6th Nordic Conference on Construction Economics and Organisation

– Shaping the Construction/Society Nexus

Volume 2: Transforming Practices

Danish Building Research Institute
AALBORG UNIVERSITY

EDITED BY:
Kim Haugbølle, Stefan Christoffer Gottlieb, Kalle E. Kähkönen,
Ole Jonny Klakegg, Göran A. Lindahl & Kristian Widén

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Proceedings of the 6th Nordic Conference on Construction Economics and Organisation – Shaping the Construction/Society Nexus, Volume 2: Transforming Practices

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Organising Committee’s declaration:
All the papers in these proceedings were double-blind refereed at abstract and full paper stage by members of the scientific committee. This process involved, detailed reading of the abstracts and papers, reporting of comments to authors, modifications of papers by authors and re-evaluation of re-submitted papers to ensure quality of content.

FOREWORD

On behalf of the Organising Committee, it is my pleasure to welcome you to Copenhagen and the Conference Centre of the Danish Association of Engineers for the 6th Nordic Conference on Construction Economics and Organisation.

When we commenced with the planning of the this year's conference, we had great hopes and expectations to be able to invite you to the largest Nordic Conference on Construction Economics and Organisation yet, along with a number of associated events, and with papers of high scientific rigour and quality – and we are pleased to announce that our expectations have been fulfilled.

Focusing on the nexus between construction and the built environment, we invited papers that would explore the various ways in which construction and the use of constructions are interlinked and mutually constituting and transforming each other. We received more than 150 abstracts, which through a double-blind peer review process resulted in 56 papers being published here in these proceedings under the theme: "Shaping the construction/society nexus." The published papers are of a high quality and display a growing tendency with our field of research: namely the application of theoretically informed approaches to raise the quality of the analyses and the generalisation of conclusions.

The road to the conference has, however, been long and arduous, which has presented organisers, committee members, reviewers and authors with a series of minor and major technical and organisational issues. We apologise and are at the same time confident that these sorts of problems will be a thing of the past when the 7th Nordic Conference on Construction Economics and Organisation will be held in 2013.

Thus, in the two years until the next conference, we will work hard to establish a more professional or at least a more permanent, organisation behind the conference series by forming a network for Construction Researchers on Economics and Organisation in the Nordic region. We have already taken the first step by signing a Memorandum of Understanding with our friends in both ARCOM and CIB who have cordially helped us promote this year's conference. It is our hope that we in the years to come will be able to return the favour and help develop the field of construction management for the benefit of all of us.

An event like this is only possible with the help of many individuals and organisations. First and foremost, I wish to thank the members of the Organising Committee and in particular Stefan Christoffer Gottlieb and Göran Lindahl. Further, I would like to thank all members of the Scientific Committee, who have helped us maintain a high standard and quality of papers. Finally, I would like to thank our partners and sponsors for their collaborative contributions and financial support.

I wish you a pleasant and profitable conference.

Kim Haugbølle
6th Nordic Conference Chair
Danish Building Research Institute, Aalborg University

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SENSEMAKING OF CORPORATE CULTURAL VALUES

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This paper sets out to explore how an organisation guides their employees towards making the same sense out of the organisation's core values, in order to develop a common frame of meaning. This kind of framework helps the employees work as a single entity, rather than as a group of individuals, striving towards the corporate goals. It draws on a study conducted on a Swedish construction company, pseudonym: TOM. This company has developed a framework that encompasses their key values, known as the DDPR framework. The purpose of this study was to find out to what extent a framework like this can be made to permeate throughout an organisation and how individual employees work with it. The results show that core values can be a part of a company's trade mark and that they can be a valuable tool that helps shape the company on all levels. This can in turn create a strong image of the organisation both internally and externally and facilitate the work towards a mutual goal.

KEYWORDS: basic assumptions, core values, corporate culture, sensemaking.

INTRODUCTION

In corporate organisations it has become important to create an image for the organisation which reflects its goals and visions. This gives the organisation character and unique properties, creating a common frame of meaning. The purpose is to try to differentiate themselves from others and present their way of working to the world. For this to be possible, it is vital that the employees make the same understanding out of the organisational stimuli. For such an image to be persistent, all employees have to agree and correspond to the organisation's view, strategic goals and way of working. A way often used by organisations today is the implementation of keywords that frame these aspects, coming across as a single entity rather than a group of individuals, and then spreading their coherent identity not only to their external clients but also towards their colleagues within the company itself. (Clegg, Kornberger & Pitsis, 2008)

Looking to the construction industry and the majority of project organisations within it, Klakegg (2009, pp. 191) recognises that the governance of projects has become increasingly important during the last decade. He argues that to be able to integrate the different levels within such organisations there is a need for an institutional framework that spans over the whole organisation.

Hill, C. and Jones, G. (2008) define organisational culture as the specific collection of values and norms that control organisational interaction both internally and externally. This leads to the idea of organisational values which they describe as beliefs and ideas about what goals members should pursue, and what behaviours are appropriate to achieve these goals. *"From organizational values develop organizational norms, guidelines, or expectations that prescribe appropriate kinds of behavior by employees in particular situations and control the behavior of organizational members toward one another."* (2008, pp. 394)

One of the largest construction companies in Sweden, here referred to as TOM, has made use of the technique of framing the organisation's culture. This is done by introducing four core values whose acronym makes up the name of the framework, the DDPR-framework. These values are: Down-to-earth, Developing, Personal and Reliable.

The main aim of this study is to explore how an organisation steers their employees towards making the same sense out of the organisation's core values and how the management use this to develop a strong corporate culture. The two research questions posed for this paper are: How can core values be made to permeate throughout an organisation's structure? Do core values affect the way an individual employee conducts his/her work in a large construction company?

The theoretical frame of reference is the starting point of this paper. First the concept of core values is described as an instrument for making members of an organisation work towards a mutual goal. This is followed by an overview of the theories on sensemaking and sensegiving which is crucial for the understanding of how core values are implemented. The theoretical frame is ended with a part of Schein's theory on culture, namely basic assumptions, and how these affect the decision-making of the individual. The case is then presented including a short historical background of the company TOM and a description of the four core values in the DDPR-framework. The case has served as the empirical ground for examining the concept of core values in a practical context. From this point the results are presented with a focus on the core values' impact on different hierarchical levels of the company TOM. Then the limitations of this paper are accounted for. Finally, the issues arising from the study are discussed with reference to the theories and some concluding remarks are made.

METHOD

The main method of research used in this study was interviews with employees from the large construction and civil engineering company TOM. Three interviews were conducted with employees representing three different levels within the hierarchy of the organisation. The interviewees are currently in the roles of business manager, site manager and foreman. Even though there were only a small number of interviews the opinions of the interviewees can be viewed as indicative of how others at the same organisational level work regarding the core values. The interviews, which were qualitative, were conducted in a semi-structured manner in order to get more dynamic and open answers. Due to the interviewees' different positions in the organisational hierarchy comparisons could be made between their interpretations of DDPR and ways of working with the framework. To complement the interviews a theoretical framework was produced. This framework is based upon literature such as academic texts, articles and corporate reports.

THEORETICAL FRAME OF REFERENCE

Sensemaking is part of the foundation that core values rely upon. It is a process that rationalise what people perceive. This is not necessarily equal to individuals sharing the same understanding. However, to be sure that the employees do not choose different paths, companies can use sensegiving as a solution. With sensegiving organisations frame the elements which are important to them while other elements are kept in the dark. (Fiss & Zajac, 2006)

After the employees have interpreted the core values with the help of sensemaking, the next stage is to make sure they become a part of the organisational culture. Schein defines three levels of organisational culture which will be developed later in the text. It is desirable for organisations to have core values integrated into the deepest of these three levels; the basic assumptions. (Clegg et al, 2008)

Core values

Core values, and hence organisational strategy, are set out by the owner in conjunction with the board of directors and the top management. The basic core values should describe the evaluation of activities and outcomes and also what ambition the company have for making decisions. The stakeholders' interests should be a vital factor in the process of framing the organisation's strategy. The published core values are only a small piece of the whole concept but have an important role since it creates an image, both inside and outside the company. Another purpose is to improve the working environment and make the employees feel that they are a part of something unique. (Jaakson, 2010)

"Core values have been used to denote highly congruent values between organizational members as well as between the organization and its members and as such, these refer to at least some overlap between what is actually believed in and what is said to be believed in." (Liedtka, 1989; Jehn, 1994 cited in Jaakson, 2010 pp. 797)

Core values are different from other types of organisational values. The acceptance of core values is higher and they are explicit. The main purposes of organisational core values are to get through to the employees and make their beliefs coherent as well as make their work aim for a higher level. The core values are used as an instrument to reach a required end-result, and these end-results often define the organisation. (Jaakson, 2010)

Sensemaking

Within the last decade, the concept of sensemaking has become more and more relevant in management circles, especially in academic quarters. The concept of organisational sensemaking was first introduced by Karl Weick. He defined sensemaking as *"the ongoing retrospective development of plausible images that rationalize what people are doing"* (Weick 2008 cited in Clegg et al 2008 pp.18) In organisations, sensemaking is particularly relevant since an organisation relies on its employees to work together towards a mutual goal. This has been proven to be a difficult task since individuals can make different sense of the same thing. (Clegg et al, 2008)

Fiss and Zajak argue that organisational frameworks, such as those consistent of core values, give employees a simplified work environment where they have some main elements to think about while other elements do not need the same level of attention. They also state that for sensemaking to work amongst the employees of an organisation, there also has to be sensegiving; i.e. a frame that is put around a strategic change and spread out as mutual sense. (Fiss & Zajac, 2006)

Sensegiving in organisations

In order to counteract that individual employees go down diverging paths, companies like to frame a common way of working. This ensures that all employees remain congruent with the organisation's vision and strategic goals. The way in which organisations do so is by sensegiving, i.e. creating a common frame of meaning for all employees. (Fiss & Zajac, 2006) In TOM's case the common frame is their core values, DDPR.

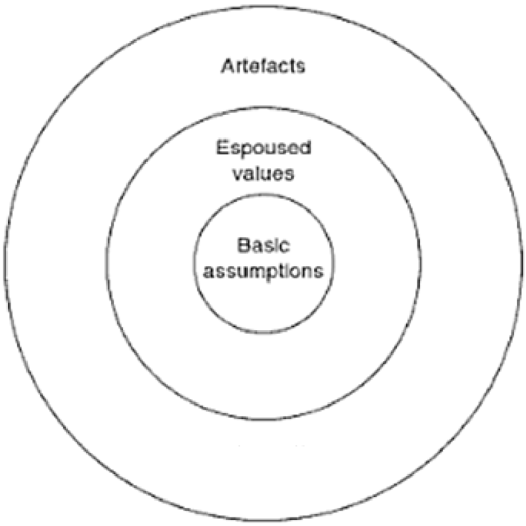
Sensegiving related to values in organisations starts with the top management's understanding of the specific change that they want to implement and the consequences this change will have on the organisation. A change has to have some kind of meaning or purpose which the management have to make sense of. After this stage, the vision of the change is diffused amongst the employees and stakeholders. This is done by conducting workshops or other activities where sense is given from the top management to the employees, who then interpret the information. (Fiss & Zajac, 2006)

As Gioia and Chittipeddi (1991) state in their article, *"the interpretive approach turns on the assumption that human understanding and action are based on the interpretation of information and events by the people experiencing them"* (1991, pp. 435). The better prepared they are, and the more knowledge the top management have about the change, the better they are at giving sense to their employees.

Basic assumptions

Beneath the artefacts and the espoused values, the basic assumptions are found (see figure 1). These are norms and beliefs that guide how we behave and are almost impossible to change. This level is deep down in our subconscious and is therefore hard to spot. (Clegg et al, 2008)

Figure 1: Schein´s model shown three levels of culture where the deepest level represents the basic assumptions which can be described as fundamental norms. (Clegg et al, 2008)



Schein (2004) describes a basic assumption as a theory based on a value which in time becomes taken for granted, or the answer to a problem which can be applied again and again.

Implementing an organisation’s core values as basic assumptions is the ultimate goal since they are then used without question and will in the end drive the decision making process. It is necessary for future employees to easily adapt to the culture at the workplace and have the same sort of basic assumptions, since other behaviours will seem bizarre and inconvenient. Culture can be looked at as a very powerful tool since after a basic assumption is implemented into a system, it is non-debatable and blindly taken for granted and it makes members inside the system vulnerable and uncomfortable if these assumptions would be ignored.

THE CASE

The company TOM is a Swedish construction and civil engineering company founded in the end of 1950s by two brothers. These brothers started out by assisting farmers with sanitation and waste management. In the beginning of 1960 they started a stone crushing plant. The company was further expanded and developed into the construction sector over time. TOM is today one of the largest construction companies in Sweden with over 13,000 employee. It covers a variety of fields in the sector. The company is on the stock market’s A-list and a major player in the Nordic region.

During the last decade, TOM has developed and implemented a framework that describes the company’s corporate values. The framework is known by its acronym: DDPR, the letters standing for Down-to earth, Developing, Personal and Reliable. This framework was developed from a survey conducted, where all employees and customers got to answer what they associated the company with. The framework is outlined in further detail below:

- *Down-to-earth.* Business has to be practical and realistic, both in order to keep the customers satisfied, but also in handling resources and making decisions.

- *Developing.* A successful company grows and evolves alongside society and its needs. Development can be seen as the main key in keeping a company on the top, making changes and being flexible in the direction of improvement. Never neglect an employee’s ideas and competences.

- *Personal.* Honesty and understanding both for customers and employees will make everyone involved feel good, promote a good business atmosphere and an admirable working environment. It will help create trustworthy relationships and good communication.

- *Reliable.* To be dependable in achievements, accurate and honest will show in high work competence and professional qualification. Always being on the right side of laws and regulations and prioritise environmental friendly methods will result in clients’ trust and further business opportunities.

Stated on the company’s website: *“TOM’s core values describe how we are as individuals, what we stand for, how we work, what it is we want to achieve and what we want people to think of us.“*

RESULTS AND ANALYSIS

We have found that a strong corporate culture has been induced in TOM as a result of management's strategy to frame the core values, giving them sense and meaning. Each one of our three interviewees knew what DDPR was, what it meant and why it existed. They all felt that they worked with it at some level. However, each person had a slightly different outlook on it and way of using it.

The business manager, the top of the hierarchy of the interviewees, works with the core values on a day-to-day basis. He has a lot of contact with customers, employees, sub-contractors and clients, and uses the core values when communicating with them. He also emphasizes that the relationship to these are of highest importance which he describes as they *"do not have to earn every crown"*. This makes TOM more focused on cooperation than competition. The business manager believes that the most important core values of the DDPR-framework are Reliable and Personal. *"I like to think big from time to time, and then Down-to-earth can draw you back a bit"*.

The site manager, in the middle of the hierarchy, does not use the core values as actively as the business manager. He noted that the core values have to be described in project plans and also in protocols from meetings with clients, something that he is a part of. He values Down-to-earth the most because he thinks that with this attitude it is possible to approach people both above and below you without difficulties.

The foreman, lowest in the hierarchy of our interviewees, was well aware of the core values but did not use them hands-on in his work. Neither did he see anyone else around him using them, but he pointed out that they are sometimes used in the site jargon and this is more on a humorous basis. However, he stressed the importance of having a corporate philosophy since this made work between different units and levels easier. He thought that the core values supported him when communicating with colleagues. Like the site manager, he finds Down-to-earth as the most important core value, although he finds it a bit hard to define, because it helps you stay on the same level as other people in the company.

There are several ways that TOM has made it possible to implement the DDPR-framework. One is that all the interviewees mentioned the owners and how they have institutionalized the values. Both the business and the site manager feel that they have a personal contact with the owner still active in the company board and that he is approachable. Due to this the interviewees have perceived that the owner's act in accordance with the core values. Even though all the interviewees only have worked at TOM for between four and six years, they all felt they were well integrated with the company history. They felt that the words in the DDPR-framework came after the culture, which they saw as a result of the owners' wish of keeping the culture they had created. Secondly, an induction course that has a strong focus on the core values also helps implement the framework. This course goes on for one or two days and it is compulsory for all new employees. However, two of the interviewees encountered the core values before the introduction course. They stated that they first heard about them during their employment interview. Finally, there seems to be a constant information flow about the core values since they are integrated in protocols, plans, reports, the company magazine and other corporate documents.

DISCUSSION AND CONCLUDING REMARKS

The interviews have shown that the core values do permeate throughout the organisation and that they affect how the employees conduct their work. As the business manager explained, it took him half a year before he understood that TOM really worked with the core values and did not just use them as symbolic attributes. The theoretical framework mentioned that making the same sense of core values can be tricky due to the fact that it is different people with different basic assumptions who do the sensemaking. It is also evident in the case of TOM that the interviewees have made slightly different interpretations and given different importance to the core values.

However, this might not be strange considering their work roles and the environment they act in. It is not surprising to find that the business manager sets Reliable and Personal above the others while the foreman and the site manager values Down-to-earth the most. The business manager communicates with a lot of actors for TOM and it is important for him to have a trustworthy relationship with all of them. In other words, his work is to a large extent directed outwards. In contrast, the foreman and the site manager, who are working on site, have relations more solely within the company and have to give more direct orders to sub-ordinates. Therefore it is important that they communicate on the same level as these.

The case also shows that the interviewees use the core values to a different extent when conducting their work. However, what is most important might not be how the core values are used, but the fact that they are being used and that they have been implemented to such a degree that all employees are aware of them. This is also congruent with Jaakson's theory, that core values are highly accepted.

This case has provided examples of how core values can be successfully implemented so that they permeate throughout an organisation. The introduction course can be seen as a strategic opportunity for the company to present the framework of core values, which acts as the sensegiving part of this case. This makes the employees aware of the company's way of working quickly. After the framework has been given it is up to the employees themselves to do the sensemaking. This is facilitated by the fact that a lot of the documents contain the core values. As the site manager mentioned, even the company magazine describes and phrases the core values in connection with the company's work.

Strong owners are also a reason for how the values have been institutionalized in the company, as Jaakson's theory suggests. Furthermore, the way the owners work and act is perceived as giving substance to the words that describe the core values. As the interviewees mentioned, they feel that the framework is connected to the company's history. This could be explained by the fact that the core values came from a survey taken by customers and employees. Their answers reflected what they thought of the corporate culture which that to a large extent comes from the owners.

All of our interviewees emphasized the importance of having an intelligible communication with work colleagues both above and below them in the hierarchy. In addition, they feel that it is the core values that guide them when approaching actors for TOM. This can be seen as a foundation for equal treatment within the company, which also gives a strong image of the company to people outside the organisation. TOM has chosen core values which the employees can recognize from their own basic assumptions. Looking to the meaning of the core values and bearing the context in mind, we can see that the way they are made sense of is in connection to moral and ethical principles. These in turn reflect deep basic assumptions that can be found within our national culture. As stated earlier, Schein (2004) argues that the ultimate goal for an organisation would be to implement the core values as basic assumptions. The company in our study seems to be on the right way of accomplishing this.

Core values can be a part of a company's trade mark and it has been shown that they can be an important piece in the relationship to actors both within and outside the organisation. The framework serves as a tool that helps shape the company on all levels. Therefore a strategic choice of core values is to choose such that people can relate to through their own basic assumptions. If this is achieved, the result can be both a strong coherent image of the organisation as well as a governed way of working.

The empirical ground for this research is based on one company and its use of core values. The study indicates that there could be a correlation between these and corporate identity. However, the concept of core values is wide and therefore further research is necessary to provide any substantial conclusions. More companies should be investigated and compared in order to discover if the correlation between core values and identity is strengthened or disproved. Other methods in addition to interviews should also be included, such as observational studies and questionnaires. As a starting point for this, the question if there are similarities between different companies due to their use of core values could be brought up. Are the same methods of implementation used? If not, are some methods more effective than others?

LIMITATIONS

This case is based on interviews with three different employees of one corporate construction company and the conclusions were made accordingly. However, we do concede that this case study does have some significant limitations. The interviews were performed in English, which does not represent the interviewees' mother tongue. Therefore the language became a barrier since the employees were not used to speaking English, so they could not express themselves fully.

In order for this research to be more reliable, holistic and comprehensive we would like to have interviewed staff from all levels of the hierarchy of the construction company as well as people outside the company. It would also benefit the research if we could follow-up the first analysis of the interviews with new questions.

Even though workshops about DDPR have been held and everyone knows about the concept, the risk still remains that the interviewees express how they have been told to work with the core values rather than how they actually work.

Finally, the data collected from articles is limited and therefore the subject in this research can be investigated further. The theoretical framework deals with one perspective of corporate identity that might be a bit simplified. To achieve a more realistic view, this study would benefit from supplementing research that take other perspectives in mind to see whether or not these findings would complement the results in this paper.

REFERENCES

Clegg, S., Kornberger, M. & Pitsis, T. (2008). *Managing & Organisations – An Introduction to Theory & Practice*. Second edition. London: Sage.

Fiss, P.C. & Zajac, E.J. (2006). The symbolic management of strategic change: sensegiving via framing and decoupling. *Academy of Management Journal*, **49**(6), 1173-1193.

Gioia, D. & Chittipedd, K. (1991). Sensemaking and sensegiving in strategic change initiation. *Strategic Management Journal*, **12**, 433-448.

Hill, C. & Jones, G. (2008). *Strategic Management Theory: An Integrated Approach.* Webpage accessed 18-12-2010 at: http://books.google.com, search for title.

Jaakson, K. (2010). *Management by values: are some values better than others?* Webpage accessed 25-11-2010 at: http://www.emeraldinsight.com/journals.htm?articleid=1881779&show=html

Klakegg, O. (2009). Challenging the interface between governance and management in construction projects. In: *5th Nordic Conference on Construction Economics and Organisation*. Reykjavik, Iceland, 10-12 June 2009.

Schein, E. (2004). *Organizational culture and leadership*. Third edition. San Francisco: Jossey Bass – A Wiley Imprint.

THE STUDY OF A KITCHEN ASSEMBLY PROCESS IN INDUSTRIALIZED HOUSING

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The kitchen is the heart of the house where people spend much of their time. It is, therefore, an important room that requires high quality. Because construction is argued to be unproductive and wasteful with low quality, studying a kitchen assemblage in detail is of particular interest due to its complexity with many details. In lean, the visualization and transparency of processes is the core for waste reduction and improvement. Low productivity levels are often argued to depend on a lack of information about the root causes of process problems. Thus, more information about the installation process of kitchens by studying the process is needed to target the sources of problems in terms of waste. The purpose of this paper is to gain a further understanding of how value stream mapping can be used to identify different types of waste that occur when acquiring and installing kitchens. Value stream mapping is carried out through observations and interviews at an industrialized timber house manufacturer. Data analysis resulted in information about inconsistencies in the kitchen installation process, i.e. the root causes of costs and delays for the entire housing project.

KEYWORDS: industrialized housing, waste, kitchen assembly, value stream mapping

INTRODUCTION

The housing construction industry in the West has long been accused of being wasteful and underperforming, where quality is often poor and the building times are long and costly with endless corrections to defects after completion (Latham, 1994; Egan, 1998; London & Kenley, 2001; Briscoe *et al*., 2004). Houses are "unique products of art" (Bertelsen, 2004, p.51) with an undocumented and complex production process (Gidado, 1996; Winch, 1998), considered as craft production (Barlow, 1999). This makes it hard to control the process and its outcome. In contrast, the manufacturing industry is more efficient. Therefore, the housing construction industry has been advised to learn from manufacturing and in particular lean production to become more efficient (Koskela, 1992; Ballard & Howell, 1994a, b; Gann, 1996; Koskela; 2000; Ballard *et al*. 2001; Bertelsen, 2004).

In industrialized timber housing constructed with volume elements, 80% are made inside a factory (Stehn et al., 2008). Thus, standardized industrial procedures replace much of the craftsmanship procedures. The volume elements are standardized parts made by industrial workers using automated production, though specialized craftsmen still make the interiors. The procedure of installing kitchen cabinets is a complex assemblage with many details. The purpose of this paper is to gain a further understanding of how value stream mapping can be used to identify different types of waste that occur when acquiring and installing kitchens.

THEORETICAL FRAMEWORK

Lean thinking

"Lean" has been frequently discussed in the Western construction industry during the last 15 years (Koskela, 1992; Ballard & Howell, 1994a, b; Gann, 1996; Koskela; 2000; Bertelsen, 2004). The reason is that house construction, as most other industries, is an industry in need of high variety and high efficiency to satisfy demand. Many writers, e.g. Koskela (2000), argue that lean is the "medicine" to make this come true through lean construction. Lean is a business system that originates from Japan (Womack *et al*., 1990). It all began when Taiichi Ohno, a Japanese businessman, visited a Ford factory in the USA and became impressed by its fast assembly. However, through studies of the Ford factory, Ohno saw waste, the worst of which was all the unfinished cars that required rework after leaving the expensive, non-stoppable production line of Ford (Womack *et al*., 1990). Therefore, Ohno created the Toyota Production System, known to the world as lean production.

The core of lean is to reduce all forms of waste in a process (Ohno, 1988; Womack *et al*., 1990). Ohno (1988) identified seven types of waste, described in Table 1 below.

Table 1: Seven wastes (Ohno, 1988)

Type of waste	Explanation
Overproduction	Producing products not demanded by customer
Defect products	Producing incomplete or faulty products
Unnecessary movements	Moving around of people
Waiting	People not working
Unnecessary transports	Moving around of material
Excessive stock	Raw materials, semi-finished or finished goods not in process
Unnecessary processes	Extra work on products not required by customer

This original classification from Table 1 has also been accepted by lean construction scholars (Mossman, 2009). In lean, value is determined by what the customer is willing to pay for, what Ohno (1988) defines as "real work", the rest is waste. Therefore, all waste must be banished to maximize value. Rother & Shook (2003) argue that value stream mapping (VSM) is an excellent tool to identify waste.

Value stream mapping (VSM)

A tool within lean, value stream mapping (VSM) is used to visualize a *value stream* on a large-scale map and measure value in relation to waste (Rother & Shook, 2003). The total value stream is a series of actions that are required to bring a product through the flow from raw materials to the customer (Abdulmalek and Rajgopal, 2007; Rother and Shook, 2003). Still, mapping the total value stream is an extensive task and Rother & Shook (2003) argue that the value stream from the incoming truck to the outgoing truck of a manufacturing company is the most critical to begin with. Therefore, it is the value stream from incoming to outgoing truck that will be treated in this paper.

How to carry out VSM

According to Tapping *et al*. (2002) and Rother & Shook (2003), the procedure of conducting VSM is basically, through the use of pen and paper, to draw all the materials and information flows of a product starting with outgoing truck and ending with incoming truck to immediately see the root cause of actions. The product chosen should be one in need of an improved flow. When value stream mapping is visualized on a large scale, it is possible to see where value is created and find sources of waste. This first map is called the current state map. The map is then changed into a future state map that represents the ideal production process. Rother & Shook (2003) also propose a definition of a working plan with a follow-up to reach the future state. In this paper, a product in need of an improved process flow is chosen (here kitchen cabinets) and the value stream of the product is drawn from incoming to outgoing truck. Waste is then identified through the mapping. However, the preceding steps from Tapping *et al*. (2002) or Rother & Shook (2003) concerning future state mapping, etc. are not treated.

Potentials in using VSM

Many writers see great potential in the use of VSM. Álvarez *et al*. (2009) and Rother & Shook (2003) believe that the value stream mapping (VSM) tool is effective and provides both a good communication tool for practitioners and a reference model for theoretical analysis. Pavnaskar *et al*. (2003) emphasis the advantage of analysing the current state through the visualization of the relationship between material and information flows. They argue moreover that systemic vision provided for a product’s flow reflects manufacturing system inefficiencies and can be the starting point of a strategic improvement plan.

Limitations with VSM

There are, nevertheless, also limitations with VSM. VSM requires a massive data collection that must be repetitive to be worth the effort. Construction steps are often lengthy with high variability, making it difficult to collect meaningful data. Braglia *et al.* (2006) comment that VSM is a suitable tool for mapping the production processes of ‘low variety-high volume’ type companies. However, many companies are actually rather of a ‘high variety-low volume’ type with complex processes, where a VSM application will fail because of the inherent multiple flows. Another problem, as Kawasala *et al*. (2001) note, is that VSM lacks an economic measurement for “value”. Moreover, it is a paper-and-pencil based technique, so its level of accuracy is limited (Braglia, 2006).

Still, house construction is regarded as repetitive enough to benefit from VSM (Yu *et al*., 2007). Previous research of VSM in house construction has been conducted in onsite construction (e.g. Yu *et al*., 2009), but not in factory-build houses. Hence, the use of VSM in factory-built houses is considered important and relevant.

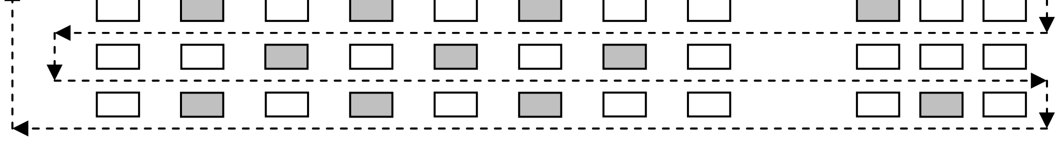
METHOD

A critical case study (Flyvbjerg, 2006) was chosen as an example of a housing factory that has emerged towards becoming a lean enterprise and thus a model for other house builders. The factory builds multi-storey timber houses through the construction of volume elements. Kitchen cabinets that are installed into the volume elements were chosen for the value stream mapping process (see Figure 1). The craftsmen installing the kitchen cabinets were observed for three months. During this time, all the steps in the kitchen assembly process, from delivery of the cabinets to assembled kitchens leaving the shop floor, were identified.

Figure 1: Kitchen installation in a volume element

The installation of the cabinets was rather complex and consisted of several steps that were observed in detail over several weeks. Thereafter, the cycle time for all of the different installation steps for 10 kitchens was measured. The operation times were measured by observing the kitchens for eight days during factory working hours 6.30-16. Each kitchen was observed every 15 minutes and how far the installation of the cabinets had proceeded was noted. Visiting the kitchens every 15 minutes was done systematically (see Figure 2).

Figure 2: Path of making observations in the three production lines

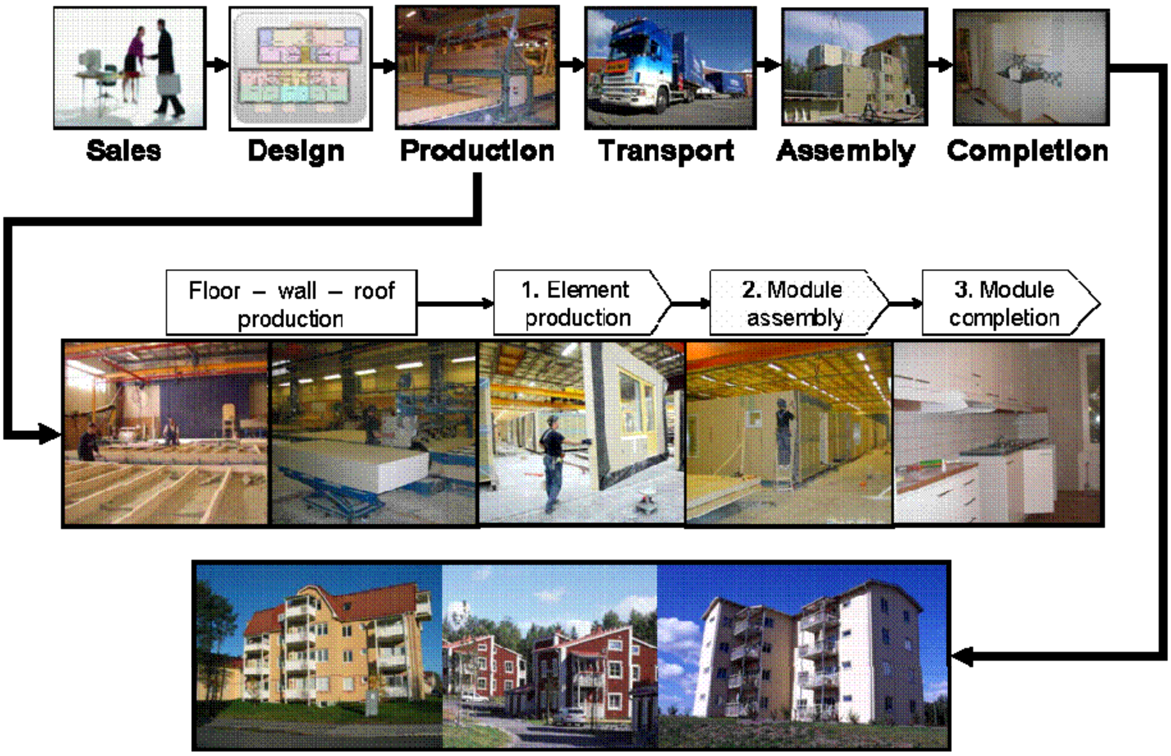


Three production lines of timber volume elements were observed where every second or third element contained a kitchen, shown as shadowed squares in Figure 2. Ten craftsmen were observed and interviewed, and asked the five whys to get to the bottom of problems. The five whys method means asking “why?” to someone five times about a cause to pin-point the source of problems (Ohno, 1988). The cycle times and waiting times were then plotted into a value stream mapping diagram (see Appendix).

