is attained by the builder through the use of NHBC (or other approval body).

The current snagging systems operating within new home builders quality procedures provide little comfort to the most important member of the house building supply chain “the customer” (Sommerville et al., 2004). Many homeowners are forced into purchasing sub-standard homes with promises of remedial work to follow only to find that once the missives are complete the house builder is reluctant to rectify any outstanding snagging items.

3. SNAGGING: CLASSIFICATION MAPPING

Snagging is a common phenomenon within the industry and this has a deleterious effect upon the parties to the contract and the wider industry image. Snagging within the industry is inevitable and can be attributed to a number of sub-processes which act as indicators and moderators. The initiation of any construction or house building project involves two central aspects: tasks, which are to be executed, and people, who must carry out the various tasks. Snagging occurs when these tasks are not carried out to standards or specification or are not properly performed by industry trades. Georgiou et al., (1999) have grouped snagging items under three different headings.

1. Technical, when workmanship, materials or design elements of a building reduce its ability to function.
2. Omissions, parts or features of a home that are simply "omitted".
3. Aesthetic, when the appearance or finish of a building is adversely affected.

A single snagging item (for example "a missing air brick) can be considered separately under each heading or can be grouped under or can overlap all three. Either way, the snagging item has occurred. Figure 1 indicates that there are 7 possible snagging scenarios to be considered.

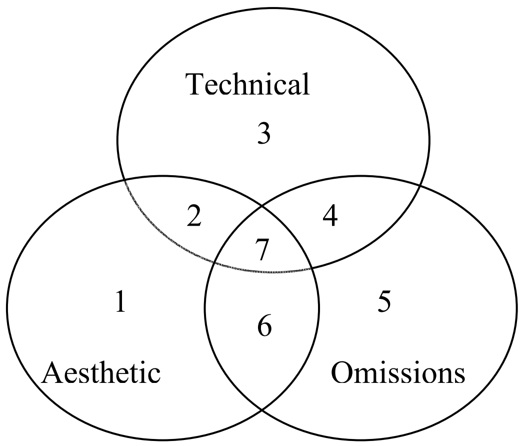

Figure 1: Possible snagging scenarios

The ability to allocate a snagging item within one or more of the above scenarios will allow timely decisions to be made and appropriate actions to be executed. Allocating an item under a specific heading however is not straight forward. For example a missing airbrick could be considered and grouped under all seven headings as follows:

1. Aesthetic – because the air brick is missing the building is unsightly.
2. Aesthetic/technical - because the air brick is missing the building is unsightly and the issue is technical because it does not comply with building regulations.

3. Technical - the issue is technical because it does not comply with building regulations.
4. Technical/omission - the issue is technical because it does not comply with building regulations and is an omission because the brick is “not there”.
5. Omission – it is an omission because the brick is “not there”.
6. Omission/aesthetic - it is an omission because the brick is “not there” and because the brick is missing the building is unsightly.
7. Aesthetic/technical/omission – a combination of all three aspects.

Snagging tends to be identified once practical completion has been awarded by the local authority or National House Building Council (NHBC) and often involves items that are found by the architect, NHBC inspector, clerk of works, project manager, site manager and home owner during a walk around the new home. However, each of the parties that identify the snagging items have differing priorities when concerned with the aspects of snagging (items 1-7 above) as displayed in table 1. For example the home owner is more concerned with the aesthetic items identified where as the compliance inspector tends to sway towards the items that are technical.

Table 1: Importance of snag factors to respective parties (I = importance, H= high, L = low)

Snag Factor	**Home Buyer**	**Builder**	**Compliance Inspector**	**Independent Inspector**
1 - Aesthetic	I^H	I^L	I^L	I^H
2 - Aesthetic/technical	I^L	I^L	I^H	I^L
3 - Technical	I^L	I^H	I^H	I^L
4 - Technical/Omission	I^L	I^H	I^H	I^L
5 - Omission	I^H	I^H	I^L	I^H
6 - Omission/Aesthetic	I^H	I^L	I^L	I^H
7 - Combination of 3	I^H	I^H	I^H	I^H

It is important is to understand the processes of snagging which may be witnessed within construction and house building projects. To consider the origins of the snagging (especially the individual parties concerned), its evolutionary processes and the eventual effects of the snagging situation require examination. The identification and analysis of these important facets of snagging will allow the development of a greater understanding of the snagging situation and so enable a more comprehensive approach to its reduction in levels or even complete elimination.

Within the majority of construction projects there are a clear set of originators or sources of snagging:

1. From the Client (their organisation or their representatives) through design changes to the project
2. From the Client (their organisation or their representatives) through material changes to the project
3. From within the contractor's organisation
4. From within the sub-contractors through workmanship issues
5. From professional bodies (Inspectors) through technical issues
6. From bodies external to the above.

These originators may act either in isolation or interact simultaneously with each other, ensuring that the process of locating the finite source of the snagging item is extremely difficult. The originators give rise to several common causes of snagging which may be grouped under the following broad headings:

1. Material faults and failures
2. Omissions (brought about through supply chain delivery failure or poor practice on site)
3. Design faults and functional changes
4. Variations in working practises
5. Workmanship and poor practice issues caused through a lack of understanding and a lack of skilled operatives
6. Time issues which determine the speed of progress
7. Cost issues which may force a combination of the above

The sources and causes of snagging are part of the larger territory of the snagging event, which may be analogous to any project i.e. there is a start point, discernible intermediate stages, and some form of ending (usually to the builders benefit). The larger dimension is considered in Figure 2 which maps and integrates the sources, the causes and the snagging event itself.

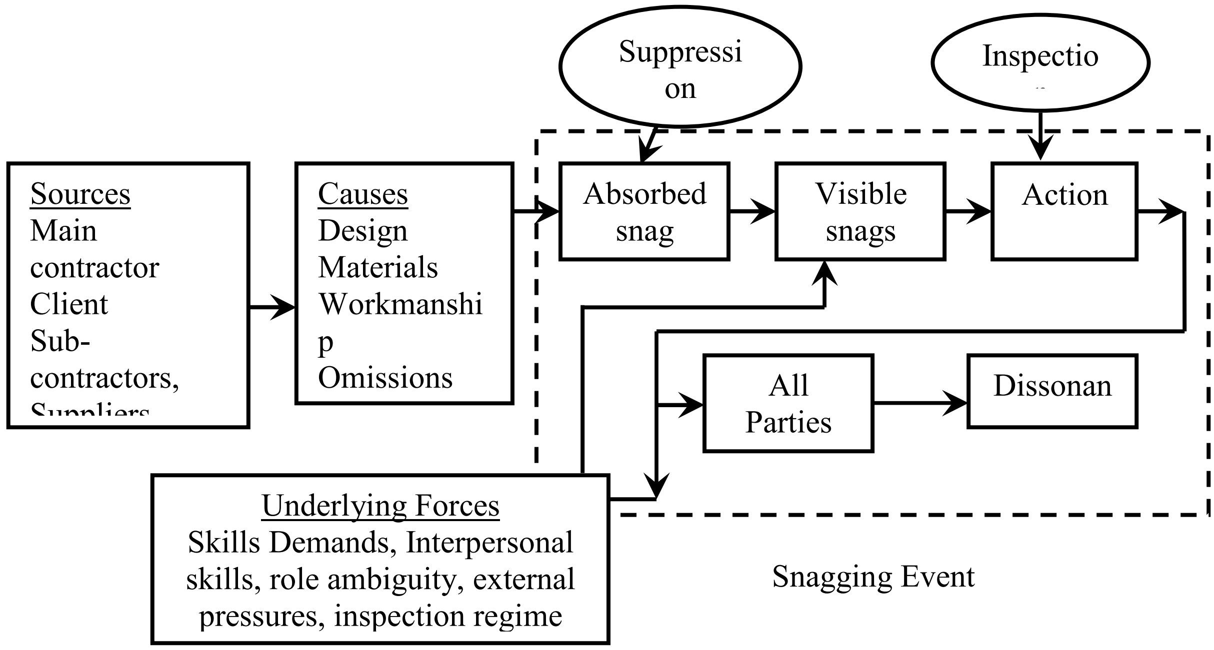

Figure 2: Snagging event mapping (adapted from Sommerville, 1992)

It may be argued that project performance is a variable which is dependant upon: the functionality of the snagging event; its significance, and its certainty. These variables may be mapped (as shown in Figure 3.) to produce a classification structure for the eight potential scenarios. These scenarios are listed in Table 2.

The current scenario within the construction industry is that snagging is significant, unavoidable and dysfunctional. The industry however needs to move away from this extremely damaging scenario and ensure snagging becomes insignificant, avoidable and functional as displayed in Figure 3. This significant change in scenarios would almost certainly require a change in working attitudes, a change in working practises and more importantly a shift in attitude towards the home buyer with the ultimate goal of becoming "customer focused".

Table 2: Snagging Classification Potentials

Potential		**Expansion**	
	Significance	**Certainty**	**Functionality**
S.U.D.	significant	unavoidable	dysfunctional
I.U.D.	insignificant	unavoidable	dysfunctional
S.U.F.	significant	unavoidable	functional
I.U.F.	insignificant	unavoidable	functional
S.A.D.	significant	avoidable	dysfunctional
I.A.D.	insignificant	avoidable	dysfunctional
S.A.F.	significant	avoidable	functional
I.A.F.	insignificant	avoidable	functional

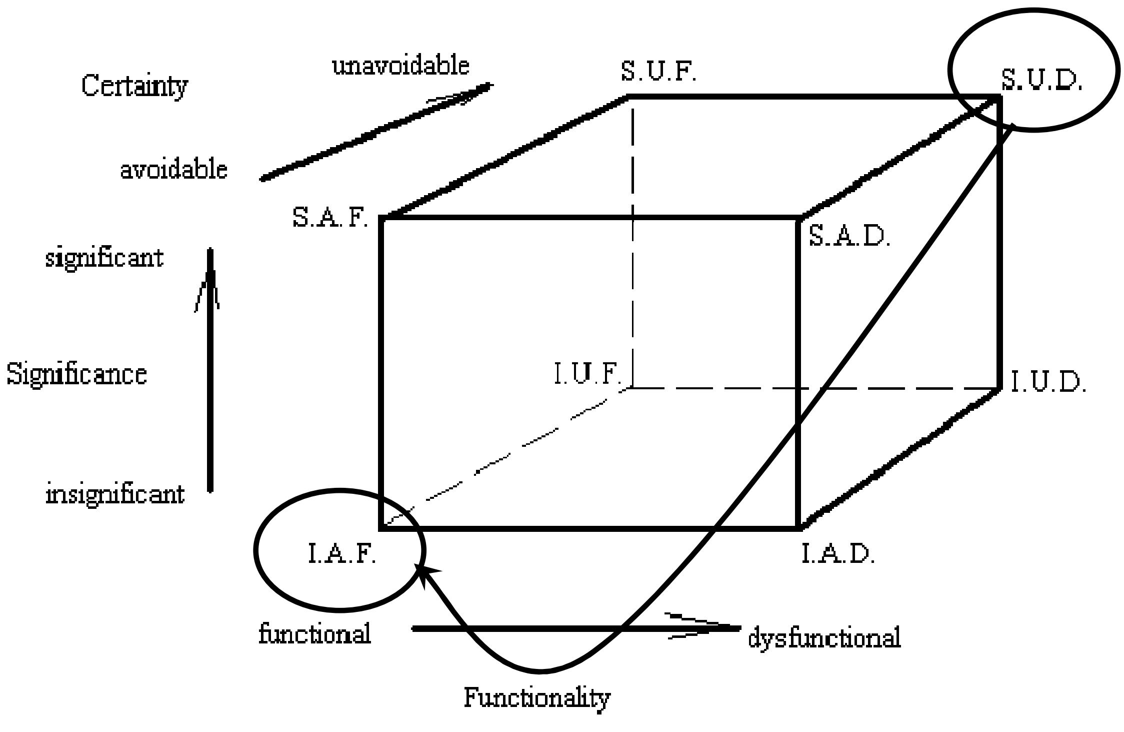

Figure 3: Snagging Classification Mapping (adapted from Sommerville, 1992)

4. METHODOLOGY AND DATA ANALYSIS APPROACH

The snagging process or indeed the collection of snagging data has rarely been written or reported upon within the UK construction and housing industry which has resulted in a dearth of literature and data sets available to the authors of this paper. The data sets available for analysis within this research are limited: both in terms of the actual quantity of data available and the access to such data sets from different members of the snagging process chain. There is an implicit constraint within the methodology that the data used in this research was extracted from a data set provided by the UK's leading independent home snagging company. The argument would be that this is a biased population. Indeed it is the only detailed independent dataset available and as such is deemed to be robust until new data sets are made available within the public domain. The independent inspection company provides a 'snagging' or defect reporting system for buyers of new homes (under the instructions of the home buyer) through 43 inspectors based around the UK. Detailed inspection reports for 1696 homes have been formatted and analysed with the resultant dataset containing detailed information on circa 100,000 snagging items found within the 1696 properties built by some 271 house builders.

Data available for extraction from the inspection reports included a host of matter on: the name of the client, the location of the property, the type of property, the house builder, the independent inspector, date of inspection, number and type of snag and so on. For the sake of clarity in this paper the list noted above has been truncated. The variables within the datasets were numerically coded for statistical analysis. The names of 'clients', 'inspectors' and 'building companies' are not specified for confidentiality reasons. Data analysis was performed using different computer packages.

After the initial examination of the data it was clear that for many of the factors, such as builders and inspectors, there were a number of categories with very little data. These categories with low frequencies were then excluded from further analysis. The formatting of the data involved the examination and analysis of over 1m individual data cells. This paper will include analysis on select variables contained in the dataset which will give an initial picture of the extent of snagging in the construction industry in the UK.

5. DATA RESULTS AND DISCUSSION

The first factor considered during the analysis was the average number of snags across the 1697 properties over a 4 year period 2002 – 2005. Figure 4 below shows the average results obtained from the data: despite a decrease in the average number from year on year for 2002 – 2004, the average number for 2005 increased by 53%. There is a considerable range between the highest and lowest number of snags found within a new home, the lowest being one and the highest being 389 found within a five bedroom house situated in the North of England. Of these 389 snagging items, 380 were associated with a specific industry trade and related to "extremely poor workmanship".

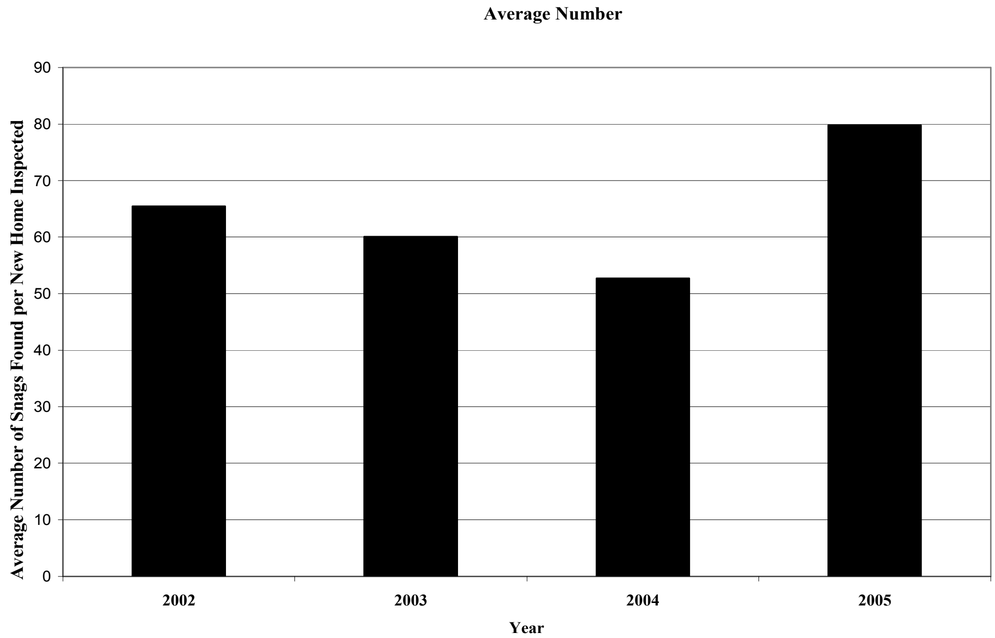

Figure 4: Average number of snags per property 2002 – 2005

Through observation of the different house sizes (by number of bedrooms) it has been discerned that the average number of snagging items found in each property type during the period 2002-2005 is as displayed in figure 5. It can be concluded that as the number of bedrooms within a property increases then so does the average number and range of snags found within each property. The rise in the average number for the majority of properties within the 2005 period follows the general trend set within figure 4.

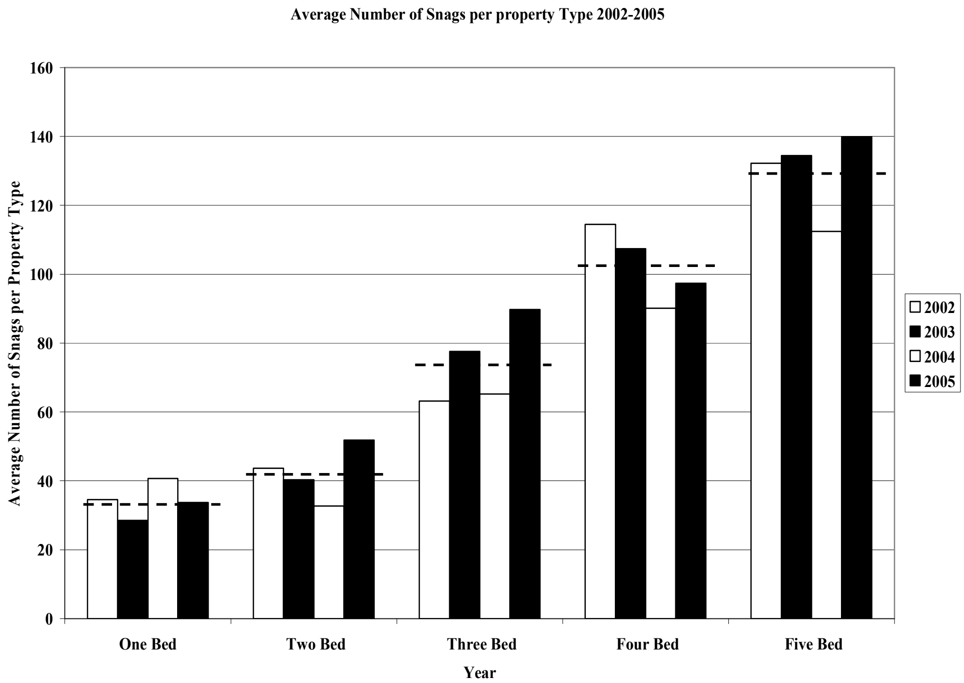

Figure 5: Average number of snags per property type 2002-2005

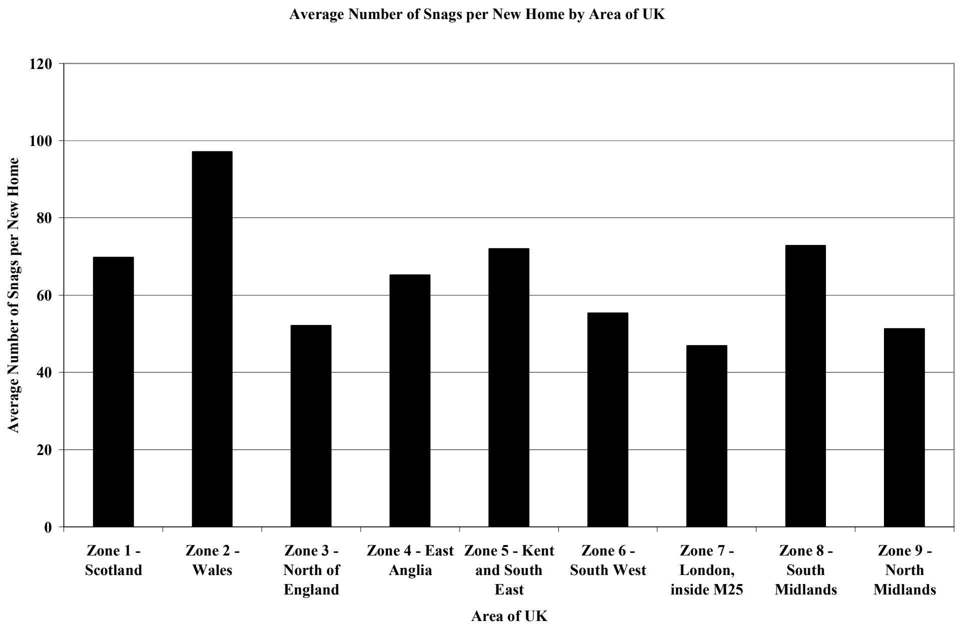

Figure 6: Average number of snags found per new home by area of UK

To investigate whether there was any differences in the number of snagging items found in properties within different geographical sectors of the UK, the data set was split into 9 UK regions. The results of the geographical analysis can be seen in Figure 6. The area within the M25 (London) was the area with the lowest amount of snagging items per property.

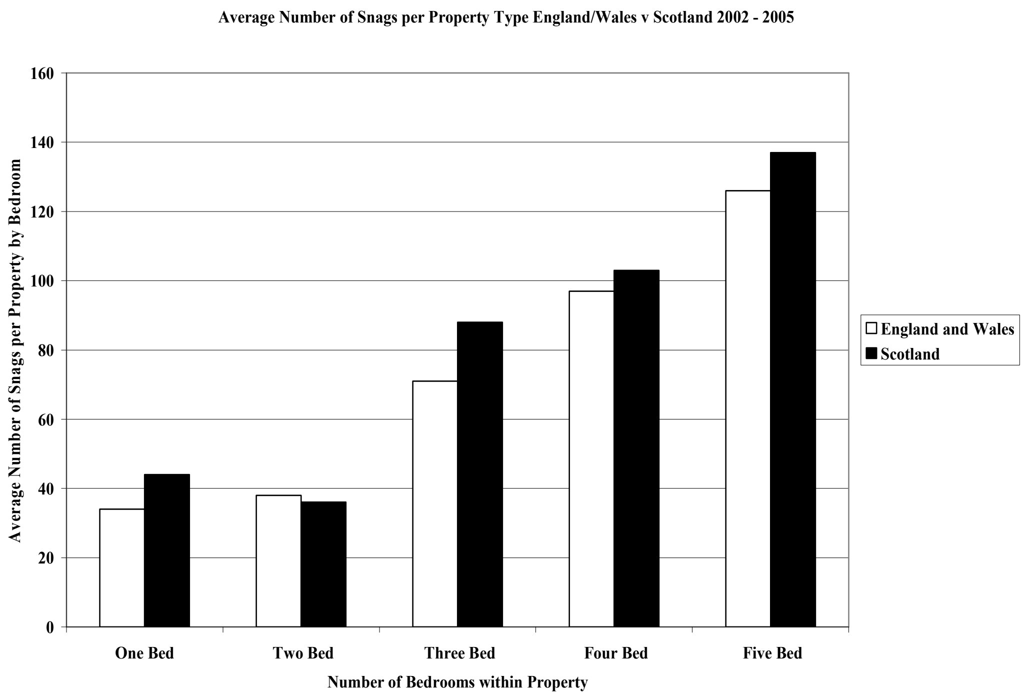

Figure 7: Average number of snags per property England/Wales v Scotland

Historically, Scotland has always been seen as a separate part of the UK due to its unique and distinct laws. This has been further highlighted through the process of devolution. Therefore, a UK regional analysis invariably seeks to compare Scotland with the rest of the UK. Figure 7 highlights the average number of snags per property type between Scotland and England/Wales. It can be seen that Scotland has a higher number of snagging items per property type in all of the categories except two bedroom properties.

5. CONCLUSIONS

The end-product within the house building supply chain "the new home" still has a number of snags which causes the customer to be repeatedly dissatisfied. Whilst the research in this paper has been to some extent exploratory, it has demonstrated that snagging levels in new homes in the UK are at a level which is damaging to the house building sector's image and they detract from customer satisfaction.

Quality systems that will effectively control the snagging process within the UK construction industry have been implemented to some extent although these are at best basic and therefore "snagging" has become an accepted and unwanted feature of the whole house building process and will remain so until the necessary legislation is put in place that will alleviate this problem.
The analysis provided within this paper although basic and descriptive has given an insight into the potential range of research which can be conducted from inspection reports undertaken on newly built homes. The research has provided evidence that a large number of snagging items can be found in newly built homes within the UK which are assumed to be "complete". Analysis on the number of snags found by house size was also undertaken and although an average was given the method should prove reliable for predicting the number of snags a home buyer could expect to find within a particular property type.

Geographically, the analysis highlighted some interesting differences in the levels of snagging found within 9 areas of the UK. The results have indicated that Scotland has a higher level of snagging per property type when compared to the same property types in England. The reasoning for this however could be caused by many factors such as the type of construction, attitudes of site managers, quality control procedures in existence, and trade skill/experience.

The investigations have provided some strong results as to the extent of the snagging problem within the industry. The results can be used by practitioners and built upon to investigate a problem which affects the most important member of the house building supply chain "the customer". Future research will mine the roots of the 'snags' problem and identify the types of activities and the types of tradesman that are responsible for the creation of snags within new homes. Future work will also examine in detail the snagging data collected from contractors and comparisons will be made against data collected by the independent inspectors to give an overall view of snags within the house building industry.

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TACIT VS. EXPLICIT KNOWLEDGE – THE CURRENT APPROACHES TO KNOWLEDGE MANAGEMENT

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Abstract: The use of computers has over the last two decades led to the dominance of a database-centred view of organisational information resources. It is this school of thought that has become the focal point of many conceptualisations of knowledge management (KM). Many proponents of this school of thought propagate the development and implementation of KM databases. But knowledge is more organic than mechanical. Therefore, substituting database structures for the people who actually creates organisational knowledge will ultimately remove the intrinsic meaning of knowledge. This paper, based on an on-going doctoral work, takes a dichotomous view of knowledge as either explicit or tacit and argues that the management of tacit knowledge, so far neglected in the literature on KM, is very important in conferring competitive advantages on organisations. Using empirical results from the research, it reveals the advantages of managing tacit knowledge. These benefits range from better customer service to prevention of project period escalation and improved workmanship. This paper concludes that behavioural approach to KM ensures that employees, who are the source of organisational knowledge, are well motivated to 'go the extra mile' in pursuit of organisational goals.

Key words: Human Resource Management, Knowledge Management, Tacit, Explicit, Knowledge

1. INTRODUCTION

With the advent of knowledge management (KM), different approaches towards the management of organisational knowledge have surfaced. These approaches can be grouped into two major categories as either technocratic or behavioural (Earl, 1998). The technocratic approach to KM proposes a system solutions while the behavioural approach proposes an organisational development and training solutions. These approaches are based on the dichotomous view of knowledge as either tacit or explicit. The technocratic approach to KM views knowledge as explicit, whilst the behavioural approach views knowledge as tacit. But it has been observed that knowledge is one of the most perplexing notions in our vocabulary because the problems of understanding what knowledge is have been the subject of vigorous philosophical debate for many thousands of years (Spender, 2002). Much is understood but much is still under debate. Newell *et al* (2002) suggest that while knowledge can be actively shared through interaction between people or groups, it cannot be passively transferred. Therefore, any KM approach that is purely based on information and communication technology (ICT) is bound to be less successful because people issues, which are not readily solved by ICT systems, would need to be resolved (Kamara et al, 2002). This has led to calls, both within the academic and practitioner communities, for a more people-centric approach to knowledge management.

2. DATA, INFORMATION AND KNOWLEDGE

It is evident in the body of literature that a great importance is attached to the definition of knowledge (Chauvel and Despres, 2002). How knowledge is defined influences how it would be managed (Allee, 1997). In order to be able to grasp the meaning of knowledge, it is important to examine the meanings of data and information which are the foundations of knowledge.

According to Huseman and Goodman (1999) data are objective facts describing an event without any judgement, perspective or context. Data on its own lack any meaning except that data is the foundation for the creation of information. Information can be defined as data points, drawn together, put into context, added perspective and delivered to people's minds (Huseman and Goodman, 1999).

Uniquely, the human capability of making meaning out of information is deemed very important to knowledge (Miller, 1999). Knowledge is seen as highly context dependent (Nonaka, 1994). Knowledge has no meaning outside of a context, for example black has no meaning apart from white (Despres and Chauvel, 1999; Miller, 1999). The knowledge produced by an individual will vary from that which another person will produce if the context is not the same. There are different types of knowledge depending on the complexity of codification.