CASE STUDY: INDUSTRIALIZED HOUSING FACTORY

The company studied is a housing factory in Sweden with a turnover of approximately 50 M€. The company produces multi-storey timber houses of two to six floors. At present, the company is in the process of implementing lean throughout the entire organisation.

Figure 3: The production of industrialized housing (our scope is in the module completion process)



The value stream mapping process started through the identification of the different kitchen installation steps and the start and end of the process. The different installation steps in production were identified as arrival, sorting, carpentry, tiling, electrical installations, plumbing, air check and preparation for transportation. Once identified, all the steps were studied in detail.

Arrival of cabinets

The cabinets arrived by truck every Tuesday morning, and the cabinets were placed outside the storage room. The time was measured for the unloading of the cabinets and estimated to an average of 15 minutes per truck load.

Sorting of cabinets

After the cabinets arrived, they were placed inside the storage room and sorted depending on which department they belonged to. All of the small pieces that fasten the cabinets to the wall and ceiling, belonging to each of the departments, were sorted according to type. The cabinets were then gradually moved down to be quickly accessible for transportation to the production line. The small pieces were sorted again according to their approximate usage for the specific kitchen. However, many of the small pieces were disposed of.

Carpentry

The process of installing the cabinets into the volume elements starts by measuring where the upper cabinets should be placed. A supportive board is placed to facilitate attachment of cabinets to the wall. The cabinets are then installed one-by-one and attached to each other where any accessible timber frame inside the wall is lacking. When installation of the upper cabinets is complete, it is time to install the lower cabinets. These cabinets have feet to create a space between them and the floor. The process of installing the lower cabinets begins by attaching the feet under the cabinets. A supportive board is attached to the side of the wall before putting the first cabinet in place, creating a space to open the cabinet door. The cabinets are installed one-by-one just as the upper cabinets. However, the cabinet under the sink is different, since holes must be drilled for the plumbing and electrical installations before installation. When all the cabinets properly installed, it is time to attach the sink. To attach the sink, glue is placed around the edges and the sink is pressed into place. Tools hold the sink in place as it is attached further with screws. The carpentry around the cabinets and the countertop are then put in place. This is the longest phase, since the pieces have to be cut to exactly fit the spaces. Running back and forth to the saw on numerous occasions is common here. One carpenter said, “Once I put a step counter in my pocket and it showed that I walked 3 km during one workday in the factory”. This shows many movements during the carpentry. All the edges are then sealed with silicon suture and tippex is used to cover the spots. After, the doors are attached and adjusted to the cabinets. The whole installation phase takes 11 hours.

Tiling

Tiles in the kitchens between the upper and lower cabinets are called the splashboard. A prerequisite before beginning the tiling is that the countertop, sink and upper cabinets are already installed. The process begins by applying mortar to the wall, and then applying the tiles to the mortar. Tiles lacking the appropriate size are cut to fit. A thread is placed underneath to create a space for the silicon suture. The tiling takes around 2.5 hours.

Electrical installations

A sub-contractor carries out the installation of electrical sockets. Drawings of where the electrical sockets should be placed guide the electrician. The electrician prepares a box of electrical sockets and installs them in the kitchen. Each kitchen has an average of 10 electrical sockets. If the placement of the electrical sockets is accessible, a socket installation takes approximately 5 minutes. However, the sockets are occasionally placed in hard-to-access areas, e.g. inside a narrow cabinet under the refrigerator, and installation then takes approximately 15 minutes. The electricians complete a form when the electrical installations have been made. However if the tiling has not already been made, all sockets cannot be installed. Depending on the number of sockets and their accessibility, the time for electrical installation varies from 30 minutes to 2 hours.

Plumbing

The plumbing is carried out by the house manufacturer’s own plumbers. The work of installing pipes below the sink does not vary greatly between kitchens. The only prerequisite before installing the plumbing is that the sink is installed. The plumber installs the tap and the pipes connecting the tap to the pipes, which penetrate the floor from below. Installation of the pipes and tap takes approximately 30 minutes.

Air check of pipes

The pipes are exposed to an air pressure of 1.5 bars for at least 30 minutes to ensure no leaks. Before exposure, all pipe-ends are sealed and the closures are removed after testing. A visual quality control of the pipes is made after the air test. The whole procedure of testing and controlling the pipes takes about 1 hour and 30 minutes.

Preparation for transportation

At the end of the production line, the volume elements including the kitchens are controlled before transport to the warehouse. At the quality control station, a check is conducted that all the cabinets are installed with no missing parts, that the electrical installations and plumbing have been made, and that there is no damage. Missing materials are documented in an online system connected to the purchasing department. Incomplete kitchens are often caused by customers not making choices on-time. Borders between volume elements can sometimes be a hindrance for some cabinets to be installed which prevents the execution of subsequent steps. This workstation also has the responsibility to sweep the floors and remove garbage that other workers have left behind and add some extra silicon suture where needed. The quality control takes approximately 45 minutes. The volume elements then exit the factory in a special order to facilitate assembly.

ANALYSIS

During the observations of the process of kitchen installations, different kinds of waste were found. The waste found in each of the installation steps will hereby be described.

The beginning of the process, as previously mentioned, is the arrival of the truck with cabinets. After the cabinets are discharged from the truck, they are not immediately put into their proper places, but aside, outside the warehouse. This causes unnecessary extra transport later when bringing them inside the warehouse, which is a form of waste.

The cabinets and adjoining pieces are then sorted. Here, the pieces are sorted twice, first according to type and thereafter to a specific kitchen. This is waste in terms of the unnecessary transport of materials. Moreover, the cabinets had to be moved around in the warehouse due to the lack of space, which also is a waste.

Carpentry is the most time-consuming step in the process of kitchen installation, accounting for approximately 40 per cent of the total production time. The calculation is based on data in the Appendix for cycle time of the processes. Carpentry is probably the most non-standardized and skill-intensive work compared to other steps in kitchen installation. The carpentry procedure of kitchen installations is not a standardized industrial process at present, it requires skilled carpenters. Therefore, the pace and quality of the work depends on the person's ability to structure the work and evaluate quality. Working independently can be a source of waste because of a lack of coordination, communication and motivation, which are necessary to drive up the pace of production. When observing the carpentry, many issues were discovered, such as half-finished kitchens that had to be further worked upon on-site. The causes were many, such as inadequate drawings, the customers' choices were not available and parts were missing, or the volume elements had borders that prevented complete cabinet installation. The carpenters moved around a great deal to saw the pieces, putting into questions the placement of the saw and the accuracy of measurements of the volume elements. After installation, the cabinets were constantly in need of finishing, such as silicon suture and tippex to hide defects.

Tiling, electrical installations, plumbing and the air check of pipes were all rather quick steps considering the total process time. In these processes, no waste was detected other than the lack of communication with upstream and downstream workers, which could cause interruptions of the production process. Although the activities themselves did not have any waste, if all the cabinets including the sink were not installed, most of these activities could not be executed. This caused half-finished kitchens without any activity for many hours, taking up space while waiting to be transported out of the factory.

The last step is the preparation for transport of the volume elements and ensuring that everything is included or backordered. Controlling this at the very end can be regarded as waste, because it is in fact rework of the previous quality checks. Everything should already have been completed! However, due to the inconsistencies in the process, it is necessary with this control.

In Table 2, different wastes detected in the process are categorized into the different kinds of waste that Ohno (1988) describes.

Table 2: Wastes detected in the process

Type of waste	Where waste is found in the process
Overproduction	There was no overproduction detected. Everything is make-to-order/engineer-to-order.
Defect products	The factory produces incomplete kitchens because the customers' choices were not available so parts were missing or the drawings were inadequate. The volume elements have borders that sometimes prevent complete installation of the cabinets. The cabinets need finishing, such as silicon suture and tippex to hide defects.
Unnecessary movements	There are a lot of movements to walk back and forth to saw new pieces and make the cabinets fit inside the volume element.
Waiting	As the carpenters are multi-skilled, they normally do not have to wait to assess a task. There are always different tasks ready for execution. However, when drawings are unclear, carpenters have to wait for instructions.
Unnecessary transports	The kitchen cabinets are moved around in the warehouse three times before reaching the assembly line.
Excessive stock	There are a lot of semi-finished kitchens waiting for the next step. A lack of communication between upstream and downstream workers can sometimes cause interruptions in the production process.
Unnecessary processes	Control of all previous craftsmen's work at the end of the line.

CONCLUSIONS

Value stream mapping with detailed observations of the product flow through the factory is valuable for detecting waste. By writing down the process on paper, the process is visual for discussion. Otherwise, undocumented processes can be interpreted differently by different people in the organisation. Hence, management may not be aware of the problems that cause waste and costs in a process on the shop floor might not be detected. To systematically follow a process is lengthy, though a deeper knowledge is obtained than assuming the character of the value stream through second-hand descriptions.

In this study, waste occurred mainly in terms of defect products, e.g. the products were unfinished when leaving the factory. Ohno (1988) saw this as the worst waste when studying Ford. It becomes rather expensive to fix all the completions afterwards. The roots of the problems were inadequate drawings and customers not making choices on-time. Through enforcing choices to be made on-time and avoiding cabinet being placed on borders between the volume elements, the kitchens can all be completed in the factory. This saves a lot of money in extra work and transports to the final location of the house.

The inaccurate sizes of the volume elements require an extensive amount of sawing when installing the kitchen cabinets. By placing the saw closer to the carpenter or working on improving the accurateness in size of the volume elements, the waste in form of unnecessary movements can be eliminated.

Since there is a problem with unclear drawings, standardizing and documentation of “best practise procedure” of installation with improved drawings and proper work instructions can make the installation process more efficient. Hence, instant comprehension in how to proceed with the next task can be achieved and waste in terms of waiting is eliminated.

There is waste in terms of unnecessary transports inside the factory. When the cabinets arrive, they should be placed at a given place until it is time for installation. This prevents damages and waste in terms of rework when moving them around the factory.

The semi-finished kitchens could be finished faster to prevent bottlenecks if a signal system is installed to signal downstream workers to prioritize the most critical work tasks. This prevents waste in terms of excessive stock and delays in the process.

If all the workers do self-check of their own tasks and report errors of their own work, the quality control could be eliminated and inconsistences in the process can be better visualized through everyone’s participation in improving the process and quality of the kitchens.

It can be concluded that a detailed study of the production process is important for process improvement. Without a close study of the value stream in progress, there is a lack of understanding regarding wastes that become hidden costs in the process.

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REFERENCES

Abdulmalek, F.A. & Rajgopal, J. (2007). Analyzing the benefits of lean manufacturing and value stream mapping via simulation: a process sector case study", *International Journal of Production Economics*, 107, 223-236.

Álvarez, R., Calvo, R., Peña, M. & Domingo, R. (2009). Redesigning an assembly line through lean manufacturing Tools. *International Journal of Advanced Manufacturing Technology*, 43, 949-958.

Ballard, G. & Howell, G. (1994a). Implementing Lean Construction: Stabilizing Work Flow. *Proceedings of the 2nd Annual Conference of the International Group for Lean Construction*, Santiago, Chile.

Ballard, G. & Howell, G. (1994b). Implementing Lean Construction: Improving Performance Behind the Shield. *Proceedings of the 2nd Annual Conference of the International Group for Lean Construction*, Santiago, Chile.

Ballard, G., Koskela, L., Howell, G. & Zabelle, T. (2001). Production System Design in Construction. *Proceedings of the 9th Annual Conference of the International Group for Lean Construction*. Singapore.

Barlow, J. (1999). From Craft Production to Mass Customisation. Innovation Requirements for the UK Housebuilding Industry. *Housing Studies*, **14** (1), 23-42.

Bertelsen, S. (2004). Lean Construction: Where are we and how to proceed? Lean Construction Journal. **1**, October.

Braglia, M., Carmignani, G. & Zammori, F. (2006). A new value stream mapping approach for complex production systems. *International Journal of Production Research*, 44 (18-19), 3929-3952.

Briscoe, G.H., Dainty, A.R.J., Millett, S.J. & Neale, R.H. (2004). Client-led strategies for construction supply chain improvement. *Construction Management and Economics*, **22**, 193-201.

Egan, J. (1998). *Rethinking construction.* DETR, London.

Flyvberg, B. (2006). Five misunderstandings about case-study research. *Qualitative Inquiry*, **12** (2), 219-245.

Gann, D. (1996). Construction as a manufacturing process? Similarities and differences between industrialized housing and car production in Japan. *Construction Management and Economics*, 14, 437-450.

Gidado, K.I. (1996). Project complexity: The focal point of construction production planning. *Construction Management and Economics*, 14, 213-225.

Khaswala, Z. and Irani, S. (2001). Value Network Mapping (VNM): visualization and analysis of multiple flows Value Stream Maps. *Proceedings of the Lean Management Solutions Conference*, St. Louis, 2001.

Koskela, L. (1992). *Application of the New Production Philosophy to Construction*. Technical Report # 72, Center for Integrated Facility Engineering, Department of Civil Engineering, Stanford University, CA.

Koskela, L. (2000). *An exploration towards a production theory and its application to construction*. VVT Technical Research Centre of Finland.

Latham, M. (1994). *Constructing the Team*. HMSO, London.

Lessing, J., Stehn, L. & Ekholm, A. (2005). Industrialised housing: definition and categorization of the concept. *Proceedings of the 13th Annual Conference of the International Group for Lean Construction,* Sydney, Australia.

London, K.A. & Kenley, R. (2001). An industrial organization economic supply chain approach for the construction industry: a review. *Construction Management and Economics,* **19** (8), 777-788.

Mossman, A. (2009). Creating value: a sufficient way to eliminate waste in lean design and lean production. *Lean Construction Journal*, **5**, 13-23.

Ohno, T. (1988). *Toyota Production System: Beyond Large-scale Production*. New York: Productivity Press.

Rother, M. & Shook, J. (2003). *Learning to See – Value-Stream Mapping to Create Value and Eliminate Muda*. Cambridge: Lean Enterprise Institute.

Stehn, S., L.-O. Rask, L., Nygren, I. & Östman, B. (2008). *Byggandet av flervåningshus i trä: Erfarenheter efter tre års observation av träbyggandets utveckling.* Technical report. Luleå University of Technology

Tapping, D., Luyster, T. and Shuker, T. (2002). *Value Stream Management*, Productivity Press: New York.

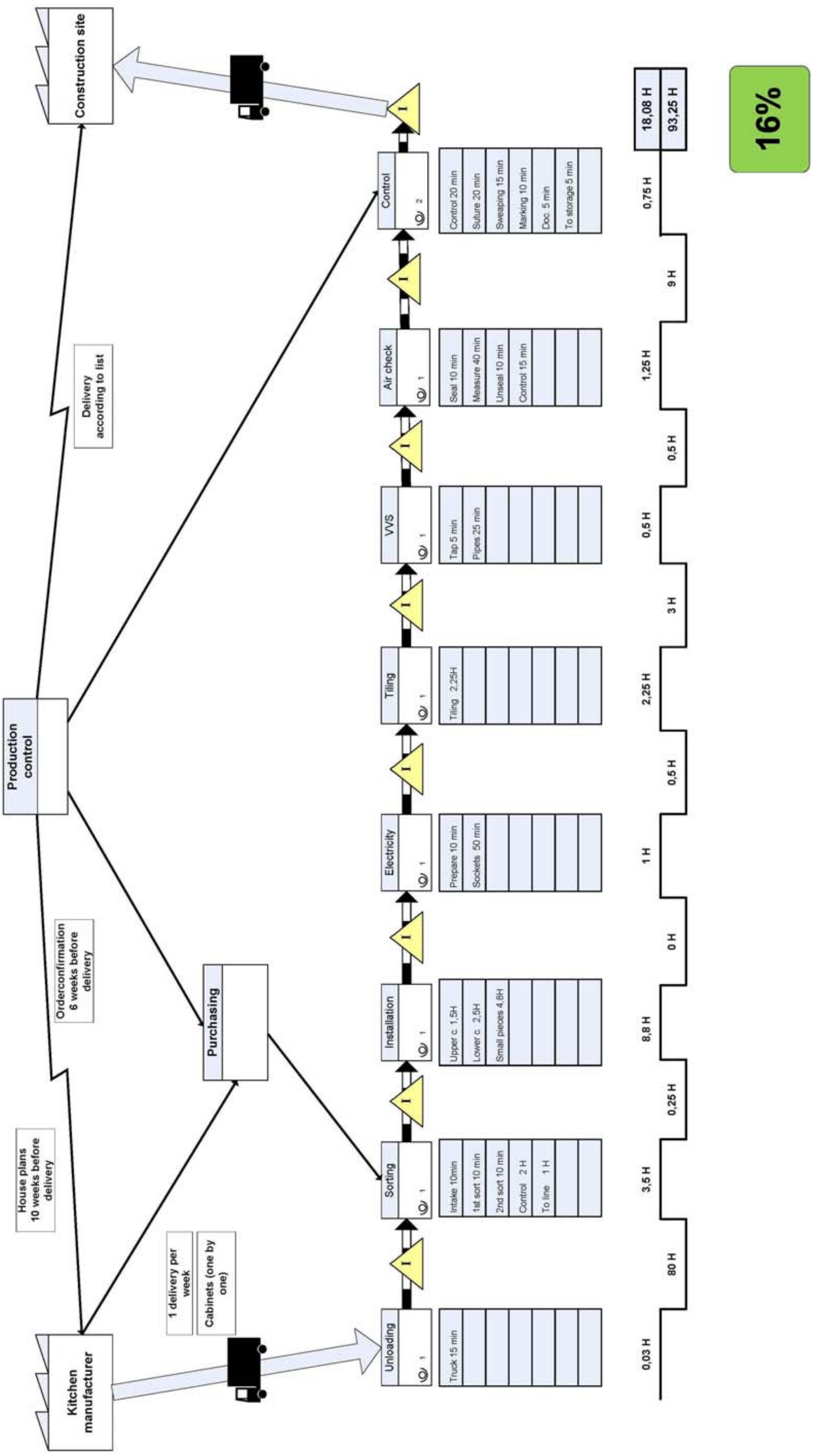
Winch, G. (1998). Zephyrs of creative destruction: understanding the management of innovation in construction. *Building Research and Information*, **26** (5), 268-279.

Womack, J. P., Jones D. T. & Roos, D. (2007). *The Machine that changed the World.* Free Press.

Yu, H., Tweed, T., Al-Hussein, M. & Nasseri, R. (2007). Management variability in house production. *Proceedings of the 15th Annual Conference of the International Group for Lean Construction,* Lansing, Michigan.

Yu, H., Tweed, T., Al-Hussein, M., and Nasseri, R. (2009). Development of lean model for house construction using value stream mapping. *Journal of Construction Engineering and Management*, **135** (8), 782-790.

APPENDIX


Construction site
Kitchen manufacturer
Production control
Purchasing
House plans 10 weeks before delivery
Orderconfirmation 6 weeks before delivery
Delivery according to list
1 delivery per week
Cabinets (one by one)
Unloading
Sorting
Installation
Electricity
Tiling
VVS
Air check
Control
Truck 15 min
Intake 10min
1st sort 10 min
2nd sort 10 min
Control 2 H
To line 1 H
Upper c. 1,5H
Lower c. 2,5H
Small pieces 4,8H
Prepare 10 min
Sockets 50 min
Tiling 2,25H
Tap 5 min
Pipes 25 min
Seal 10 min
Measure 40 min
Unseal 10 min
Control 15 min
Control 20 min
Suture 20 min
Sweaping 15 min
Marking 10 min
Doc. 5 min
To storage 5 min
0,03 H
80 H
3,5 H
0,25 H
8,8 H
0 H
1 H
0,5 H
2,25 H
3 H
0,5 H
0,5 H
1,25 H
9 H
0,75 H
18,08 H
93,25 H
16%

THE IMPORTANCE OF ACQUAINTANCES – KNOWLEDGE DIFFUSION IN THE CONSTRUCTION INDUSTRY

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A forgetting-phenomenon seems to exist in the construction industry which causes that useful experience from the construction process to disappear after ended projects. For decades initiatives have been implemented in construction projects in order to develop the construction process, and participants' general impression of such projects has been that the initiatives were useful. Even so, experience from these projects has only left few marks on subsequent projects. This paper seeks an explanation of this phenomenon from the perspective of the skilled workers. They mostly appreciate tacit and practice embedded knowledge, and from this perspective experience diffuses through social settings, whereas the facilitation of knowledge diffusion is focused on explicit knowledge such as written evaluation reports. On the basis of qualitative case research, knowledge diffusion is analysed and unused potential for further facilitation of such is presented. Hence, the conclusion is that there is an unused potential for increased knowledge sharing in the social network among skilled workers in construction projects. There are though some barriers; among others the people involved are not familiar with knowledge exchange or sharing. Therefore, the diffusion of knowledge in the construction industry is so difficult.

KEYWORDS: Construction process, knowledge diffusion, development, communities of practice, weak ties

IT IS THOUGHT-PROVOKING

"It is thought-provoking: This Company brands itself as innovative and professional regarding process management, and yet it handles the construction process very differently from region to region. When such a large company cannot diffuse its experience internally, it is not surprising that the industry keeps re-inventing the wheel during each project".

The above is a quotation from a client and expresses his frustration when working with a nationwide contractor. What is the reason for the limited re-use of experience and knowledge in the construction industry?

Initiatives have for decades been implemented on construction projects in order to develop the process, and usually the involved practitioners find the initiatives useful. Initiatives have included concepts such as: partnering (Bennet & Jayes, 1998; Bresnen & Marshall, 2000; Chan et al., 2006; Erhversfremme Styrelsen, 2000), Lean Construction (Ballard 2000; Bertelsen, 2005; Fearne et al., 2006), and logistics (Bygge- og Boligstyrelsen, 1993). Despite the resources put into implementation the new ideas and the enthusiasm seems to die after end of project without leaving any or rather few marks.

The quality of effort in facilitating project based learning and bringing this learning experience back into the organisation are poor (Keegan & Turner, 2001). Construction companies also view lack of evaluation, common language and knowledge base as a critical issue (Bønnelykke, 2003). One reason for this lack of common knowledge base could stem from the industry being a loosely coupled network of companies (Christensen & Kreiner, 1999). Even in small projects, it is normal to involve several companies, and each company is present in several projects at the same time. This diversity in time and place makes it difficult to support knowledge diffusion in the industry.

However, the answer to this has for many years been to make evaluation reports to summarise the main experience from the projects. The focus in these reports has been on statistics and benchmarks, whereas the reports only have given a vague representation of the experience derived from the projects. It is agreed that evaluation reports seldom are read or even used on subsequent projects. Therefore, it seems like a dead-end solution to keep making reports with the objective of diffusing experience.

This paper focuses on how to facilitate the knowledge of the skilled workers with the objective to support an incremental development of the construction industry. Several different types of knowledge co-exist (Christensen, 2004). Here, the professional knowledge of the workers is not addressed and neither is the object based knowledge which focuses on how to perform. Instead, focus is on the coordinating knowledge and the relation based knowledge used for transforming blueprints into constructions.

Based on findings from a case, this paper first discusses the nature of knowledge used by the skilled workers. Second, different strategies of knowledge diffusion are presented, and finally the challenges when working with knowledge diffusion are discussed with the objective to detect unused potential of the skilled workers as knowledge workers.

CASE DESCRIPTION

The case was monitored for more than three years where qualitative research methods were used to examine learning, knowledge diffusion, and development of the construction process with focus on the skilled workers. As a part of the case study formal and informal interviews were conducted with representatives from the client's organisation, the project manager and the skilled workers at the construction site. Furthermore, observations and action research were carried out in order to understand and support learning and knowledge diffusion activities at the site (Kristiansen & Krogstrup, 1999; Nielsen, 2004).

The case project was the third in a sequence of four construction projects. The client's idea was to use the same team of consultants, designers, contractors etc. for all projects using partnering like methods (Bennet & Jayes, 1998) and Lean Construction planning methods (Ballard, 2000). Moreover, the client took several initiatives to promote a better construction process: In order to facilitate at better informal communication, the client insisted on setting up a common workmen's shed which the skilled workers should use for breaks and meetings and for hosting several social and informal events at the construction site.

The objective was to get more value for money by supporting continuous learning among the participants throughout the four projects. However, due to delays most of the skilled workers were replaced from project 2 to project 3, despite that most of the companies remained the same.

THE NATURE OF KNOWLEDGE AT THE CONSTRUCTION SITE

Much literature addresses the problem of diffusing and managing knowledge. However, the nature of knowledge is seldom addressed which can lead to some confusion because of many different understandings of knowledge.

Tacit or explicit knowledge

Schön (1987) uses the expression "professional artistry" to describe the competence used by practitioners if they experience unique, insecure and conflicting situations, and he underlines that competence are not dependent on our ability to describe or reflect on our acts. Polyani also carries this point that humans often know more than they can tell, Polyani in (Smith, 2003). Brown and Duguid (1998) make a distinction between know-what and know-how. Where know-what embrace the explicit knowledge, which easily can be shared with others, know-how is how know-what is brought into practice. This distinction is also seen in Ryle's work in "The Concept of Mind", (Ryle, 1949). This leads to a differentiation between knowledge we can express, explicit knowledge, and knowledge that we cannot express but only act upon, tacit knowledge.

Tacit knowledge is highly personal and hard to formalise, which makes it hard to communicate or to share with others. Traditionally, explicit knowledge has enjoyed privileged status in western culture (Blackler, 1995), an moreover, much theory on learning and training courses values this abstract knowledge over actual practice (Brown & Duguid, 1991).

However, knowledge is not merely something substantial that can be passed on to others, and more and more view knowledge as primarily tacit and deeply rooted in an individual's actions and experiences (Nonaka & Takeuchi, 1995). It seems that more and more value tacit knowledge as a way to develop practice, and some even ague that this form of knowledge is the only usable in order to improve production flow. This perception of knowledge as something embedded in practice implies that knowledge is not stored in brains, books or information systems (Elkjær, 2005; Gherardi et al., 1998).

In summa, knowledge is either tacit and practice based, which makes it hard to communicate, or abstract and relatively easy to transfer. However, some claim that knowledge cannot be divided into classes. It is also claimed that it is not possible to split the subject who know from the object known. This is compared to separation of mind and body, which is also known as the Cartesian split (Nonaka & Takeuchi, 1995). It is claimed that the one form of knowledge could not exist without the other.

The case reveals great diversity in knowledge used by the skilled workers. Some relied mostly on tacit knowledge; there was a sense of "that is how things are done here", and some explained that they liked to know what to do without having to discuss it. Explicit work descriptions would have made them feel like machines. Instead they acknowledge that each new project started with a couple of weeks were work routines had to be adjusted. Others were more likely to use explicit knowledge, while discussing their work situation. However, this discussion also included quite a bit of tacit knowledge as they often knew each other very well. But almost none used formalised knowledge such as blueprints and written documents as media for communication.

Collective or individual knowledge

Literature on organisational learning often discuss if knowledge is held by individuals or collectives, and how learning can be transferred from individuals to organisations (Elkjær & Walgren, 2006). In general, literature on organisational learning is concerned with new routines and procedures based on new knowledge (Örtenblad, 2002). Whereas former organisational learning focused on how individuals learn as agents for the organisation (Argyris, 1992), recent literature on organisational learning also perceives learning as a collective process (Örtenblad, 2001). Literature on work-based-learning also assumes that individuals acquire knowledge cognitively and then put it into practice (Fenwick, 2005). However, another option is that knowledge is held by individuals and put into social context, where the individuals are nodes in a network memory (Lindkvist, 2004a). So, various perceptions as to whether learning is an individual or social process exist (Illeris, 2000), this perhaps also affects the discussion on whether knowledge is individual or social.

Some argue that experience at work creates its own knowledge, and as most work is a collective and cooperative venture it follows that most dispositional knowledge is intriguingly collective (Brown & Duguid, 1998; Yanow, 2000). In other words: because we live in a collective context knowledge is also social (Gomez et al., 2003). In recent years this perspective has become more popular in connection with the increased focus on practice-based learning (Nicolini et al., 2003; Wenger, 2003).

The earth construction workers in the case studied frequently met in the workmen's shed for breaks, and at first glance it seemed like they stayed for longer breaks in the shed to chat. But listening to what they talked about showed otherwise. They continuously made narratives sometimes illustrated by a drawing on a napkin to remember their job process: what they had done, what they ought to do next and situations requiring special attentions. They repeated the story over and over again to remember the details.

Knowledge at the construction site

In order to choose a strategy for managing knowledge in the construction industry, it is highly important to understand the nature of this knowledge. Through hermeneutic analysis of qualitative material collected at the case-project, the following table was created, see table 1. It represents differences in crew composition, learning style and valued knowledge type in different crews in the case.

Table 1: Learning styles and knowledge type of four different types of crews.

	Concrete Workers	Carpenters	Installation (Electrician and plumber)	Earth workers
Crew composition	Stable. Varies only if need of resources varies.	Stable for decades.	Varies according to available resources and needed competencies.	Highly unstable. Can vary from hour to hour.
Learning style	Learning by doing.	Learning by doing, discussions and reflections.	Learning by doing and supplementary training.	Learning by doing and by piecing knowledge together.
Knowledge type	Tacit, social and highly embedded in practice.	Tacit, verbal, social and embedded in practice.	Tacit, explicit and embedded in practice.	Tacit, verbal and highly embedded in practice.

As table 1 illustrates, most workers learn by doing, which primarily leads to tacit knowledge.

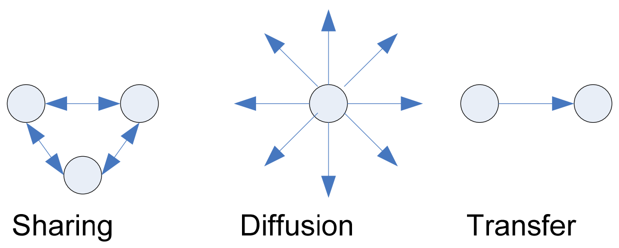
Especially the concrete workers' and the carpenters' crews can be perceived as social learning settings, whereas installations are more individually learners due to use of more explicit knowledge in connection with new technologies and supplementary training. The earth workers also learn in social settings, but because they can shift between several projects during a week, they need to use much time on updating their knowledge with their colleagues at the current project. The most significant difference between the concrete workers and the carpenters was the use of verbal communication. The carpenters often discussed alternative solutions on problems whereas the concrete workers perceived verbal communication as distractions from effective production.

THE NATURE OF KNOWLEDGE DIFFUSION AT SITE

Knowledge diffusion is a process, which allows knowledge to be used without having to use the same amount of resources as was necessary to create the knowledge in the first place (Christensen, 2004). There are different scenarios for wanting knowledge diffusion. This paper concentrates on knowledge diffusion from project to project and how it can be supported to avoid that the wheel is reinvented during each new project. The perspective of knowledge diffusion is typically closely connected to the perspective of the nature of knowledge. Nevertheless, this paper seeks an overview and splits knowledge and knowledge diffusion.

When looking trough literature on knowledge and knowledge diffusion several synonyms occur. For some this would be a delightful variation in language, colouring up an otherwise monotone explanation of knowledge travelling from one place to another. Others would perhaps perceive this as a distracting muddle of conceptions. So, to avoid confusions some definitions will be made for use in this paper. Diffusion is used as an umbrella term for knowledge travelling from origin to an unnamed recipient(s). Sharing is when individuals in collective exchanges knowledge, whereas transfer implies a direction, see figure 1.

Figure 1: Illustrations of knowledge sharing, diffusion and transfer



In the following, different strategies for knowledge diffusion are presented and related to findings from the case with the objective to find explanations to why the knowledge diffusion in the construction industry is limited and to find new methods for facilitating incremental development based on the experience of the skilled workers.

Transfer of explicit knowledge

Traditional knowledge management programmes focus on acquisition, codification and transfer of knowledge. One objective is to separate knowledge from the "knower" in order to prevent knowledge to disappear with the employer. Another objective is to be able to communicate the knowledge to non-participants by documenting the experiences from the project (Schindler & Eppler, 2003).