2.1 Types of Knowledge

There is, in fact, little agreement on a universal classification of the types of knowledge but wide consensus abound that they are multiple and consequential (Despres and Chauvel, 2002). Rennie (1999) sees knowledge from five different perspectives such as "know-why" (scientific knowledge of the principle and laws of nature), "know-how" (skills or capability), "know-where" (ability for finding the right information), "know-what" (accumulation of facts), "know-when" (sense of timing) and "know-who" (information about who knows what)". Blacker (1995) also identifies five different categories of knowledge which are: "embrained" (conceptual skills and abilities), "embodied" (acquired by doing), "encultured" (acquired through socialisation), "embedded" (organisational routines) and "encoded" (signs and symbols). But the most widely accepted classification of knowledge is that of Polanyi (1958) who classifies knowledge as either tacit or explicit (see **Table 1**). This classification of knowledge is based on the level of its complexity on knowledge continuum (Koulopoulos and Frappaolo, 1999).

'Tacit' means 'hidden', tacit knowledge is knowledge hidden from the consciousness of the knower. Tacit knowledge resides in human brain and cannot be easily captured or codified (Wong and Radcliffe, 2000; Nonaka and Takeuchi, 1995). Sveiby (1997) asserts that all our knowledge rests in a tacit dimension. Tacit knowledge expresses itself in human actions in form of evaluations, attitudes, points of view, conpetences, experiences and skills stored so deep in the worldview of an individual that it is often taken for granted (Koskinen *et al*, 2003). It can be observed through action.

While tacit knowledge represent great value to the organisation, by it is nature, it is far more difficult and sometimes impossible to capture and diffuse (Koulopoulos and Frappolo, 1999; Nonaka, 1994). Davenport and Prusak (1998) show the difficulty associated with '*capturing*' tacit knowledge in their example of an attempt to transfer the skill of the world best aerial photo analyst into an expert system by a computer scientist. The expert system failed. But the time the computer scientist spent with the expert trying to extract and understand the expert's knowledge served as an apprenticeship, to the extent that the computer scientist became the second best analyser of aerial photographs in the world.

Explicit knowledge, on the other hand, is that knowledge that can be articulated in formal language and easily transmitted amongst individual (Koulopoulos and Frappolo, 1999). Explicit knowledge implies factual statements about such matters as material properties, technical information and tool characteristics (Koskinen *et al*, 2003). Thus explicit knowledge can be compressed into a few summary symbols that can be encoded by language in written words and/or machine. By its very nature, explicit knowledge is capable of being capture and widely distributed throughout the organisation.

Table 1: Categories of Knowledge (Adapted from Stephens, 2002)

Tacit knowledge	**Explicit knowledge**
Personal knowledge embedded in individual	Fact based, publicly available and beyond dispute.
Experience and involving such intangible factors as personal belief, perspective and values.	Possibly recorded in documents, also includes scientific and technical knowledge, common understandings, the 'right way of doing things' and socially accepted norms.
Informal, action and discourse orientated	Easily verbalised, and stated in the form of rules or notes. Includes knowledge of organizational structures, business rules, etc
Acting with rather than acting on.	Easier to deal with in ICT developments as it is easily articulated, communicated and represented in formal languages.
Real key to getting things done	Formalised

3. ORGANISATIONAL APPROACH TO KM

The key findings of a longitudinal study by Hansen *et al* (1999) suggest that there are basically two strategies for managing knowledge (see **Table 2**). These strategies were termed 'codification' and 'personalisation'. The agenda of the codification strategy is ensuring that knowledge is carefully codified and stored in databases where it can be accessed and used readily by anyone in the company. But the personalisation strategy ensures that knowledge is closely tied to the person who developed it and is shared mainly through direct person-to-person contacts. The codification and personalisation strategies, as identified by Hansen *et al* (1999), are similar to 'technocratic' and 'behavioural' approaches to KM developed by Earl (1998). Most likely, the approach that any construction organisation will adopt towards KM, either technocratic or behavioural, will strongly depend on either the 'codification' or 'personalisation' strategy of the organisation.

Whilst there has been no claim that any particular organisation practices these approaches exclusively, research shows that organisations pursue one approach predominantly. It would seem that the technocratic approach to KM has enjoyed more prominence than the behavioural approach. One of the major limitations of the technocratic approach is the idea that the management of knowledge work is all about creating massive databases (Newell *et al*, 2002). Empirical support has been provided showing KM to be more about people than technology (Scarbrough *et al*, 1999).

3.1 Technocratic Approach to KM

The technocratic approach to KM assumes that the fundamental problem of KM is concerned with the flow of knowledge within the organization. The focus is on increasing the flow of knowledge by capturing, codifying and transferring knowledge through technology components (Scarbrough *et al*, 1999). This is because technology has made it possible to treat knowledge as 'objective' (i.e. explicit) to the neglect of its more important 'subjective' (i.e. tacit) nature. This is based on the fact that every important process is information and communication technology (ICT) enabled. Some proponents of this approach to KM believe that technological inputs, rather than human resources, would play a predominant role in the field of KM. This is reflected in the views of Applegate *et al* (1988):

> "*Information systems will maintain the corporate history, experience and expertise that long-term employees now hold. The information systems themselves -- not the people -- can become the stable structure of the organization. People will be free to come and go, but the value of their experience will be incorporated in the systems that help them and their successors run the business*."

Putting the approach of Applegate *et al* (1988) into the KM context implies that investing heavily in ICT and new technology would transform any organization into a knowledge-based organization (Yahya and Goh, 2002). But Wiig (2002) seems to oppose this view when he suggested that:

> *"One key lesson to be learned is that we must adopt greater people-centric perspectives of knowledge. Technology can only provide a rudimentary reasoning devoid of innovation. People are the intelligent agent that create and act on new opportunities. It is those opportunities that will bring the world forward".*

Not surprisingly, many business and technology executives trained in similar reasoning as Applegate *et al* (1988) have been trying to push for adoption of computer technologies for '*storing'* their employees' *knowledge* in computerized databases and programmed logic of the computing machinery with mixed results (Malhotra, 2003). This has led into some ICT vendors proposing software/groupware for KM, which in many cases have some virtues but, in most cases they represent neither management practices nor a valid definition of knowledge (Godbout, 1996). Such ICT tools that support different types of knowledge management processes as identified by Hlupic *et al* (2002) are: groupware, expert systems, intranets, neural networks, internet, etc.

Traditionally, the focus of the ICT industry has always been on the management of information. But nowadays ICT is being used to increase organisational "knowledge assets" and the creation of "knowledge bases", "knowledge webs" and knowledge exchanges" (Bank, 1996). The reason for the domination of the KM domain by the ICT industry is because of its facilitation of one-to-one, one-to-many, many-to-one and many-to-many communication distributed across time and space (Thruraisingham *et al*, 2002; Despres and Chauvel, 2002; Swan *et al*, 1999).

Not surprisingly, many KM practitioners and researchers who identify with this approach consider information and knowledge as synonymous constructs but knowledge, unlike information, is about *beliefs* and *commitmen*t (Nonaka and Takeuchi, 1995). Thus, it is not appropriate to use the terms 'knowledge' and 'information' interchangeably. Swan *et al* (1999) illustrate three fundamental problems with ICT-driven approach to KM as:

- Firstly, they assume that all, or most, relevant knowledge in an organisation can be made explicit and codified.
- Secondly, they are founded on the partial view of KM, focusing more on processes of exploitation rather than on processes of exploration.
- Thirdly, they are supply driven and assume that the extensive availability of information will automatically be applied and used to develop innovative solutions.

But just because knowledge is encoded in some way in a database or system does not guarantee its usage, it may make its usage less likely as the system become increasingly more complex and integrated (Wensley, 2001). These limitations of the techno-centric approach to KM are rooted in its neglect of the critical social construct nature of knowledge (Ruddy, 2000; Nonaka and Takeuchi, 1995). Knowledge is more organic than mechanical (Allee, 1997). Therefore, substituting database structures for the people who actually creates organisational knowledge will ultimately remove the intrinsic meaning of knowledge (Miller, 1999). Thereby making it easy for competitors to 'pilfer' such knowledge and eliminate the competitive advantages enjoyed by the organisation. Moreover knowledge is the unique human capability of making meaning from information (Miller, 1999).

3.2 Behavioural Approach to KM

Knowledge is viewed by this school of thought as embodied in people with an underlying believe that effective KM ensures people with needs can find people who can meet those needs within the organisation (Gourlay, 2001). This approach to KM is more concerned with the motivation and attitudes of users, and usually includes reward strategies and ways of encouraging knowledge sharing. Early KM literature paid little attention to people, both individually and collectively, until it was realised that the knowledge asset being considered cannot be totally separated from them (Spender, 2002). It is impossible to talk about knowledge without addressing the way people work together, learn together, and grow (Allee, 1997). According to this school, knowledge must continuously be re-created and given meaning through active networking processes which allow those involved to engage in negotiation and sense making (Swan *et al*, 1999). The behavioural school also endeavours to create a business culture which stimulates the production, sharing and (re)use of knowledge (Egbu *et al*, 2003).

This approach to KM sees the people aspect of knowledge as paramount to successful knowledge management. However, there has been insufficient attention given to the role of human resources in KM literature (Scarbrough *et al*., 1999). Also the implications of HR on KM have not been fully appreciated and investigated. Research in this area has the potential to contribute to an improved understanding of how to manage those who create knowledge in organisations so as to improve the performance of KM.

Table 2: Approaches to KM (adapted from Scarbrough et al, 1999 & Hansen et al, 1999)

	Technocratic Approach	**Behavioural Approach**
Purpose	Flow of knowledge and information within organisation	Users' perspective and their motivation, attitudes seen as important
Objective	To increase the flow of knowledge and information by capturing, codifying and transmitting knowledge	To work flexibly and adapt to changing business environments
Use of ICT	Invest heavily in ICT – connect people with reusable knowledge	Invest moderately in ICT to facilitate conversations and exchange of tacit knowledge
Recruitment & Selection	Hire new college graduates who are well-suited to the reuse of knowledge and the implementation of solutions	Hire MBAs who like problem-solving and can tolerate ambiguity
Training & Development	Train employees in groups and through computer-based distance learning	Train employees through one-on-one mentoring
Reward systems	Reward employees for using and contributing to document databases	Reward employees for directly sharing knowledge with others.

The function of experienced workers within this structure is seen as strongly associated with the motivational practices inside the organisation (Newell *et al,* 2002). This is because one of the aims of behavioural approach to KM is to allow newcomers to be able to learn best practices from old-timers through active participation. To successfully exploit the skills and retain workers who participate in KM, organisations must specially cater for their needs and operations (Scarbrough *et al*; 1999).

4. RESEARCH METHODOLOGY

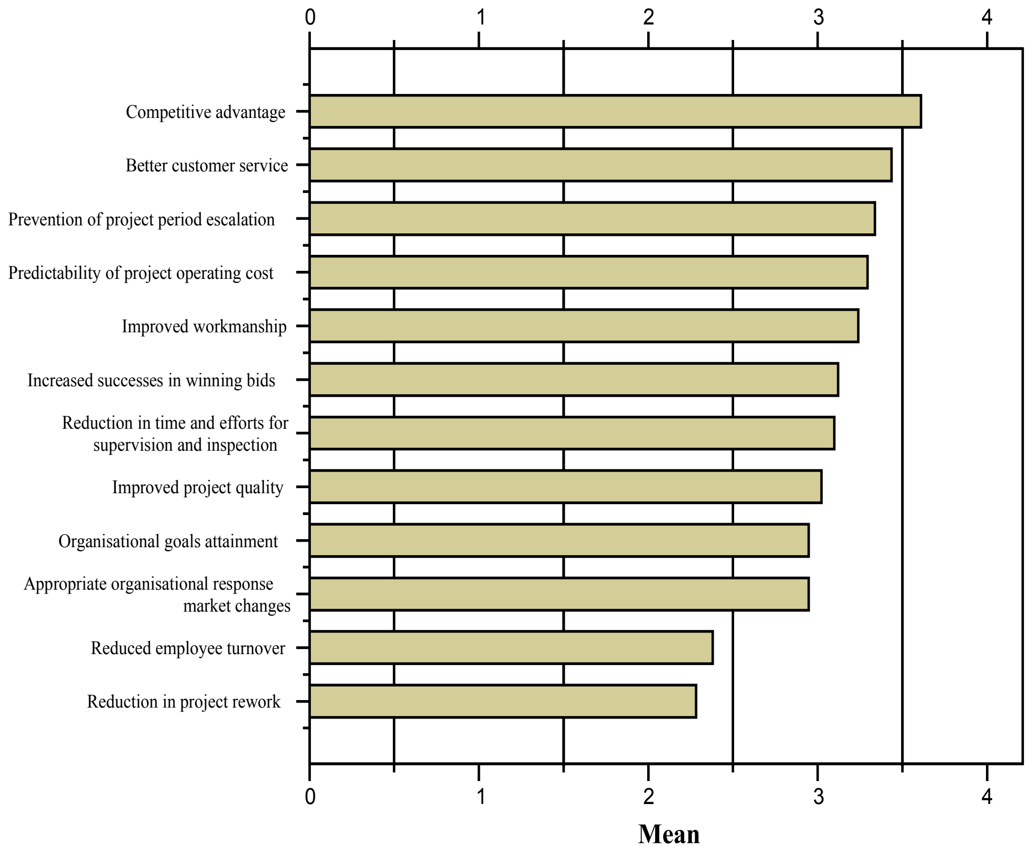
This paper is part of on-going PhD research on how construction organisations can capitalise on HR aspects of KM for performance improvements. The data collection employed the use of postal questionnaires to ascertain respondents' view on how HR aspects of KM could be capitalised upon for performance improvements in construction organisations. The target respondents are managerial-level employees of 580 UK construction organisations. The questionnaire together with a cover letter, an introductory page and self-addressed return envelopes were sent to these organisations. The questionnaire results provided only an indicative measure of the respondents' view. However, it was selected as an appropriate measure for the purposes of this research because questionnaires are quick and easy to administer. Simple, quick and easy tools often work best with busy construction personnel whose time is limited.

The questionnaire comprised eight different sections with one of the sections specifically measuring the benefits of focusing on people issues in KM. Respondents were asked to indicate their extent of agreement on the impact of people's issues in KM on organisational performance using a four-point Likert scale (with 4 = very high impact, to 1 = no impact). Keeping the number of response options as small as possible allows the respondents to make a useful choice from among the listed informative answers. It has also been suggested that questions about which nearly everyone has enough information to form some opinion should be stated without a no-opinion option (Scheaffer *et al*, 1996; Hoinville *et al*, 1978). A total of 100 sets of usable questionnaires were successfully collected and analysed using SPSS v13.0.

5. FINDINGS AND DISCUSSIONS

The real value of focusing on people's issues in KM is in the benefits it brings to the bottom-line of any organisation. Figure 1 shows the result of the analysis of respondents' view on the benefits that accrue to the organisation when behavioural approach to KM is adopted. The five most important benefits of behavioural approach to KM, according to the hierarchy of mean score, are competitive advantage (3.6), better customer service (3.42), prevention of project period escalation (3.32), predictability of project operating cost (3.30) and improved workmanship (3.22).

Figure 1: Benefits of focusing on people issues in KM



More than ninety percent (90%) of the respondents agreed that the major benefit of implementing a behavioural approach to KM is about conferring competitive advantage (mean = 3.60) on the organisation. Behavioural approach to KM has a very high impact on conferring competitive advantage on the organisation. Competitive advantage is the result of differences in the combinations of critical organisational resources and the characteristics of such resources are that they are hard to substitute, imitate and transfer (Venzin *et al*, 1998). Due to the nature of tacit knowledge which makes it difficult for other organisations to imitate or import, it is an important organisational resource for securing competitive advantage. Behavioural approach to KM ensures that employees, who are the source of organisational knowledge, are well motivated to 'go the extra mile' in pursuit of organisational goals and facilitate improved communication within teams to provide informed and insightful advice to project managers and project teams.

The analysis of respondents' views also show that there are increasing possibilities of the organisation offering better services to customers (mean = 3.42) when behavioural approach to KM is adopted. Customer satisfaction touches many areas of the organisational performance including project duration (mean = 3.32), cost (mean = 3.30) and product quality (mean = 3.22) but one key area of customer satisfaction occurs when the organisation is able to respond quickly to customer's needs. Focusing on the people-issues in KM could increase organisational successes in winning bids (mean = 3.08) and improve efficiency gains since the behavioural approach to KM ensures that employees actively participate in processes that improves quality and reduces project time. Such approach to KM allows employees to exercise responsible autonomy/self-motivation and self-control; reducing the need for supervisory and inspection staff (mean = 3.11).

Respondents to the survey questionnaire perceives the behavioural approach to KM as been capable of breeding conducive working environment and encouraging employees to stay with the organisation, thereby ensuring a return on investment and low labour turn-over (mean = 2.36). Such workers are most likely to focus on improved sharing of best practices, lessons learned, project management systems, engineering methodologies and the rationale for strategic decision making. The motivational levels of employees working in an organisation that practices behavioural approach to KM are seen as very high and such atmosphere prevent the failure to capture and transfer project knowledge which might lead to an increased risk of 'reinventing the wheel', wasted activity, and impaired project performance. Also a learning and knowledge sharing environment could be instilled.

6. CONCLUSIONS

While the debate surrounding the subject of knowledge is still raging, there has been a general consensus within the knowledge management community that knowledge can be either tacit or explicit. This has led to most organisations approaching KM from either the technocratic or behavioural perspectives. But by questioning the technocratic approach to KM, their current inadequacies have been revealed and the continuing importance of human interaction has been emphasized. This paper has endeavoured to illustrate that knowledge management is not a simple question of building knowledge databases rather it requires active participation of employees whose knowledge are critical to organisational development. ICT can be used to increase the efficiency of employees and increase information flow. But information is not synonymous to knowledge and for KM to be successful more attention must be paid to the people who use and create organisational knowledge. An impressive benefit from adopting behavioural approach to KM involves the conferment of sustainable competitive advantage on the organisation. Construction organisations whose senior managers understand this will be greatly rewarded – with knowledge, of course!

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CULTURAL PROFILE OF CONSTRUCTION SECTOR MANAGERS: A CASE EXAMPLE FROM TURKEY

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Abstract: This paper presents part of a major research into cultural differences in construction industry. The main purpose of the paper is to investigate similarities and differences in work-goal orientation of managers involved with the construction industry. The sample for the study consists of 576 participants from the contracting firms. The Turkish version of the Hofstede's VSM questionnaire was used to establish cultural profile of participants in the sample. Results indicate significant differences in terms of gender and age. Implications of the results are discussed.

Keywords: work-goals, culture, construction industry

1. INTRODUCTION

Due to the increasing globalization of the construction industry and the spread of alliances, it is important to understand cultural differences across countries and projects. However, little is known about the specific characteristics of the construction industry's culture and how it differs between countries because the number of research studies that have addressed this issue is limited (see Hancock, 2000; Pheng & Yuquan, 2002; Rowlinson & Root ,1996, and Root, 2002 among others)

Many researchers have reported that one of the reasons for the lack of success in construction project management is misunderstanding of cultural differences (see Gould, 1977 among others), and that especially the international projects are subject to cultural conflicts. Thus, the study of cultural issues appears warranted.

This paper reports part of the study performed within a major research project which has been carried out in collaboration with CIB TG-23 "Culture in Construction". The main purpose of the study is to establish cultural profiles of managers from contacting firms. In particular, this paper aims to provide information on the work goals of managers involved with the construction sector.

2. THE NATURE OF CULTURE

According to Williams (1983) "culture" is one of the most complex words in the English language. It can be traced to the Latin word *colere* (to inhabit, to cultivate, or to honor). In 1871 E.B. Taylor defined culture as "that complex whole which includes knowledge, belief, art, morals, law, custom, any other capabilities and habits acquired by members of society". Kroeber and Kluckhohn in their classic review of culture (1952) reported 156 different definitions, which they arranged six different generic headings. In the years since they wrote many other definitions have been proposed and still there is no consensus among scholars as to what exactly the concept should include. Perhaps the neatest is that from Hofstede (2001), who said that "culture is defined as a collective programming of the mind; it manifests itself not only in values, but in more superficial ways; in symbols, heroes, and rituals. This understanding of the word seems to be supported by Kempner (1987) who defines culture as "the sum total of belief, knowledge, attitudes of mind and customs to which people are exposed during their social conditioning".

2.1 Dimensions and Levels of Culture

There are several basic dimensions that differentiate cultures. Drawing on a large sample of 116,000 employees of IBM in 72 countries, Hofstede identified four dimensions. These four dimensions used to differentiate between cultures are:

▪ **Power Distance (PDI):** This dimension deals with the issue of human inequality and how within different groups power is resolved. Within the work environment, PDI is generally evidenced in the superior-subordinate relationship. A low PDI indicates a perceived equity of ability, autonomy and independence being highly valued, while a high PDI indicates prevalence for authoritarian behavior, conformity and centralized decision making.

▪ **Uncertainty Avoidance (UAI):** This dimension is related to the level of stress in a society in the face of an unknown future. Different groups adapt to uncertainty in different ways. Hosted (2001) argues that in high-UAI cultures fewer people would risk self-employment.

▪ **Individualism (IDV)**: This dimension describes the relationship between the individual and the collectivity that is reflected in the way people live together. Within the work environment IDV is often explicitly linked to the individual's relationship with his/her employing organization.

▪ **Masculinity (MAS)**: It refers to the extent of roles division between the genders to which people in a society put different emphasis on work goals and assertiveness as opposed to personal goals and nurturance.

Above-summarized dimensions, which are founded on the factor analysis of the data from Hofstede's questionnaire, represent the basic elements of common structure in the cultural systems of societies. Thus, it may be concluded that they provide an important framework not only for analyzing national culture, but also considering the effects of cultural differences on managerial practices (Pheng & Yuquan, 2002).

2.2 Studying Cultural Differences

Measurement of culture represents difficulties, particularly in respect of the identification of cultural groups and boundaries. This is further complicated by the nature of the construction industry in which projects are temporary and participants are subject to the values and beliefs of their employing organization, professional groups and project organizations.

There is currently a debate concerning the study of culture among construction management scholars (see, Seymour, Crook & Rooke, 1997 among others). However, it is not the scope of this paper to explore the methodology for the study of culture in the construction industry. Hofstede's general methodology will be adopted as the conceptual paradigm for analysis in this study.

3. RESEARCH METHODOLOGY

In this study, Hofstede's questionnaire, usually referred to as the Value Survey Module (VSM) was used. The VSM is a well established methodology which has been widely replicated and has also led to the development of similar questionnaires by others (Hancock, 2000). As a questionnaire, the major concern of its validity is related to its ethnocentric bias. For the purposes of this study, the limitations of the VSM questionnaire were accepted.

3.1 Sample

The unit of analysis was managers from contracting firms in the Turkish Construction Industry. There were 567 managers who participated in this study. Different managerial levels were represented in the sample. 268 (47.27%) were lower/first line managers, 192 (33.86%) were middle managers, and 107 (18.87%) upper managers (executives). 20.11 per cent of the sample consisted of female managers.

3.2 Measures of the Questionnaire

The questionnaire was divided into three main groups. Section A consisted of questions identifying ecological factors such as age, sex, education etc. Section B had questions identifying work goals and preferences. Most questions in the questionnaire used 5-point Likert scale.

Work-goal importance questions form a self-contained block in the questionnaire (see Appendix). In this article, discussion will be limited to the work-goal questions. However, one major problem here is how to reduce meaningfully the amount of information in 19 work-goals to a smaller number of underlying variables. Hofstede (2001) argued that work goal patterns could be classified into two dimensions: intrinsic (work related)/extrinsic (non-work related). In an early study, Herzberg (1959) developed a theory which partitioned job characteristics into extrinsic and intrinsic factors, with the latter having motivational power. Intrinsic factors such as achievement and recognition produce job satisfaction whereas extrinsic factors produce such as pay and job security produce job satisfaction.

Since the scope of this study is limited to work-goal questions, the mean scores for all individuals who responded to the questionnaire will be used to determine the characteristics of a preferred job as have been done in some prior studies (Hofstede et.al, 1996; Pheng & Yuquan, 2002; Harpaz, 1990; Corney & Richards). The importance of certain work goals will be evaluated across different managerial levels, between the genders and among different age categories.

4. ANALYSIS OF RESULTS

The primary focus of the study presented in this paper was to determine whether differences existed in work values among managers involved with the construction sector. Statistical Package for the Social Sciences computer program was used to analyze the data. ANOVA, and separate independent t-test were used for the analysis. The overall reliability of work goal importance questions as measured by the Alpha Cronbach was 80 per cent.
Table (1) sets out the mean scores and standard deviations of the19 work goals for managerial personnel. As is seen from the table, respondents in the managerial sample ranked "Manager" as the most important goal of their life. The goals of "Employment Security", "Cooperation" and "Physical Conditions" followed in order. "Benefits" was insignificant by the managerial group in this study. It ranked 19th in order of importance.

In Table 1, means and standard deviations of the 19 work goals are also presented for three management levels: first line managers, middle managers, and upper level managers (executives). ANOVA revealed that no significant differences existed among the scores of three managerial levels within this sample.

As is seen from Table 1, "Manager" was ranked to be the most important work goal for both upper and middle managers. "Physical conditions" and "Employment Security" were second and third in importance for upper managers, respectively. For junior managers, the highest ranking work goal was "Employment Security" and the next two items were "Manager" and "Cooperation".

Table 1: ANOVA for comparing work goal importance scores by management levels

Work Goals	Total (N=567)		s.d.	Upper Level Managers (N=107)		Mid-Level Managers (N=192)		First Line Managers (N=268)		F
Personal time	1.61	(5.5)	0.76	1.64	(5)	1.58	(4.5)	1.63	(5.5)	0.305
Physical conditions	1.60	(4)	0.69	1.53	(2)	1.61	(6)	1.63	(5.5)	0.707
Manager	1.46	(1)	0.61	1.50	(1)	1.45	(1)	1.45	(2)	0.375
Employment Security	1.47	(2)	0.70	1.57	(3)	1.49	(2)	1.42	(1)	1.846
Cooperation	1.58	(3)	0.64	1.64	(5)	1.58	(4.5)	1.56	(3)	0.695
Be consulted	1.96	(17)	0.74	1.90	(17)	1.99	(18)	1.97	(17)	0.608
Advancement	1.77	(13)	0.77	1.79	(12)	1.85	(14)	1.70	(9)	2.001
Variety	1.72	(11)	0.76	1.75	(11)	1.67	(9.5)	1.75	(12)	0.796
Challenge	1.87	(16)	0.80	1.81	(13)	1.94	(17)	1.84	(16)	1.234
Earnings	1.83	(14.5)	0.74	1.82	(14.5)	1.84	(13)	1.82	(15)	0.740
Desirable area	2.02	(18)	0.92	2.12	(18)	1.91	(16)	2.06	(18)	2.360
Prestige	1.68	(8)	0.78	1.71	(9)	1.63	(7)	1.71	(10)	0.698
Freedom	1.75	(12)	0.72	1.72	(10)	1.76	(12)	1.76	(13.5)	0.149
Benefits	2.28	(19)	0.99	2.30	(19)	2.26	(19)	2.28	(19)	0.053
Training	1.83	(14.5)	0.85	1.88	(16)	1.90	(15)	1.76	(13.5)	1.550
Use of skills	1.65	(7)	0.69	1.69	(8)	1.65	(8)	1.63	(5.5)	0.265
Clear requirements	1.70	(10)	0.77	1.82	(14.5)	1.69	(11)	1.67	(8.0)	1.561
Stress	1.61	(5.5)	0.79	1.66	(7)	1.57	(3)	1.63	(5.5)	0.593
Recognition	1.69	(9)	0.90	1.64	(5)	1.67	(9.5)	1.73	(11)	0.666

Note: 1=of utmost importance, 5=of very little or no importance

With regard to gender, Table 2 represents the means and standard deviations of the 19 work goals for female and male managers. As is seen from Table 2, “Manager” was ranked first among female managers and second among male managers. Another highly rated work goal was “Employment Security”. This item was ranked first among male managers and second among female managers. It is also interesting to note that for female managers “Stress” was ranked as third in degree of importance. For female managers, the third-ranking work-goal was “Cooperation”.

Separate independent t-test was carried out in order to find out the effects of gender in work goal importance. The results are also shown in Table 2. Females reported significantly higher scores of “Physical Conditions”, “Variety”, “Clear Requirements”, “Stress”, and “Recognition” than males (t=2.555,p<0.05; t=1.987, p<0.05; t=2.080, p<0.05; t=3.425, p<0.01; t=3.731, p<0.01 respectively).