This tradition is also reinforced by the introduction of computer technologies capable of storing and processing extensive amounts of data. In a project environment, this tradition of documentation has lead to end-evaluations made by consultants, because the participants have moved on to the next project. Furthermore, project documentation tends to emphasise status more than learning outcome for further investigation (Schindler, 2003).

Several have worked with the challenge of making tacit knowledge explicit in order to store it for later use (Kreiner, 2001; Nonaka & Takeuchi, 1995). But when the knowledge is made explicit it is also de-contextualised, and therefore removed from practice (Lindkvist, 2004b). Moreover, project work processes often require immediate response, and on that basis project participants do not favour extended ventures about lessons learnt in previous projects, and project members are reluctant to go through formal documents. Instead they favour a swift exchange of information and knowledge with fellows having relevant insights or experience (Lindkvist, 2004a).

Knowledge sharing in communities of practice

Despite development in information and communication technologies, it has long been realised that creation and diffusion of knowledge within organisations rely on social networks (Bresnen et al., 2004). Communities of Practice, a current topic of interest, have been widely discussed and some differences could be found in the way the notion is defined (Cox, 2005). However, some common characteristics seems to exist. Communities are groups of individuals, who feel connected and which share a history that makes the group coherent and able to communicate implicitly within the group. The group has a centre of persons who set the direction. However, peripheral members can move their way to the centre by negotiations and thereby move the direction of the group. (Brown & Duguid, 1991; Wenger, 1998a; Wenger, 1998b; Wenger, 2003)

An example of a community of practice was the crew of concrete workers. They did not have a formal leader; however, everybody knew who made the decisions. They seldom talked about the process of work; instead the members joined the job routines with as little communication as possible. Especially one man often came with ideas for changes in work processes, but as he was a very peripheral member of the crew, it was not likely that his proposals were followed or even responded to. Or perhaps because he came with suggestions for changes he was a peripheral member?

The force of communities of practice is that tacit knowledge easily flows within the crew. However, strongly tied project teams are less likely than weakly tied teams to search for knowledge outside their existing contacts and forge new ties while conducting searches for useful knowledge (Edelman et al., 2004; Hansen, 1999). Therefore, isolated communities can get stuck in ruts, turning core competencies into core rigidities. When they do, they need external stimuli to propel them forward (Brown & Duguid, 1998). But how interaction in small groups aggregates to form large-scale patterns eludes us in most cases (Granovetter, 1973).

The perception of explicit knowledge transfer at the construction site was double sided. They seldom, or perhaps never, read anything to which they could not be held responsible. This included for example evaluation reports from former projects or former phases within the project. On the other side they were highly dependent on blueprints and work descriptions sometimes supplemented by handbook information from suppliers of materials or machinery.

Knowledge diffusion across community boundaries

Where communities of practice are a social construction of people with a shared history, informal communication across community boundaries often goes through “ties”, which are personal connections between individuals or groups. The understanding of ties used in this paper origins in the work of Granovetter (1973; 1983). The notion “tie” mostly implies the strength of a connection and the function of the connection could be explained by the following notions: boundary objects, translators, and knowledge brokers. (Brown & Duguid, 1998; Wenger, 2003).

Ties as means for knowledge diffusion across communities of practice

The strength of a tie is a combination of the amount of time, the emotional intensity, the intimacy (mutual confiding), and the reciprocal services which characterise the tie. Ties are by nature informal and more extensive and significant than formal ones.

Strong ties are likely to create redundancy whereas weak ties are more likely to link members of different small groups than strong ones. If a tie is the only connection between two points (persons or groups) it is also called a bridge. More people can be reached by weak ties, and the fewer indirect contacts a crew has the more encapsulated it will be in terms of knowledge of the world beyond its circle of immediate contacts. Explicit knowledge is more effectively transferred with weak ties, whereas transfer of tacit knowledge requires stronger ties (Bresnen et al., 2004; Hansen, 1999).

Remarkably few examples of knowledge diffusion through ties were found in the case. Directly asked, few could point to examples of connections outside their crew or the projects as sources for knowledge. An apprentice within the plumber crew said that if problems occur they primarily call their project manager within the company. Sometimes they could consider calling others within the company "If it is someone you know, and you are sure he can help you". The skilled workers never call anyone outside the company, not even school mates.

Boundary objects as means for knowledge diffusion across communities of practice

Boundary objects are objects of interest of two or more communities. Boundary objects could be artefacts (Carlile, 2004) such as shared tools or documents; shared discourses, or shared processes (Wenger, 2003). The boundary objects can lead communities to understand what is common and what is distinct between them. However, it could also lead to misunderstandings and different interpretation.

In the case, the weekly-work-plan and the process of making it acted as a boundary object. The different crews met to discuss and plan the work of the following weeks at the site which resulted in a weekly-work-plan. During the process of making the plan fruitful discussion emerged as the construction workers did not always perceive the situation at the construction site in the same way. If they had not met to discuss the plan, it is not likely that they would have experienced disagreements until practical consequences occurred.

Translators as means for knowledge diffusion across communities of practice

Translators are individuals who can mediate between communities, so each community understands the settings of one another. It requires the translator to have knowledge about the work in both communities, and the communities should trust the translator not to favour one above the other (Elkjær, 2005).

Because crews were not good at expressing themselves and being understood by other professions, they kept their dissatisfaction internal in the crew where it reinforced their feeling of the job situation being hopeless to change. However, by talking to the workers face-by-face an understanding of their problems surfaced, and by explaining this to others they got an understanding for each other which helped them reach out for each other to continue the common process of planning.

Brokers as means for knowledge diffusion across communities of practice

Brokers participate in two or more communities and make the communities overlap (Wenger, 2003). Because brokers participate in the communities they also experience the consequences of knowledge diffusion between these communities.

During the time on the construction site, no direct brokers of knowledge occurred. Some would argue that the middle management, for example foremen or project manager, should be the broker of knowledge (Nonaka and Takeuchi, 1995). However, this seemed not to be the case. In stead, just as Brown and Duguid (1998) argue, hierarchical divisions of labour often distinguish thinkers from doers, mental from manual labour, strategy (the knowledge required at the top of the hierarchy) from tactics (the knowledge used at the bottom). Besides in the case of plumbers where the project manager acted as broker, no use of brokers of knowledge were observed.

Knowledge diffusion at the construction site

Experience from the case showed great diversity in the way different crews learned and diffused knowledge. Table 2 summarises the main findings on knowledge diffusion in crews from four different professions.

Table 2: Knowledge diffusion in different types of crews.

	Concrete Workers	Carpenters	Installation (Electrician and plumber)	Earth workers
Primary sources of knowledge	Experience in the crew.	Colleagues and suppliers of materials and machinery.	Project manager in company and work instructions.	Colleagues.
Knowledge sharing in crew	None verbal. Shared work process and negotiations.	Frequent discussions in crew.	Some professional discussion.	Narratives.
Knowledge transfer in company	None. Sometimes the engineer from their company is consulted.	None.	Project manager sometimes serves as a broker.	None.
External knowledge diffusion	None except from representatives from the union.	None.	None.	None.

Most of the crews could be considered communities of practice as they are close and stable groups which have an internal understanding of own practice. However, the earth workers were a bit different. Even though they knew each other very well, they did not know with whom they were supposed to work the following day. Therefore, they accumulated their knowledge in narratives, which they repeated in order to share knowledge.

The concrete workers were a tight and closed community. They even arranged their own Christmas party as alternative to the one held by their company which also included other professions. Most of them were un-skilled in the sense that they had never attended formal training.

The carpenters had worked together for decades and were very close. They never attended supplementary training, but perceived the suppliers as a sufficient source of knowledge. “If the handbook is outdated, we just get a new one from the timber yard - for free!”

The installation crews also used formalised knowledge and it seemed like their crews were not as close as the others. The electricians were offered supplementary training in required disciplines according to their interests. However, they seldom had the time to attend, or the courses were cancelled because of to few participants. Instead, they got their knowledge from the project manager, who served as a broker of information between projects.

In conclusion it could be said; that the skilled workers at a construction site mostly focus on practical experience and their primary source of knowledge is their nearest colleagues. In the case studied, there was limited communication across demarcation lines, and the crews rarely sought knowledge outside the project.

Even in the companies, little seems to be done in order to diffuse knowledge. Often the workers did not know in what other projects their company participated or the names of the colleagues with whom they did not work. Furthermore, they never contacted acquaintances outside the company to retrieve information.

During an interview with a plumber apprentice the following came up: As the project was the third in a sequence with the aim to continuously learn and develop the construction process, he was asked about knowledge from the prior two projects. However, the apprentice did not know that his company participated in the prior two projects.

REASONS FOR LACK OF KNOWLEDGE DIFFUSION

Crews at construction sites work as independent groups that almost never seek or get knowledge from outside. Some of the reason for this situation could be elements such as payment, time pressure, ignorance and tradition.

About 30 % of craft work hours are paid by piece in the Danish Construction Industry (Spohr, 2004). This form of payment suits the self organising crews which work with well defined job tasks and motivates them to execute the job as fast as possible. However, this form of payment also inhibits innovation as there is no motivation for new processes or products. Furthermore, it reinforces the fragmented industry and the missing communication across demarcation lines. (Copenhagen Economics, 2004; Spohr, 2004).

At the construction site the form of payment were also considered a hindrance for knowledge diffusion and cooperation. Professions dependent of other professions which is paid by piece often complained about the attitude of the former professions and lack in respect for others work. But the absolutely most used explanation for not seeking knowledge or reflect on practice was the time pressure. The skilled workers as well as the project manager always felt they were rushing things, thereby evaluation etc. was always downgraded.

Tradition also plays a role. The fragmented structure of the industry as well as the tradition for labour-only contracting has reinforced the separation of head and body. Therefore, there is no tradition for involving the skilled workers in learning and development processes, and the loose employment of skilled workers in construction companies does not invite to common development between employer and employee (Spohr, 2004).

The analysis has shown that the skilled workers rely on social networks for creating and diffusing knowledge. Thereby, the fragmented nature of the construction industry and the temporality of organisations inhibit long term relationship to develop across different professions and even within the companies. But if the employers and others in the industry with the ability to facilitate knowledge diffusion were aware of the characteristic of the skilled workers' knowledge creation and diffusion, then perhaps an incremental development could be initiated.

A meeting was held with the purpose that the skilled workers should discuss the overall settings of the construction site. First, a formal presentation was made by a consultant who described the development initiatives at the site. The presentation was short and precise. Nevertheless, most of the skilled workers had crossed their arms and were laid back. Their body language was very informative: They did not appreciate this presentation. Afterwards no one referred to the presentation when asked about their outcome of the meeting. Secondly, a subject teacher from the local training centre initiated a debate around the tables about the working conditions at the site. Here, the workers sat on the front of the chair and were very active, and the debate leads to several changes at the site. Thirdly, a football coach told about team work and the composition of a winning team. Again, the workers were very interested, however, when asked afterwards they could not translate this talk to their own practice, but they found it amusing to hear about the football players.

The example showed the importance of knowing the skilled workers' knowledge base and form of communication in order to get a successful return of facilitating knowledge diffusion. The consultant made a good presentation, but the setting reminded too much of a school setting, which is not appreciated by the workers, and the content seemed too abstract in order to be used at the construction site immediately after the meeting. Or perhaps the consultant being a woman made the workers reluctant? The football coach was entertaining, however, he used football as the context for his points, and most of the workers did not seem to be able to translate his points to the work on the construction site. But discussing their own work setting facilitated by one of their kind, the local teacher, was a success.

UNUSED POTENTIAL FOR KNOWLEDGE SHARING

Even though the methods for internal knowledge sharing varied in the different crews, all of them seemed to be successful with it. However, as the analysis showed, the knowledge diffusion across community boundaries was scarce, which can cause the crews to be fragmented and incoherent (Granovetter, 1983). The analysis also pointed out several unused methods for diffusing knowledge across boundaries, and facilitating these could lead to competitive advantages for the companies and increase development in the industry.

First of all, knowledge sharing in social networks should be considered as useful. The traditions of one sided focus on diffusion of abstract knowledge through written documents such as evaluation reports could have hindered knowledge sharing though social networks. Perhaps skilled workers should be supported in using written documentations as media for knowledge sharing. However, sole focus on written documentation to some extent leaves out the experience of the skilled workers.

Companies could gain from using brokers more strategically by letting people with special skills or experiences work with different crews in periods. In another case, a coach from the local training centre participated in different practices in a company for a period of several weeks. The purpose was to make a pilot-study of the competencies at use and thereby tailor a supplementary training programme for all employees. However, the use of brokers would require a change in attitude towards newcomers in some of the professions. For example the concrete workers would not gain from a broker unless it was supplemented by hourly paid time for knowledge sharing. Managers in the construction industry could furthermore experiment with different types of events where the skilled workers meet face-to-face to discuss challenges in their work-life (Styhre et al., 2006). This could be a way of letting the skilled workers point out a broker of knowledge at the construction site.

Consultants could be used as translators of knowledge across demarcation lines and hierarchical boundaries. In the case, I worked as a translator with some success. However, this task is time consuming for an outsider and might instead be fulfilled by a project or process manager at the construction site.

The use of boundary objects was very successful at the case studied, but it was not implemented on purpose. If for example the project manager is more aware of the role the weekly work-plan play as a boundary object he could more easily support knowledge transfer. But in the case studied, this was not the case and the project manager took too much ownership of the plans and thereby made the plans unfamiliar for the workers.

Surprisingly little knowledge came from outside the crews. There seems to be a culture of not sharing knowledge, which could be caused by the strained relation the workers has to school (Ebbesen, 2006). There are no networks or associations where the workers can meet informally to discuss and get to know other workers. And likely the workers do not find a need for this, as they do not even keep in contact with old classmates or meet informal with other workers in the same company. However, some training centre and companies are beginning to facilitate knowledge sharing processes.

CONCLUDING REMARKS

The case showed that the crews internally are excellent in sharing knowledge, even though the methods used varies a lot. Contrary to this there seems to be no or little knowledge diffusion across boundaries of the crews.

The case also showed some unused potential for diffusing knowledge through social networks. However, it is all about keeping a balance between protecting the stable crews so they can keep being excellent knowledge sharing groups and on the other side connecting the different crews, in order for knowledge to diffuse and support incremental development of the industry.

The problem is double sided: first, the knowledge in play is embedded in practice in isolated crews. Secondly, the people involved are not familiar with knowledge exchange or sharing. Therefore, the diffusion of knowledge in the construction industry is so difficult.

REFERENCES

Argyris, C. 1992. *On Organizational Learning*. 2 ed. Blackwell Publishing.

Ballard, G. 2000. *The Last Planner System of Production Control*.

Bennet, J., and Jayes, S. 1998. *The Seven Pillars of Partnering*. Thomas Telford Publisihng.

Bertelsen, S. 2005. *Håndbog i Trimmet Byggeri*. Forening Lean Construction DK.

Blackler, F. 1995. *Knowledge, Knowledge Work an Orgnaiszations: An Overview and Interpretation*. Organization Studies : 1021-1046.

Bønnelykke, M. 2003. *Kvalitativ undersøgelse af byggeriets udførende virksomheders læring og behov for videnformidling for Fonden Realdania*. Alsted Research A/S.

Bresnen, M., Edelman, L., Newel, S., Scarbrough, H., and Swan, J. 2004. *The impact of social capital on project-based learning*. 231-268: Huysman,M; Wulf,V.

Bresnen, M., and Marshall, D. 2000. *Partnering in Construction: a critical Review of Issues, Problems and Dilemmas*. Construction Management and Economics 18: 229-237.

Brown, J. S., and Duguid, P. 1991. *Organizational learning and communities-of-practice: Toward a unified view of working, learning and innovation*. Organization Science **2**(1): 40-57.

Brown, J. S., and Duguid, P. 1998. *Organizing Knowledge*. California Management Review **40**(3): 90-111.

Bygge- og Boligstyrelsen. 1993. *Byggelogistik I*, Materialestyring i byggeprocessen.

Carlile, P. R. 2004. *Transferring, Translating, and Transforming: An Integrative Framework for Managing Knowledge Across Boundaries*. Organization Science **15**(5): 555-568.

Chan, A. P. C., Chan, D. W. M., Fan, P. T. I., and Yeung, J. F. Y. 2006. *Exploring barriers to implementing construction partnering to a public sector housing project in Hong Kong*. WCAEBE World of Accelerating Excellence in the Building Enviroment.

Christensen, P. H. 2004. *Vidensdeling - Perspektiver og praksis*. Handelshøjskolens Forlag.

Christensen, S., and Kreiner, K. 1999. *Projektledelse i løst koblede systemer - ledelse og læring i en ufuldkommen verden*. 1 ed. Jurist- og Økonomforbundets Forlag.

Copenhagen Economics. 2004. *Akkordløn og produktivitet i den danske byggebranche*.

Cox, A. 2005. *What are communities of practice? A comparative review of four seminal works*. Journal of Information Science **31**(6): 527-540.

Ebbesen, R. M. 2006. *Educations in the Building Indutry* (in Danish: Byggeriets Uddanelser).

Edelman, L., Bresnen, M., Scarbrough, H., and Swan, J. 2004. *The benefits and pitfalls of social capital: emperical evidence from two organisations in the UK*. 59-69.

Elkjær, B. 2005. *Når læring går på arbejde*. 1 ed. Forlaget Samfundslitteratur.

Elkjær, B., and Walgren, B. 2006. *Organizational Learning and Workplace Learning - Similarities and Differences*. In Learning, Working and Living, 15-32. Antonacopoulou, E., Jarvis, P., Andersen, V., Elkjær, B., and Høyrup, S., eds. New York: Palgrave Macmillan.

Erhvervsfremme Styrelen. 2000. *Partnering - et studie af nye samarbejdsformer i byggeriet*. Erhvervsministeriet.

Fearne, D. A., Fowler, N., and Gosling, J. 2006. *Efficiency versus Effectiveness in Construction - The Case for Agile Supply Chains*. WCAEBE World of Accelerating Excellence in the Building Enviroment.

Fenwick, T. 2005. *Taking Stock: A Review of Research on Learning in Work 1999-2004*. Proceedings of the International Conference of Research in Work and Learning, Sydney.

Gherardi, S., Nicolini, D., and Odella, F. 1998. *Towards a Social Understanding of How People Learn in Organizations, The Notion of Situated Curriculum*. Management learning **29**(3): 273-297.

Gomez, M.-L., Bouty, I., and Drucker-Godard, C. 2003. *Developing Knowing in Practice; Behind the Scenes of Haute Cuisine. In Knowing in Organisationa, A Practice-Based Approach*. Nicolini, D., Gherardi, S., and Yanow, D., eds.

Granovetter, M. S. 1973. *The strength of weak ties*. The Amarican Journal of sociology **78**(6): 1360-1380.

Granovetter, M. S. 1983. *The Strength of Weak Ties: A Network Theory Revisited*. Sociological Theory 1.

Hansen, M. T. 1999. *The searc-Transfer Problem: The Role of Weak Ties in Sharing Knowledge across Organization Subunits*. Administrative Science Quarterly **44**: 82-111.

Illeris, K. 2000. *Tekster om læring*. In Tekster om læring, 9-8. Illeris, K., ed: Roskilde Universitetsforlag.

Keegan, A., and Turner, J. R. 2001. *Quantity versus Quality in Project-based Learning Practices*. Management learning **32**(1): 77-98.

Kreiner, K. 2001. *Tacit Knowledge Management - The Role of Atifacts*. Journal of Knowledge Management .

Kristiansen, S., and Krogstrup, H. K. 1999. *Deltagende Observation, Introduktion til en forskningsmetodik.* Hans Reitzels forlag.

Lindkvist, L. 2004a. *Governing project-based firms. Promoting market-like interaction in hierarchies*. 3-25.

Lindkvist, L. 2004b. *Knowledge communities and Knowledge Collectiveties. A typology of knowledge work in groups*.

Nicolini, D., Gherardi, S., and Yanow, D. 2003. *Knowing in Organisationa, A Practice-Based Approach.*

Nielsen, K. A. 2004. *Aktionsforskningens videnskabsteori, forskning somforandring. In Videnskabsteori på tværs af fagkulturer og paradigmer i samfundsvidenskaberne*, 517-546. Fuglsang, L., and Olsen, P. B., eds: Roskilde Universitetsforlag.

Nonaka, I., and Konno, N. 1998. *The Concept of Ba*. California Management Review **40**(3): 40-54.

Nonaka, I., and Takeuchi, H. 1995. *The knowledge creating company*. Oxford University Press.

Õrtenblad, A. 2001. *On Differences between Organizational Learning and Learning Organization*. The Learning Organization **8**(3): 125-133.

Õrtenblad, A. 2002. *A Typology of the Idea of Learning Organization*. Management learning **33**(2): 123-230.

Ryle, G. 1949. *The Concept of Mind*. Chicago: The University of Chicago Press.

Schindler, M., and Eppler, M. J. 2003. *Harvesting project knowledge: a review of project learning methods and succes factors*. International Journal of Project Management **21**: 219-228.

Schön, D. A. 1987. *Udvikling af ekspertise gennem refleksion-i-handling*. In Tekster om Læring, 254-269. Illeris, K., ed: Roskile Universitets Forlag.

Smith, M. K. 2003. *Michale Polyani an tacit knowledge*.

Spohr, J. 2004. Præstationsløn *som element i værdikædeoptimering i byggebranchen*. Institut for Produktudvikling, DTU.

Styhre, A., Josephson, P.-E., and Knauseder, I. 2006. *Organization Learning in Non-writing Communities*. Management learning **37**(1): 83-100.

Wenger, E. 1998a. *Communities of Practice - Learning as a social system*. Systems Thinker .

Wenger, E. 1998b. *Praksis Fællesskaber*. Hans Reitzels Forlag.

Wenger, E. 2003. *Communities of Practice and Social Leaning Systems. In Knowing in Organisationa, A Practice-Based Approach*. Nicolini, D., Gherardi, S., and Yanow, D., eds.

Yanow, D. 2000. *Seeing Organizational Learning: A "Cultural" View*. Organization **7**(2): 247-268.

DEVELOPING COLLABORATIVE CONTRACTING – THREE RAILWAY PROJECT CASES

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Collaborative contracting models are often associated with a set of tools and techniques to manage relationships, but the efficiency of such formalization in changing project culture has been doubted. Further, although many projects are successful, collaboration often is more limited than policies and guidelines suggest. In this paper, we view partnering practice as a learning process related to a management innovation and analyse how collaboration practice develops in three major railway projects, all using the same partnering model. We find that partnering is easy to introduce due to the flexibility and adaptability of the concept, but that practitioners prefer to keep collaboration informal and groups small. Also, tangible benefits can often be reached with basic and common-sense approaches. When ambitions and complexity increase, however, more sophisticated relationship management becomes inevitable, calling also for integration with core project processes. Yet, partnering tools and systems do not seem to provide much guidance when it comes to organizing such complex multiparty collaboration. Findings suggest that shortcomings relating to organizational issues are underestimated as causes of conflicts and inefficiencies.

KEYWORDS: partnering, trust, collaboration, infrastructure projects, railway construction

INTRODUCTION

In the past years, there has been significant dissatisfaction with many Swedish infrastructure projects. Insufficient risk management has resulted in high cost overruns and lawsuits, impacting on contractors' interest in submitting bids for major projects with high risks. In 2003, an industry-wide collaborative initiative was established by major industry actors to promote efficiency and learning in the infrastructure sector (www.fiasverige.se). An important part of this initiative has been to encourage more collaborative contracting models for infrastructure projects, and a general model called Extended Collaboration (EC) has been developed to guide project managers. The former Swedish government sector clients for road and railway construction decided that their projects should normally apply the principles of Extended Collaboration and the new Swedish Transport Administration continues this policy. However, although government clients have been applying these principles since around

2006, there is little information to date about how the model is applied in practice and the experiences from using it.

In most European countries, the need to improve inter-organizational collaboration in construction projects is a subject of industry discussion as well as of various initiatives and policies (Rigby, Courtney and Lowe, 2009). To facilitate implementation of collaborative contracting, numerous guidelines have been issued and a rather standardized set of practices has emerged (Bresnen and Marshall, 2002, Nyström, 2005; Eriksson, 2010). Still, the general perception of the construction sector is that of an industry with low trust and high levels of conflict, and improving collaboration is often considered to require a cultural change. It has been questioned if this kind of more fundamental transformation can be brought about by a set of formal practices and systems (Bresnen and Marshall, 2002), and several authors have observed that partnering in practice often is more limited than the policies and guidelines envisage (Mason, 2007; Bygballe et al., 2010; Gadde and Dubois, 2010).

However, it may take time for organizations and individuals to adapt to and modify a new practice to a specific context, and partnering can also be seen as an emergent practice (Bresnen, 2009). In this paper, we describe the forms that collaboration practice take in the projects and analyse the causes of similarities and variations as well as implications for future development. We view partnering practice as a learning process related to a management innovation: partnering guidelines provide sets of tools and techniques which project decision-makers interpret when they design and negotiate an approach that they think is suitable for the specific project. The resulting practice will reflect the formal model, but also managers' own practice-based understandings and preferences regarding what collaboration implies and requires in terms of management and communication.

The discussion is based on a study of how the EC model is applied in three recent and ongoing railway projects. We take an inside perspective, aiming to understand partnering related decisions from the perspective of the managers involved (Van Marrewijk et al., 2008), and the empirical questions addressed are: Which aspects and processes are used, and which are less likely to be prioritized? Which actors are included and in what way? Which are the experiences and problems encountered? What is the role of everyday relational competence and where does it lead? What is the role of the formal partnering model and tools?

FRAME OF REFERENCE

There is a set of tools, procedures and characteristics generally associated with partnering, although few partnering projects apply all of these (Nyström, 2005). Bresnen and Marshall (2002) mention selection procedures, formal teambuilding exercises, appropriate financial incentive systems, formal integrative mechanisms (such as charters, dispute resolution procedures, teambuilding workshops and the use of facilitators), continuous improvement programmes and benchmarking as being typical partnering tools and techniques. Based on case studies of four Swedish projects, Eriksson (2010) recently compiled a list which is very similar to that of Bresnen and Marshall (2002). Although partnering practices are likely to vary between countries, the core elements seem to be largely the same.

According to Ansari, Fiss and Zajac (2010) a practice that operates on an abstract level, has an interpretive viability and can lend itself to multiple interpretations has a greater likelihood of adaptation (but with greater variation and lower fidelity to the source model). Further, high divisibility, i e the degree to which an innovation may be experimented with at low cost (small trials), will facilitate adoption. Accordingly, adoption will be constrained if the innovation has a high complexity or is perceived as difficult to understand. Initially, a new practice may then be partially adopted in a simple low cost version, to be further adapted to the specific context and perhaps also more sophisticated and costly with time (Ansari, Fiss and Zajac, 2010).

Partnering is often described as a combination of highly defined practices and rather abstract concepts such as "trust" and "collaboration" (Nyström, 2005). The latter are general concepts that are parts of our everyday language as well as of a general social competence that most people feel familiar with. This combination of commonsense competencies and a relatively simple toolbox with high divisibility means that the threshold for applying partnering should be low, especially if there is a top management or government policy to legitimize collaboration. Research on construction partnering has focused on the problem of establishing trust between partners that have traditionally been more of opponents. Still, it is not only relationship building that requires communication and interaction, but the project collaboration per se. "Extra" partnering activities compete for resources with more directly instrumental project work such as design and construction. Further, there is often a need to balance between different goals and management approaches (Huxham and Vangen, 2005; Enberg et al. 2006; Lawrence, 2006; Koppenjan et al., 2010), and this problem increases with the number of participants. Thus, the apparent simplicity may mask difficulties and complexities that will arise as the reality of interparty collaboration unfolds. In this paper, we focus on how practitioners prioritize in designing their project-specific collaboration models.

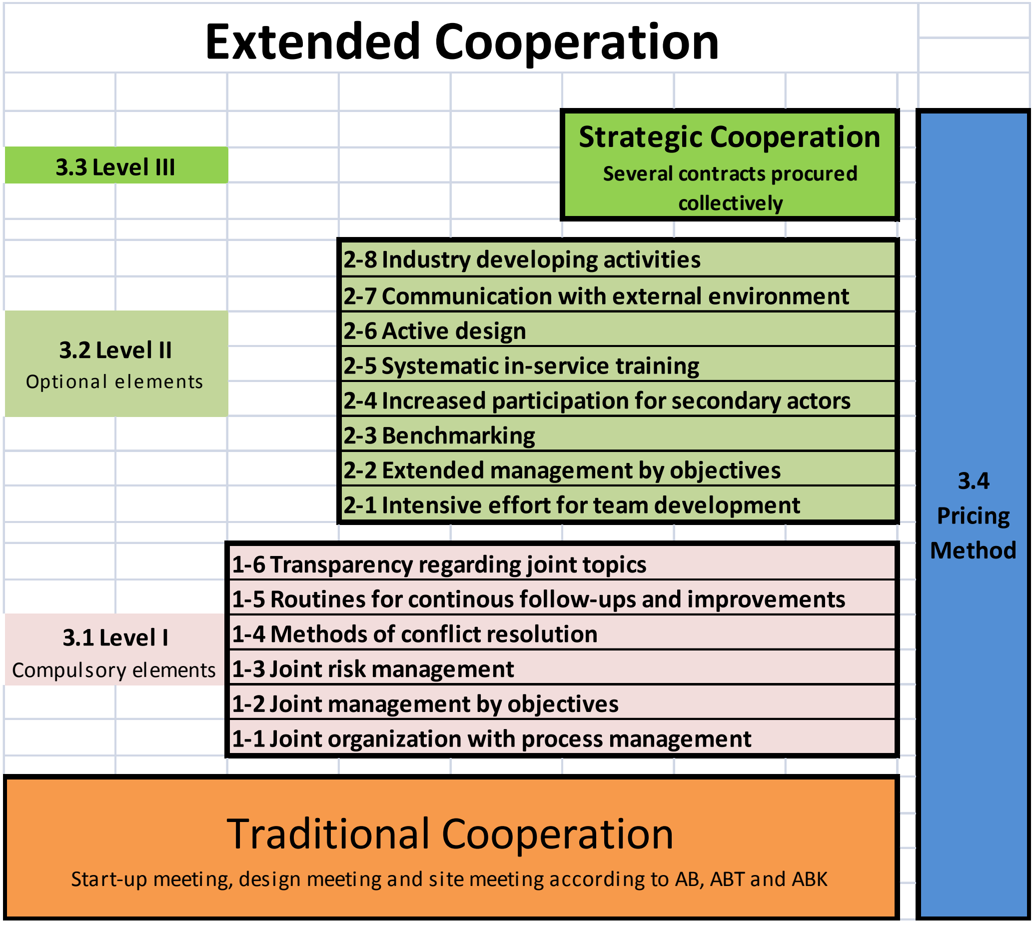
In the next section, we move on to present the model for "Extended Collaboration", and then further to present and discuss the cases.

THE MODEL OF EXTENDED COLLABORATION

In 2003 a construction forum for civil works FIA, Förnyelse i anläggningsbranschen (Renewal in the civil works industry), was created by initiative of the former Swedish Road and Rail Administrations in collaboration with major engineering and contractor firms. The purpose of FIA is to encourage Swedish construction companies to jointly strive for renewal in the civil works sector to achieve higher quality, lower costs and higher profits. Enhanced interaction and collaboration between different actors has been suggested as an approach to reduce adversarial relationships and conservatism. Better incentives for research, development and learning within the industry are other important goals brought up by FIA, as well as improving the image of the industry in order to attract future employees (FIA, 2010). FIA presented a Swedish model for partnering called "Extended Cooperation" in 2006, the name suggesting a type of collaboration that goes beyond that of traditional contracts (see Fig. 1). To date, this is the only larger Swedish policy initiative that is formally promoting collaborative contracting.

The model is intended to be applicable in all types of construction contracts used within the industry, although use of target cost contracts with a gainshare-painshare mechanism is recommended. The model is designed in three levels, where the first level is compulsory for projects claiming to work according to the model. In the basic level, the following elements are included (the numbers refer to Fig. 1):

Figure 1: The model of Extended Collaboration. Source: www.fiasverige.se.



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Joint organization with process management (1-1)

- An organization based on a steering group (partners' project sponsors) and cooperation group (executive managers)
- A process leader (external to project, responsible for EC aspects and activities)
- Workshops (meetings for dialogue concerning e.g. common goals, management, working environment, work processes, cooperation, relations and communication). At the initial meetings, common goals and ways of working are established. Max 25 participants. No technical or economic discussions.
- Leadership and top management support to change traditional attitudes and behaviour.