Table 2: Results of t-test comparing work goal importance scores of males and females

	Males (N= 453)			Females (N=114)			
Work Goals	Mean[1]		s.d.	Mean[1]		s.d.	t-stat
Personal time	1.64	(5)	0.77	1.51	(6)	0.72	1.632
Physical conditions	1.63	(4)	0.71	1.47	(4.5)	0.57	2.555*
Manager	1.48	(2)	0.62	1.38	(1)	0.57	1.669
Employment Security	1.47	(1)	0.71	1.46	(3)	0.64	0.087
Cooperation	1.60	(3)	0.65	1.54	(7)	0.60	0.891
Be consulted	1.96	(17)	0.75	1.96	(18)	0.69	-0.03
Advancement	1.80	(13)	0.80	1.65	(12)	0.65	1.765
Variety	1.75	(11)	0.78	1.60	(10.5)	0.66	1.987*
Challenge	1.89	(16)	0.81	1.79	(16)	0.73	1.246
Earnings	1.85	(14)	0.76	1.75	(14)	0.64	1.315
Desirable area	2.04	(18)	0.92	1.91	(17)	0.89	1.376
Prestige	1.71	(8)	0.80	1.58	(9)	0.70	1.587
Freedom	1.75	(11)	0.73	1.78	(15)	0.70	-0.441
Benefits	2.29	(19)	1.01	2.20	(19)	0.89	0.867
Training	1.86	(15)	0.87	1.72	(13)	0.76	1.574
Use of skills	1.66	(6.5)	0.70	1.60	(10.5)	0.65	0.945
Clear requirements	1.74	(9)	0.79	1.57	(8)	0.69	2.080*
Stress	1.66	(6.5)	0.81	1.42	(2)	0.64	3.425**
Recognition	1.75	(11)	0.94	1.47	(4.5)	0.63	3.731**

Note: 1=of utmost importance, 5=of very little or no importance

The results of the analysis of work goals according to age are presented in Table 3. “Manager” was the most salient goal across all age categories. A slight deviation was observed for managers in the youngest group (≤30), among whom this item ranked second. “Employment Security” was the second most important work goal in every age category. This aspect was of particular importance for managers in the age category of 30 and less, who ranked it in first place. “Cooperation” was considered most important by those in the 31-40 age bracket. “Use of Skills” was important for young respondents and less important for the oldest. Finally, “Cooperation” was held to be of more importance, while “prestige” was considered to be more important for the older managers.

The results of ANOVA indicated four significant differences. First, younger managers tend to place great importance on “Advancement” while 50 years of age and above receive the lowest scores on this construct (F=5.448, p<0.01). Second, young respondents have higher scores on "Training" than the other age groups, while those in the 41-50 age bracket have the lowest scores on this construct (F=7.753, p<0.01). Third, the younger respondents obtain the highest scores on the work goals of "Use of Skills" (F=3.879, p<0.01). Finally, a similar trend is observed with "Clear Requirements" where the younger respondents have significantly higher scores (F=2.923, p<0.05).

5. CONCLUDING DISCUSSION

A major dimension in the study of culture is values. Important trends in recent years have been a focusing on the recognition among scholars that culture is important to understanding differences in work values. Therefore, work values have been the subject of numerous intercultural studies. This study, which adds to this literature, stressed the empirical evaluations of the similarities and differences in work-related values for managers involved with the construction sector.

There has been substantial research comparing the differences in the importance of work goals of various job facets. Hofstede (2001) found differences by nationality and by occupational group, while Harpaz (1996) and England & Harpaz (1990) found differences in work goals by gender, nationality, age and organizational level.

Table 3: ANOVA for comparing work goal importance scores by age

Work Goals	≤30 (N=144)		31-40 (N=193)		41-50 (N=147)		>50 (N=81)		F
Personal time	1.69	(11)	1.56	(4)	1.54	(4)	1.74	(8)	1.901
Physical conditions	1.61	(8)	1.62	(5)	1.56	(5)	1.83	(10)	0.258
Manager	1.47	(2)	1.46	(1)	1.46	(1)	1.46	(1)	0.009
Employment Security	1.44	(1)	1.48	(2)	1.48	(2)	1.49	(2)	0.166
Cooperation	1.58	(5)	1.53	(3)	1.62	(6)	1.67	(6)	1.049
Be consulted	2.06	(18)	1.95	(17)	1.95	(17)	1.88	(12)	1.149
Advancement	1.64	(9)	1.69	(8)	1.86	(15)	2.01	(18)	5.448**
Variety	1.69	(11)	1.74	(11)	1.75	(12)	1.69	(7)	0.202
Challenge	1.80	(16)	1.92	(16)	1.82	(13)	1.99	(17)	1.418
Earnings	1.79	(15)	1.81	(13.5)	1.84	(14)	1.93	(14)	0.651
Desirable area	1.99	(17)	2.12	(18)	1.94	(16)	1.98	(16)	1.246
Prestige	1.75	(14)	1.69	(8)	1.67	(8)	1.56	(3)	1.005
Freedom	1.73	(13)	1.77	(12)	1.69	(9.5)	1.85	(11)	0.900
Benefits	2.22	(19)	2.32	(19)	2.31	(19)	2.23	(19)	0.438
Training	1.56	(4)	1.85	(15)	2.00	(18)	1.96	(15)	7.753**
Use of skills	1.51	(3)	1.73	(10)	1.63	(7)	1.78	(9)	3.879**
Clear requirements	1.59	(6)	1.69	(8)	1.72	(11)	1.90	(13)	2.923*
Stress	1.69	(11)	1.65	(6)	1.50	(3)	1.61	(5)	1.750
Recognition	1.60	(7)	1.81	(13.5)	1.69	(9.5)	1.60	(4)	1.880

Note: 1=of utmost importance, 5=of very little or no importance

The results presented in this paper indicate that for managers in the construction sector, the characteristics of a preferred job will have four major elements.

- *Manager* -Have a good working relationship with your direct superior
- *Employment Security* -Have security of employment

▪ *Cooperation* -Work with people who cooperate well with one another
▪ *Physical Conditions* -Have good physical working conditions (good ventilation and lighting, adequate work space, etc)

The findings show that managers in the construction sector tend to put more emphasis on extrinsic goals. This is in contrast with the view that many managers are intrinsically motivated (Jones, George, and Hill, 2000). It is also interesting to note that employment security was ranked second by the respondents in the sample. This evidence supports the contentions of others (i.e., Hofstede, 2001; Robbins, 2001) that in countries such as Turkey, where UAI characteristics are strong, security needs would be on top of the need hierarchy. On the other hand, the higher ranking of "employment security" may be an indication of the greater impact that the high rate of actual and potential unemployment has had for these groups in the Turkish construction industry in recent years.

A comparison of these results to Maslow's theory indicates that the range of motivational factors may be reshuffled according to a country's prevailing culture pattern. Maslow's conclusions that lower level motivational factors must be met before ascending to the next level were not confirmed by this study.

It is also clear from the results of the study that the respondents in the sample attached more importance to feminine goals such as manager, cooperation, and physical conditions. This finding supports the view that individuals in low MAS societies such as Turkey will be motivated by relationships and physical conditions (Hofstede, 2001).

When it comes to gender, females and males reveal both similarities and differences in their work-goal rankings. Both genders place the highest value on "Manager" and "Employment Security" and regard "Be consulted" and "Desirable Area" as nonessential. As shown in the results, female managers vary between intrinsic and extrinsic while male managers are always extrinsic, but both tend to be social oriented. This evidence is in contrast with the view that almost universally women attach more importance to social goals, and men attach more importance to ego goals. Based on the foregoing, there appears to be an alignment between the work-goal patterns of the respondents in the sample and the Turkish social value of femininity. This confirms the conclusion that the national cultural characteristics dominated all other factors such as age, gender, level, and profession (Hofstede, 2001).

In the study, the genders exhibit significant differences in their rankings of "Physical Conditions", "Variety", "Clear Requirements", "Stress", and "Recognition", all favoring females. As Harpaz (1989) has argued some of the explanations for gender differences can be related to men's and women's differing orientation to work as a life role. Further, higher scores of female managers on some of these items may be attributed to the masculine culture of the construction industry. With regard to recognition, for example, one possible explanation could derive from women's expectations that despite their actual managerial ability, others in the organization would not recognize them as managers. This evidence is consistent with the findings of Bennett et al (1999), who concluded that "recognition" is significantly more important for female professionals than for their female counterparts in the construction industry.

Similarly, gender differences in the importance of physical conditions had been reported in a 1957 US review by Herzbeg, Mausner, Peterson, and Capwell (cited in Hofstede, 2001). Further, data collected by Hofstede from IBM employees in 72 countries showed that women compared with men tended to score physical conditions as more important.

The results of comparison by age show that "Manager" and "Employment Security" are preeminent for all age groups. On the other hand, young respondents value "Advancement", "Training", "Use of Skills", and "Clear Requirements" more than do their older counterparts. This finding provides confirming evidence that "Advancement", "Training", and "Use of Skills" are less important with age (Hofstede, 2001). It is also clear from the results of the study that young respondents place a higher degree of importance on questions related to collectivism (training, use of skills). Hofstede (2001) argues that these goals reflect a more "local mentality". This evidence can be interpreted as being a direct result of nature of the construction industry, which the sample population was drawn.

These conclusions are obviously limited by this sample. They are significant however, not only because of the contribution that they can make to a better understanding of what motivates construction sector managers but also for the insights that they may bring to the more general issue of focusing on the importance of work-goals in the international construction arena.

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APPENDIX

Work Goals

Short Name	Full Questionnaire Wording
Personal time	Have sufficient time left for your personal or family life
Challenge	Have challenging tasks to do, from which you can get a personal sense of accomplishment
Stress	Have little tension and stress on the job
Physical conditions	Have good physical working conditions (good ventilation and lighting, adequate work space, etc)
Manager	Have a good working relationship with your direct superior
Employment Security	Have security of employment
Freedom	Have considerable freedom to adopt your own approach to the job
Cooperation	Work with people who cooperate well with one another
Be consulted	Be consulted by your direct superior in his/her decisions
Earnings	Have an opportunity for higher earnings
Desirable area	Live in an area desirable to you and your family
Advancement	Have an opportunity for advancement to high-level jobs
Variety	Have an element of variety and adventure in the job
Prestige	Work in a prestigious, successful company or organization
Training	Have training opportunities to improve your skills and knowledge or to learn new skills and knowledge
Recognition	Get the recognition you deserve when you do a good job
Benefits	Have good fringe benefits
Use of skills	Fully use of your skills and abilities on the job
Clear requirements	Work in a well-defined job situation where the requirements are clear

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A WEB-BASED KNOWLEDGE MANAGEMENT SYSTEM FOR CONSTRUCTION PROJECTS

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Abstract: Knowledge has become an important competitive tool for almost every industry. Managing knowledge effectively is critical to the survival and advance of a company especially in project-based industries such as construction. Proper knowledge management can reduce project time and cost, improve quality and provide a vital competitive advantage for the construction organisations in today's knowledge-based economy. Knowledge consists of explicit and tacit knowledge. Tacit knowledge is based on the experience of individuals and is not easily visible or expressible. This type of knowledge usually is not captured during the construction phase. Capturing tacit knowledge and reusing in future projects can give construction companies a strong competitive advantage. Sharing and reusing knowledge can improve the business performance of the companies. In this study, a survey was carried out among eight leading Turkish construction contractors that are operating within the international construction market. The specific objectives of this survey were to find out how these organisations share and reuse knowledge, the opinions of senior engineers and experts on the capture and reuse of knowledge and experience in construction projects, and the main barriers for implementing knowledge management. Based on the survey, it was found that most of these firms do not manage knowledge effectively. A web-based knowledge management system is proposed in order to manage knowledge, both tacit and explicit, effectively in construction projects. This system enables companies to store, share and reuse knowledge, and save time and cost.

Keywords: Construction Projects, Knowledge Management in Construction, Knowledge Sharing, Reusing Knowledge, Web-Based Technology.

1. INTRODUCTION

According to Davenport et al., knowledge is defined as 'a fluid mix of framed experience, values, contextual information and expert insight' [1]. Knowledge is a broader, deeper and richer concept than information. It comes in two different types as explicit and tacit knowledge. Explicit knowledge can readily be codified in words and numbers, easily shared in manuals and is easy to distribute [2]. According to Polanyi's definition, tacit knowledge is highly personal and context-specific, therefore it is hard to formalize and communicate [3]. Tacit knowledge is stored in people's heads, so it is difficult to pass on to others. Tacit knowledge can give companies a strong advantage over their competitors since it is difficult to see and copy [2].

There is no universal definition for knowledge management (KM). According to the definition of Davenport et al., KM is the process of creating value from an organisation's intangible assets [1]. Another definition for KM is made by Laudon et al. as 'the process of systematically and actively managing and leveraging the stores of knowledge in an organisation' [4]. The management of knowledge is not a new concept. Many organisations already manage their knowledge through some ways such as databases and social interaction between people.

The construction industry (CI) is a knowledge-based industry. The production and management of knowledge is therefore highly essential for businesses operating within this industry and for projects on which they work [5]. During the construction phase of projects, most know-how, know-what and experience exist in the minds of individuals. In order to improve the construction process and reduce the time and cost of solving problems, it is highly essential to capture knowledge of experts involved in projects and reuse in future projects [6].

In this study, a survey was conducted among eight leading Turkish construction contractors. A web-based prototype system is proposed in order to manage knowledge effectively in construction projects.

2. KNOWLEDGE MANAGEMENT IN CONSTRUCTION

The main drivers for KM in the CI are the need for innovation, improved business performance and client satisfaction [7]. Kamara et al. stated that innovation and efficiency are related to the delivery of projects since the industry is organised around projects [8].

An enormous volume of architecture, engineering and construction knowledge is generated during the phases of design, planning, construction and maintenance of a facility [9]. During these facilities, capturing tacit knowledge and making it available as explicit knowledge are very important to KM in the construction phase. Since most project-related problems, solutions, experiences and know-how are in the heads of individual engineers and experts during the construction phase, capturing them and reusing in future projects can create several advantages for a company [10].

2.1 Advantages of Knowledge Management for Construction Companies

The following are advantages to adopting formal KM procedures [5]:

- Increased efficiency in project implementation:

  Organisations that manage knowledge better, can easily find solutions to problems when they arise.
- Reduction in wasteful costs:

  Organisations that manage knowledge better, can reduce time and money in finding solutions to problems already solved by individuals / teams working on other projects. As a result, the same problems in the construction phase do not need to be solved again.
- Greater innovation:

  Organisations that manage knowledge better, can stumble upon new and innovative ways of working.
- Competitive advantage:

  Organisations that manage knowledge better, can discover something extra that separates them from their competitors.
- Greater success:

Organisations that manage knowledge better, can win more new and repeat business than their competitors.

3. THE SURVEY

The survey was conducted in Turkey among 8 leading Turkish construction contractors that are all members of the Turkish Contractors Association (TCA). The companies are large size contractors and operating within the international construction market. A total of 12 top-level managers including general managers, business development managers, bid proposal managers and IT managers from these companies were interviewed for this research. The twelve interviews took place over a five month period between February – June 2005. The survey questionnaire has been administered during face-to-face interviews. Some of the questions allowed the participants to give multiple responses to a question. The specific objectives of this survey were to find out how these organisations share and reuse knowledge, the opinions of senior engineers and experts on the capture and reuse of knowledge and experience in construction projects, and the main barriers for implementing knowledge management. The surveys referred were conducted in the UK [11, 12] and Finland [13].

4. SURVEY RESULTS

The survey results are classified in four categories as capturing knowledge, storing knowledge, reusing and sharing knowledge, and KM strategies.

4.1 Capturing Knowledge

All of the respondents stated that their firms have been successful at capturing knowledge from external sources.

Tacit knowledge is the key component in reusing knowledge. Half of the respondents considered their company knowledge to be 41-60 % as tacit nature. It can be stated that these firms do not capture their expert's knowledge successfully since more than half of the company knowledge exists in individual's heads. On the other hand, the companies that implemented a KM strategy within their organisations are more successful at capturing tacit knowledge since the participants of these firms considered their company knowledge to be only 0-20 % as tacit nature (Fig. 1).

The most important knowledge sources for the firms are determined as colleagues and company's experience (Fig. 2). The majority of the respondents stated that they rely on their colleagues as a knowledge source. This result correlates well with the research done in the UK, in which the most important knowledge source was also considered as the other individuals in the firms [12]. However, major Turkish contractors rely more on their company's experience and current project documentation as a knowledge source than UK firms.

Some knowledge sources were reported to be less significant than might be expected. For example, Internet was not considered of a major knowledge source. It has been determined that the usage of Internet in these firms is limited with only some business activities such as exchanging and sharing documents via e-mail.

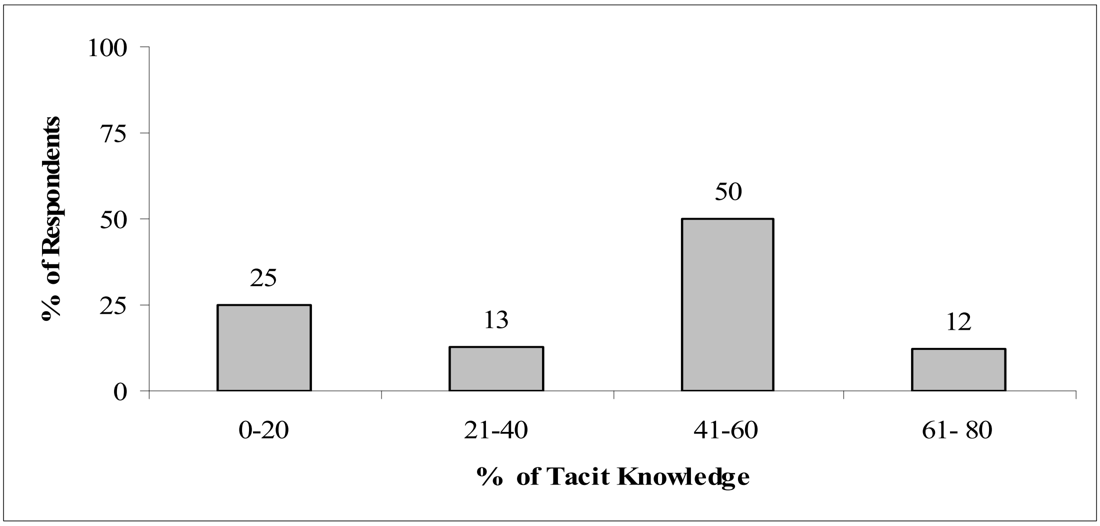

Figure 1: The percentage of company knowledge as tacit nature

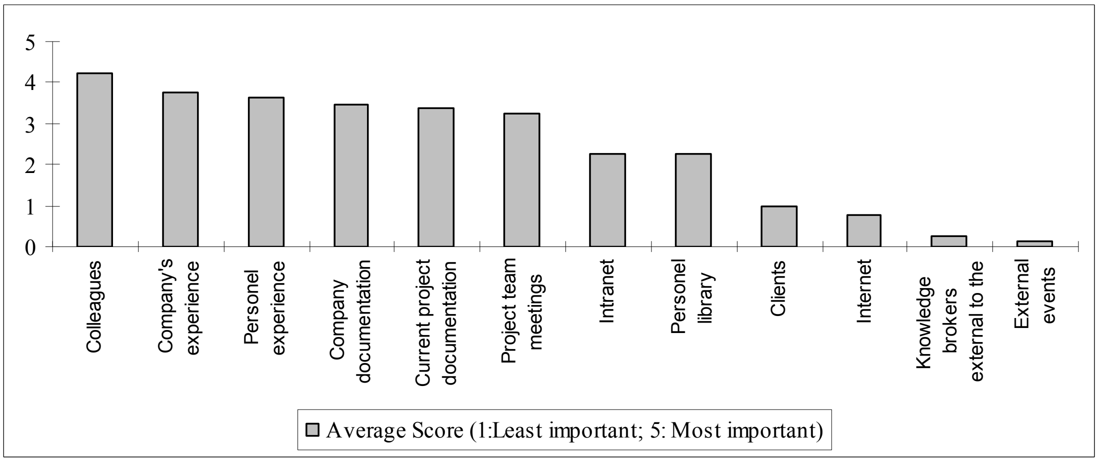

Figure 2: Knowledge sources

4.2 Storing Knowledge

The respondents were asked the availability of a database in their company related to past projects. Most of the respondents indicated that post-project appraisals have been used for learning from past projects and are available only in paper format. Only few companies have stored these documents in digital format. This results show that companies mostly use post-project appraisals for learning from past projects. In addition, most of the firms store the problems and solutions during the construction phase. However, the participants also stated that there has been difficulties to find the necessary documents since they were not systematically stored.

Reports are indicated as the most used tool to accumulate and store knowledge gained in the projects (Fig. 3). The folder, computer files and personal archives are determined as the following important tools.

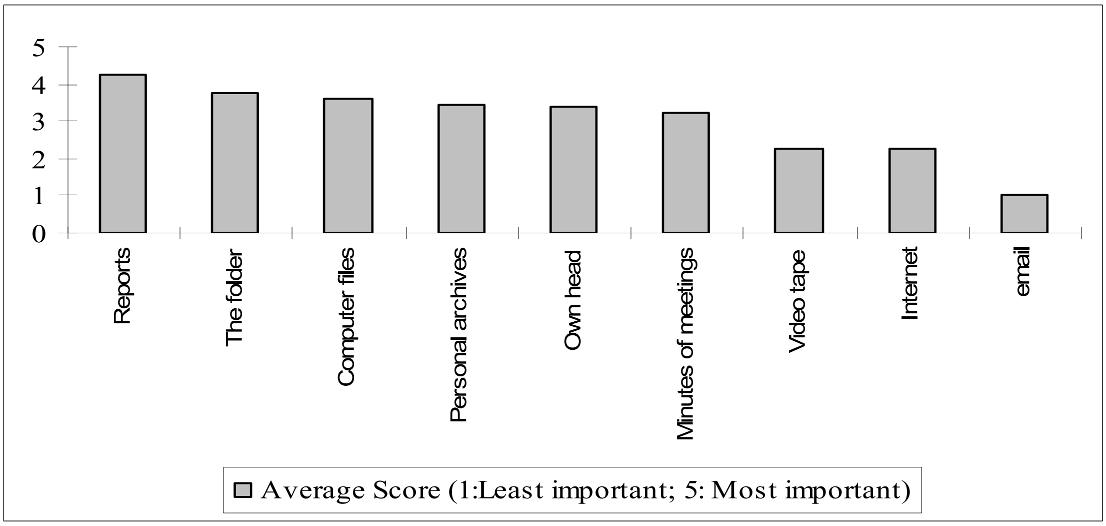

Figure 3: Tools used to accumulate and store knowledge

4.3 Reusing and Sharing Knowledge

Most of the respondents stated that their firms have been successful in effective knowledge sharing. In addition, most of them indicated that the company culture supports knowledge sharing within their firms.

The respondents were asked how often they reuse knowledge gained from other projects. The results show that knowledge gained in past projects has not been used very often in company's current projects. Clearly, this will lead to inefficiencies in companies' activities since the problems should have to re-solve again in their ongoing projects. The respondents stated that they rely mostly on the experience of individuals in problem solving.

4.4 Knowledge Management Strategies

The respondents were asked the availability of an intranet within their firms. It was found that all the firms involved in this study use an intranet. The intranet is seen by the firms as a key aspect of the IT infrastructure. The results correlate well with the research done in the UK by Carrillo et al. carried out among 170 UK construction firms [11]. In the UK, 90.5 % of the large organisations use an intranet to support the KM process.

In this study, it was found that 25 % of the companies already have a KM strategy, while another 25 % plan to have a strategy in the future. It has been observed that the ones that have a KM strategy are more successful in their projects and their business volume is higher than the others. This result shows that KM could be one of the major factors for the companies in their business success.
The respondents were asked the drivers for KM. Only the respondents of the firms that have a KM strategy were asked the drivers for KM. All of them addressed the main driver as reducing rework (Fig. 4). Responding to the customers quickly is determined as the following important driver. The results obtained in this study are quite different

from the survey done in the UK in which the most important driver for KM was determined as sharing tacit knowledge [11].

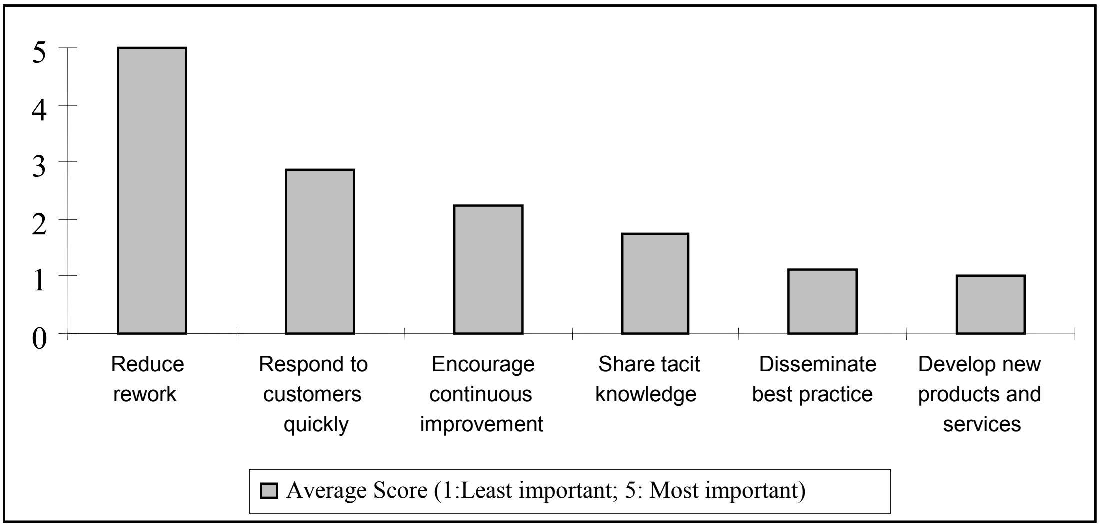

Figure 4: Drivers for KM

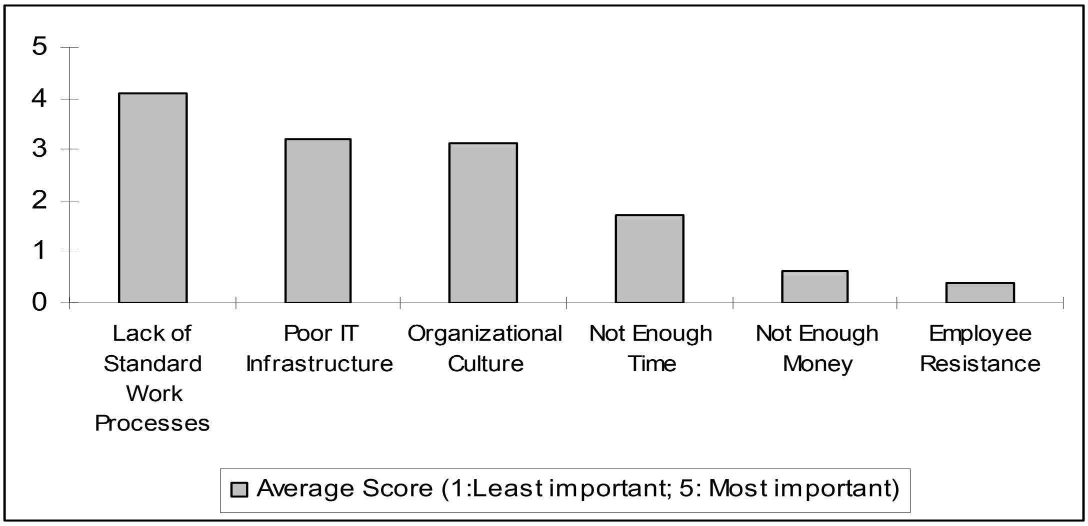

Figure 5: Barriers to KM Implementation

Based on the responses, lack of standard work processes is identified as the main key barrier to KM implementation (Fig. 5). This result correlates well with the research done in the UK in which lack of standard work processes was also considered as the most important barrier to KM implementation [11]. The number of different processes in performing different activities and lack of systematic procedures for undertaking and documenting lessons learned is addressed as major shortcomings in accessing and sharing knowledge as like in the UK organizations [11].

Poor IT infrastructure and the organizational culture are seen as the other major barriers to KM implementation. Although the participants stated that there exists mutual trust and collaboration between employees, this result shows that the companies should put much more effort to promote knowledge sharing within their organizations.

Finally, the respondents were asked their opinions for a system by which knowledge, especially tacit knowledge, could be captured during the construction phase of a project, stored and reused in other projects. The majority of the respondents (63 %) indicated that such a system could be beneficial to their companies. However, 37 % of the respondents considered this proposed system as unusable due to the difficulties in capturing tacit knowledge and stated that the ongoing procedures were enough to manage knowledge effectively.