Joint management by objectives (1-2)
Documents expressing joint goals and plans for how to reach goals.

Joint risk management (1-3)
Risk management system according to other FIA guidelines.

Methods for conflict resolution (1-4)
A routine for conflict management, where problems are initially discussed in the cooperation group and then in the steering group. Processing times at each stage are defined.

Routines for continuous follow-ups and improvements (1-5)

Follow-up routines and measurement of improvements regarding common goals, plan of action, cooperation and working practice, improvement actions and feedback for project participants.

Transparency regarding joint topics (1-6)

It is a strong recommendation to use open book accounting.

Appendices

Appendices include templates for texts which can be included in tendering documents and contracts for contractors and consultants.

General structure and style of the guideline

There are strong similarities between the systems and tools included in the EC model and those mentioned in the literature. Apart from a section describing these components, the EC guideline includes both various general statements about the importance of changing attitudes and establishing trust, and advice regarding the pricing of construction contracts (mainly open book accounting and target cost agreements). The guideline document is developed by a group of practitioners and in terms of style and structure it is a mix of a research report and a handbook. It may be noted that since the client avoids using the concept of "partnering", we primarily use "collaboration" in the empirical description below, although the practices are similar to what is internationally referred to as partnering.

CASE STUDIES

Method

Three rail construction contracts were selected for case studies. One project was in the middle of construction at the time of the study B, while the two others were more recently started. In each project, representatives from the client (Swedish Transport Administration), contractors and consultants were interviewed (see Table 1). The interviews were semi-structured, lasted around one hour each. They were transcribed and statements sorted into different areas.

Table 1: Interviews performed

Actor	Project A	Project B	Project C
Client	Project Manager Process Leader	Ass. Project Manager	Ass. Project Manager
Contractor	Site Manager, Ass. Site Manager	Project Manager	Purchasing Manager
Consultant	Lead Engineer	Lead Engineer	Lead Engineer
Other		Process Leader	

Project A

This contract includes the new construction of all railway specifics for a double track with the length of approximately 7.5 kilometers, i.e. rail, electric, signal and telecommunication works (REST works), constructed on the area of an existing up and running single track. The demolition of all current railway structures is also included, as well as the construction/demolition of temporary tracks to allow continuous traffic. The contract further involves developing the final construction documents for the temporary constructions in cooperation with the client and designer. The REST contractor is also responsible for coordinating the four separate ground and bridge contracts for the entire railway distance.

Contract: General contract with REST contractor, contract sum ~ MEUR 26.

The pricing method for the contractor is a cost reimbursable contract with a fixed part and incentive, where the parties share the profit or loss in relation to a target cost equally, and an open-book agreement. The contractor company has estimated a tentative target cost in their bid, but this will be adjusted when the design for the temporary solutions has been completed. Regarding the change of target cost after this point, no formal criteria had been established at the time of the interviews. However, the parties agree that the target cost should be changed when there are large changes from the original document. The engineering consultant is procured on a reimbursable contract and has no incentive related to total project costs.

Cooperation Model: The compulsory level 1 of Extended Cooperation is applied between the client and the REST contractor (but not the engineer). The four ground and bridge contracts are not included but have separate EC relationships with the client.

EC was initiated on the project level. Two related reasons for this choice were mentioned: that the client wanted the contractor to be involved in designing the temporary constructions and that this requires a flexible pricing model. Time is also very short for the project.

The collaboration group involves key personnel from the client and the REST contractor with matching competences and levels: the project chiefs, the project managers and the foremen from both sides, approximately eight to ten participants. A start workshop was held, involving staff from the client and the REST contractor. Values, expectations and goals for the project were discussed, but there was no explicit agreement on joint goals. No systems for performance evaluations, conflict resolution and risk management have been established, but there was an intention to develop such plans later. The agreement was to have collaboration group meetings when they “are needed”, approximately once every quarter of a year.

The process leader of the collaboration work is a consultant who previously served as the client’s project manager. There has been no education about the EC model, and the client expects contractors, designers to educate their own staff. This also applies to the clients’ organization, which mostly consists of consultants hired for the project.

Although the interviewees think that co-location of primarily client and contractor project offices would have been valuable, this has not been possible since the total project organization for five contracts would have been too large.

Views: According to the client, the financial set-up is the most important element, since it is perceived to remove all conflicts of interests regarding variation work. The view is that it would almost not have been possible to set a fixed price on this contract, and that the target cost contract has reduced both costs and conflicts substantially compared to a traditional fixed price. The contractor agrees about the advantages of the contract for the client, but adds that it is very hard to estimate also a target cost for the contract.

The joint design meetings and other project meetings involving client, designer and contractor were perceived as very constructive and filling the function of cooperation meetings. A better integration between designer and contractor has led to better knowledge sharing and also to fewer changes in the design. All parties think that the engineering consultant should be formally involved in the EC cooperation since design-construction integration was an important reason for choosing this model.

The process leader tried to keep collaboration simple, and thought that it was important not to forget that parties have their different roles also in a collaborative project. He preferred to avoid formal performance evaluations not to threaten relationships, and emphasized informal mechanisms and evaluations performed in the cooperation group.

For the REST contractor, however, it is a problem to have the coordination responsibility for the ground and bridge contracts when they do not have any authority over the contractors that are to be coordinated. The REST contractor would like all contractors to be involved in the same EC work with joint cooperation group meeting and joint goals for the entire project stretching.

Project B

In Project B, a railway yard in the middle of one of Sweden's largest cities was refurbished and rebuilt from a cul-de-sac station into a run-through station. The construction time was 2 years and the project was completed in 2010. The contract included ground, rail, electric, signal and telecommunication work.

Contract: General contract with the construction contractor, contract sum ~ MEUR 27.

The pricing method for the contractor was a cost reimbursable contract with target cost and incentive, where the parties shared profit or loss in relation to a target cost equally. There were no fixed rules for target cost adjustments, but the target cost was changed when there were important changes and additions. The REST contractor, which in this case was a subcontractor, had the same pricing model. There were also bonuses related to time. The engineering consultant had a cost-reimbursable contract and no incentives related to project cost. Unlike the contractor, the engineering consultants were procured as resources and not as individuals, which meant that a large number of consultants were involved in the project over time.

Collaboration model: EC involved the client, the construction contractor and the engineering consultant (but not the REST contractor). To choose EC was a central initiative, due to complexity and temporary constructions.

There were two phases in the EC process. Initially, a large cooperation group was set up consisting of 15 individuals and with a process leader from the client. Workshops were large, sometimes involving up to 60 participants. This model did not work; people found meetings a waste of time since they lacked decision-making power and attitudes towards EC became negative. A new, external process leader (from a management consultant) was engaged and a new group was formed, involving only four people: the client's assistant project leader, the contractor's site manager, the lead engineer and the process leader. This way the collaboration group could make decisions and after some initial discussions and teambuilding assistance by the process leader this collaboration became successful.

The decided joint overall goals were "No serious injuries" and "No traffic disruptions", and specific goals were also set for each phase. These goals were measured, while relational aspects were only discussed more informally in the cooperation group meetings every third week. It was however seen as important to keep meeting contents and notes confidential to be able to talk openly about problems. Instead, a monthly newsletter was used to inform the whole project.

As in project A, no education on the EC model was offered. There was no formal conflict resolution model, issues were primarily resolved by the cooperation group and sometimes lifted to the steering group. The project was a pilot for a new risk management system, so this aspect was advanced. The contractor's management and the lead engineer were located at the client's project office, but no engineers doing design work.

Views: The small cooperation group and the co-location with common facilities for coffee and lunch were perceived as key success factors in the project, since this allowed for a lot of informal communication which increased mutual understanding and enabled people to efficiently solve minor problems. Both the client and the contractor in retrospect thought that the engineering consultant staff as well should have been located at the project office. The lead engineer agreed, but said that this would have required that they were procured as individuals and not as resources, which would have be more expensive in terms of costs for travel and accommodation. The client thought that the number of involved consultants could then have been significantly reduced (from 130 to 10). The contractor stated that co-locating and contracting for individuals could result in over-sized organizations where people are locked up for long periods, which is good for the project but perhaps not for the companies involved.

Another opinion was that the contractor should have been contracted at the same time as engineer, since this would have reduced design changes. There were also some different opinions about the meaning of design collaboration between the contractor and the engineer, and the process leader thought that the parties should have spent more time analyzing and planning the project jointly before starting the joint design work. In the view of the process leader, people involved in a collaboration project should forget their traditional roles and focus on the project.

Project C

The project studied concerns a part of a major underground commuter train tunnel in a large city. The contract in our study is the single largest contract in the project and consists of tunneling works and an underground station. At the time of the interviews the project was in the early stages of the construction phase. The estimated construction time for project C is 9 years, being finalized in 2017.

Contract: General contract with the construction contractor, contract sum ~ MEUR 130.

The pricing method for the contractor is a cost reimbursable contract with target cost and gainshare incentive. Below the target cost, the client and the contractor share gains 60/40, while the client assumes all risk if the target cost is exceeded. There are also bonuses related to quality, collaboration ability and not disturbing residents in the area. The target cost is to be changed when there is a change in function and the cost exceeds 5000 EUR.

Collaboration model: EC involves the client, the construction contractor and the lead engineering consultant. To choose EC was a central initiative early in the project. Also in this case, collaboration and pooling of competences were considered necessary due to the high complexity and technical difficulties. To transfer these risks to the contractor was not seen a a realistic option, since the risk premiums would have been too high and few if any contractors would be accept these risks at all.

The cooperation group consists of members from the client, the contractor and the lead engineer. There are thoughts about involving subcontractors, but no specific plans. The process leader is a partnering specialist employed by the contractor but not involved in their project organization. Cooperation meetings were held every or every other month.

At the start workshop, 30 key employees attended from the client and the contractor, as well as the lead engineer. The joint goals decided at the workshop were to "strive for full bonus", "keep a good mood" and "keeping the ceiling high/be able to express opinions freely". The joint collaboration is evaluated every sixth month through an internet-based questionnaire system, owned by the contractor. Goals are also more informally evaluated at each cooperation group meeting.

Regarding conflict resolution there is a set time before unresolved issues are brought up to, first, the cooperation group and, second, to the steering group. There is an ambitious joint risk management system which also includes external actors, primarily the city and the local traffic service provider.

No EC education was provided, only broader information regarding the contract and economy. The contractor, however, has internal partnering courses. There are information events to the whole project every 3rd month, and the contractor tries to involve workers and subcontractors in workshops. The client site management is co-located with the contractor's site office. The lead engineer is located at the client's project office, but not the design team.

The contractor was procured on the basis of design development documents, and the intention was to have contractor input in the design. However, the public planning and permission process was delayed and the large design team had to proceed with the detailed design although contractor procurement was postponed. The project planning and design organization is strongly tied to a highly structured document delivery plan involving design verification by the client and contractor, but the contractor and client do not have sufficient resources to contribute fully to this process since they also have to plan and manage the construction activities. Design meetings are therefore held in 5 parallel sessions for different technical areas, and the client and contractor can easily go between to give their input. Further, there are weekly meetings between the engineer and the contractor, where all problems related to design collaboration are discussed.

The lead engineer had internal initiatives for the design team involving workshops and meetings discussing collaboration and each design area has their own workshops. Some design sub-consultants are located at the office of the main engineering consultant.

Views: All parties see collaboration as the only option for this project, and the interviewees are all very satisfied with the relational aspects. However, it is emphasized that collaboration, relationship building and communication need to be highly structured and formalized in a large and complex project of this type.

According to the contractor, the client organization was composed of people who had not worked together before, partly internal and partly external consultants, and they were not an established team in the same way as the contractor was. Thus, the client project manager had to start with getting his own group together and communicate partnering values internally.

The engineer emphasized that feedback from construction to design is very important to improve design quality. He said that since there are not enough experienced engineering consultants, the direct feedback is important to educate younger staff. Thus, this more integrated way of working will benefit the whole industry and lead to better quality in future projects. He also thinks that it is important that the documents are seen as a joint responsibility of the project and not of the design team. However, there is a tendency that when construction starts, client and contractor attention shifts from design to site work.

DISCUSSION

The opinions of the collaboration were generally very favourable among those interviewed. In all three projects, collaborative contracting was perceived as the only way to handle high complexity. Thus, the alternative to EC collaboration was not traditional contracts, but contracts with high client risk without explicit goals and partnering processes.

Collaboration goals and perceived needs varied between the projects. In project A, the ambition was to improve flexibility with small means, primarily using the target cost contract. No formal evaluations were organized and the larger project was divided into smaller EC groups which could each cooperate more informally. The downside of this arrangement was that there was still uncertainty in coordinating between the five interdependent contracts. In the much more complex project C, extensive formalization and planning of both EC and design collaboration was seen as absolutely necessary to control the project. Communication between the subparts was carefully planned, and formal meetings and evaluations were important parts of the system. In project B, conflicts occurring in an approach with wider participation were solved by reducing organizational complexity and establishing strong trust within a smaller co-located core group. Here, formal evaluations were avoided but the external process leader was continuously involved.

Thus, EC cooperation took different forms in the projects and not all of the formal elements mentioned in the guidelines were used in all cases. The EC guideline seems to have influenced mainly the organization forms (steering groups, cooperation groups, process leaders and conflict management systems). Workshops and target cost contracts were also used. Meeting frequency, follow-up workshops and evaluation, by contrast, varied much, as well as interaction complexity in core project processes. Further, the EC guideline was not mentioned spontaneously and preparatory EC education or training had not been offered in any of the projects. Most likely, the guideline had been read by very few people in the projects, and the general understanding of the EC concept, its fundamental building blocks and application in practice is probably built more on informal and personal communication within the client organization. Notably, the project with the most elaborated collaboration (C) uses the contractor's system and resources and not the EC model.

Practitioners seem to prefer informal collaboration in smaller groups to wider participation requiring more planning and formalization, and the positive views indicate that these basic approaches may produce significant improvements. However, there are also tendencies that complexity is suppressed, thereby introducing relational risks. Still, the step to take from the informal and rather basic approach of project A to a more ambitious approach may be higher than practitioners think. For example, Project B illustrates the difficulties in organizing meaningful collaboration between a wide range of participants and meet expectations of influence and efficiency. Further, all projects failed to fully anticipate the organizational prerequisites for successful design collaboration. In both A and B, the alignment between the collaboration goals and the way the engineering consultant was involved was perceived as insufficient. In A, the consultant was not involved in the cooperation group; in B they were involved but as an organization and not as individuals. In C, the contractor was procured earlier and design collaboration was intended. Still, delays inhibited some of this collaboration, indicating that higher design/construction integration increases vulnerability and demands better control in earlier parts of the process. Also, while the design process was carefully planned not to delay production, client and contractor resources for design participation did not fully match this plan. In part, all this probably reflects a client preoccupancy with preventing problems associated with traditional contracts, focusing on establishing trust and collaboration with contractors.

CONCLUSIONS

As a management innovation, partnering is clearly very flexible. It can be applied with very varying levels of ambition regarding depth and width, and the return of investment of a basic common sense approach is often high. A more complex collaboration that involves the design team, subcontractors or external actors is significantly more demanding, since it requires not only more partnering activities, but that core project organizations and processes are designed and staffed to enable collaboration. Partnering tools and systems, however, seem to be too general to be truly helpful in managing this totality of specific partnering processes and core project activities and systems.

So what can be said regarding future development? It is not surprising that managers prefer simple and informal approaches, and it is possible that the presence of low hanging fruits may prevent the spread of more sophisticated models except for in very complex projects. However, many of those interviewed proposed further improvements, for example including more participants and involving contractors earlier. Such seemingly minor changes may radically raise requirements for formalization and planning.

An aspect that is specific for large infrastructure projects is that there is time for learning during the process. With a flexible pricing mechanism parties may develop their collaboration model as their mutual experience increases. However, early phases of the collaboration are more dependent on careful preparation, and design collaboration is thus more vulnerable than construction. Failing to prepare upfront may therefore still be costly for the project. Further, while in shorter building projects project managers may improve their own direct collaboration competence from one project to the next, learning in the infrastructure sector requires exchange of experience between different project organizations.

Finally, most partnering literature tends to emphasize attitude problems, distrust and cultural change as main challenges in establishing collaboration. Our case studies, however, point more at shortcomings in organizing collaboration primary sources of conflicts and inefficiencies. It is unfortunate if an excessive preoccupation with emotionally “hot” trust issues among both practitioners and researchers cause attention to be unduly shifted from “cool” concrete organizational issues. This further urges both research and guidelines to deal with the intersection between organization and collaboration.

REFERENCES

Ansari, S. M., Fiss, Peer C. and Zajac, E. J. (2010) Made to fit; how practices vary as they diffuse. *Academy of Management Review*, Vol. 35, No. 1, 67-92.

Bresnen, M. (2009) Living the dream? Understanding partnering as emergent practice. *Construction Management and Economics*, Vol. 27, No. 10, 923 - 933

Bresnen M. and Marshall, N. (2002) The engineering or evolution of cooperation? The tale of two partnering projects. *International Journal of Project Management*, Vol 20, 497-505.

Bygballe, L., Jahre, M. and Swärd, A: (2010) Partnering relationships in construction: A literature review. *Journal of Purchasing and Supply Management*, Vol. 16, 239-253.

Enberg, C., Lindkvist, L. and Tell, F. (2006) Exploring the dynamics of knowledge integration. Acting and interacting in project teams. *Management Learning*, Vol. 37, No. 2, 143-165.

Eriksson, P.E. (2010) Partnering: what is it, when should it be used, and how should it be implemented? *Construction Management and Economics*, Vol. 28, No. 9, 905 – 917.

Gadde, L.E. and Dubois, A: (2010) Partnering in the construction industry – Problems and opportunities. *Journal of Purchasing and Supply Management*, Vol. 16, 254-263

Huxham, C. and Vangen, S. (2005) *Managing to collaborate: the theory and practice of collaborative advantage*. Oxford: Routledge.

Koppenjan, J., Veeneman, W., van den Voort, H., ten Heuvelhof, E: and Leijten, M. (2010) Competing management approaches in large engineering projects: The Dutch RandstandRail project. Forthcoming in International Journal of Project Management.

Mason, J. B. (2007) The views and experiences of specialist contractors on partnering in the UK. *Construction Management and Economics*, Vol. 25, 519-527.

Nyström, J. (2005) The definition of partnering as a Wittgenstein family-resemblance concept. *Construction Management and Economics*, Vol. 23, 473-481,

Lawrence, K. A. (2006) Walking the Tightrope: The Balancing Acts of a Large e-Research Project. *Computer Supported Cooperative Work*, Vol. 15, 385–411

Rigby J., Courtney, R. and Lowe, D. (2009). Study on voluntary arrangements for collaborative working in the field of construction services. Manchester Business School, University of Manchester.

Van Marrewijk, A., Clegg, S R, Pitsis, T and Veenswijk, M (2008) Managing public-private megaprojects: Paradoxes, complexity and project design. *International Journal of Project Management*, Vol. 26, 591-600.

SUSTAINABILITY IN THE BUILT ENVIRONMENT BY USING EMBEDDED TECHNOLOGY

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Various studies have demonstrated that innovation of sustainable products and solutions in the built environment using embedded technology in constructions generates value both by reducing emissions of green-house gasses from buildings and by optimising comfort for the end-user. Based on a project on User-driven Innovation and Embedded Technology in Construction, this paper presents a number of potential products and solutions for sustainability. This covers a variety of areas such as recycling, energy efficiency. In addition, the paper addresses a new concept of sustainable products designated Open Built Source products (OBS), by applying two principles: compatibility and reuse of building products with embedded technology. The methods used in the User-driven Innovation are presented, with focus on user engagement, interest and acceptance of the ideas arising from the process. Sustainability is categorised in the three dimensions environmental, social and economic sustainability. In this paper a fourth sustainability field is introduced; Adoption of sustainability. User adoption of sustainable solutions is not only achieved by developing the solutions, the user also needs to adopt the solution, before it may be implemented in practise. Several barriers need to be taken into consideration, such as usability, functionality and value for the user, technology fear, cultural and social backgrounds. The paper presents a new approach for dealing with User-driven innovation as a mean for developing sustainable solutions. The methodology is analysed, exemplified by innovated products and show how sustainable solutions may be implemented much more efficiently, by applying this new approach.

KEYWORDS: Userdriven innovation, embedded technology, sustainability, energy efficiency, recycling.

INTRODUCTION

Sustainable developments are often achieved through technological discoveries, but they need to be able to be carried out as business in a value creating way at the same time to be a commercial success. The main focus in this paper is to show how firms may use collaborative innovation methods and user-driven innovation in the early-stage of innovation to realize high-technology sustainable products with a high degree of user adoption. The technical angles may be many, but in this paper technology advances of embedded technologies in building materials, developed in the project 'User-driven Innovation and Embedded Technology in Construction' (BIIB) [1], will be used as example. The main barrier is the

[1] The project, Brugerdreven Innovation og Indlejret Teknologi i Byggeriet, BIIB, is carried out by the Confederation of Danish Industry, Building Materials and IT, 28 firms from the organisation and the Danish

adoption of the end-users, hence, if end-users do not accept developments, they will not be realized.

In the endeavour to create sustainable solutions taking into account i.a. the barrier presented by adoption, the project 'User-driven Innovation and Embedded Technology in Construction' was established, which involved firms manufacturing building materials and IT developer companies. The main purpose was to bring the developers from the companies together with the end-users and lead-users, and to create an innovation climate, which would generate realizable sustainable solutions by using collaborative innovation and taking into account the drivers and barriers of the users. The project was divided into four segments. In each segment the focus was on different users in the built environment, i.e. segment one deals with *building process*, segment two with *facility management*, both in regard to continuous operation and maintenance, the third and fourth segments focused on the user of the finished house, i.e. *end -user, in rental and private residences respectively*.

A new approach combining collaborative innovation with user-driven innovation is presented, analysed from the point of adoption of the end-user. As a basis, the approach will be developed using principles from recognised methods of technology acceptance e.g. the TRA (Theory of Reasoned Action) and TAM (Technology Acceptance Model) models, keeping the focus on the effect of the interaction between the users and developers in the development of sustainable solution.

Sustainable solutions are characterised by being either environmentally, economically or socially improving solutions. In the process of innovating sustainable solutions, there are several barriers to be taken into account, if the solutions are to meet the users' needs, be accepted and realized. Examples are privacy and lack of experience of the new technology. Therefore it is important to create the right surroundings for creating the collaborative innovation climate for the users, which will give the realizable solutions. For this purpose a theoretical approach to deal with these items will first be presented in the paper, followed by presentation of the methods used. Next some examples of sustainable solutions developed in this project will be presented and discussed in the context of the new approach.

It will be shown that given the right condition and surroundings, and with the rightly chosen users, collaborative innovation combined with user-driven innovation is a useful approach for developing sustainable solutions.

THEORETICAL APPROACH

Apart from classical innovation such as innovation driven by entrepreneurship or innovation driven by strategic technological innovation, the innovation process may exclusively focus on the customers need or more precisely on what the costumer *might* need without yet knowing it. This type of innovation is called user-driven innovation. One might say that user-driven innovation is as old as the market economy itself. This is true since companies generally focus on the customer. However, this is merely a normal routine rather than involving the user directly in the innovation process. The expression 'user-driven innovation' was originally

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Building Research Institute. The project is financed by support from Governmental funds on User-Driven Innovation.

introduced by von Hippel (Hippel, 1986) from MIT. He also defined the lead-users as those whose present strong needs will become general in a marketplace months or years in the future. Identifying the lead-users is important, for understanding the end-user's adoption of new products. In the effort to innovate new *sustainable* solutions, user-driven innovation may be useful, also being aware of the importance of identifying the relevant users.

Sustainable Solutions with Embedded Technology

Sustainable developments are the future innovation fundament for maintaining economic growth in the world, without compromising the environment or our life quality. There are three main dimensions in sustainable developments. The first dimension is to control the environmental challenges as a consequence of the increasing amount of chemicals, materials/substances and waste, which will affect our health, environment and nature. The second one is to optimise economic benefits for example by controlling the use of the limited energy resources, which will at the same time diminish the discharge of CO2 concentration. And finally the third dimension is to maintain or improve our living standard both socially, but also our degree of comfort and life quality. The three dimensions are normally referred to as the environmental, the economic and the social dimensions.

The solution is to develop technical solutions, which improve at least one of the three dimensions compared with existing solutions, without compromising the other dimensions e.g. achieving environmental benefits without reducing economic or social standard. Since buildings is the centre of many human activities, i.e. working, educating, sleeping etc. it is a relevant area to look at, when innovating new solutions. Embedded technology is a technology, that embeds various sorts of technology from sensors to more advanced information technology into building materials. For example a sensor, that can measure moisture content. The sensor is built into a gypsum board. The sensor register moisture data and the data may be collected through a connected data logger to a computer. When the moisture content reaches a certain critical value, the computer may be used as a pre-warning before severe damage may occur in the building construction, and from that point save the building owner the unreasonably high costs of repair. Instead the building owner is able to stop the development of damage in due time. More advanced IT technology like RFID (Radio Frequency Identification chip) is a wireless identification system, which consist of RFID-tags with unique identification numbers, which may be built into a building material. Using RFID-reader the product can be identified and from a database like for example integrated in a BIM model (Building Information Model) information can be obtained about the production date and place, information about replacing or repairing the building material, logistic management and much more. Also supplementary information technology devices may be used like a PDA (Personal Digital Assistant) both for scanning and operation.

To achieve adoption of the advanced technological solutions, it is rewarding to take into consideration the barriers of the end user in the early-stage innovation.

Adoption of Sustainable Solutions

Adoption of new technology developments depends on various factors. Personal factors e.g. social background, willingness to use, privacy and level of technology fear. Further it depends on technology characteristics such as relative advantage, meaning the extent to which the solution offers improvements over existing solutions, compatibility, meaning its consistency with social practices and norms among its users, complexity, meaning its ease of using or ease of learning to use. More detailed reading is given in (Dillon, 2001). In this Paper we will assume that the most important personal factors when dealing with high sustainable advanced technologic solutions are:

- Cultural and social background
- Privacy
- Technology fear

and the corresponding most influencing technical characteristics are:

- Relative advantage
- Compatibility

Compatibility means that the solutions are consistent with social practice and norms among the users. These factors have been considered in the project when using user-driven innovation with the end-users, with the aim to develop the most likely solutions to be realized.

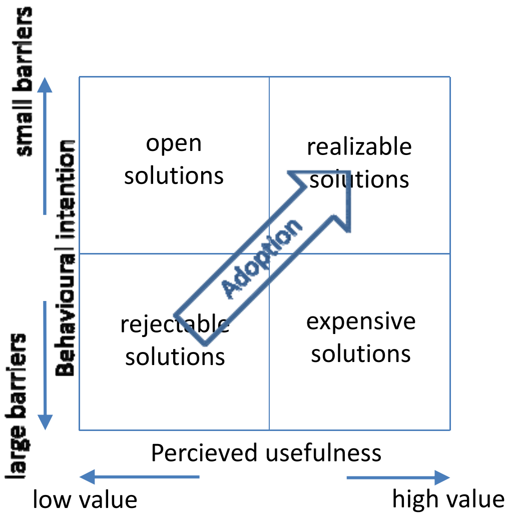
Technology Acceptance Model

In the field of information technology the widely used and proven Technology Acceptance Model (TAM) was developed by Fred Davis (Davis, 1989). The model is an extension of the Theory of Reasoned Action TRA, (Ajzen, 1980), mainly replacing several attitude measures such as consumer attitude or consumer behaviour like e.g. when privacy issues may limit the users acceptance of new technology. Two technology acceptance measures are perceived ease of use and perceived usefulness, where ‘ease of use’ is defined as the degree to which the user believes that the new development may be used effortlessly and ’usefulness’ defined by the user believing there is an advantage or benefit when using the new development. Several methods have been developed on the basis of TAM. Venkatesh et al. gives an overview of various models of technology acceptance models and compares the models by means of a unified model entitled ‘The Unified Theory of Acceptance and Use of Technology’ (UTAUT), see (Venkatesh et al., 2003).

It has not been the main intention to adopt the technological acceptance models directly in this project since these models are normally used in measuring the acceptance parameters, where users are exposed to ready-made solutions. Nevertheless it has been the aim to increase the likelihood of reaching realizable solutions by taking these parameters into consideration in the early-stage innovation, i.e. we assume that we will achieve an even higher degree of success, when combining the basic principles of user-driven innovation with the parameters influencing the technological acceptance models.

We therefore assumed that adoption of sustainable solutions was highly dependent on the level of user acceptance from the perspective of a user-driven innovation, i.e. keeping the users aware of barriers and usefulness from their own point of view, when developing the ideas for solutions. It was expected that increasing adoption would achieve the highest rate of realizable solutions, i.e. if they the user barriers are small and the user had a high level of perceived usefulness at the same time in the early-stage innovation, we would expect to achieve high realizable solutions, as illustrated in figure 1.

Figur 1. Principle of user driven innovation model for the new approach.



TAM defines behavioural intention as a measure of the strength of one's intention to perform a specific behaviour, i.e. it may indicate willingness to use a new solution. In early-stage innovation this is assumed to be approximately correspondent to the user awareness of his own barriers on the possible solution. Percieved usefulness is in the context of user driven innovation considered as the users own perception of the value if the solution, e.g. increased relative advantage.

An open solution is defined as a solution that is not obvious to continue developing. However since the barriers are small, it should be kept open as a possible solution for further investigation, i.e. involving user-driven innovation in later stages like further marked investigation or even pilot testing. Expensive solutions may similarly be kept open, but need more investigation of the necessary investments since the marked may be limited due to the amount of barriers.

The complete approach to developing sustainable advanced technology solutions involves focus on the adoption parameters presented above, controlled through well prepared facilitation, including the user-driven innovation methods, see next section. The intention to use this approach is to enhance the guarantee of success, before the solution is accomplished and it is finally implemented in the market. This new approach illustrated in Figure 1 developed in this project is named the 'Technical Adoption with User-driven Innovation Model', abbreviated the *TAU-model*.

METHODS USED FOR USER DRIVEN INNOVATION

User-driven innovation is increasingly used in research and development. The main idea is to differ from traditional linear innovation starting at the manufacturer and ending at the end - user, by shifting the focus directly to the end-user and thereby get improved innovation. In Denmark two programmes for user-driven innovation were recently established. A research programme for Strategic Research (Forsknings- og Innovationsstyrelsen, 2006) and an Innovation Programme for User-driven innovation (EBST, 2011), the latter being the one in which this project was established.

The project was divided into four segments, see Table 1. In each segment two main meetings were held with the relevant users. Firstly a *Focus Meeting (FM)*, with the main purpose of identifying possible needs for the end-user, which it might be possible to satisfy by innovating new solutions using embedded technology. The FM was followed up by a *Dialogue Meeting (DM)* with the main purpose of making collaborative innovation, with the developers, end-users and advanced-users - including lead-users. At the FM it was also important to identify the main barriers for using potential solutions, mainly with regard to the end-user. Several methods for achieving these goals were used, e.g. interviews, assigning the user with predefined assignments like taking photos of relevant items that might be improved, and thus establish a picture of relevant needs or problems and barriers. The methods used are described in detail in (Storgaard et al, 2011).

Table 1. Overview main subjects of Focus Meeting (FM) and Dialogue Meetings (DM).

Project meetings	**FMI/DMI**	**FMII/DMII**	**FMIII/DMIII**	**FMIV/DMIV**
Segments	building process	facility management	apartment residence	private residence

The first FM was established at a building site. Various stakeholders from contracting businesses represented the end-user. Subjects like logistics, assembling methods and many more were considered. Similarly the second FM concerning facility management of housing, i.e. continuous operation and maintenance, was held at a large apartment building. Stakeholders from the housing administration, the caretaker and operating and maintaining firms represented the end-users. The third FM was held inside the apartments of the end-user. Similar the fourth focus meeting was carried through at the residence of the end-user, i.e. town house, villa or summer house.

At the third and fourth FM typically four to five end-users were chosen. To get some variation of the needs and barriers, the end-users were chosen based on different criteria, e.g. age, social background, occupation etc. At the first and second focus meetings the variation of end-user was characterised by their role in the building phase examined, e.g. carpenter and building owner respectively in the facility-management phase.

The resulting scenarios from the FM were used to establish the surroundings at the second meeting – the *Dialogue Meeting*. At the DM all the users, technological experts and developers from the firms and an extended group of stakeholders, were brought together and involved in different settings, with the main purpose of brainstorming and creating ideas i.e. early-stage innovation. Two main methods were used: ‘Scenarios’ and ‘Design Games’, see (Brandt, 2004).