According to the survey results, it has been determined that the firms do not manage knowledge effectively. Half of the firms do not even have a KM strategy. Since knowledge has not been re-used often, the advantage of reducing rework by implementing KM activities is still not fully achieved by these firms.

The firms surveyed have not been successful at capturing and reusing tacit knowledge which could be a strong advantage for them in their future projects. Know-how and experience are still remaining mostly in individual's heads.

According to the results obtained from this study, it can be stated that the leading Turkish construction contractors have not been successful at capturing tacit knowledge. A framework is proposed in order to capture tacit knowledge during construction projects and reuse in future projects (Fig. 6).

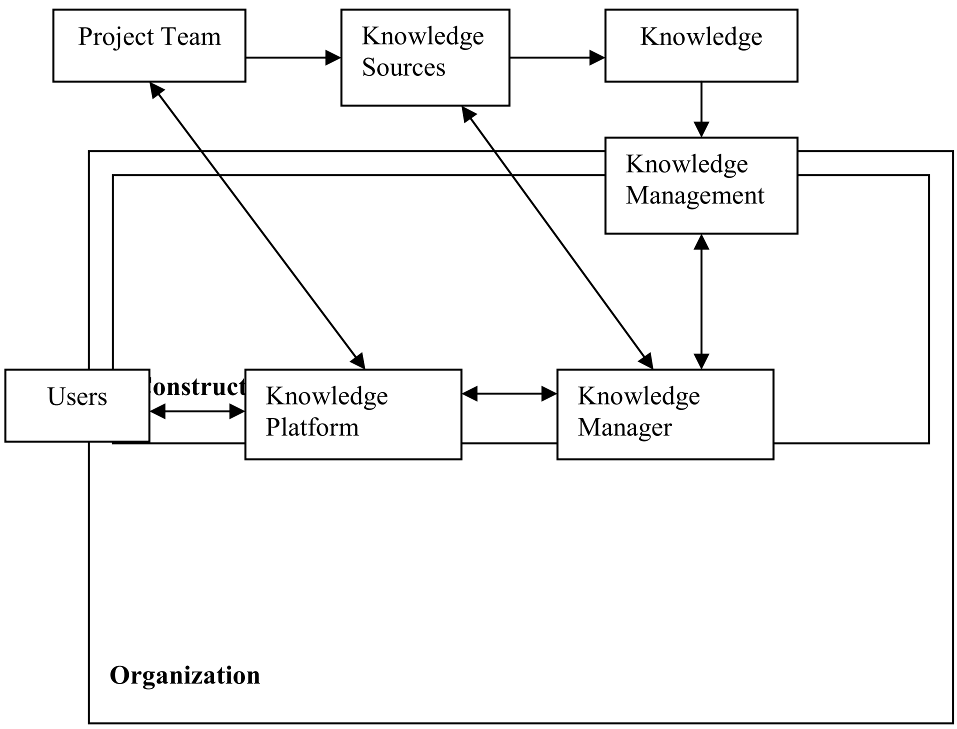

Figure 6: A framework for capturing and reusing knowledge

In this framework, the project team consists of the technical staff involved in a construction project. Knowledge sources include the organizational knowledge, internal and external knowledge sources. Knowledge consists of both tacit and explicit knowledge. The role of the knowledge manager is to collect, store and approve knowledge so that it could be re-used by accessing into the system called knowledge platform which will be described in the next section.

5. THE SYSTEM

In this part of the study, a proposed prototype system for capturing knowledge during the construction phase of a project and reusing in future projects is described briefly. The flowchart of this system is given in Fig. 7.

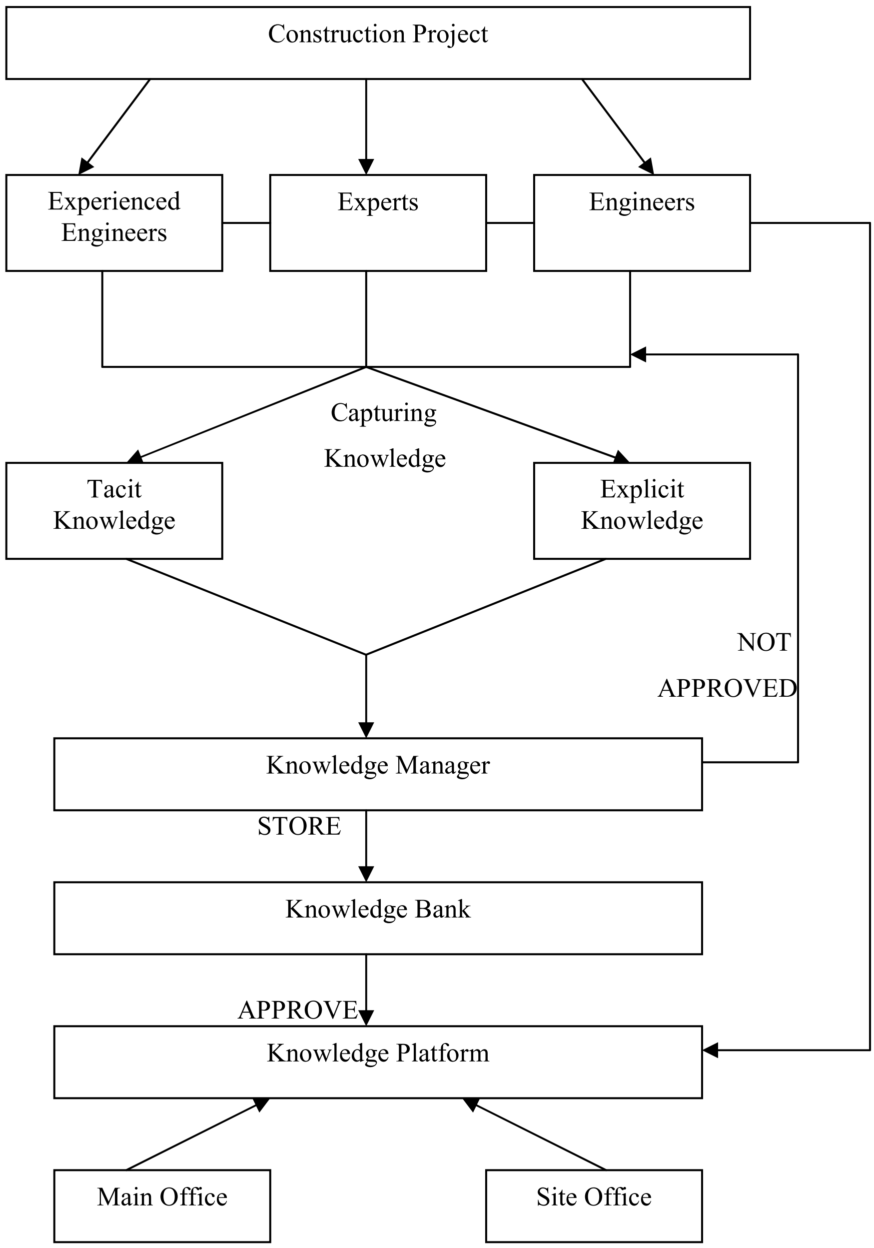

Figure 7: Flowchart of the knowledge platform

Technical staff can access into this system by having a password authorized by the company. The knowledge manager has the responsibility to collect knowledge and store it into the knowledge bank. Having approved the knowledge by the knowledge manager, it will be then available in the knowledge platform. The knowledge platform includes tacit knowledge such as know-how, expert suggestions, innovations and also explicit knowledge such as reports and contract documents. Construction companies have not been successful at capturing tacit knowledge during the construction phase. The system is mostly based on accumulating and reusing tacit knowledge to overcome this problem.

The main page of the system contains the projects option where information about ongoing and finished projects of the company is available; the knowledge type option where users can access to tacit knowledge such as know-how, innovations, problems / solutions and explicit knowledge such as specifications, contracts and reports; and the add new knowledge option which is used only by the knowledge manager to add new knowledge into the system. The knowledge platform should also be updated by the knowledge manager. The users can find the relevant knowledge in this system by using the following search options; knowledge type search, author search and project search. On each web page the submitted date and approved date of the knowledge are given and the description of the knowledge is presented.

Using this system can provide time and cost savings for the companies. Time and cost savings are difficult to calculate. The following example is given to explain how the firms can save time and cost by using this system. An engineer working in an office or a site spends approximately 10 minutes to find a relevant knowledge without using this system. The duration (10 min.) includes; asking information to the person about the knowledge (1 min.), going to the person's office (1 min), finding knowledge from computer or files (2 min.), printing and saving knowledge (2 min.), reloading the knowledge into the computer and executing (4 min). Obviously the time duration is approximate and can vary. If an engineer is supposed to find 5-10 relevant knowledge during a day, he might spend approximately 50-100 minutes only for finding knowledge. This is equivalent to approximately 1000-2000 minutes in a month (assume 20 working days). Assuming that the engineer is working 40 hrs in a month (9600 min.), then the ratio of finding knowledge hrs / total working hrs in a month will be (1000-2000) / 9600 = 10-20 %. This result shows that an engineer will spend approximately 10-20 % of his total working hours in a month only for finding knowledge. Assuming the salary of this engineer as $ 2000, the cost of finding knowledge would be approximately $ 200-400 / month and $ 2400-4800 / year. This simple example shows that even for an individual engineer, finding knowledge is time consuming and expensive. Immediate access to the relevant knowledge can be provided by using this system. Therefore, it can reduce the time consumption and cost of finding knowledge. Besides finding the relevant knowledge, the company can also save time and cost by reducing rework.

6. CONCLUSIONS

Construction companies have to manage their knowledge better if they want to survive in the competitive business world. Construction firms have been successful at collecting and storing explicit knowledge, but they are poor at knowledge retrieval and exchange [9].

In this study, the survey carried out among eight leading Turkish construction firms has been examined. It was found that the firms do not capture tacit knowledge from experts' minds effectively. A framework is proposed in order to capture, store and reuse knowledge in projects. Finally, a prototype system that enables companies to capture knowledge during the construction phase of a project and reuse in future projects is described. The system could be a very helpful tool for the companies in saving time and cost by reusing knowledge.

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CONSTRUCTION INDUSTRY DESIGN BRIEF

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Abstract: This study looks at the meaning of the design brief in the construction industry in relations to facilities management. The construction process was examined to identify the purpose and specific requirement for the facility. The study also probed into the dynamics of the design team in relation to facility provision. The interface between the client and the design process was established, and the need for consultation rather than the one way meeting between the client and the designers. The methodology for the pilot study was exploratory survey by means of structured interview of key players and professionals in the industry. The study revealed the importance of good decision making after strategic planning and feasibility study have been conducted to establish viability and suitability of the facility. The need for review of performance and the maintenance of facility was stressed.

Keywords: design brief, construction process, design team, client, facility.

1. INTRODUCTION

The scope of this project looks at a whole range of activities from inception through delivery to operation that will ultimately influence the building's performance and the maintenance of the performance. A good design brief should provide strong client and user satisfaction, transforming the client's desire into design specifications and eliminating activities that don't add value to the facility. The briefing is the interface between the client and the project, and the starting data for the design and it also configure the essence of the client interaction with the design process. It communicate the owner's expectation to the design team, it is a written document, which will be translated spatially and technically by the design team.

Identifying the purpose of a construction facility or project and identifying the specific requirements are the first of stages of the construction process. When you are confronted with a construction situation, you need to analyse the situation before you attempt to solve the problem. Once the problem is fully understood, then you write a design brief. The design brief should only occur after the need for the facility has been identified and a feasibility study has been carried out to ascertain the suitability and viability of the proposal. Management plan and design brief should be put in place after the decision to proceed with the development has been made.

2. METHODOLOGY

The methodology employed for the research presented in this paper, examined different methods in use in the construction industry before conducting the survey, for example experimental, literature review and exploratory survey. But exploratory survey seems to offer the most opportunities, because it was more likely to reveal the key features of the problem rather than any of the other two. Questionnaires were not considered appropriate as a primary research method due to it obvious disadvantages, of been very rigid, and the fact that the result can not be anticipated.

Interviews were preferred to questionnaire because it could allow you probe a lot further into matters of interest than questionnaires could. So a structured interview was conducted to solicit response on the current state of design brief and the briefing tools used in the construction industry. Those chosen for the interviews were professionals with good knowledge and experience in the provision of facilities, those involved on a regular basis in design brief and the briefing process, regular members of the design team. A total of seven professionals were interviewed, four of them were project team manager and the other three were project team leaders at different times and have all been involved in the brief process. The interview centred on what design brief met in construction, how it was conducted and what should be improved if any. Some specific area were also covered like facility planning process, decision making, design development, the design team, roles and responsibilities of facilities manager, and suggestions for improvement. This pilot investigation is a part of an ongoing study, trying to determine the roles of facilities management at the Scottish airports, currently a list of key performance indicators are being complied for the Scottish airports, testing and validating the list will follow shortly.

3. DESIGN BRIEF

This is a document that is used as a guide in the design process. It really set out the term for the entire process. It is believed that a full brief development will address all the relevant issues, resulting in a design that is a proper response to the requirement of the client/owner, the building users and content. Follow this; the design will be a perfect model of the facility that is proposed. Detailed design and construction will produce the facility. Chanter and Swallow (1996) in seeking the evolution of a solution to satisfy the requirements for a building identified four guiding principles.

1- To produce a building that is appropriate and efficient for the function.
2- To produce a building that provides the optimum physical and psychological environment for the contents of the building, both animate and inanimate.
3- To produce a building that strikes an appropriate balance between initial cost and operating costs.
4- To produce a building that is consistent with the needs and aspirations of the community at large

The design brief is a clear statement of problem, which the designer has to solve; in this respect the brief must be short and complete. It must give all the information available about the problem. It will not give answers but information, listing all things to be thought about then leaving the designer to solve the problem.

4. DESIGN PROCESS

In construction the process consists of briefings, seminars and workshops. And it normally will starts with a briefing meetings, a situation were the architects are made aware of the client’s requirement. There are usually no written brief on the part of the small or individual clients/owners to the architects or quantity surveyors. Quantity surveyors are not always present in at briefing meetings; this is clearly unsatisfactory from the communication point of view.

A good design brief should contain information about the problem at hand, a problem statement, the design task, and what the successful design will do. The problem situation is the basis for the design brief and any subsequent design activities. A good understanding of the situation is essential if the correct problem is to be identified and an appropriate solution found. For client organisation, the brief will need to articulate the needs and aspirations as a client organisation, address issues relating to policy and funding, the site and the situation you wish the design team to address and respond to in their design. Before the appointment of the design team the brief writer may be an experienced project manager or an expert employed specially to fill that task in case of large projects. It could be someone from the client organisation. The process can involve producing a series of draft, to which contributors can review and amend. Blyth and Worthington (2001) believe that every brief should set out the mission, the objectives, performance requirements and measures, priorities, management decisions and responsibilities, timeframe and who is expected to respond.