A scenario is a story describing a future scene introducing a social context, needs and introducing solutions were embedded technologies are implemented in building materials. The scenarios were developed on the basis of the input from the FM.

In each segment several scenarios were developed. The participants at the DM were divided into groups across the type of participants, each with the objectives to validate one scenario, with special focus on whether the solutions presented were realistic both from an economic and a technical angle. All the scenarios will be published in (Nielsen, 2011).

The Design Games were designed for the main purpose to facilitate a collaborative brainstorming over new ideas for solutions with embedded technology. A game board was prepared for each DM. Again participants were divided into new groups and brought into a context controlled both by the facilitators and the game board with complementing game cards with questions or other types of challenges that escalated the brainstorm process.

In the Design Game, several stage gates are passed in order to access the relevant information in the brainstorming process e.g. firstly a building material is chosen, then possible future functions and/or properties for the actual building material are proposed, and then relevant embedded technology is decided and so on. Typically the upcoming ideas in the process were written down on post it's, and placed on the game board, to make the process flow, not interrupted by time consuming writing manoeuvres, and making the ideas common knowledge both in the group – and later – between all participants. The game board is then designed from the information generated. Both in the Scenarios and in the Design Games it was influential for the social and collaborative processes, that the processes were thoroughly facilitated and that the facilitation was well prepared.

RESULTS

In this section three developed sustainable solutions in the BIIB project will be presented, as examples. Each of them covers the three dimensions of sustainability in the built environment. Actually it might be more correct to denote the solutions: Concepts. This is because, the solutions involve embedded technologies and building materials and in some cases information technology as a whole concept.

The *first* solution to be presented was developed in DMII, i.e. facility management. The users were grouped around a table with a game board. The users were led through a process, and confronted with a series of questions to be decided on in the group. Firstly they should consider which building materials could be used for embedded technology in general. Secondly they should consider what type of user and needs/ problems could be relevant to find solutions for. And then to bring through a solution, describe it and test it against the users need, acceptance, usability, through the developers and the technological experts assessment of how to produce the technical solution, and through the extended stakeholders assessment of functional value. This process continued until a solution was proposed including considerations of how the solution would be realized. Costs of maintenance and operations of a building had a very high focus, seen in relation to the total lifetime of building. Sustainable solution are therefore of importance when considering the energy efficiency of the building. Several solutions were developed in this area. As an example it was proposed to make windows with transparent glass, denoted the *intelligent window*, which could vary the amount of incoming solar radiation. When the building is overheated the glass can diminish the income of sun light, instead of installing cooling systems, and conversely solar heat can be used to warm up the residence, when beneficial. Furthermore a lot of research in this area also considers saving energy in the developments of Smart Windows, which use electrochromic devices, suspended particle devices, micro-blinds or liquid crystal devices built into the window glazing, See also (Grandqvist, 2008). It is well known that solution that exploits the sun are very cost beneficial, especially in regard to the passive-house building design.

The *second* solution comprises two closely related solutions developed in DMVI, i.e. the private residence. The starting point in the Design Game was to guide the users to define a combination of embedded technology and building materials. One of the three dimensions in sustainability is the social dimension. A sustainable solution was developed, focusing on health in the effort of achieving higher living standard in general. One of the solutions was to embed sensors measuring the moisture content and temperature to evaluate the Relative Humidity (RF) i.e. the climate in the rooms in the house. The benefits of the idea were to ensure healthy climate in the rooms, and prevent eventual growth of mould fungus and similar problems. The embedded technology was implemented by creating intelligent doors controlled by a Building Information Model (BIM-model[2]). The concept was named 'The sensor door'.

In regards to sustainable solutions the *third* solution to be presented covered basically all three sustainable dimensions. The solution was named Open Building Source (OBS) by the users. The idea behind the solution was to create a standard with harmonised requirements covering the interfaces in the built environment, e.g. the connections between different building materials. The standard should make sure that developments of different building materials were always standardised, in regard to how they would *be connected* with each other on site, independently of what company or institution developed the solution. This could lead to a standard which could provide the space for independent developments, from which the definition 'Open Building Source' followed. The standard should cover both requirements for technical connections e.g. reinforced shear connections in concrete structures, bolted steel connection etc. But also electrical and plumbing connections i.e. cables, wires, pipes etc. must be covered. Complications often arise in the interfaces, when connecting different building materials. Having the standard defining a common base would ensure *compatibility* with other building materials as they are developed. Furthermore such a standard would encourage the use of sustainable solutions, if it considers connections which may be easy to dismantle and reinstall. In other words it may be a basis for reusing and recycling building materials in general.

A solution was proposed that uses embedded technology by incorporating a sensor in the product which register the life history of the product, e.g. condition, temperature and moisture influence etc. The information may be useful when following the product from cradle to grave – or even be used to recreate part of the product if necessary. Additionally the product may be connected to a BIM model, so that it would be easy to obtain the necessary data when the product need to be demolished and reused in some other form, and in this sense the product may even be followed from cradle to cradle.

ANALYSIS OF APPROACH AND DISCUSSION

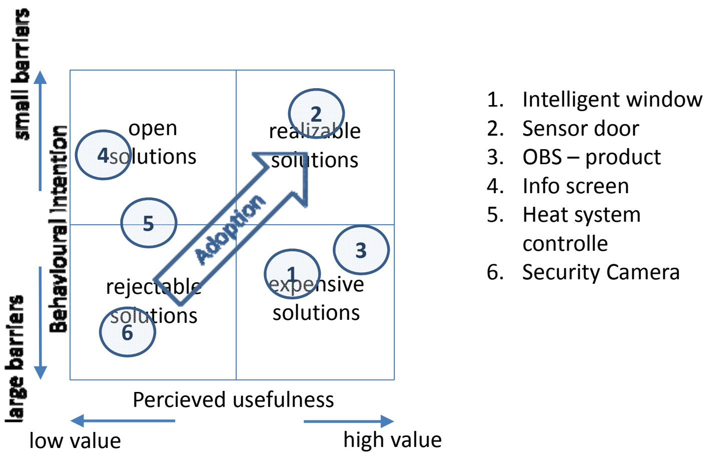
During the process of developing the solutions several phases were undertaken with the users, both end-users and users from the industry, e.g. brainstorming sessions where the user

[2] Building Information Modelling (BIM) is the process of generating and managing building data during its life cycle (Lee et al, 2006). Typically it uses three-dimensional, real-time, dynamic building modelling software to increase productivity in building design and construction. The process produces the Building Information Model (also abbreviated BIM), which encompasses building geometry, spatial relationships, geographic information, and quantities and properties of building components.

intuitively came up with needs and solutions involving building materials and embedded technology. In some phases the focus was put on barriers and the usefulness of the solutions by the facilitators, with the main purpose to validate the proposed solutions. The users were indirectly forced to select the best solution, facilitated for instance by using surroundings involving competition. On the contrary this led to several other solutions being given a lower priority. As an example it was proposed to embed sensors to measure the *history* of the climate, i.e. moisture etc., in the apartments. The users preferred privacy in their whereabouts, and preferred sensors to discover only just in time damage, not to reveal their daily routines. In contrast to the privacy issue, it was proposed to install cameras to increase security, and surprisingly enough this solution was not rejected for reasons of privacy, but purely from the lack of *relative advantage*, since the users felt it would have the exact opposite effect, i.e. cameras leave residences with a 'fake' feeling of in-security.

From these examples, it was clear that it was important to identify barriers as well as the solutions at the early-stage innovation, since it will determine the adoption level of the solution, see Figure 2.

Figur 2. Early-stage developed solution introduced in the TAU-model.



Together with several solutions it was proposed to install info-screens for various purposes locally in the apartments, e.g. for reporting activities of common interest, for showing any monitoring of the apartment, news about residence regulative etc. In regard to some of the solutions, the users were very keen on making the system easy to use. In some cases this was clearly technology fear, but in some cases it was more ambiguous. In other cases it was a lack of relative advantage, which ruled out the proposals. In the first case the solution would be rejected with regard to the approach shown in figure 1, due to barriers and lack of relative advantage. While in the other case the solution should be classified as an *open solution*, to be more thoroughly studied. This could for example be implemented by using user-driven innovation in a future pilot test. Several models were discussed, among others, an idea of slowly introducing the info screen with ease of use solutions, and test other solutions one by one. Agreement was achieved on that the economic benefits to use such a procedure was obvious.

Some other ideas involved highly advanced technological solutions, i.e. partly manually controlled heating systems in the house. The social background played a significant role in these types of solutions, mainly due to technology fear. In DMVI, this was not an issue. On the contrary, to some degree, the more complicated technological advanced the solutions were even more interesting for the users. This may nevertheless in some cases not relate solely to social background, since the majority of the users involved in this last DM were classified as lead-users. It was generally confirmed in the project that barriers influenced the decision process on the chosen solutions.

After each DM an evaluation was carried through, i.a. the facilitation level was evaluated on the various methods used. One common picture was observed, that when facilitation was well prepared and the process thoroughly controlled by prescheduled plans, the most stringent solutions were obtained. As an example the motivation among the participants was clearly increased with a high level of facilitation and consequently more and better ideas arose. Therefore the facilitation procedures were improved through the DM during the project, by means of preparation and thoroughness at the meetings.

At the end of the DM IV the developers from the industry were put together in a match making process, where the selected solutions, i.e. the solutions presented in the section: ‘Results’, were evaluated discussed and action for the next step was considered. *The first solution*: ‘the intelligent window’, led to intense discussion of costs compared with the market possibilities. The solution was classified as *expensive solution* and the stakeholders decided to continue with collaborative investigations, with some reservations of the possibility of continuing the development to final implementation. It may be argued whether a solution, which may have high socio-economic value can be realizable if individual developers solely are to implement the innovation process. The intelligent window is a good example of such a solution, which may fail to be realized, even though it is highly valued. It is not possible to generalise, but it could be argued that *expensive solutions* in some cases need to be innovated through PPI models[3] or other type of corporate innovation systems.

When developing sustainable solutions the relative advantage may not be directly clear in all solutions. On the one hand we may have solutions that are profitable from a socio-economical point of view, but will not be realized due to the lack of adoption by the end-user. Surprisingly it was observed in the project that the phenomenon of talking about sustainable solution in itself added some value for the end-user, i.e. if the adoption is focus of the developments also this effect is positively included in the early-stage innovation process. The *second solution* with the social dimension was a good example of this phenomenon, since the main part of the users were not pre aware of the social dimension in sustainability, which intrigued them to rate the experience solutions, e.g. ‘the sensor door’, on relatively higher ranking, when discovering this third dimension, social sustainability. The solution was classified as *realizable solution* in the context of the new approach.

The third solution focused on the compatibility of standardised solutions. So they can be built in or replaced with no further considerations, i.e. the principle of plug and play in the built environment, see (Marechal:2010). Furthermore the success of this solution is highly dependant on the compatibility, meaning its consistency with social practice and norms among the users, since the adoption by the users of the system is evident, i.e. are the users willingness sufficient to support the investments for the developments of the system. Therefore the OBS idea also should be classified as an *expensive solution*. This solution is highly dependent on the behavioral intention of the end-user and could be interesting to

[3] PPI models: ’Public-Private Innovation models’, Partnerships between public and private organizations in innovations, see for instance (OECD, 2004).

investigate in the near future with a technology acceptance model like UTAUT: 'The Unified Theory of Acceptance and Use of Technology', see (Venkatesh et al., 2003).

CONCLUSIONS

It was shown that given the right condition and surroundings, and with the rightly chosen users, collaborative innovation with a strong focus on the adoption combined with user-driven innovation seems to be a useful approach for developing sustainable solutions in the early-stage innovation.

It was shown that an even higher degree of success could be achieved, when combining the basic principles of user-driven innovation with the parameters influencing the Technological Acceptance Models (TAM). Even though TAM models are normally used on IT solutions, it seems likely that these models may be extended to be used on other advanced technology solutions, e.g. sustainable solutions in the built environment.

The complete approach presented: 'the TAU – model', for developing sustainable advanced technology solutions involves focus on the adoption parameters presented in the model, controlled through well prepared facilitation, including the user-driven innovation methods applied. The approach is not solely limited to sustainable solutions, but can also be employed on other advanced technology developments in general.

Furthermore several early-stage innovated sustainable advanced technology solutions have been the outcome of this project. Whether these solutions may be realized throughout the innovation process is far too early to estimate. It would therefore be of interest to follow these ideas in the near future. It is further recommendable to carry out regular tests with Technology Acceptance Models, e.g. UTAUT, on ready-made solutions, and reflect back to the experiences from this project, to draw more precise conclusions and further validate the early-stage innovation approach used in this project.

REFERENCES

Ajzen, I.; Fishbein, M (1980), Understanding attitudes and predicting social behavior, *Englewood Cliffs, NJ: Prentice-Hall*

Brandt, E., Messeter, J. (2004) Facilitating Collobaroration through Design Games. *Proceedings Participatory Design Conference*, 121-130, Toronto: ACM.

Nielsen, M. B. et al. (2011), Scenariebøger for indlejret teknologi i byggeriet, bog 1-5. København: DI Byggematerialer.

Davis, F. D. (1989), Perceived usefulness, perceived ease of use, and user acceptance of information technology, *MIS Quarterly* **13(3)**: 319-340

Dillon, A. (2001) User Acceptance of Information Technology. In W. Karwowski (ed). *Encyclopedia of Human Factors and Ergonomics*. London: Taylor and Francis.

Erhvervs- og Byggestyrelsen (EBST) (2011). *Brugerdreven Innovation – Baggrunden for programmet*. Webpage accessed 10-01-2011 at: http://www.ebst.dk/brugerdreveninnovation.dk/baggrunden_for_programmet

Forsknings- og Innovationsstyrelsen (FI) (2006). Brugerdreven innovation – Baggrundsrapport til et strategisk forskningsprogram. København: Forsknings- og Innovationsstyrelsen, Ministeriet for Videnskab, Teknologi og Udvikling.

Granqvist C.G., (2008), Smart windows, *Advances in Science and Technology*, Vol **55** pp 205-212.

von Hippel, E. (1986), Lead users: a source of novel product concepts, *Management Science* **32**: 791–805

Lee, G., Sacks, R., and Eastman, C. M. (2006). Specifying parametric building object behaviour (BOB) for a building information modelling system. Automation in Construction, 15(6), 758-776.

Marechal, P., Bourdeau, M. (2010), *ICT-based Energy efficiency in Construction – Best Practice Guide*. Report from eu-project REEB. Bruxelles: European Commission Information Society and Media.

OECD report, 2004, *Public-Private partnerships for research and innovation: an evaluation of the Dutch experience*. Paris:OECD.

Storgaard, K., Cornelius, T. & Ærenlund, L. (2010). Involving users in the development of embedded technology in Construction. 6th Nordic Conference on construction economics and organisation, Copenhagen.

Venkatesh, V.; Morris, M. G.; Davis, G. B.; Davis, F. D. (2003), User acceptance of information technology: Toward a unified view, *MIS Quarterly* **27(3)**: 425-478

PREFABRICATION AS A SOURCE FOR CO-CREATION: AN INVESTIGATION INTO THE POTENTIALS FOR LARGE-SCALE PREFABRICATION IN THE UK

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Prefabrication, as a means of customer co-creation, can offer great opportunities if perceived accordingly. The research evaluates the use of prefabrication within the hospitality sector in the UK and identifies the advantages of, and hindrances on, its application as a tool to encourage client participation in the design process. A mixed methodology has been used to gauge the general attitudes towards prefabrication, prevailing technical understanding and knowledge of the concept, its applicability, and its perceived advantages and disadvantages. The research indicates decreased construction times and increased quality as the main advantages and poor current education within the industry regarding prefabricated practices, the archaic nature of the industry lacking trust, reluctance to embrace new and innovative techniques, and the absence of a proven holistic and encompassing evaluation technique to provide accurate and reliable comparisons between differing construction methods as main obstacles on the way . The study facilitates the identification of key factors associated with stimulating more efficient use of prefabrication within the UK construction industry. The outcomes will help the industry to develop and evolve to suit the needs of, and overcome the constraints imposed by and on, today's clients towards a more customer-centred construction industry.

KEYWORDS: modern methods of construction, modern prefabrication, new modularisation, customer co-creation, value co-creation, mass customisation.

INTRODUCTION

Prefabrication is a term subject to open interpretation within the construction industry, denoting any component or product that is fabricated off-site, transported to and assembled on site. In its broadest sense this could be a clay brick, moulded and blasted in a furnace off-site, and then transported to site and assembled with other prefabricated bricks to form a wall. Curl (1993) attempts to show the vast diverseness of this description by defining prefabrication as 'the manufacture of building components in a factory or elsewhere before transportation and erection on site'. He then continues to highlight that due to the encapsulating nature of prefabrication as a classifying term, the 'line between a prefabricated and non-prefabricated house is blurred' (Curl 2006). White (1965) states that 'prefabrication need not be linked with mass production as understood in the modern factory'. This is correct in a true definition of the term, but to understand the concept of prefabrication within the construction industry mass production, and more importantly standardisation of elements, need to be carefully taken into account. The classification of the term prefabrication as an evolving concept can produce controversial opinions and arguments, depending on the depth, timeframe, and context.

Co-creation is arguably a market-driven production strategy which sets out to enhance customers' participation in the value-chain by developing its extensionality beyond the traditional market definitions. Probably first coined by Prahalad and Ramaswamy (2000, 2004), it was primarily aiming at deployment of customer competence. It eventually turned to address the transition of design/creation process from a closed one inside the firm to a dynamic interaction between customer and the firm to add value. As a result the traditional one-off transaction as the contact point between each customer and the firm, evolved to a continuum of an experience which starts well before the actual purchase takes place but also continues way beyond that. In this sense co-creation is still a new concept in its disciplines of origin and even newer in built environment and construction industry.

Origins of prefabricated techniques

Standardisation forms an integral part of Nissen's (1972) model of modular systems (see Figure 1), and is devised to increase productivity within the industrial sector through effective allocation of resources. CIRIA (1999) describes standardisation as 'the extensive use of *components*, *methods*, or *processes* in which there is *regularity*, *repetition* and a *background of successful practice*'. These factors, when applied correctly, increase productivity as anticipated by Nissen. CIRIA (1999) further defines standardisation as providing *predictability and efficiency,* offering *significant benefits* to differing participants in the construction process, which they ascertain can then be passed on to the end-users.

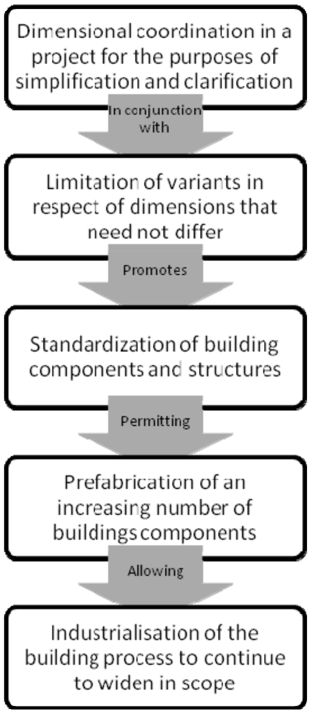


Figure 1: Concept of non-traditional construction methods. Adopted from Nissen (1972)

Prefabrication is the natural development from standardisation, with the now standardised and defined components requiring assembly. The ideal of repeatedly producing identical prefabricated components that are assembled on site to produce a fully finished product is a concept that is rarely achievable within the diverse demands of today's construction industry.

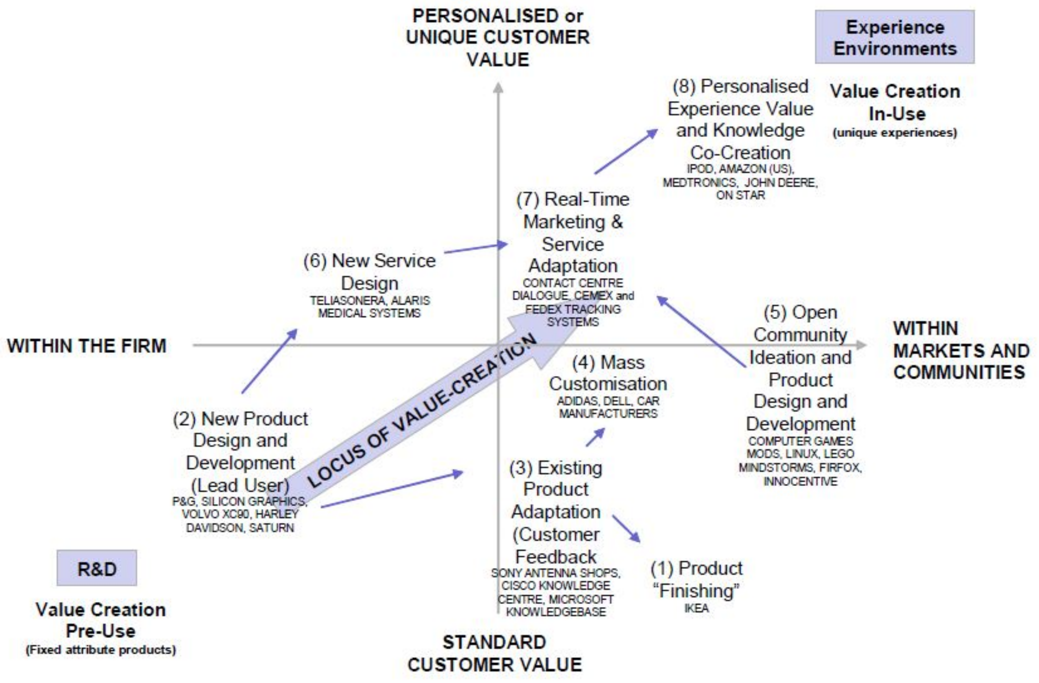
Design constraints vary immensely between different projects, with clients and architects visions and requirements, constraints of the locality of site, the environmental implications placed upon the project, and the differing user requirements, influencing the final design outcome.
For the purpose of this research, prefabrication will be defined as "the fabrication of components offsite, prior to transportation and erection on site". Clarification of the level of prefabrication being referred to within the research is to be provided wherever required.

Co-creation theories

Co-creation is a business phenomenon which can facilitate value appreciation for both consumer and supplier. The concept is centred around the ideal that as suppliers learn more about the customer, more opportunities become available for improvement of the design of the relationship experience and to enhance co-creation with customers (Payne, Storbacka & Frow 2007, Payne *et al.* 2009). A premise for co-creation is that involved parties will acquire a deeper understanding of the interaction from both perspectives, enabling them to optimise the value gained by both parties. In this sense, co-creation is 'outside in' in that it starts from developing an understanding of the customers value creating processes, and aims at providing better support for value achievement for all parties (Payne, Storbacka & Frow 2007). Co-creation is a highly individualised process, with each person's uniqueness affecting the process (Etgar 2007). It is about placing human experience at the centre of the design process and developing partnerships to maximise the value gained (Ramaswamy and Gouillart 2010).

Claiming that the definitions for co-creation (and co-design) even in online sources such as Wikipedia are few and far between, Sandersa and Stapperstake (2008) take co-creation to refer to any act of collective creativity, i.e. creativity that is shared by two or more people. Co-creation as a concept in any scenario must not be limited to a two dimensional interaction. All stakeholders involved in the process must be included and take value from the facilitation of the concept for successful implementation (Ramaswamy and Gouillart 2010). Lawer (2006) suggests eight styles of firm-customer knowledge co-creation (see Figure 2).

Figure 2: Eight style of firm-customer knowledge co-creation (Lawer 2006)

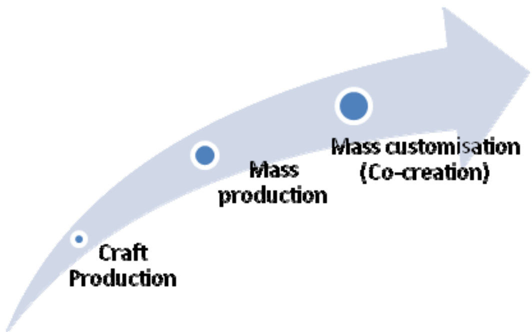


Within the construction industry these stakeholders may include the client, supplier, main contractor, sub-contractor and manufacturer. The definition and quantification of value is a complicated and highly personalised phenomenon due to the vast diversity of interpretations across varying sectors and parties. The value created for each stakeholder within prefabricated processes will also vary greatly, and will be intrinsically linked to the experience of their individual process as well as the entire process itself from conceptual design to operational maintenance. Management of the interaction of stakeholders is key and will allow them to decide and manage how they work with each other through a structured process is an effective example of this. Direct interaction is essential to fully develop the concept and realise value for all.

Customer co-creation in the building industry

Co-creation is considered as a sub-strategy of mass customisation. Chronologically (mass) customisation is an historical development of mass production which was developed subsequent to American System of Manufacturing (Pine 1993, Piroozfar 2008) as an industrial respond to the growth in the demand due to the industrial revolution which made a shift from traditional niche production an inevitable destiny (see Figure 3).

Figure 3: The production paradigm from craft to mass customisation

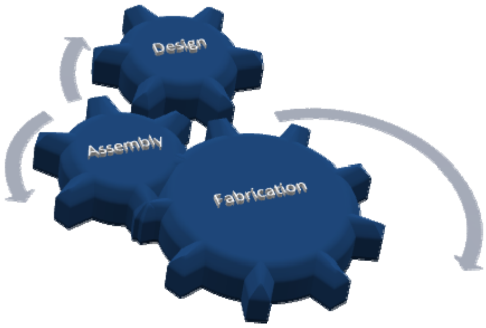


The concept of co-creation is novel enough in its very generating disciplines that leave a great black hole in existing literature and calls for practically and efficiently clinging to the notion of knowledge transfer to use those outcomes in building industry. However, there are still lessons to be learnt from other pioneering industries in the field.

Customer co-creation needs to be devised with advanced technologies. Not only does this necessity comprises of ICT as a means of real-time communication with customer, but it also includes high level of modularity in its modern meaning in design, fabrication and assembly paradigms as used in manufacture industries.

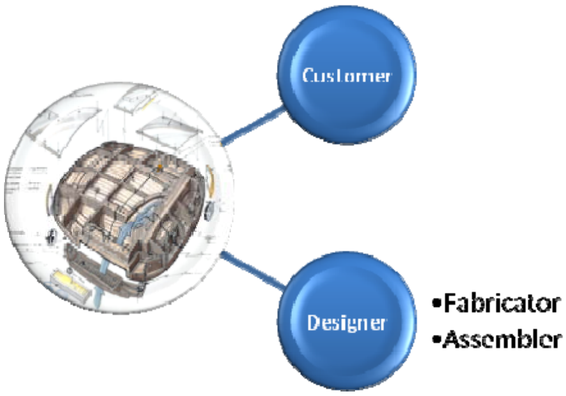
With the current pace of change as demanded by the market, no more is the customer role only to present their needs, requirements and preferences in their brief of the final product. The design, fabrication, assembly triangle is seeking to limit the rigidity within the circle and offer as much flexibility to the customer as possible (see Figure 4).

Figure 4: New relationship between design, fabrication and assembly.



These will include customer participation in the real design/fabrication/assembly process wherever applicable. This has revolutionised the old linear process between design, fabrication and assembly in manufacture industry or what was perceived as design, construction, delivery triumph in construction industry for centuries. In this new correlation the customer finds a more substantial standing quite close and similar to the role of other generative parties within the production process of space, as demonstrated in Figure 5.

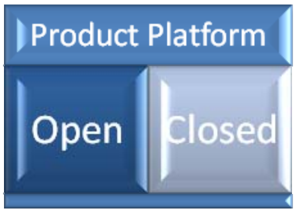
Figure 5:The new customer role as co-creator of the space in conjunction with the traditional producers of space.



In co-creation what forms the core debate is that each and every product regardless of their size, nature or specification can be broken down into two boundaries: One in which there exists flexibility of design supported by the corresponding technologies in fabrication and assembly stages; known as open area, and the other in which change and modification is restricted to the non-customer co-creators i.e. the designer, fabricator and assembler. This is known as closed area.

The concept of open/closed areas of a product platform (see Figure 6) becomes more important in construction industry (compared to other manufacture and service industries) because of the concrete nature of the final product in construction industry. However, what contradicts with this very fact is that the added value in building industry is not merely determined by the performance. Despite other industries, in building industry in many cases the value is measured through aesthetics and representation. Nevertheless, the more the technology advances, the bigger the open space and the smaller the close area become.

Figure 6: Open and closed areas for customer co-creation.



In this sense prefabrication has been studied as a means of enhancement of the product platform by promoting the modern concept of modularisation. This will provide the production process with more open areas than before to be communicated with the customer and engage them in the production process more interactively and more efficiently.

RESEARCH METHODOLOGY

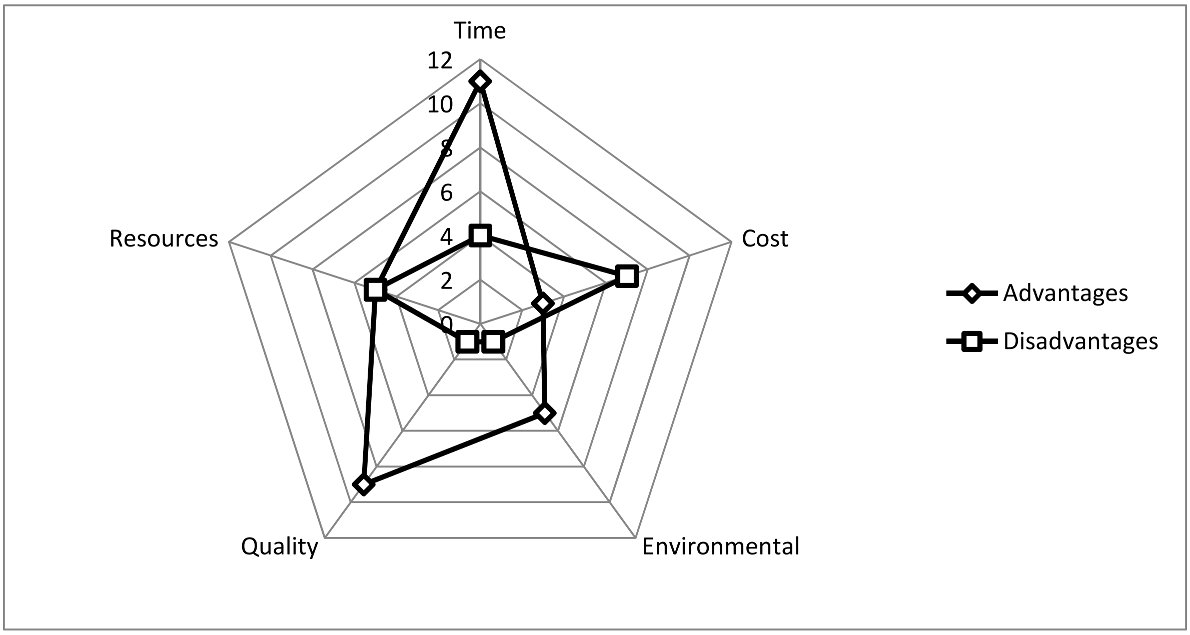
With prefabrication in the centre of this research, a study was designed and carried out to figure out the extents to which MMC's are used in the UK construction industry, and the potentials to enhance this level as a facilitator of customer co-creation. The research sample consisted of eleven professionals currently operating within the UK construction industry, with an average experience level of 17 years. Representatives from the design, manufacture and construction sectors of the industry participated. The research was conducted in two stages. Using a pilot questionnaire general attitudes and opinions were gauged, and a semi-structured interview was used to further develop an understanding of the reasons for the current levels of use of prefabrication within the hospitality sector, and the hindrances and stimulants for increasing this.

RESEARCH FINDINGS

Advantages of prefabrication

The main perceived advantages of the use of prefabrication were clearly identified as time savings and quality improvements, whereas the main disadvantages are shown as increased costs and resources (see Figure 7). The two advantages identified are supported by the work of Goodier and Gibb (2007) and Tam et al. (2007), who ranked increased quality first, with reduced construction time second. Gibb and Isack (2003) also identify time and quality as the main benefits, with their research conducted in the client sector. This consistency in the data collected within the four research projects may be used to draw the conclusion that the main perceived benefits of prefabrication are consistent throughout the industry as time savings and an increase in quality.

Figure 7: Spider diagram depicting the perceived advantages and disadvantages of prefabricated techniques.



Identification of the actual benefit realised from a reduction in construction time was not addressed within the responses to the questionnaire. The British Research Establishment (2001) suggest two main advantages of 'faster' construction; a reduced impact on the local environment and the ability to rapidly erect a weather tight building shell, allowing internal 'fit out' works to be instigated earlier in the project programme.

It could be assumed that the responses to the questionnaire indirectly referred to economical benefit to be gained from reduced construction periods, for example savings on preliminary costs, but with no direct reference this claim would be unjustified. The limited spectrum of response when discussing the advantages of prefabricated techniques within the research may suggest a lack of co-creative awareness within the construction industry. Value gain may not necessarily be derived directly from an identified advantage; for example a satisfied client may well return to a product or supplier for future projects on past experience. Through the client's initial value appreciation, value is in turn appreciated by the supplier at a later date.

Education and evaluation of construction methods

75% of interviewees stated that a client will almost always have a preconception on the use of prefabrication prior to inviting tenders from the design team. It was widely recognised within the research that a good understanding and knowledge of all potential methods is required to substantiate this; an attribute that it may be claimed is not possessed by those influencing projects at this stage. The research also cited that the client will almost always have decided upon a construction method prior to appointment of the main contractor. The research identifies the potential for a symbiotic relationship between the client, design team and contractor; with the client's requirements, architects technical knowledge, and the contractors experience and practical knowledge facilitating optimum efficiency. The realisation of this directly correlates with the definition of co-creation provided by (Payne, Storbacka & Frow 2007, and Payne et al. 2008), in that as stakeholders learn more about each other, more opportunities become available for value gain. The Egan Report (1998) identified that at the time of writing *"current processes do not use contractors and suppliers knowledge in* *design"*. The research suggests that this remains prevalent within the construction industry today, with all respondents claiming that advice is sometimes or almost always sought; but all paying reference to the timing and utilisation of this advice. It is unanimously claimed within the research that advice is not sought at the earliest possible stage, with a perceived hierarchy within the industry placing contractors at 'the foot of the ladder'. It is clearly evident that the potential for co-creation within the prefabrication sector exists, but the barriers and hindrances to its inception and acceptance as an adopted phenomenon were prevalent throughout the research. These were centred on an archaic industry, reluctant to adopt new and innovative techniques, preferring instead to remain with 'tried and tested' methods, displaying an inherent lack of trust, and determined not to engage with perceived risk.

This correlates directly with the work of Goodier & Gibb (2007), who identified seven methods of education regarding prefabricated techniques currently employed within the construction industry; four of which being of a formal nature. This classification however does not validate the authenticity or accuracy of the information being portrayed. Statements within the interviews suggested that promotional material can conceal a lot of the obstacles and applicability criteria that are essential knowledge tools in the successful selection and implementation of construction methods. This demonstrates a clear example of poor attitudes with regard to co-creation, with a one dimensional perspective adopted seeking to make an immediate gain for one sole party. With the lack of identification with research originating from an independent party, seeking to reveal a true and accurate representation of prefabricated practices and techniques, from a cross section of professionals from across the industry, it is evident that this research is either not being conducted or is not being channelled to the 'front line' of the UK construction industry. The prevalence of informal education routes, as identified within the research, also indicates a lack of available valid and specific information regarding prefabrication, with many studies centred upon the perceived benefits and advantages rather than proven and achievable results. This again points to poor co-creative attitudes within the industry, with manufacturers focussing on a 'quick, off-the-shelf, one-off sale', rather than engage in mutual development of a product that provides value for all parties. The concept of co-creation is focussed upon an understanding of other stakeholders needs and definition of value, rather than a specific product or concept. The research, supported by the findings of Goodier and Gibb (2007), reveals that the industry at present identifies a direct correlation between increase in education levels and adoption of prefabricated techniques. This may be true in a pure marketing sense but for the phenomenon of prefabrication to truly fulfil its potential in any scenario, co-creative processes must be adopted.

The independent nature of accurate learning is reinforced through the respondent's identification with practical experience based learning. This method allows individuals to review and assess procedures and activities in first person perspective in a 'real world' situation, providing relevant and supported conclusions. This process of constant review and feedback was identified as being present within companies by two of the respondents, but not so outside of the organisational confines. Three respondents called for sharing of practical experience based knowledge and information, with this being identified as key to developing the use of prefabrication as an efficient and effective construction method. The values of understanding each parties experiences again suggest the scenario lending itself extensively to co-creation, but none of the research participants truly identified with the mutual benefit achievable through all stakeholders within a project. All respondents within the research stated that an increase in formal education routes would catalyse an increase in the use of prefabrication, again suggesting that provision for education at present is poor. This correlates directly with Egan (1998), who identified a lack of provision for research within the construction industry. The BRE (2001) summarise the importance of knowledge within the selection of prefabricated techniques by concluding that the procurement of such systems is often a matter of relevant parties being aware of the systems that are available.

Traits of the current UK construction industry

The research identified an archaic UK construction industry, reluctant to adopt new and innovative techniques and change. A resistance to early decision making, developed from the timing of information production and flow within a more traditional project, is associated with by the respondents; with previous identification within the research of the need for an early design freeze in successful projects adopting prefabricating techniques facilitating a conflict of interests. Respondents stated that design teams 'prefer' to develop items of works concurrently and retain the freedom of change upon reflection during the preceding works, rather than to produce a defined scheme with little or no flexibility available post design freeze. This is an example of the indoctrinated and rigid form that the UK construction industry exists within, and respondents identified with the difficulties involved in breaking away from these. The one dimensional attitudes, abrasive to any co-creative intentions, are again evident here. Mental-preconditions within not only the industry itself but clients were evident within the research, with respondents supporting the findings of BRE (2001), who state that the adoption of prefabrication is hindered by the perception of the requirement for traditional brick houses, by revealing an association between the industry and 'good old bricks and mortar'. The basing of skills training and research around such perceptions is highlighted within the research, relating directly to the need for provision of relevant and independent research works. Egan (1998) identified with these issues twelve years ago, and yet still they are prominent and influential to the steering of the UK construction industry today.

The economically based analytical practices commonly adopted within the industry not only correlate with the archaic labelling, but also with the lack of uptake of prefabricated techniques. Through relating all achievable gains to economic measurement, and so limiting the stakeholders that include this in their definition of value, the potentials for any co-creative experiences are destroyed. Previous research by Blismas et al (2006), Gibb (2001), Sullivan (1980) and Pasquire et al (2004) all associate with the difficulties in accurately itemising the economic comparisons between traditional and prefabricated techniques. Associated costs are identified as being the main hindrance to a traditional standard method of measurement approach; within the unit cost of prefabricated products are included the overhead costs of the factory and transport, where as in a more traditional approach of in situ construction the preliminary costs are rarely attributed to each individual element of construction. A further example of this would be the cost savings associated with waste reduction. Respondent's within the research identified with the potential for cost savings deriving from reduced waste, but without the contractor conducting detailed analysis on their existing practices and the waste produced, it was stated that the financial gain from managing this cannot be quantified. This elementary analysis of cost within the industry was evident throughout the research, with all interview respondents associating with it. Pasqurie et al (2004) relate to the "*historically powerful tendering framework in which tenders are assessed and decisions made primarily on the grounds of cost and time*" which still plagues the industry. It was identified within the research that it was not only the economic structures of the clients that may require review, but also those of the suppliers and manufacturers. Prefabricated units often require a large portion of the cost to be provided for prior to inception of manufacture. This statement reveals the beginnings of co-creative thinking, with other stakeholders identifying with the client's needs as well as their own. This may well be attributed to the fact that the client is seen as the source of 'value' for the contractor and design team who are employed, and so the 'client's gain is their gain'.

Value appreciation

The accurate representation of the value of prefabrication was identified by one of the interviewees as a major hindrance to the adoption of such techniques, citing the use of bathroom pods as an example. The benefits of reduced waste and reduced site trades in one confined area were identified, with the difficulty in attributing a definite value to these meaning that the saving could not be quantified. The definition of value is in itself a dynamic and highly influenced phenomenon depending on the project scenario, constraints, and success factors. The basis of co-creation is the appreciation of value in differing scenarios, and to different parties. Through identifying this lack of measurement of value in bathroom pods, the respondent is inadvertently associating with a lack of holistic understanding within the construction industry of the needs and values of other stakeholders. The value taken from a reduction in wet trades on site needs to be understood in terms of logistics, rather than a monetary figure. Without the appreciation of the tasks and constraints that the contractor may have to work within, it is impossible for a client to disregard prefabricated techniques on the face of perceived economic expenditure. The industries current classification of value relates directly back to its economical driving factors as previously identified. Blismas et al. (2006), Pasquire *et al.* (2004) and Egan (1998) all associate with the inappropriateness of purely economical comparisons of construction methods, rather than holistic value based comparisons. Blismas *et al.* (2006) concurs with and summarises the ineffectiveness of current measures, and the need for task specific definition of value by stating that 'a more holistic and thorough value-based comparative is required by the industry to ascertain the true benefits of off-site-production for particular project settings'. Co-creation takes this ideal further by including an understanding of each stakeholders characteristics in this analysis also, which would allow true mapping of the value to be gained.

It is highly unlikely at present, given the identified fabricated relationship between unit output and cost, that these savings are considered during the comparison of construction methods. The inclusion of resource consumption analysis within comparisons was further developed by one of the interviewees, who referred to studies conducted by individual contractors on waste production. It was stated that resistance to adopt prefabricated techniques was often centred on companies that had not carried out detailed studies on the potential economic savings achievable through waste reduction, specific to their activities and processes. A further comparison is often conducted by contractors reviewing the potential for waste production analysis; that of research cost against potential savings. An initial investment is required to conduct such research, with Egan (1998) identifying with a lack of provision for this investment; 'it (the industry) invests little in research and development and in capital. In-house R&D has fallen by 80% since 1981 and capital investment is a third of what is was twenty years ago. This lack of investment is damaging the industry's ability to keep abreast of innovation processes and technology'. With the UK construction industry currently operating within a recession in the UK economy, it could be argued that this capital required for research and development within individual contractors is simply not a viable investment at present. Such research, combined with a holistic analysis tool, would allow for the production of more complete and balanced data regarding the use of prefabrication; identified by Blismas *et. al* (2006) as being key to the development of its use. It is this constant development of raw data processed through a holistic and independent comparison tool, combined with mutually conducted research developing stakeholders understanding of how value is appreciated by differing parties that will provide the basis for sound and justifiable decision making processes.

Sharing and utilising resources

The research reveals a reluctance to seek consultation at an early stage by clients and their design teams, especially from contractors and suppliers. Gibb and Isack (2003) concur with this, identifying that 'only a few firms overtly involve the supplier in this decision making process, and then as part of the team'. They also found that clients identified with this need for early consultation, but in practice this was rarely followed through. This depicts an evident lack of trust within the industry, with clients preferring to keep the decision making process in-house with economical, ethical and privacy motives.

The findings of the research differ greatly from those of Gibb and Isack (2003) with regard to clients seeking consultation. 90% of clients were identified as having taken advice by the outline conceptual design stage within Gibb and Isack's research, whereas it was identified within the interviews that clients often make decisions regarding the use of prefabrication early in the design stages, with 75% of interviewees stating that this decision is taken prior to consultation with specialist manufacturers or main contractors. Gibb and Isack's research was conducted within the client sector, meaning that either the industries perception of client's active seeking of knowledge is inaccurate, or the client responses to their research were the theoretical correct practice and potentially not the actual processes adopted within the industry today. The lack of evidence of consultation is directly linked with the lack of trust within an archaic UK construction industry, with clients fearful of the financial and competition based implications of sharing information with other parties within the industry. The importance of a comparison tool between construction methods is augmented by this reluctance to confer and consult, with clients retaining decision making processes requiring tools and processes to assist with these. This model of individual analytical processes contradicts co-creation extensively, and appears to reflect the attitudes present within the industry today. It may be suggested that especially within the current climate market risks may outweigh potential gains, but with no understanding of other stakeholders needs, a one dimensional and individualistic assessment of construction methods will not produce justifiable, accountable, and appropriate outcomes.

CONCLUSION

We discussed how, if redefined with the time and context specific needs and requirements, prefabrication can facilitate co-creation in building industry. With this as a core of this discussion then we moved on to discover why this crucial enabler of co-creation in building industry stands where it stands; with very low profile, low application and as underdeveloped as it is at the time being in building industry. The research set out to discover what is perceived as the advantages and disadvantages of prefabrication. The main advantages of prefabrication were found as decreased construction times and increased levels of quality within the finished product, in comparison to more traditional construction methods. Within the research the main hindrances to the successful and effective use of prefabrication were identified. Education levels within the industry were identified as being poor, with a significant lack of formal routes of education provided for and an evident deficit in impartial and founded information regarding prefabricated techniques. The UK construction industry also demonstrated an inherent resistance to new and innovative techniques through the adoption of minimalistic and elementary unit based comparison methods. Whilst conducting comparisons between prefabricated and more traditional techniques, it is evident that the concept in its entirety is not considered; but instead certain individual elements that do not reflect the true encompassing value of the concept. A severe lack of trust is prevalent within the UK construction industry between all parties, with the provision for open and symbiotic knowledge and information sharing relationships non-existent. The potential benefit of these appears to be offset by the perceived risk of detrimental effect, be it in a commercial, social, or practical form. The research identified the potential benefits and optimisation of current practices that could be realised through the establishment of these symbiotic relationships, but co-creation as a concept can never be realised whilst the exposed preconceptions and inherent traits are present within the UK construction industry. The reasons for this evident reluctance to adopt co-creative practices within the UK construction industry need to be explored, and the viability of the concept within the industry considered. With any new and innovative phenomenon there will always exist the issue of 'who jumps first'; which party is willing to openly share information and encourage others to adopt a similar mutually agreeable exchange.

Client decision making over the construction method to be employed directly relates to these findings, with it stated that this is often conducted without consulting suitable expertise, and without possessing sufficient knowledge to do so. These uninformed and irrational decisions are very hard to influence and change by an outside party, rendering any consultation sought post decision making processes futile. Comparisons between different construction methods are currently based on the assessment of individual components, rather than the concept as a holistic working phenomenon, and so at present do not provide substantiated or accurate outcomes. Current techniques focus solely on economic factors and include non-economic phenomena into inaccurate monetary comparisons.

With it evident that clients within the UK construction industry prefer to keep decision making 'in-house' the development of a proven holistic and encompassing evaluation technique that is accessible and applicable to all relevant projects is extenuated, to allow clients to retain a certain element of decision control. The research identified that an increase and improvement of the knowledge base across the industry with regard to prefabrication would improve awareness of the concepts potentials and applicability, and enable decisions to be undertaken upon a more valid and factual grounding. The research closely associated with the requirement for collective decision making to compliment the realistic benefits of a symbiotic process. Alleviation of the lack of trust within the industry is essential for the potential of any co-creative relationships being forged to be realised, with the significant benefits of these identified within the research.

Throughout the research two key factors have remained prevalent in the realisation of prefabrication as a efficient and effective construction method; increase and improvement in the current knowledge levels through an increased availability of accurate and founded comparison data, and the development and provision for an accurate and industry-wide accepted evaluation technique regarding the selection of construction methods. The potential for co-creative symbiotic relationships has been identified, with the enormous benefits of these to all parties evident. The identification of a requirement for valid and independent research to improve education and knowledge levels shows the beginnings of appreciation towards the concept of co-creation, and subsequently promotes a sustainable and developing prefabrication industry based on a mutual understanding of all stakeholders requirements.

It could be suggested that the multidimensional nature of the construction industry, with all projects and stakeholders imposing and requiring differing constraints, may impact upon the viability of the adoption of co-creation. On the contrary, a rapidly evolving and changing industry requires re-evaluation for each and every scenario encountered, and co-creation provides a concept and basis for a thorough and accountable analysis from all perspectives.

Prefabrication provides a suited and appropriate tool for the evaluation of the effectiveness of co-creative techniques within the UK construction industry, but the dynamic nature of projects with regard to scale, scenario, constraints, and stakeholders will ultimately determine the suitability and adoption of such techniques.

REFERENCES

Bender, R. 1973. A crack in the rear-view mirror: a view of industrialized building. New York: Van Nostrand-Reinhold.

Blismas, N., C. Pasquire & A. Gibb. 2006. Benefit evaluation for off-site production in construction. *Construction Management & Economics,* 24**,** pp.121-130.

British Research Establishment. 2001. Current practice and potential uses of prefabrication. Watford: Department for Trade and Industry.

CIRIA. 1999. Standardisation and pre-assembly: adding value to construction projects. London: CIRIA.

Cox, A. 2010. Evaluation of use of prefabrication within the hospitality construction sector in the UK. Honours Project Dissertation. Brighton. Brighton University, School of Environment and Technology.

Curl, J. S. 1993. Prefabrication. In *Encyclopedia of architectural terms*. Donhead St Mary: Donhead Publishing.

Curl, J. S. 2006. Prefabrication. In *A dictionary of architecture and landscape architecture*. Oxford: Oxford Press.

Egan, J. 1998. Rethinking construction: The report of the Construction Task Force to the Deputy Prime Minister, John Prescott, on the scope for improving the quality and efficiency of UK construction. London.

Etgar, M. 2007. A descriptive model of the customer co-production process. *Journal of the Academy of Marketing Science,* 36, pp. 97-108.

Gibb, A. 2001. Standardization and pre-assembly- distinguishing myth from reality using case study research. *Construction Management & Economics,* 19**,** pp. 307-315.

Gibb, A. & Isack, F. 2003. Re-engineering through pre-assembly: client expectations and drivers. *Building Research & Information,* 31**,** 14.

Goodier, C. & Gibb, A. 2007. Future opportunities for offsite in the UK. *Construction Management and Economics,* 25**,** pp. 585-595.

Lawer, C. 2006. Eight Styles of Firm-Customer Knowledge Co-Creation. No.4 in a series of short papers on new perspectives in customer strategy and innovation. The OMC Group. Webpage accessed 14-02-2011 at:
http://www.theomcgroup.com/omcpapers/Eight%20Styles%20of%20Firm-Customer%20Knowledge%20Co-Creation.pdf.

Nissen, H. 1972. *Industrialized building and modular design*. London: Cement and Concrete Association.

Pasquire, C., Gibb, A. & Blismas, N. 2004. Off-site production: Evaluating the drivers and constraints. In *12th Annual Conference on Lean Construction*. Copenhagen, Denmark.

Payne, A., Storbacka, K. & Frow, P. 2007. Managing the co-creation of value. *Journal of the Academy of Marketing Science,* 36, pp. 83-90.

Payne, A., Storbacka, K., Frow, P. & Knox, S. 2009. Co-creating brands: Diagnosing and designing the relationship experience. *Journal of Business Research,* 62(3), 379-389.

Pine, B. Joseph II. 1993. Mass Customisation - The New Frontier in Business Competition. Boston, Mass: Harvard Business School Press

Piroozfar, A. E. 2008. Mass-Customisation: the application on design, fabrication and implementation (DFI) processes of building envelopes. PhD Thesis. Sheffield. University of Sheffield, School of Architecture.

Piroozfar, A.E. and Popovic-Larsen, O. 2009. Customizing Building Envelopes: Retrospects and Prospects of Customization in the Building Industry. In: *Piller, F. and Tseng, M (eds). Handbook of Research in Mass Customization and Personalization.* Vol 2. Singapore. World Scientific Publishing Co Ple Ltd. pp. 925-948.

Prahalad, C. K. and V. Ramaswamy. 2000. "Co-opting Customer Competence." Harvard Business Review 78(1): pp. 79-87

Prahalad, C. K. and V. Ramaswamy. 2004. The future of competition : co-creating unique value with customers. Boston, Mass., Harvard Business School Pub

Ramaswamy, V. & Gouillart, F. 2010. Building the co-creative enterprise. *Harvard Business Review,* October 2010, pp. 100-109.

Sanders, Elizabeth B. -N. and Stappers, Pieter Jan(2008) 'Co-creation and the new landscapes of design', CoDesign, 4:1, pp. 5-18

Sullivan, B. J. 1980. Industrialization in the building industry. New York: Van Nostrand Reinhold Company.

Tam, V., Tam, C., Zeng, S. & Ng, W. 2007. Towards adoption of prefabrication in construction. *Building and Environment,* 42**,** pp. 3642-3654.

White, R. B. 1965. Prefabrication: a history of its development in Great Britain. London: H.M.S.O.

BUILDING INFORMATION MODELLING AS INNOVATION JOURNEY: BIM EXPERIENCES ON A MAJOR UK HEALTHCARE INFRASTRUCTURE PROJECT

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The evolving digital technologies and emerging practices of Building Information Modelling (BIM) represent an opportunity to transform existing modes of design, construction and operation. This paper discusses empirical findings from an ongoing longitudinal case study of a BIM implementation, specific the transition of BIM from the design office to the site environment and from the design phase to delivery phase. Interviews were conducted with BIM innovators and users working for a large international contractor on a major hospital development project in the United Kingdom. The analysis draws on Van de Ven's model of the 'innovation journey' and the associated analytical categories of; ideas, people, transactions, context and outcomes. Analysis of the development and use of BIM on the project reveals the emergent and dynamic nature of the innovation process as it unfolded over time. Although the accounts of the BIM development bore many similarities with the innovation journey findings, we found suggestions of differences in the areas of 'people' and 'context' where our respondents seems too have created more stable and manageable situation than the innovation journey concept would predict.

KEYWORDS: BIM, innovation journey, hospital

INTRODUCTION

The study of innovation is prominent in the construction management literature with uncontested agreement that more and better innovation is important and necessary with. Slaughter (2000), among others, arguing that "Innovations can form the backbone of a company's strategy" (2000: 2). The importance placed on innovation is further underlined by concerns that construction is less innovative than other industries (Winch, 1998). Koskela & Vrijhoef (2001) point out that construction's productivity and quality are low in comparison to other industries and report that the 'major explanation' for this is a lack of innovation.

Given that the benefits of innovation are uncontested, research has focussed on how best to foster and encourage innovation. An example of this is Peansuapp & Walker's (2006) case studies of ICT implementation by construction contractors. Research of this sort seeks to understand the 'barriers' to innovation highlighting among others lack of management support and some user's personal learning capability. More broadly, Winch (1998) attributes construction's low rate of innovation to structural features of the industry (a project-based complex product system industry with separate and conflicting systems integrators. Gann & Salter (2000) argue that, in light of these challenges, a higher-level enabling infrastructure is necessary to overcome these problems and support innovation.

Although such high-level enabling structures are important and worthy of study (see e.g. Seaden & Manseau, 2001), our approach is to focus on drawing lessons from specific cases of innovation (Flyvbjerg, 2004). In the area of digital construction research, Moum etal (2009) have identified “a growing interest among several research communities in the experiences gained from applying new technologies to practice” (2009: 229-30). The research described in this paper, reflects that interest. It is a case study of a project-centred innovation to develop and implement Building Information Modelling (BIM) technologies for use on a major UK healthcare infrastructure project. Our analysis draws on Van De Ven etal’s (1999) concept of the ‘innovation journey’.

The Innovation Journey

The ‘innovation journey’ is a term used by a group of researchers to encapsulate their findings into a series of studies into the “inherently uncertain and dynamic” processes of making an innovation happen (Van de Ven et al, 1999: 3). The Minnesota Innovation Research Programme (MIRP) consisted of fourteen in-depth, longitudinal case studies of significant innovation projects within American companies and public bodies. The research was undertaken within organisations by thirty researchers over a period of ten years studying and tracking innovations as they happened (Van de Ven et al, 1989).

The MIRP studies challenged ‘traditional’ innovation models in which the innovation are thought to move through a series of stages or phases of development. In these traditional models the innovation process was seen as a series of planned, linear predictable moves from equilibrium to equilibrium stabilised by trial-and-error learning and sense making. The MIRP researchers rejected these models as a way of describing innovations as they found no evidence for up-front strategic planning or linear stages in the innovations they studied. It is significant that these findings were not for small, limited innovations. Each study was of significant changes that met the following criteria (Van de Ven et al, 1999):

1. Consists of a purposeful, concentrated effort to develop and implement a novel idea
2. Is of substantial technical, organizational, and market uncertainty
3. Entails a collective effort of considerable duration
4. Requires greater resources than are held by the people undertaking the effort.

The main analytical focus of the MIRP studies was the ‘incident’ (a major recurrent activity or whenever changes were observed to occur). These incidents were recorded and coded in terms of a set of ‘key constructs’, namely; ideas, people, transaction, context, and outcomes. The summary findings of this analysis (compared with the literature on traditional innovation models is shown in Table 1.

Table 1: Summary findings of the MIRP studies (Van de Ven, 1999)..

Category	Literature implicitly assumes:	But we see this:
Ideas	One invention, operationalised.	Reinvention, proliferation, reimplementation, discarding and termination.
People	An entrepreneur with fixed set of full-time people over time.	Many entrepreneurs, distracted fluidly engaging & disengaging over time in a variety of roles.
Transaction	Fixed network of people/firms working out details of an idea.	Expanding, contracting network or partisan stakeholders who converge & diverge on ideas.
Context	Environment provides opportunities and constraints on innovation processes.	Innovation process creates and constrained by multiple enacted environments.
Outcomes	Final result orientation: A stable new order comes into being.	Final result indeterminate; Many in-process assessments and spinoffs; Integration of new orders with old.

The reasons for adopting the innovation journey concept for the analysis of our research was the resonance between the MIRP findings and our own observations from earlier phases of our research of the emergent, negotiated and non-linear nature of the technology innovation process (Harty, 2008). In the following sections we present some initial findings from our own study of an innovation journey; efforts on the part of members of a construction project team to implement Building Information Modelling (BIM) technologies. We briefly present some background on BIM and a description of the case study before an analysis of the innovation in terms of the MIRP categories presented in Table 1. We conclude with some reflections on the usefulness of the MIRP-based analysis and the extent to which our analysis reflects those of the MIRP.

Building Information Modelling

Building Information Modelling (BIM) is a term used to refer to a family of technologies and related practices used to represent and manage the information used for, and created by, the process of designing, constructing and operating buildings. Aspects of BIM such as computer-aided design and 3D representation along with various forms of electronic communication are well established, even ubiquitous, technologies for any reasonably sized construction project (Whyte, 2002)

Of interest now are attempts to gain further benefits from the possibilities of the technologies to integrate the production, sharing and representation of information to join up the design and construction processes, to re-use the same information down the supply chain and to digitally mediate construction activities. To achieve these broader, more ambitious objectives BIM needs to be more than just the use of these various tools. There are technical challenges of software and data inter-operability as well as the need to create appropriate business and social practices and processes.

This wider view is reflected in recent attempts to define BIM in publications aimed at practice audiences. For example,

“[BIM is] a modelling technology and associated set of processes to produce, communicate and analyse building models” (Eastman et al, 2007: 13).

“BIM is the management of information and the complex relationships between the social and the technical resources that represent the complexity, collaboration and interrelationships of today’s organizations and environment. The focus is on managing projects to get the right information to the right place at the right time” (Jernigan, 2007: 23)

These definitions highlight the increasing recognition of the importance of understanding the inter-relations between organisational, social and technological constituents of any given ‘BIM system’ and also the environment in which it operates.

Given the complexity of this undertaking it is perhaps not surprising that even flagship projects have found it difficult to achieve the vision implied by these definitions.

Specific difficulties include: the significant resource requirements and re-configurations of existing practices they demand; the challenge of capturing new practices developed through project work for subsequent re-use; the lack of a clear market leader or of robust integrated technological solutions to guide technology choices. These problems have been revealed both through attempts to develop and implement such technologies in practice, and through research which has followed and traced these efforts (Harty, 2005; 2007a b). The apparently simple introduction of BIM technologies and, crucially, developing the practices and processes to support them is a significant undertaking. It has implications throughout the design and construction process, and that go beyond a simple adoption of new technologies, requiring considerable change to current ways of working.

Case description

The construction project is combination of new build, demolition and refurbishment work across two London hospitals, with a total value of approximately £1 billion. At the time the interviews were conducted design was complete and construction well progressed with the larger new build hospital in the process of handing over areas of the building for commissioning. Final completion of the construction work is scheduled for 2014. The project was funded through a PFI package and contracted on a design-and-build basis with a multi-national contractor leading the project team. The contractor also has responsibility for the facilities management of the project for thirty years after handover.

The innovation project is the development, adaption and adoption of a range of BIM tools by the main contractor. An earlier phase of the research (Harty, 2008) concentrated on the development of coordinated 3D BIM models and related design tools. This phase is concerned with technologies intended to support ‘site’ applications of BIM. The significant components are:

- Portable tablet computers (with standard corporate builds plus the specific BIM components that synchronise when the tablet is ‘docked’).

- Coordinated 3D BIM models (local copies of model files split into floors and/or zones for each building).

- Document management system (DMS: customised, in-house corporate system, accessible over the internet to upload and receive information. Manages the explicit issue of drawings by Document Controllers).

- Site BIM integration database. (externally produced product from a small software vendor. Consists of a 3D model viewer and database functionality to allow attribute metadata to be associated with objects in the model and to use these relationships for display, searching and reporting. A link to the DMS presents latest drawings if model objects are selected. New functional elements implemented as user-completed forms for electronic completion of compliance checklists, progress monitoring and defects.)

Method

The research design is an on-going longitudinal case study undertaken in phases of retrospective data collection. The main empirical method is formal, semi-structured interviews with supplementary document analysis, informal meetings and discussions, observations, and feedback on reports. For the current phase, interviews were conducted with main contractor project staff responsible for oversight, implementation and use of BIM on the project (Design Director(2), Project Manager & Operations Manager(2), Document Manager(2), Quantity Surveyor(2), Compliance Manager(2), BIM Co-ordinator, Design & Compliance Manager, Environmental Manager, Project Information Manager, BIM & 3D CAD Manager.)

Our data collection is not theory-led and was not designed to test MIRP hypotheses or to collect MIRP-friendly data so the analysis adopted in the paper takes an exploratory approach to post-hoc application of the MIRP analytical categories. An subsidiary objective is to shed some light on the process of interpreting retrospective case study data. Many case studies use data of this type. The MIRP studies are rare in respect of the ongoing, embedded, longitudinal access to emerging innovations. It is hoped that applying the MIRP framework to our more modest data will allow some reflection on the data's limitations.

Analysis: The BIM innovation journey

The starting point for the innovation journey for 'site BIM' was the previous use of BIM for design coordination (Harty, 2008). This had given the construction teams a "*great visual diagram*" but also "*information in the background that nobody knew about*". Much of the BIM developments have been ways of exploiting that background information. The remaining sections of the report expand on some aspects of this in terms of the MIRP framework that was outlined in Table 1.

Ideas

a coding of the substantive ideas or strategies that innovation group members use to describe the content of their innovation at a given point in time.

In common with other broad approaches to motivation, and with much of the construction management literature (e.g. Slaughter, 2000), the MIRP researchers saw innovation as the implementation of any idea new to those responsible for it. The process of innovation can then include the creation of ideas or the adoption or recombination of existing ideas into a new setting. The major challenge to previous innovation studies is that rather than innovation consisting of one single idea retained and implemented throughout the innovation process, the MIRP researchers found many, emergent ideas and their, "reinvention, proliferation, reimplementation, discarding and termination."

In our case study, the change from design to construction to design has coincided with a significant change in the idea of what BIM is for. The use of the 3D BIM models was originally intended to be used to produce a coordinated design only.

"*no one knew that back then, this is all served off the back of the work that was done in the early days so our mind set was, we are going to produce a 3D model, we are going to check it for compliance, we are going to clash detect it, we are going to convert it into 2D and then we are going to scrap it.*"

"*the part we've got is a part I never thought we'd have…we didn't have the concept back two or three years ago, which is the database linking, which has been so beneficial now*"

The major shift of idea appears to have been to regard the 3D information as an exploitable resource that can be used to support site operations. Even in retrospect though there appears to have been multiple ideas as to what the nature of that support should entail. So, for example one participant stated that the intention for the tablets was to simply get correct, usable information to site users without any particular exploitation of the data.

"*We've got to the construction stage and we are worried about how bloke at the sharp end is going to get his information so that he knows what he's building. […] My responsibility was making sure or trying to do whatever I could for the man at the sharp end to have the latest correct information.*"

Another idea was that using tablet PCs for monitoring progress and compliance was the driver and the information function arose our of that. In another account the purchase of the software that allowed the 'site BIM' functionality was originally motivated solely to produce electronic handover documentation. These accounts suggest the emergent and dynamic evolution of ideas found in the MIRP studies was also the way in which the BIM tools developed.

What does is appear consistent is the idea that BIM is seen as a set of technologies to manage work and to support and drive a 'right first time' precision engineering approach to construction. BIM (and particularly site BIM) is a way to ensure work is done correctly rather than as the provision of a set of open user tools.