Design task

The design task clearly identifies what the designers are expected to do or how the designer is expected to proceed. A list of things, a schedule of things and all that is required to be delivered as part of the solutions. What the successful design will do is a description of what the solution will accomplish. It could indicate how well the solution is expected to work and under what conditions it is expected to work.

Bowen and Edwards (1996) believe that subject to certain qualifications the brief is a representation of the client's needs. (1) The extent to which the brief represent the client's need is a function of the client sophistication. (2) The brief is seen as a representation of needs at a specific point in the time, since clients do not always know what they want at the initial stage of the project. (3) The brief is a living concept. Initially uncertain, providing a good basis for preliminary discussion and developed in an evolutionary manner. (4) The brief represent a source of information and is essential communication instrument.

5. DEVELOPMENT IN DESIGN BRIEF

Earlier literatures on design brief have extensive review of the need for the development of a conventional design and construction process in the construction industry. And later literature review tends to concentrate on establishing client briefing as a process to be analysed and improved upon. Turin (1966), Goodacre et al. (1982), Latham (1994), Murray(1995), Koskela (2003) all agreed that there is the need for change by making it more efficient and effective. The poor performances of constructed building projects made the need for change more imperative. Cheong et al (2002) were of the view that any constructed project, the design and construction process should cover the project's expected life span, from the identification of needs to the operation of the facility. By using the project life cycle, it ensures that all issues are considered and provision is made for the interdependence of the different activities throughout the duration of the project. Spencer and Winch (2002) believe in the continuous interaction and involvement of the client as the basis for satisfying the needs of the client, good understanding of the client's situation will provide a means of working within the design construction process. Construction clients need to be able to express their requirement in a way that describes the operations intention with the facilities and buildings.

The design brief is a development and expansion of the statement of need and feasibility report undertaking during the project appraisal stage. This includes the strategic requirement for the project, which is then translated into technical specifications. Before the design process, there is usually a design programme, which outlines all the design activities, and their related responsibilities, which will then be incorporated in the overall project plan for monitoring, plan and control changes.

Each design brief includes the following parts 1.the situation, which set the context and rationale for the activity. 2. The problem, or challenge statement which clarifies the problem 3. The resources, which are the materials, tools, machines, software and computers available to assist in the development of the solution. 4. The constraints, the limitations, in terms of time and resources, unforeseen circumstances.

6. BRIEFING-DESIGN INTERFACE

Briefing should introduce clients and users requirements for design. Kamara et al. (2001), Green and Simister (1999) all express similar opinion. It is through the briefing that clients explain their needs, their financial possibilities and their requisitions with regards to the project. Lots of designers believe that frequent changes in the brief can result in result in poor development of design. Understanding the client and ability to take strategic decisions are needed for excellent brief representation. Mesquita et al. (2002) stressed that without an intense exchange of information among the players during project development; the result is a badly defined, badly specified and badly resolved project resulting in increasing costs and time overrun.

By ensuring a structured approach is in place during the briefing stage, there is a higher probability that the client's requirement will be attained. Developing a concrete, controlled and consistent approach will avoid unnecessary and costly changes during the design process. The consultation undertaking during the feasibility study should identify the major components of the facility and the design features required. However to refine the plans into design specifications there is the need to consult a wide range of audience, for example potential users, suppliers of materials, design consultants, owners or manager of similar facilities, government and local authority.

People and information are the major resources in an event of this nature. People design and create technology; they are available for consultation and guidance, they make the law and polices in use in the industry. On the other hand information relates to things you already know or may want to know in developing a solution to aid the design brief. Information about other project with similar problems and solutions are important.

Ryd (2004) believes that the construction client is not only active concerning his/her own building stock but also in letting out premises. Therefore, in many ways the role of the client may be said as being the same as applying to functions with facilities management in companies and organisations using a large stock of premises on account of their own activities.

7. FACILITY PLANNING PROCESS

The design brief is a phase in the facility planning process. The plan for a facility is usually integrated with the strategic plan, which looks into the long term development of the facility, after a review of existing facilities, the need and opportunities for development couple with the aims and objectives. A feasibility study is embarked on to determine financial viability, suitability, market analysis, at this stage concept and draft management plan are drawn. Both the strategic planning and feasibility study form the proposal stage in the planning process.

The decision to proceed with the project is made after the feasibility has been adopted and a move from the proposal to the project. The project enters the design phase and the management plan and design brief should be prepared. The project stage has the design, the construction and the evaluation stages. Facilities management is at the evaluation stage, where the facility is been operated and evaluated. There is a clear separation of the design stage from the construction stage and both from the evaluation or operations stage. The facility manager at the evaluation stage is responsible for the day to day operation and planning for the maintenance/replacement of the facility through out its useful life. There is the need for FM to be involved early in the life of the facility to ensure optimal resource provision.

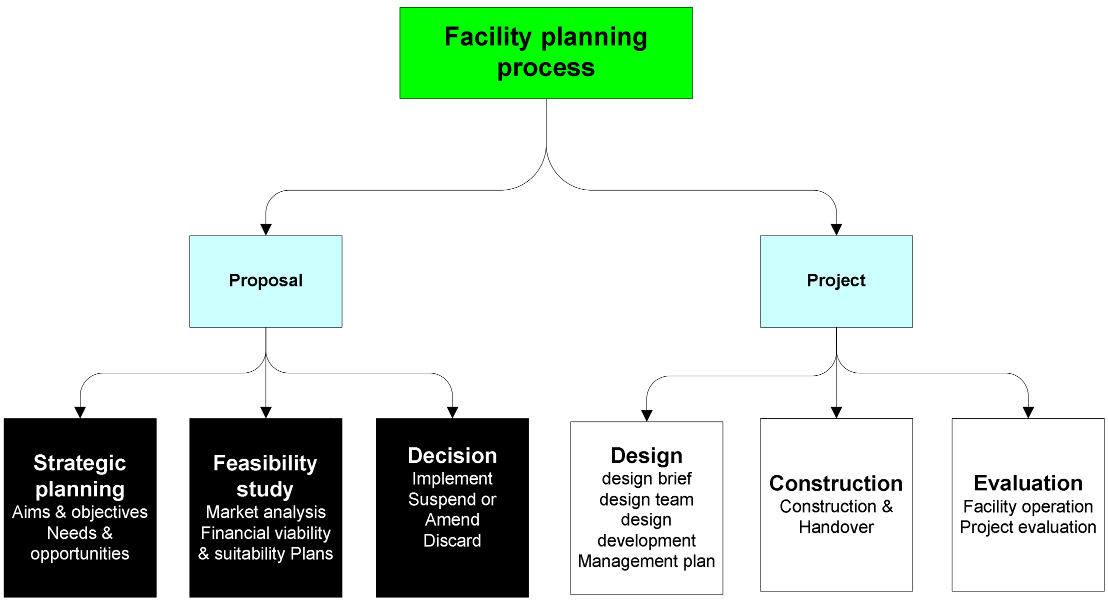

Figure 1: Facility planning process

8. DESIGN DEVELOPMENT

After the decision to implement or procure a facility has being taken, based on the strategic planning and feasibility study, the design development becomes the next logical thing to do in the facility planning process. Here designers review the brief, background materials and identify standards to ensure we understand the project context and requirement. The designers develop draft concept and initial design and select the most appropriate options for further development. This stage is the development of a solution to all the needs and requirement for the facility. It is a major production section of the design projects, all ideas are developed into working solution. Knowledge and skills developed in the previous stages are then applied and tested. At the design development stage, management plans for the facility is put in place, all the design stages are finalised, the design brief written, the design team selected, the schematic design in place. We are now ready for the next phase which is construction, production of the facility.

9. DESIGN STAGE REVIEW

The purpose of the design stage review is to evaluate; the design options against predetermined criteria, to review general development of the design, to review design for compliance with the brief and cost plan, to review the design quality, and to look into the design team's implementation of procedure.

Smith and Jackson (2000) believe that the design team and the facilities managers must make more significant contribution to the initiation stages of a project, since these are the most important for the client. Also there is the need to ensure that before a client commits to any specific, they first should work through their strategic need objectives before allocating resource to action. Aiming to achieve client objective and providing solutions that are effective, efficient and innovative.

In the supplement to the client guide for ACP Projects (2002), when the first draft is completed you can review the content of the brief as a whole:

- Does the brief communicate succinctly the particular qualities
- of your organisation and your existing and planned arts activities?
- Does it clearly state your aims for the project and set limits
- for cost and time?
- Does it clearly state your expectations for design quality?
- Does it require the design team to devise a method for
- including the input of artists?
- Does it ask the design team to exploit the opportunities for making
- links to adjacent public space and wider context?
- Have you considered future flexibility and changing needs?

Design Team

The design team is made up different profession; it is a collective noun for a team of architects, quantity surveyor, structural engineers, service engineers, mechanical and

electrical engineers. Some times fire and acoustic engineers will be part of the team depending on the nature of the project. The design team leader (DTL) is a position often taken by the architect as part of their commission, they are responsible for coordination; strategic design, overall responsibility if there is no project manager
Consultant is an expert or a specialist employed by the client early in the procurement process to provide specialist advice or design. They interpret and devise solution to the client's requirement.

Architects are responsible for overall configuration, building contract supervisor if no separate PM or DTL, spatial design, planning the layout of the building, submission of statutory consent, preparation of project specification and tender documentation.
Quantity surveyor (QS) are responsible for cost and budgetary advice, preparation of cost plan, bill of quantities, estimate of rates and quantities, preparation of specification and documents for tenders.

Structural engineers are responsible for foundation and structural design: inputs for statutory consent, principles, loadings and calculations.

Services engineers are responsible for electrical and mechanical services, heating and water services design, cost of services and input for statutory consents.

Facilities manager (FM)

At the procurement stage, the FM should be aware of the contractual responsibilities of the design team and ensure that the contractual requirements of the project team are being fulfilled. Ensure that adequate time is allowed for briefing and that best practice documentation is known to those who need to know. Also all relevant information is provided and the needs of the client are taken care of. Changes to the specifications must be handled in a discipline manner to ensure that the design is not compromised.

It is the responsibility of the FM to identify any space planning needs during the briefing process, and also ensure that a special brief is required for non core areas. Ensure designs are appropriate and conform to functionality; checks are made through out the design and construction process. FM should always identify future needs as far as possible and request whole life costing calculations were necessary.

FM must appraise them self of maintenance implications at an early stage in the building design, check for easy of maintenance as part of the services design review. The design team and client should agree on the balance between cost and users needs. FM should ensure that provisions are made for both disable staff and members of the public that will access the facility. Ensure that special or occasional requirement are considered, i.e. storage provision and adequate exist procedure in case of emergencies and fire safety.

In all the FM needs to be very clear on requirements and needs of the facility. Ensure that every single activity is carried out in the most professional manner and that regulation and standards are kept.

10. RESULT

The aim of a design brief is to convert your expectations into reality, by translating the conceptual ideas developed in the feasibility study, into a set of instructions which will guide the design and construction of the facility. And provide value for money through efficient management and allocation of resources. Some of the respondent raised the issue of location, pointing out that the proposed facility should be located such that it can easily be integrated into the surrounding environment. For example the planning of a recreational facility should be sited in an area where there will be enough people to make use of the facility. The input of experienced facility manager is very important in ensure that the design promotes optimum staff efficiency.

On the meaning of design brief and how it was conducted, they were fairly in agreement as to what the meaning was, and only varied on the conduct. It was clear that the design brief is a set of instructions from the client to the designers outlining what he expects the facility to provide. To say what should be included in the design brief, we will need to answer the; why, when, what, where, how process.

Why do we want the facility? The need
When is the facility to be built? The timescale
What is to be built? The need, requirement, type of facility
Where is the facility to be built? Location, site details
How is the facility to be built? Finance

The answer to these questions will provide solution to our situation and guide us on how to fashion our design brief. The conduct has a lot to do with the experience and resources available to the client or the client organisation, the size and complexity of the project. From the interview it was clear that the brief designers or the design team expect to be told what to do by the client irrespective of the experience of the client in such matters. It is possible for the team to let the client know what is available, so that consultation rather than one way brief from the client to the team will be the case. Most of those interviewed stressed the importance of good decision as this can spell the difference between success and failure in the performance of the facility. Barrett and Stanley (1999) were of the view that by improving the quality of information during the design process the client is better equipped to understand the different issues implicated in the project. Design engineers should be in a position to present situations, and their consequences with the effect of their decision, to the client. Most clients rely sole on their consultant to resolve any issue.

One respondent refer to a situation from his own experience how administrative and official bottleneck impaired the ability of the briefing document from acting as a guide for the provision of the facility. Effort should therefore be made to remove any obstacle that will impair the brief from achieving its goal.

All the respondents agreed on the role of the facility planning process and integrated business development plans as being very vital move in the success of briefing process. Existing literature have shown that there is much interest in the area of strategic briefing tools, but this study has shown that there is limited knowledge of the different types of tools available, and their use within different organisation. Blyth and Worthington (2001) were of the opinion that the more conventional need initiated briefing process was based on the assumption that the requirements for a structure must meet and can be described with the help of existing work processes and interviews with employees and management.

11. CONCLUSION

The importance of a good design brief in the construction of a facility can not be undermined. Chanter and Swallow (1996) also emphasise that the effectiveness with which these activities are carried out determine the success or otherwise for the venture, it is important then to have a common basis against which these activities can be initiated, planned, monitored and controlled. Good communication between the parties should be encouraged for better result, partnering and team work is also vital. There is the need for the facility manager to be involved early in the design stages so that he can express the needs of the user group and input plans for the operation, maintenance of the facility and create value for money. From all indications therefore, the analytical process outlined in this study is more of an intellectual activity, but in practise there is a structured approach to brief presentation.

Brief collection is a highly skilled requirement; it is usually advice that the designer of the facility be responsible for the collection of the brief from the client or client organisation.

More research need to be done in the area of communication needs and patterns in the construction process, this will lead to investigating the design brief process and the information need of all the design team players. Team work and partnering is the key to successful procurement in construction. Work is currently going on in trying to emphasise the role of facilities in the efficient delivery of the airport performance, and efforts are be made to identify, test and validate the key performance indicators that can be benchmarked in this regard.

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