"*So what we're forcing the Construction Managers to do is to actually go down the road of actually double checking and job checking everything they're doing and not just sweeping anything under the carpet." "It's controlling them to do their job because it's got to be done in a certain mode. It can't be done any other way, i.e. it's either yes or no in terms of room compliance.*"

It appears that the implementation of BIM implicitly adopts a phased sequential view of operations in which the use of BIM during the design phase is intended to support the development of a correct and therefore fixable 'final design' that can be presented to construction teams for error-free implementation. This broader idea about the purpose and place of BIM can be seen to have influenced many decisions throughout the process.

People

a coding of the people/groups involved in an incident, the roles and activities they perform at a given point in time.

Any complex innovation requires the recruitment and coordination of a group of people to create facilitate the change. In the MIRP studies, this group (rather than a solo entrepreneur or 'champion' executing a fixed project plan) was best characterised as a network of many stakeholders who engage in and disengage from the innovation process over time. The key classes of people are 'innovation entrepreneurs' who risk delivering the innovation and senior managers or investors (often numerous) who sponsor the innovation and make decisions where needed. "Many entrepreneurs, distracted fluidly engaging & disengaging over time in a variety of roles."

On this project on of the most significant events in the launch and ongoing development of information management on the project explicitly and BIM / 3D CAD in particular was the employing of people with specific objectives and responsibilities in those areas (BIM & 3D CAD Manager, BIM Coordinator, Senior Document Controllers).

These people made up a core team of project office staff who took responsibility for delivering the technology and worked on BIM or related systems more of less full-time.

"*But its took a long time to get it because basically its been [BIM & 3D CAD Manager] who's now on board and really involved with it [BIM Coordinator, software vendor] and myself (Senior Document Controller) getting everything up and running and its, you know, we couldn't devote a serious amount of time to it at the start because we only had a couple of tablets but now everything is kind of flowing, the Directors have really impressed with the tablets and can understand why we spend [money on the project]*."

The decisions to start developing IT systems, combined with employment of specific peoples and the involvement of the sizeable Document Controller teams allowed people to develop roles that included a project-specific IT capacity which supported subsequent developments.

The reference to "Directors" in the previous quotation highlights the importance for this project of the other major group of people identified by the MIRP, namely senior managers. There were a number of project directors who approved and supported the project. Specifically these were project directors who provided resources and approvals for the project independent, and sometimes in spite of, the wider corporate system: "*With this project our director… he's given us the go ahead for us to say right [corporate IT], you can be involved but we are going down the [external vendor] route*"

A more peripheral group of actors also participated in the innovation process. These included those with responsibility for aspects of the construction project (e.g. Compliance Managers) who spent time on the BIM project because they saw it as a way of helping to achieve their business objectives and users who interacted with the innovation with requests, ideas or complaints that influenced the ways in which the innovation progressed. One example of the latter is two people (Environmental Manager, Quantity Surveyor) who requested help in extracting quantities of materials from the building models. These were provided (via querying functionality in the site integration database) but, more importantly, the request provided another idea of what BIM was 'for' and provided evidence of need.

This peripheral group, and the approving Directors, appear to have the characteristics of the fluid network of actors described by the MIRP studies. The core, in some cases full-time, core innovation team seem to have been a more stable, consistent group of people than the MIRP studies anticipate. This may have been due to the relatively short duration plus fairly simple nature of our innovation case study. Tentatively though, this could be a significant difference arising out of the project-based nature of the innovation and the apparent ability on the part of the team to hold this aspect constant.

Transactions

the informal and formal relationships among innovation group members, other firms, and groups involved in the incident.

As previously discussed in the section on 'people', relationships and interactions between group members and other individuals and companies are necessary to coordinate the innovation process. These interactions also shape the innovation journey. The MIRP studies identified a wide range of relationship types from hierarchical to peer relationships and informal agreements to more legal forms. These largely bilateral relationships are also located in (and help to create) a wider network of relationships. An, "expanding, contracting network or partisan stakeholders who converge & diverge on ideas."

The relationships between core team members were not discussed by respondents. In research terms, we would anticipate that following the innovation real time would have revealed numerous interactions that would have had implications for the innovation. Our interviewees did not problematise or remember or simply chose not to talk about these issues. Rather, the salient relationships for innovation team members were between them and more peripheral or external agents. Particularly highlighted are personal relationships between innovation team members and individual software developers and more 'corporate' relationships between the project and the contractor's corporate IT department.

Interviewees have stressed that at times work on the BIM project was 'unofficial' – particularly when developing what amounted to proof-of-concept working prototypes. This made the innovation reliant on personal relationships, vulnerable to prioritisation of official work and they were presumably running at risk of being cancelled at any time. However, there is a clear narrative that the informality and small scale of the development was crucial to the success of the innovation. "*We'd never been in the position we are now had we not had [internal DMS system] on this project. The reason being is 'cause it's developed in-house and we've actually hooked up the [externally produced integration database] programmer with the [internal DMS] Programmer, they can sit down, they've sat in this room many a time and coded out the requirements to get the portability onsite and all the documentation onsite. Had that been something like Documentum (a large DMS provider) and we'd have had to go off to the costs involved and we would never have got to where we've got because the costs would have been a – there would have been an alarm bell ringing in the first instance.*" Our analysis is suggesting that the IT projects had just enough resources to achieve something but few enough that they were able to stay 'under the radar' until they could demonstrate benefits. "*[BIM Coordinator] has done it best part of three years with the [external vendor] guy, living in each other's pockets, getting the system to where it is now*". Key to this, along with the intrinsic interest in working on 'something different', was the personal trusting relationships between innovation team members and developers working sometimes without the knowledge or explicit approval of their parent organisations.

As discussed previously, the BIM implementation on Barts and the London are talked about as a project innovation. The relationship, or rather the negotiated lack of relationship, between the project and the corporate IT department (ITSD) was mentioned frequently. There was some concern that innovation was hampered by ITSD "*this is a perfect bit of software but ITSD have to approve it, it has to go through about a year of test before they say yeah, that's the one*". More broadly, ITSD don't understand what's required on site. "*A lot of the issues we've had with the Tablets is the IT Department set them up to a working format and because they're detached from the site, it's – they need to come out to site more often to actually get… what they need on the site works 'cause they're just stuck back at [head office]*".

Context

a coding of the exogenous events outside of the innovation unit in the larger organization and industry/community that are perceived by innovation group members to affect the innovation.

Context items are those 'outside' the innovation system that either support the innovation process (availability of technology, an industry training scheme, etc.) or hinders it (e.g. lack of finance, regulations). Salient context can range from broad macro features at the level of an economy or industry to micro-level factors located within a specific organisation. The, "innovation process creates and [is] constrained by multiple enacted environments."

In this study, wider contextual issues whether supportive (such as the increasing potential of computers) or constraining (like the perceived computer illiteracy of many construction users) were mentioned but not emphasised by respondents. What seem more significant in explaining what has been framed as a 'project innovation' are a number of project contextual factors that have influenced the development of the tablets and related BIM systems. It seems likely that the idea of the BIM innovation as a project-centred innovation is the reason that wider contextual issues were relatively down-played or taken for granted in the interviews. The project context issues were; scale, complexity, and project organisation.

Scale: One recurrent issue on the current stage of the project is the sheer scale of the projects and the work required to manage them. The largest new-build hospital has a programme of handing over 6,500 rooms to the client. Each handover requires a number of processes including progress monitoring, snagging (faults and damage), compliance (correct equipment installed correctly as confirmed by the client's Independent Tester) and certification. "*You know everyone's got important deadlines to achieve. I mean at the moment, we're trying to do fifty rooms a week to be finished and locked out and that goal is until July of next year*". The sheer volume of work has provided the business case for the partial computerisation of the checking and handover process.

The size of the projects also meant that the simple ability to be able to call up a drawing when out on site has the potential to save significant time just in construction managers walking back to (and getting stuck in) the office. "*Well from one end of the site to the other, you know you waste a good hour, two hours maybe. . . It's absolutely massive, you can get lost in it as well and then getting back to your office, once you get back to your office, once you've been out on the site, you know you've got to sit down and catch up on your e-mails quickly before going back out*".

Complexity: As an acute hospital the project design is also complex, especially in terms of the coordination of the many different services required and between the service, structural and architectural components. Service coordination and clash detection was one of the most important reasons for the use of 3D BIM models in the design phase (Harty, 2008). As discussed in 'ideas' the site BIM development are now seen as a way to ensure this complex design is delivered precisely on site.

Construction management approach: Another project context factor that seem significant from our analysis is the way the main contractor has organised the coordination of the works. The contractor does quite a lot of on-site coordination and supervision on the project (as opposed to a 'construction management' model of allowing trade contractors to manage their own coordination). Skanska construction Managers are responsible for handing over a spatially defined area of floor, across work packages. "*[We break] it down into little packages 'cause we have the expertise, we think, to manage it at a micro level 'cause it's cheaper. . . . So there is, therefore, an element of us acting as the Foreman in the field, … and sometimes these contractors, you know, we're in effect co-ordinating where they work next week,… so having got the Tablets and the information, we then said, "Well these should be used for progress monitoring*". So it appears that in the evolution of tablet functionality, the business strategy to let small packages and get value from expertise in management created a requirement to support progress monitoring.

Outcomes

when incidents provide evidence of results , they are coded as representing either positive, negative, or mixed.

The outcomes of interest during the process of innovation are the interim criteria and subjective assessments that entrepreneurs and managers use to make decisions about approving and directing elements of the innovation journey. MIRP researchers found that the way in which outcomes were evaluated (and specific outcome objectives were set) fluctuated over time – assessment criteria responded to changed priorities and events. The, "final result [is] indeterminate [there are] many in-process assessments and spinoffs [and] integration of new orders with old."

Our respondents did not tend to describe their innovation journey in terms of explicit outcomes. There have been attempts to demonstrate business benefits from the technology use (better control, time savings) but these are still being worked on and in any case do not do not seem to have been part of the interim outcomes that drove the innovation process.

In our data, innovation outcomes are largely implicit – the fact that a piece of software has been made available to users is an outcome in itself. "*So, when I got to a point where we've got a Tablet that delivered the latest information, I was just delighted*". Similarly, after delivery of the technology, another class of outcomes mentioned is the use or adoption by 'users' outside the innovation group. This is viewed as especially positive given the assumed reluctance of builders to use new technology. "*I mean there is one guy that couldn't switch a computer on and now he's a tablet super user, you know, whatever he's doing, he's got his tablet with him so its good to see people like that embracing the technology and understanding what it is so I think you know, a lot has changed in the last three years of this project.*"

From the perspective of innovation group members the other significant 'acceptance' outcome was when project directors approved a stage of the development or made additional funding available as in the following incident in which a team member demonstrates a stage of the development of the tablet PCs and software to the project director to gain agreement to purchase additional tablets:

"*I literally went to him and said, "Right, this is what a floor looks like, this is the room, that's your information, that's your latest C-Sheet, that's your latest room datasheet." "Fantastic. Right, now show me for that room." Dink. "Now go to the fourth floor and the mental health room. So, find the mental health room. Now, that C-Sheet is wrong, isn't it?" And you go – or is it? And you click on it and it was one hit and it was the latest version and he said, "Right, that's fine. I understand. So it works." "Yes, it works,[Project Director]." "Right." You know, and that – so he, kind of, did a little audit of his own and obviously challenged others and then was convinced*".

Accounts of specific events like this are rare in our data – during our largely unstructured and open interviews respondents tended to talks in terms of activities, generalities and descriptions of states. The insights gained from attempting to apply the MIRP incident categories to retrospective data is discussed in the following section.

Discussion

Our discussion will cover the substantive findings in terms of the extent to which our case study data matches the MIRP findings plus some refection on the methodological and analytical issues identified.

The evolution of 'ideas' and the overall innovation process for our BIM case study is well described by the innovation journey concept. Our data also has elements that seem to confirm the importance of 'transactions' required. Our findings are short on 'outcomes' but this is probably due to the research method – the post-hoc nature of the study and that outcomes are largely implicit (also people were perhaps naturally reluctant to highlight negative outcomes). Where there seems to be some variance with the was in the categories of people and context.

The context items identified were not primarily at the macro-level but project-specific. The specific innovation studied appears to have selected (or even made) its own context by being a project rather than corporate innovation. Compared to the innovations studied by the MIRP, our case study is relatively short and of limited scope and complexity. The project-based nature of construction organisations does appear to have been specific though particularly as BIM was seen as a *project* innovation that happened independent of the wider organisation (although a higher-level strategic intention to support and expand BIM does exist).

In terms of people, the MIRP studies would lead you to expect a fluid network of part-time entrepreneurs. In contrast, although a number of peripherally involved people fitted this description, the core innovation team appear to have formed a consistent and stable group for the duration of the innovation period studied. As with the relatively simplified, and more manageable project context, this appears to have been important in maintaining the innovation. Further research over a longer time scale and moving the focus of research 'up' to the contractor's wider efforts to expand BIM usage may reveal a looser more impermanent network along MIRP lines (for example as innovation team members are moved to other construction projects).

Methodologically, applying the MIRP categories to our data highlighted the difficulties of constructing precise empirical accounts of innovations from retrospective interview data. As already described, our data collection was not designed to test MIRP findings or elicit data in terms of MIRP categories and this resulted in 'missing' data. For example, the MIRP analysis was focussed around the 'incident'. It became notable that our respondents did not generally talk in terms of specific incidents or events but rather in terms of broad narratives and statements about steady states or 'how things are'. Data was also not spread evenly across

MIRP categories (there was very little discussion of ‘outcomes for example). We anticipate following up some of the gaps identified in further research.

Finally, as a coding framework, the MIRP categories were not exclusive and highly dependent on where the analyst draws boundaries. A director approval from outside the project could be people (making the director part of the innovation team), transaction, context or outcome. The presence of project Document Controllers available to provide IT support could equally be coded as ‘context’ rather than ‘people’. Other research that attempted to use MIRP categories for more rigorously empirical forms of analysis such as content analysis would need to pay attention to this issue.

CONCLUSIONS

The BIM innovation journey demonstrated many of the significant features of those studied MIRP, particularly the non-linear nature of the process, the emergent nature of the ‘ideas’ and the importance of a range of different ‘transactions’. However, the project-based nature of the innovation seems to have allowed the innovation team to have limited the complexity and turbulence of ‘people’ and ‘context’.

Comparison of retrospective case study data with MIRP findings highlights limitations of the former that can guide further research or strengthen subsequent analysis.

REFERENCES

Eastman, C., Teicholz, P., Sacks, R. & Liston, K. (2008). *BIM handbook: A guide to building information modelling*. Hoboken, Ney Jersey: John Wiley & Sons.

Flyvbjerg, B. (2004). Five misunderstandings about case-study research. In: C. Seale, G. Gobo, J.F. Gubrium and D. Silverman, Eds. *Qualitative Research Practice*. Sage, London and Thousand Oaks. 420–434.

Gann, D.M. & Salter, A.J. (2000) Innovation in project-based, service-enhanced firms: The construction of complex products and systems. *Research Policy*, **29**(7), 955-972.

Harty, C. (2005) “Innovation in Construction: A Sociology of Technology Approach” *Building Research and Information*, **33**(6), 512-522.

Harty, C. (2007a) “The social and the technological: The role of technology in the production of construction practice”, Copenhagen: Copenhagen Business School

Harty, C. (2007b) “Implementing innovation: Transforming practices and technologies in construction work” CIB Capetown SA.

Harty, C. (2008) Enacting digital coordination: Developing and implementing data management practices in construction work. In: Proc. CIB Joint International Symposium, Dubai.

Jernigan, F. (2007). *Big BIM little BIM*. Salisbury, MD: 4Site Press.

Koskela, L. & Vrijhoef, R. (2001) Is the current theory of construction a hindrance to innovation? *Building Research & Information*, **29**(3), 197-207.

Moum, A., Koch, C. & Haugen, T.I. (2008). What did you learn from practice today? Exploring experiences from a Danish R&D effort in digital construction. *Advanced Engineering* Informatics, **23**(3), 229-242.

Peansupap, V. & Walker, D. (2006) Innovation diffusion at the implementation stage of a construction project: a case study of information communication technology. *Construction Management & Economics*, **24**(3), 321-332.

Seaden, G and Manseau, A (2001) Public policy and construction innovation. *Building Research and Information*, **29**(3), 182-196.

Slaughter, S. (2000) Implementation of construction innovations. *Building Research & Information*, **28**(1), 2-17.

Van De Ven, A. & Poole, M. (1990). Methods for studying innovation in the Minnesota Innovation Research Program. *Organization Science*, **1**(3), 313-335.

Van De Ven, A., Angle, H. & Poole, M. (1989). *Research on the Management of Innovation: The Minnesota Studies*. New York, Harper & Row

Van De Ven, A., Polley, D., Garud, R. & Venkataraman, S. (1999) *The Innovation Journey*. New York: Oxford University Press.

Whyte, J. (2002). *Virtual Reality and the built environment*. Oxford: Architectural Press.

Winch, G. (1998) Zephyrs of creative destruction: understanding the management of innovation in construction. *Building Research & Information*, **26**(4), 268-279.

CONCEPTUAL FRAMEWORK FOR IMPROVING THE CONSTRUCTION SUPPLY CHAIN

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The performance of the construction industry and the construction process in particular has always been a burning issue in the industry and academia. The issue at stake is the prevalence of unsatisfactory project delivery outcomes. In order to address this issue performance improvement tools such as supply chain management (SCM) was introduced into the construction lexicon. Given the notoriety that poor performance has engendered in construction, an attempt to realise improvement through the exploitation of the potential of SCM in construction is highlighted in this paper. The methodological approach adopted entails an in-depth review of literature relative to performance and SCM in construction. Findings emanating from the study indicate that deployment of the principles of risk allocation and management, human resource development, knowledge management, organisational culture, logistics management, integrative H&S and quality management practices, not only improve the performance of the construction supply chain, but can also positively impact the construction process in terms of cost, H&S, quality and time, to the extent that project delivery outcomes will improve substantially.

KEYWORDS: Construction, Performance, Supply chain management

INTRODUCTION

Cousins et al. (2006) suggest that the optimisation of internal production through operations management tools and techniques such as world class manufacturing, benchmarking and business process reengineering, are no longer sufficient for the manufacturing environment, and the introduction of lean, which considers the optimisation of the production process as well as constraints relative to supply chain activities necessitate the application of, and research into concepts such as JIT, TQM, and their relationships with SCM practices. In addition, Storey et al. (2006) contend that SCM theories are predominately idealised schemas of optimal routes and quantities for demand fulfilment when considered from a chain perspective. They say nestled beneath the dominant big idea of SCM as a whole are a number of sub theories such as seamless flow from initial sources to final customer, demand-led supply chain (only produce what is pulled), shared information across the whole chain (end to end pipeline visibility), collaboration and partnering (mutual gains and added-value for all), information technology enabled, all products direct to self, batch / pack size configured to rate of sale, customer responsiveness, agile and lean, mass customisation, and market segmentation. Therefore, SCM in the construction context represents a move away from the project and its management, towards the supply chain and its management, as the main focus in order to engender more effective ways of creating value for clients; as a vehicle for innovation and continuous improvement, integration of systems, and maybe even improved, industry-wide, profitability levels (Pryke, 2009). This shift nonetheless retains the emphasis relative to the impact SCM has upon project objectives and performance (Bresnen, 2009).

Furthermore, the proponents of SCM believe that it is a set of approaches utilized to efficiently and effectively integrate the network of all organisations and their related activities in completing and delivering a project so that system-wide costs are minimised while maintaining or exceeding customer-service-level requirements (Venkataraman, 2004). Accordingly, SCM in construction focuses on (Walsh et al., 2004):

- the impact of the supply chain on construction site activities and aims to reduce the cost and duration of those activities: the primary concern is to establish a reliable flow of materials and labour to the site, and improve relationships between sites and direct suppliers;
- the supply chain itself and aims to reduce costs, especially those related to logistics, lead time, and inventory, and
- transferring activities from the site upstream in the supply chain and aims to reduce total cost and duration by avoiding inferior conditions on site / or achieving wider concurrency between activities barred by technical dependencies on site, and the integrated management and improvement of the supply chain and site production, that is, site production is subsumed by SCM.

Further, Croom et al. (2000) suggest that the origins of the concept of SCM are unclear, but its development was initially along the lines of physical distribution and transport using the techniques of industrial dynamics and / or total cost approach to distribution and logistics (Table 1). A situation they say implies that focusing on a single element in the chain cannot assure the effectiveness of the whole system. As an illustration, it is foolhardy to expect that a singular focus on upstream activities (strategic) instead of a holistic view of the total construction supply chain activities will result in optimum performance in the construction process.

LITERATURE REVIEW

Definitions of SCM tend to emphasise the importance of management being proactive in integrating activities and business processes across the supply chain in response to the needs of clients with the aim of improving performance (Bresnen, 2009). For instance, construction SCM can be defined as the strategic management of information flows, activities, tasks, and processes involving various networks of independent organisations and linkages (upstream and downstream) that produce value that is delivered to clients in the form of a completed project (Benton & McHenry, 2010) and / or as the management of upstream and downstream relationships with clients and suppliers (contractors, designers, subcontractors) to achieve greater project value at less cost (Rimmer, 2009).

Therefore, the effectiveness of SCM requires organisations to focus on critical issues relative to clients, suppliers, design and operations, logistics, and inventory management, a situation which in turn require a holistic focus on both the strategic and operational aspects of projects (Venkataraman & Pinto, 2008). Though the prowess of SCM in addressing production problems in the manufacturing sector is well documented, acceptance, caution, and outright rejection have characterised its introduction in construction.

For example, while Fernie (2005) suggests that it does not make sense for organisations in the construction sector to adopt, implement, and sustain SCM, Tommelein et al. (2009) contend that SCM applies to the delivery of capital projects as it does to the delivery of products or services in other industries since it refers to the management of flows of physical products, services, and information, as well as money between activities or process steps that organisations perform while aiming for customer service as the overall goal. However, there are substantial challenges militating against the implementation of SCM in construction. Factors such as failure to share information, resistance to innovation, poor procurement systems, poor collaboration, ignorance about contributions and needs of subcontractors as well as suppliers, short-termism, transient nature of construction projects, inability to recognise project goals and lack of understanding of supply chain are problems associated with the implementation of SCM in construction (Jones & Saad, 2003; Wong et al., 2004; Benton & McHenry, 2010).

Table 1: Main component bodies of supply chain literature (source: Croom et al., 2000)

Strategic management	**Relationships**
Strategic Networks	Relationship Development
Control in the supply chain	Supplier Development
Time-Based Strategy	Strategic Supplier Selection
Strategic Sourcing	Vertical Disintegration
Vertical Disintegration	Partnership Sourcing
Make or Buy decisions	Supplier Involvement
Core Competencies focus	Supply/Distribution Base Integration
Supply Network Design	Supplier Assessment (ISO)
Strategic Alliances	Guest Engineering Concept
Strategic Supplier Segmentation	Design for Manufacture
World Class Manufacturing	Mergers Acquisitions, Joint Ventures
Strategic Supplier Selection	Strategic Alliances
Global Strategy	Contract View, Trust, Commitment
Capability Development	Partnership Performances
Strategic Purchasing	Relationship Marketing
Logistics	**Best Practices**
Integration of materials and information flows	JIT, MRP, MRP 11
JIT, MRP, Waste Removal, VMI	Continuous Improvement
Physical Distribution	Tiered Supplier Partnerships
Cross Docking	Supplier Associations (kyoryoku kai)
Logistics Postponement	Leverage Learning Network
Capacity Planning	Quick Response, Time Compression
Forecast Information Management	Process Mapping, Waste Removal
Distribution Channel Management	Physically efficient Vs Market Oriented Supply Chains
Planning and Control of Materials Flow	
Marketing	**Organisational Behaviour**
Relationship Marketing	Communication
Internet Supply Chains	Human Resources Management
Customer Service Management	Employees Relationships
Efficient Consumer Response	Organisational Structure
Efficient Replenishment	Power in Relationships
After Sales Service	Organisational Culture
	Organisational Learning
	Technology Transfer
	Knowledge Transfer

Strategic and operational views in the construction process

Strategic project management can be defined as management actions that are incorporated into projects in order to meet strategic objectives of projects by adjusting not only time, cost, and resources, but also the target, while operational project management can be defined as the management actions incorporated to meet projects' target by adjusting time, cost, and resources (Lee et al., 2006). Therefore, the strategic view is anchored on the challenge for project organisations to provide client value by managing the inevitable scope changes without incurring significant project cost and time overruns (Venkataraman & Pinto, 2008).

Though, there is no single procurement system that works best for all situations in construction, a careful analysis of client needs, and implementation of procurement strategies that is best for the realisation of the needs, seems a positive way forward. For instance, Kumaraswamy et al. (2000) contend that in Hong Kong, methods used for selecting the overall procurement system, contractors, and subcontractors are not only critical, but also require integrated approach in order to synergise chosen options within each procurement sub-system that is aimed at a project-specific desired outcome.

In addition, the operations function creates value by converting raw materials and components into a finished product at every phase of the supply chain, and is responsible for ensuring quality, reducing waste, and shorter process lead times (Venkataraman & Pinto, 2008). In terms of SCM, logistics and supplier management are sub processes of the operational view (Coyle et al., 2003). In fact, empirical findings suggest that active involvement in the management of logistics not only results in an improved main contractor / subcontractor interface, but also enhances the subcontractor / subcontractor interface, that is, when subcontractors attempt to meet the product and service quality expectations of the trade that will be building upon their work, improved project culture and quality is achieved (Perera et al., 2009). More so, inventory management that is equally part of logistics management is necessary because inventories do not only represent a substantial portion of the supply chain cost, they also impact customer service levels, and constitute a cost trade-off decisions in logistics, therefore, in project environment, where inventory-related costs can be substantial, effective inventory management can be achieved only through the joint collaboration of all members of the supply chain (Venkataraman & Pinto, 2008). For example, the importance of logistics is underscored by the 2003 report of the Building Research Establishment (BRE), which indicated that 30% of construction costs are attributed to the transportation of construction materials (BRE, 2003 cited by Shakantu, 2009).

Furthermore, Venkataraman and Pinto (2008) contend that the ability of suppliers to provide quality raw materials and components when they are required at reasonable cost can lead to shorter cycle times, reduction in inventory-related costs, and improvement in end-customer service levels, which translate to added-value in the chain in spite of the fact that suppliers constitute the back-end portion of the supply chain. They say without the involvement, cooperation, and integration of upstream suppliers, value optimisation in the total supply chain cannot be a reality, that is, managing the dynamic interrelationships and interactions that exist among suppliers is considerably more complex and requires effective integration of project activities into the larger framework of SCM.

The need to manage the construction supply chain

The construction supply chain is simply a network of firms that agreed to work together in order to realise objectives relative to construction projects. Prevailing circumstances in the industry such as fragmentation necessitates a proactive approach to the management of actors / and firms involved in project conception and realisation. For example, Venkataraman and

Pinto (2008) suggest that as a direct result of factors such as globalisation, best value for customer money, inventory management, risks, uncertainties, and complexities associated with projects, the adoption of SCM approaches in construction becomes a necessity. According to them, project supply chain complexities underscore the importance and need for project-based organisations to manage their total supply chain in a more formal and organised manner, that is, SCM approaches such as partnering, information and risk sharing can greatly reduce uncertainties and complexities inherent in projects; and management approaches associated with SCM such as lean construction, TQM, purchasing, distribution, and logistics management will not only enable organisations to realise major gains through the elimination of waste in the process, but will also provide opportunities for businesses to improve their operations. In fact Shakantu (2009) contends that South African construction could benefit from supply chain optimisation tools such as reverse logistics that have proved to be effective in improving transport utility in other industries.

Therefore, given the documented dismal performance of projects in terms of cost, time, quality and H&S in South African construction (Manthe, 2008), it is reasonable and pragmatic to seek ways of realising improvement so that project performance that continues to rely upon the dynamics of the construction supply chain can measure up to the standards demanded by clients. In particular, the need for performance improvement as indicated in the Construction Industry Development Board (cidb) reports of 2004, 2007, 2009 and 2010, which identified performance gaps relative to cost, time, quality, H&S, client satisfaction, and profitability in the industry provided the catalyst for the assumed research problem statement. The problem statement states that "poor performance relative to cost, time, quality, and H&S in the South Africa construction industry hampers the smooth delivery of infrastructure projects as recurrent non-value adding activities (NVAAs) in the construction process propagate cost overruns that exacerbate budget constraint problems; time overruns / or delays that slow down service delivery; poor quality that increases maintenance cost and shorten design / or service life of infrastructure, and poor H&S that increase incidents, accidents, injuries, and fatalities in the industry." Therefore, sub-problems and hypotheses evolved thereof, together with the research objectives formed the basis for the extensive review of performance related literature and the subsequent empirical investigations. The hypotheses include:

- Inconsistent and inadequate risk allocation and management practices leads to inappropriate choice of procurement strategy in the public sector
- The lack of infrastructure delivery management skills within the public sector result in poor implementation of construction procurement strategies;
- Inadequate documentation and transfer of experiences and performance result in low organisational knowledge, learning, and transfer;
- Inappropriate organisational culture among project partners leads to resistance to change and innovation in the construction supply chain;
- Poor interface between multidisciplinary design advisor / consultants lead to delay and rework relative to construction activities;
- Inefficient and unstable logistics management leads to haphazard processing of orders, storage of materials, and poor inventory management;

- Unacceptable coordination and regard for H&S upstream and downstream of the construction supply chain result in recurrent accidents, injuries, and ill-health on construction site, and
- Inadequate coordination and integration of quality standard requirements within the supply chain result in an unusually high level of defects, rework, and non-conformance relative to quality upon construction project completion.

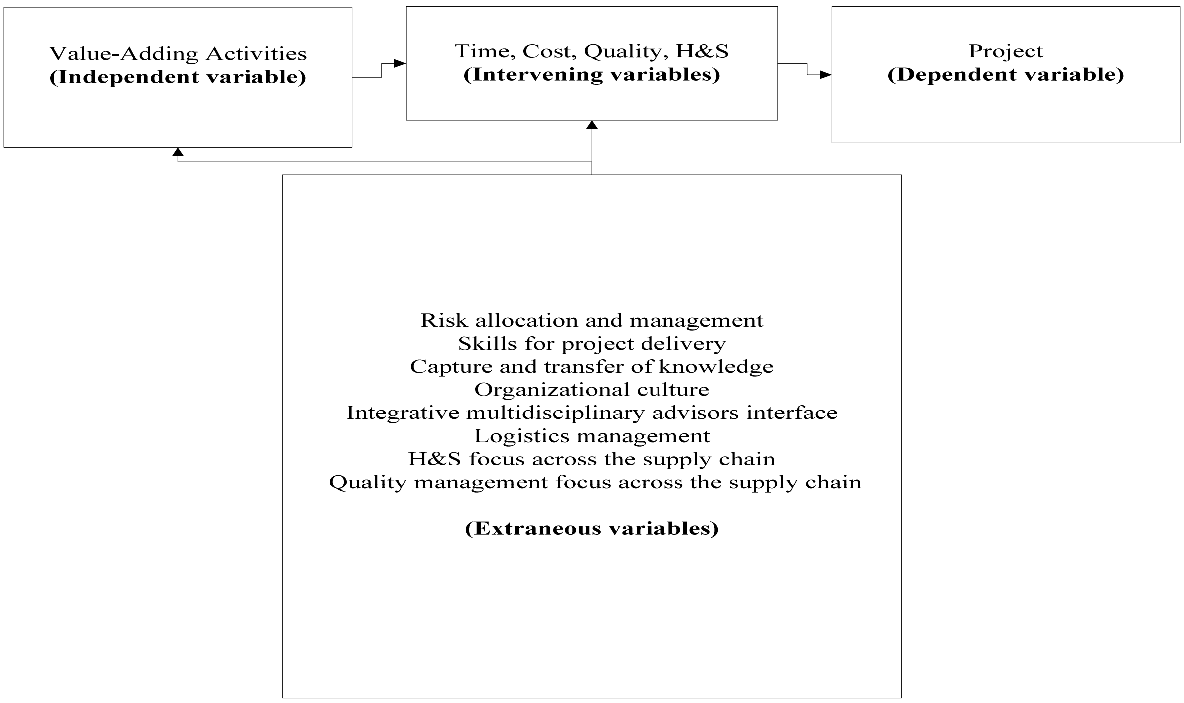
CONCEPTUAL PERSPECTIVES

Figure 1 indicates a causal network that reflects the assumed research conceptual perspective that provides a theoretical overview of the research through the use of independent, dependent, intervening, and extraneous variables (Trafford & Leshem, 2008).

Kumar (2005) suggests that the independent variable is responsible for bringing about change or changes in a phenomenon or situation, the dependent variable is the outcome of the changes brought about by the introduction of an independent variable; the extraneous variable are several factors operating in a real-life situation that effect changes in the dependent variable, that is, these factors may increase or decrease the magnitude or strength of the relationship between independent and dependent variables; and the intervening variables links the independent and dependent variables, that is, the cause variables will have effect on the dependent variable only when the intervening variable is present in the link.

As an illustration, value-adding activities are operational efforts that transform project requirements stipulated in contract data into reality (project realisation), while non-value adding activities are wasted efforts that consume time and / or resources but do not directly or indirect result in the achievement of goals stated in the contract data (Han et al., 2007).

Figure 1: Causal Network: Seamless project delivery



This transformation is indicated through the performance of the traditional project performance parameters of cost, H&S, quality, and time. For example, concrete pouring that leads to the formation of slabs, columns or beams on construction sites can be considered as value-adding activities that record progress toward the realisation of a project with performance parameters of cost, H&S, time, and quality revealing the effectiveness and efficiency inherent in the process. Therefore, value-adding activities are always explicitly identified in contract data, and they are also deemed to be drivers for cost, time, and quality estimation in construction.

However, empirical evidence suggests that an average of 49.6% of operational efforts is devoted to non-value adding activities (Horman & Kenley, 2005). Similarly, Alwi et al. (2002) contend that non-value adding activities are not only associated with waste materials in the construction process, but also other activities such as rework, waiting time, and delays. They say these issues contribute to a reduction in construction productivity and poor performance that is prevalent in construction. Such findings support the argument that poor performance relative to construction project execution seems to be the norm rather than the exception, with both clients and contractors calling for a major shift in project delivery systems. Therefore, the smooth realisation of projects has being largely marginalised by non-value adding activities (Han et al., 2007) and other sundry anomalies such as the lack of effective project team integration between clients, the supplier team and the supply chain (Office of Government Commerce, 2005). This clearly supports the contention of Flyvbjerg et al. (2003) that transport infrastructure projects do not perform as promised, and risk, as well as uncertainties associated with the cost of transport infrastructure projects are substantially high.

To be succinct, a construction project that is besieged with problems relatives to the absence or negative sides of issues identified in the extraneous variables' box will witness unlimited waste and / or non-value activities, and consequential poor performance in terms of cost, time, quality, and H&S. Conversely, a project that proactively engages and addresses issues referred to as extraneous variables may enhance value-adding activities that results in improved project performance, and subsequent successful project delivery. Therefore, the management of the construction supply chain offers the opportunity to capture increased value, and to minimise risks to clients and other members of the supply chain members since uncertainties tend to flow through the supply chain, and their ability to eventuate may depend upon the position of each member of the supply chain in the network (Edkins, 2009: Benton & McHenry, 2010).

Specifically, empirical research findings indicate that the choice of contract strategy in the public sector is largely influenced by legislation, source of finance, and project size with inequitable risk sharing practices (Baloi, 2002); adversarial exploitations and improper risk-shedding tactics continue to marginalise client-contractor relationships (Palaneeswaran et al., 2003); and client's role tends to be contractually biased in traditional procurement in spite of the fact that clients have a significant impact on the performance of construction projects (Pettit, 2000). For instance, in order to achieve value for money in public project development, the public client and private contractor need to reach the best risk allocation scheme before the contract is awarded (Li, 2003) because in an ideal situation the capability of the client organisation may also present risks, that is, departmental staff tend to be generalists, and may not have the technical expertise or experience required for large-scale construction projects (Dalton, 2007).

Further, a knowledge management based construction site management system provides a robust and an innovative approach for addressing site management problems and for preventing new problems from occurring (Mohamed, 2006). It also plays a key role in today's fast-changing business environment and contributes largely towards sustained business performance (Pathirage et al., 2007). Similarly, Olomolaiye (2007) suggests that knowledge sharing relies primarily on attracting and retaining employees most capable of communicating and synthesising knowledge and expertise with others, and the implementation of employee-focused knowledge sharing practices facilitates the integration and regeneration of otherwise fragmented, specialised, and asymmetrically distributed knowledge within the organisation, thus making feasible the production of complex and innovative products and services.

In hindsight therefore, most construction projects and their realisation supply chains include a variety of cultures (organisational and national) that necessitate intercultural competence among site management in order to get the best from the contributing stakeholders, whose position may change rapidly throughout the life of a project (Fellows, 2009). This envisaged intercultural competence requires managers to see the project through the eyes of different stakeholders and to appreciate the performance requirements that they place on the project.

In addition, Pan (2006) argues that semantic web technology cannot only improve construction information management in a number of areas such as project knowledge management, collaborative design, and communication between project partners, but it can also provide an innovative approach toward the management of construction information. This attribute translates to efficiency and precision of construction information management. Similarly, the emergence of mobile computing has the potential to enlarge the boundary of IT support from site offices to actual work sites and improve information and communication between construction workers and the design team, a situation which is the key factor for the integration of design and construction otherwise called concurrent engineering (Chen, 2008). Benefits of the implementation of mobile computing in construction include the reduction in operation and maintenance cost, the reduction in defects, accidents, and waste, the increase in productivity and the increase in predictability (Chen, 2008).

Further, a real-time tracking system provides a robust and innovative approach for addressing on-site material tracking and inventory management problems through the integration of the RFID-based materials management with resource modelling and other innovations in a project environment (Kasim, 2008; Udeaja, 2002). In brief, a holistic focus on quality (Love et al., 2005), and H&S (Smallwood & Haupt, 2005) by all project stakeholders in the construction process (upstream and downstream) may further enhance value-adding activities through the reduction of rework and fatalities, and also engender continuous improvement in the process.

While the literature relative to SCM predominates in this paper, it is instructive to note that the entire literature reviewed for the study is underpinned by publications associated with NVAAs and performance improvement. Using the research objectives (that are not stated here) with the problem statement, sub-problems, and hypotheses as a guide, issues related to project realisation were extensively closely examined. Emphasis was placed on all identified variables in Figure 1 as they individually and / or collectively influence the progress of construction projects until formal project completion. Anecdotal evidence suggests that it is an anomaly if the parameters of cost, time, quality, and H&S are not closely monitored during project execution, as they constitute criteria which can measureding tool to determine how well a project performs.

Arguably therefore, due to the nature of the variables under investigation, pluralism in the research methodology as against a single methodological approach seems a practical approach. Though construction management research is seemingly rooted in quantitative research methodology, the operational steps relative to this study intend not only to embrace pluralism (Dainty, 2008), but also to emphasise the reliability and validity of data generated through mixed-mode quantitative methods (de Leeuw & Hox, 2008). Given the number of variables, available resources, and the need to generate findings reliably and objectively in an applied research environment, the research operational steps shall be in phases. The empirical investigation that is always underway began with a pilot survey that investigated the suitability of the research hypotheses, then proceeded with a primary survey rooted in mixed-mode quantitative research method, and thereafter intend to conclude with a secondary qualitative survey investigation relative to significant issues identified through descriptive and inferential statistical analysis to be undertaken relative to data that will be generated during the primary investigation. The empirical study also intends to develop a model in line with the system dynamics approach (qualitative and quantitative) in order to capture and translate the dynamism inherent in the strategic management of projects in the South African construction context.

CONCLUSIONS

In conclusion, in as much as project coalitions continue to play key roles in the construction process, their contributions will continually influence the quality, and availability of built facilities. As a result, efforts directed towards harnessing the contributions of project partners provide a positive platform for performance improvement in construction. It is instructive to note that the robust application of risk management practices, skills development, knowledge capture and transfer, organisational culture, integrative multidisciplinary consultants interface, logistics management, integrative H&S and quality management practices as illustrated in Figure 1 within the strategic and operational aspects of the construction process may offer improvement possibilities.

Further, the paper re-emphasised the importance of value-adding activities in relation to improving performance of construction projects with the aid of the extraneous variables identified in the conceptual framework so as to engender continuous improvement in South African construction. Finally, issues that were discussed so far provide a basis for further rigorous empirical research relative to the ability of SCM to provide platforms for addressing non-value adding activities and poor performance in construction.

REFERENCES

Alwi, S., Hampson, K. and Mohamed, S.C. (2002). Factors influencing contractor performance in Indonesia: A study of non-value adding activities. In: *International Conference on Advancement in Design, Construction, Construction Management, and Maintenance of Building Structure*, March 2002. Bali: ADCCMBS, 20-34.

Baloi, D. (2002). *A framework for managing global risk factors affecting construction cost performance*. (PhD). Loughborough University.

Benton Jr, W.C. and McHenry, L.F. (2010). *Construction purchasing and supply chain management*. New York: McGraw Hill.

Bresnen, M. (2009). Learning to co-operate and co-operating to learn: knowledge, learning and innovation in construction supply chains. In: S. Pryke (ed) *Construction supply chain management: concepts and case studies*. Oxford: Wiley-Blackwell, 73-91.

Chen, Y. (2008). *Using mobile computing for construction site information management*. (PhD). Newcastle University.

Construction Industry Development Board (cidb) (2010) *The cidb Construction Industry Indicators Summary Results: 2009*. Pretoria: cidb.

Construction Industry Development Board (cidb) (2009) *Construction Health & Safety in South Africa: Status & Recommendations*. Pretoria: cidb.

Construction Industry Development Board with the Department for Public Works (2007) *Skills for infrastructure delivery in South Africa: the challenge of restoring the skills pipeline*. Pretoria: cidb.

Construction Industry Development Board (2004) *SA Construction industry status report-2004: Synthesis review on the South African construction industry and its development*. Pretoria: cidb.

Cousins, P.D., Lawson, B. and Squire, B. (2006). Supply chain management: theory and practice – the emergence of an academic discipline? *International Journal of Operations and Production Management*, **26** (7), 697-702.

Coyle, J.J., Bardi, E.J. and Langley Jr., C. J. (2003). *The management of business logistics: a supply chain perspective*. 7th ed. Cincinnati: South-Western.

Croom, S., Romano, P. and Giannakis, M. (2000). Supply chain management: an analytical framework for critical literature review. *European Journal of Purchasing & Supply Management*, **6** (1), 67-83.

Dainty, A.R.J. (2008). Methodological pluralism in construction management research. In: A. Knight and L. Ruddock (eds) *Advanced research methods in the Built Environment*. Oxford: Wiley-Blackwell, 1-11.

Dalton, M. (2007). *A risk breakdown structure for public sector construction projects*. (PhD). University of Manchester.

De Leeuw, E. and Hox, J. (2008). Mixing data collection methods: lessons from social survey research. In: M.M. Bergman (ed) *Advances in mixed methods research*. London: Sage, 138-149.

Edkins, A (2009). Risk management and the supply chain. In: S. Pryke (ed) *Construction supply chain management: concepts and case studies*. Oxford: Wiley-Blackwell, 115-134.

Fellows, R. (2009). Culture in supply chains. In: S. Pryke (ed) *Construction supply chain management: concepts and case studies*. Oxford: Wiley-Blackwell, 42-72.

Fernie, S. (2005). *Making sense of supply chain management in UK construction organisations: theory versus practice*. (PhD). Loughborough University.

Flyvbjerg, B., Holm, M.K.S. and Buhl, S.L. (2003). How common and how large are cost overruns in transport infrastructure projects. *Transport Reviews*, **23** (1), 71-88.

Han, S., Lee, S., Fard, M. G. and Pena-Mora, F. (2007). Modelling and representation of non-value adding activities due to errors and changes in design and construction projects. In: *40th* *annual Winter Simulation Conference proceedings*, December 2007. Washington D C: IEEE, 2082-2089.

Horman, M.J. and Kenley, R. (2005). Quantifying levels of wasted time in construction with meta-analysis. *Journal of Construction Engineering and Management*, **131** (1), 52-61.

Jones, M. and Saad, M. (2003). *Managing innovation in construction*. London: Thomas Telford.

Kasim, N.B. (2008). *Improving materials management on construction projects*. (PhD). Loughborough University.

Kumar, R. (2005). *Research methodology: a step by step guide for beginners*. London: Sage.

Kumaraswamy, M., Palaneeswaran, E. and Humphreys, P. (2000). Selection matters – in construction supply chain optimisation. *International Journal of Physical Distribution & Logistics Management*, **30** (7/8), 661-680.

Lee, S.H., Pena-Mora, F. and Park, M. (2006). Dynamic planning and control methodology for strategic and operational construction project management. *Automation in Construction*, **15** (1), 84-97.

Li, B. (2003). *Risk management of construction public private partnerships projects*. (PhD). Glasgow Caledonian University.

Love, P.E.D., Edwards, D.J. and Smith, J. (2005). A forensic examination of the causal mechanisms of rework in a structural steel supply chain. *Managerial Auditing Journal*, **20** (2), 187-197.

Manthe, M.F. (2008). *The appropriateness of tertiary built environment education*. (PhD). Nelson Mandela Metropolitan University.

Mohamed, S.F. (2006). *Improving construction site management practices through knowledge management*. (PhD). Loughborough University.

Nicolini, D., Holti, R., and Smalley, M. (2001). Integrating project activities: the theory and practice of managing the supply chain through clusters. *Construction Management and Economics*, **19** (1), 37-47.

Office of Government Commerce (2005) Common causes of project failure. London: OGC.

Olomolaiye, A.O. (2007). *The impact of Human Resource Management in Knowledge Management for performance improvements in construction organisations*. (PhD). Glasgow Caledonian University.

Palaneeswaran, E., Kumaraswamy, M., Rahman, M. and Ng, T. (2003). Curing congenial construction industry disorders through relationally integrated supply chains. *Building and Environment*, **38** (4), 571-582.

Pan, J. (2006). *Construction project information management in a semantic web environment*. (PhD). Loughborough University.

Pathirage, C.P., Amaratunga, D.G. and Haigh, R.P. (2007). Tacit knowledge and organisational performance: construction industry perspective. *Journal of Knowledge Management*, **11** (1), 115-126.

Pettit, J.H. (2000). *Clients: their role in the procurement of infrastructure projects*. (PhD). Loughborough University.

Perera, S., Davis, S. and Marosszeky, M. (2009). A two dimensional view of the supply chain on construction projects. In: *17th annual conference of the International Group for Lean Construction proceedings*, July 2009. Taipei: IGLC, 127- 136.

Pryke, S. (ed.) (2009). *Construction supply chain management: concepts and case studies*. Oxford: Wiley-Blackwell.

Rimmer, B. (2009). Slough Estates in the 1990s-client driven SCM. In: S. Pryke (ed) *Construction supply chain management: concepts and case studies*. Oxford: Wiley-Blackwell, 137-159.

Shakantu, W.M.W. (2009). Logistics impediments to construction supply chain optimisation. In: *6th cidb Post Graduate Conference, Johannesburg 6-8 September 2009*. Johannesburg: cidb, 221-228.

Smallwood, J.J. & Haupt, T.C., (2005). Impact of the South African Construction Regulations on construction health and safety (H&S): Architects' perceptions. *Journal of Engineering, Design, and Technology,* **5** (1), 23–24.

Storey, J., Emberson, C., Godsell, J. and Harrison, A. (2006). Supply chain management: theory, practice and future challenges. *International Journal of Operations and Production Management*, **26** (7), 754-774.

Trafford, V. and Leshem, S. (2008). *Stepping stones to achieving your doctorate*. Berkshire: Open University Press.

Tommelein, I.D., Ballard, G., and Kaminsky, P. (2009). Supply chain management for lean project delivery. In: W. J. O'Brien, C.T. Formoso, R. Vrijhoef and K. A. London (eds.) *Construction supply chain management handbook.* Boca Raton: CRC Press, 105-126.

Udeaja, C.E. (2002). *A decision support framework for construction material supply chain management using multi-agent systems*. (PhD). South Bank University.

Venkataraman, R. R. and Pinto, J.K. (2008). *Cost and value management in projects*. New Jersey: John Wiley & Sons.

Venkataraman, R. (2004). Project supply chain management: optimising value: the way we manage the total supply chain. In: P.W.G. Morris and J.K. Pinto (eds) *The Wiley guide to managing projects*. New Jersey: John Wiley & Sons, 621-642.

Walsh, K.D., Hershauer, J.C., Tommelein, I.D. and Walsh, T.A. (2004). Strategic positioning of inventory to match demand in a capital projects supply chain. *Journal of Construction Engineering and Management,* **130** (6), 818-826.

Wong, P.S.P., Tsoi, J.N.Y. and Cheung, S.O. (2004). Identifying obstacles against implementation of supply chain management in construction. *Hong Kong Surveyor*, **15** (2), 12-22.

PARTNERING AND THE FOUR DIMENSIONS OF COLLABORATION

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In order to reap the benefits of partnering implementation by improved collaboration it is vital to increase the understanding of the partnering concept and its content. This paper investigates four different dimensions of collaboration in order to enhance a better partnering conceptualisation. Empirical data was collected through a multiple case study of four engineering projects in one Swedish mining company. The empirical results show that partnering was implemented in different ways in the projects, revealing four dimensions of collaboration: width, depth, duration, and intensity. The developed framework based on four dimensions of collaboration provides opportunities for more detailed and yet more holistic practical and theoretical understanding of the partnering concept.

KEYWORDS: Partnering, Collaboration, Procurement, Project governance.

INTRODUCTION

The interest in and promotion of collaborative inter-organizational relationships, often termed partnering (Bresnen & Marshall, 2000a), has increased during the last decade in many countries (Chan et al., 2003a; Wood & Ellis, 2005; Eriksson, 2010b). Many construction projects are characterized by high complexity, customization, and uncertainty coupled with long duration, making inter-organizational collaboration in partnering arrangements suitable (Clegg et al., 2002; Rahman & Kumaraswamy, 2004; Eriksson, 2008a). Accordingly, partnering is often argued to bring about advantages in the areas of quality, sustainability, safety performance, dispute resolution, human resource management, innovation, as well as time and cost reductions (Larson, 1997; Gransberg et al., 1999; Chan et al., 2003a).

Some research efforts are of a more critical nature since they have found that collaboration and its benefits are not easily obtained in construction projects (Skaates et al., 2002; Kaluarachchi & Jones, 2007) due to various barriers to change, arising when trying to implement partnering in different countries: for example Hong Kong (Chan et al., 2003b), UK (Akintoye et al., 2000; Saad et al., 2002; Bresnen, 2007), US (Glagola & Sheedy, 2002), Australia (Ng et al., 2002) and Sweden (Eriksson et al., 2008). One part of the problem is that there is some confusion and ambiguity about what partnering really is and how it can be achieved (Eriksson, 2010b). Saad *et al*. (2002) mean that partnering is largely misunderstood and not a unified concept as other forms of procurement, which causes major problems for partnering implementation (Glagola & Sheedy, 2002; Chan et al., 2003b). In their empirical studies regarding the implementation of partnering in the supply chain Akintoye *et al.* (2000) and Saad *et al.* (2002) found that the actors perceived it important and beneficial, but they lacked an understanding of the concept and the prerequisites associated with its successful implementation. Eriksson (2010b) discussed both what partnering is and how it can be implemented through core and optional procurement procedures. The key to greater understanding of how to successfully implement partnering is deeper and more detailed knowledge (Humphreys et al., 2003), since “the devil is in the details” (Gil, 2009). Accordingly it is not sufficient to know which procurement procedures to use: one must also know when to implement them and who to involve in the partnering arrangement and for how long. The purpose of this paper is to elaborate on how four dimensions of collaboration are integral to both the theoretical conceptualisation and the practical implementation of partnering.

THEORETICAL FRAMEWORK

Eriksson (2010b) define partnering as a cooperative governance form that is based on core and optional cooperative procurement procedures to such an extent that cooperation-based coopetition is facilitated. Coopetition can be defined as the balance between cooperation and competition in a buyer-supplier relationship, derived from the actors’ simultaneous cooperative and competitive behaviors (Eriksson, 2008b). In other words, partnering is a governance form that enhances a greater focus on cooperation than on competition. Furthermore, Eriksson (2010b) argues that mandatory core procedures are: bid evaluation based on multiple criteria, payment based on open books, and core collaborative tools (e.g. start-up workshop, joint objectives, follow-up workshops, teambuilding, and conflict resolution techniques). Optional procedures are early involvement of contractors in concurrent engineering, limited bid invitation, joint selection and involvement of subcontractors in broad partnering teams, collaborative contractual clauses, incentives and bonus opportunities based on group performance, and complementary collaborative tools (e.g. partnering facilitator, joint risk management, joint project office, and joint IT-tools) (Eriksson, 2010b).

When examining the abovementioned cooperative procurement procedures that serve as the basis for partnering implementation in previous literature one can discern four dimensions of collaboration: width, depth, duration, and intensity. By explicitly discussing the partnering concept in terms of four dimensions it is easier to dig into details about how to implement partnering and achieve collaboration.

Width: how many and which companies shall get involved?

The width of collaboration involves how many and which actors to involve in the partnering team. One prominent characteristic of the construction industry is main contractors’ practice of subcontracting portions of a project to specialist subcontractors (Eccles, 1981). As much as 70-80% of the gross work done in the construction industry involves the buying-in of material and subcontracting services (Dubois & Gadde, 2000; Miller et al., 2002). In spite of this, many partnering attempts include only client and main contractor (Bresnen & Marshall, 2000a; Humphreys et al., 2003), which also is reflected in a lack of research adopting a network perspective on partnering, involving also subcontractors, suppliers, and consultants (Bygballe et al., 2010). In cases where subcontractors are not involved in the partnering team the increased collaboration between client and main contractor seldom spreads to subcontractor level (Bresnen & Marshall, 2000c; Packham et al., 2003). Many scholars therefore argue for wider partnering teams, including several key actors, both consultants (Cheung et al., 2003; Lui & Ngo, 2004; Eriksson, 2010a) and suppliers and subcontractors (Ng et al., 2002; Humphreys et al., 2003; Kaluarachchi & Jones, 2007).

Depth: What people in the companies shall get involved?

The depth of collaboration concerns the amount of hierarchical levels and different types of staff occupations involved within the participating companies. Many partnering arrangements are not so deep since they include very few hierarchical levels; mostly the companies' project managers. Since top management commitment is important when implementing partnering (Akintoye & Main, 2007) also senior management levels above project managers are useful to involve (Bayliss et al., 2004). Because the actual work at the site is executed by blue collar workers it is important that also these people collaborate across organizational boarders (Eriksson, 2010a). Hence, some of the partnering activities should be directed to the site worker level. In addition, it is critical to involve end-users in collaboration so that they can contribute with valuable insights to the design work and commit to the end-product before the hand-over (Rönnberg-Sjödin et al., 2010). The depth of collaboration is therefore critical to consider in order to improve the impact of partnering.

Duration: When and for how long shall they get involved?

The duration of construction projects is mostly long, often more than a year, making it possible to build trust-based relationships within single projects (Kadefors, 2004). However, the duration of the collaboration depends on when the partner is procured and for how long s/he is involved in the project. Is it for only a small part of the project, the whole project or even for several subsequent projects in a strategic partnering arrangement? In contrast to traditional practice in construction projects, many scholars argue that key contractors and suppliers should be procured early in order to contribute in collaborative design work (Rahman & Kumaraswamy, 2004). Early involvement is vital since it takes time for the actors to tune in the partnering spirit (Chan et al., 2006). When concurrent engineering is adopted, suppliers are involved very early in order to obtain an overlap between design and construction (Gil et al., 2008). This is therefore a very useful way of extending the duration of the collaboration (Eriksson, 2010a). Another approach is strategic partnering, but this is not yet very common in practice nor theory (Bygballe et al., 2010). Nevertheless, strategic partnering in long-term framework agreements is a powerful way of making the collaboration duration longer, thereby increasing the commercial benefits for suppliers and improving the possibilities for continuous improvements (Bresnen & Marshall, 2002).

Intensity: How intense shall we collaborate?

The intensity of collaboration is not very strong in traditionally governed projects. In fact, many authors argue that most projects involve arm-length relationships in which the actors collaborate limitedly. In partnering arrangements the intensity of collaboration is strengthened by cooperative procurement procedures such as, 1) partner selection based on multiple criteria (Rahman & Kumaraswamy, 2004), which enhance the selection of partners that are both willing and competent to collaborate with other project actors, 2) incentive-based payment (Clegg et al., 2002; Bayliss et al., 2004; Crespin-Mazet & Ghauri, 2007), which distributes benefits evenly (Akintoye & Main, 2007) and signals that collaboration among the actors is legitimate and desired (Kadefors, 2004), and 3) collaborative tools such as joint objectives and continuous follow-up meetings (Clegg et al., 2002; Bayliss et al., 2004), joint project office (Bresnen & Marshall, 2002; Clegg et al., 2002; Crespin-Mazet & Ghauri, 2007), and teambuilding (Crespin-Mazet & Ghauri, 2007), which are important elements of the socialization process among partners.

METHOD

This research involved four case studies of partnering projects procured by a Swedish mining company. In order to enhance comparisons between the empirical data and the theoretical concepts it is important to select critical cases (Yin, 2003) through theoretical sampling (Eisenhardt, 1989). Hence, projects that were governed through explicit partnering approaches were selected in order to provide opportunities for comparisons of main aspects related to the four dimensions of collaboration. Although somewhat overlapping, the four projects were procured and built in the chronological order A, B, C, and D, which made it possible to study improvements and changes among the partnering implementation efforts. Selecting cases from only one organization obviously diminish the possibilities of generalizations. Case study research should however aim for analytical rather than statistical generalizations (Yin, 2003) and an advantage of the chosen approach is that observed differences in partnering outcomes more easily can be associated with differences in how it was implemented rather than with cultural differences at organizational and national levels.

The data was collected through 50 semi-structured interviews (a total of 66 hours) with respondents mainly representing the client's project organizations (35 interviews), but also from the partner organizations (15 interviews). The client respondents included the director of the construction project department, 1st level project managers of the four projects, 2nd level project managers in Projects A and B, which were divided into smaller parts due to their large size, procurement managers, quality managers, design managers, and various specialists involved in time scheduling, and quality control. The partner respondents included site managers, contract manager, design consultants, and engineers. Additionally, approximately 20 hours of document studies were performed, focusing on partnering charters, incentive arrangements, and tendering and contractual documents. To increase reliability (transparency and future replication), case study protocols were constructed together with case study data bases, containing case study notes, documents, and the narratives collected during the study, all with the aim of facilitating retrieval for future studies (Yin, 2003).

EMPIRICAL FINDINGS

The four case study projects concerned two large pelletizing plants (Project A and B), a new main mine level (Project C), and flotation facilities (Project D), see Table 2. In 2004 the client's procurement department adopted a partnering strategy, declaring that all large and complex engineering projects should explicitly be governed by partnering arrangements. Hence, all four projects involved partnering but it was implemented differently, affecting the four dimensions of collaboration. A 2nd level project manager in Project B stated that "it is nothing wrong with partnering as such, but how it is implemented".

Width

In Projects A and B, key actors (construction contractor, mechanical supplier, electrical supplier, and key consultants) were involved in different partnering teams, which diminished the collaboration between these groups. No subcontractors were formally involved in the partnering activities in these two projects. In Projects C and especially D, wider partner teams were established, enhancing collaboration across contractual boundaries.

In Projects A, B, and D the incentive-based compensations were connected to the companies' individual performances, which hampered collaboration across contracts. In Project C the gain share/pain share arrangements and bonus opportunities were instead tied to the group performance. This was perceived to enhance a wider collaboration among all actors in the partnering team since the individual partners did not have any incentive to sub-optimize their own performance. Many respondents also perceived it important to include key consultants in the incentives, but this was not tried out in any of the projects. The respondents agreed that involvement of key subcontractors in the partnering team should have been done to a larger extent and that some of them should have been part of the incentive-based payment since they perform most of the work on site.

Table 1: Project characteristics

Project characteristics	Project A Pelletizing plant	Project B Pelletizing plant	Project C New mine level	Project D Flotation plant
Size	€ 300 M	€ 600 M	€ 20 M/year	€ 40 M
Main parts	Construction (C) Electrical engineering (E) Mechanical engineer. (M)	Construction (C) Electrical engineering (E) Mechanical engineer. (M)	Construction (C)	Construction (C) Electrical engineering (E) Mechanical engineer. (M)
Duration	2 years	2.5 years	Contract for 1 year at a time.	1.5 years
Time pressure	An initially high time pressure was increased further due to extended scope.	Extremely high time pressure.	Very high time pressure due to high requirements on the production speed: 15300 m/year.	High time pressure.
Complexity	Very high complexity. Complex coordination between C, E, and M. Totally 150 different firms were involved. 700 people were involved at most on site.	Extremely high complexity. Complex coordination between C, E, and M. 1400 people were involved at most on site.	Moderate complexity. Smaller amount of trades and disciplines in underground work. Due to limited space too many people can not work simultaneously. At most 150 people were involved	Not as complex as Projects A and B but a normal engineering project with high complexity. Complex coordination between C, E, and M.
Customization	Rather high, since the technology (straight-grate sintering machine) was not really new but customized at site.	Very high. No existing product available and process development was required. The world's largest Grate-Kiln-Cooler was built on site. It is the world's only pelletizing plant equipped for NOx reduction.	Very high. Obviously almost all work is taken place at the site. Work has to be planned carefully ahead to fit the client requirements, the time schedule and the geological conditions.	Rather high, but fairly normal for an engineering project.
Uncertainty	High. Client demands changed considerably during construction, resulting in many COs. The plant process capacity was increased by 80% in two steps.	High. Parallel design and construction increase the uncertainty.	High. Geological conditions and quality of the ore body are very hard to estimate before hand.	Moderate. Conceptual design stage was not very time pressured which resulted in less uncertainties regarding scope, technical solutions and costs.

Depth

In general, the collaboration focused on high hierarchical levels. This can be exemplified by Project A, in which almost 50% of workshop participants were top managers above and outside the project organisation. Although this top management commitment was perceived important for collaboration to emerge on lower levels, many respondents argued that more explicit attempts should have been made to reach staff on site.

Blue collar workers were only involved in Project C, through special workshops for them and by giving them bonuses if weekly tunnel production reached certain levels. A joint room for lunch and coffee breaks was also established underground, called “The Hard Rock Café”. Due to the underground work, blue collar workers were fewer and worked for a longer period of time in Project C compared to the other projects. Hence, it was perceived easier and more important to involve them in the partnering arrangement.

The input from end-users into the design work was obtained to a varying degree in the four projects. The end-users were considered very knowledgeable and their input to the design work was requested but many respondents argued that it is very difficult to get end-users deeply involved in project activities since this is outside the scope of their normal job responsibilities. In Projects A and B input from end-users was received to some extent but they were not involved in the partnering process, which was considered as a weakness. Hence, in the subsequent Projects C and D, end-users were participating in the partnering workshops and in Project D the commitment and involvement of end-users was improved by the use of the joint IT-tool “Walk inside”, which made it possible to visualise the end-product.

Duration

Project C was the only project in which design was performed solely by the client side, which is normal in underground (mining) work, before the contractors were procured. In order to save time and utilize contractors’ competence to enhance buildability concurrent engineering was performed in the other three case projects. The parallel design and construction was vital due to the high time pressure and the integration also served as a key factor enhancing collaboration. Close collaboration in early design stages developed and grew to close collaboration throughout the project life cycle. However, the timing of the involvement is not all that matters; the way in which contractors are involved and interact is also vital. Experiences from Project B show that early procurement of contractors has little effect on collaboration if the client does not have the time and resources to interact with the contractor.

In Project C, a long-term contract based on an option for continuance served as a basis for greater duration of collaboration, improving the contractor’s commitment for the project. However, one of the mechanical suppliers (MS1) in Project B had a similar contractual option for a possible delivery of similar equipment in Project D. However, the client did not perceive to gain any benefits from this continuance, since MS1 initially acted a bit lazy and uncommitted.

Intensity

In all four case projects *partner selection* procedures were based on soft parameters and earlier experiences of the partners. The explicitly low focus on lowest price resulted in harmonious relationships in which all actors were allowed to make money. However, in Project B, there was an implicitly high focus on price, which was manifested by rough price negotiations when deciding the target price. The contract manager of the construction contractor stated that “it was tough to be so suspiciously questioned already at the outset of the project”.

Gain share/pain share arrangements coupled with bonus opportunities were adopted in all four case projects and considered to be beneficial but not crucial. The size of the bonus opportunities were frequently discussed among the respondents. If bonuses are to affect attitudes and behaviour, many respondents argued that they have to be relatively large. Hence, the bonus opportunities were amplified in Project D to approximately 5% of the project value. This was considered more influential than in the preceding projects.

In all four case projects a broad range of *collaborative tools* was utilized: start workshop, joint objectives, partnering questionnaire, follow-up workshops, teambuilding, facilitator, joint IT-tools, joint project office, and conflict resolution. The respondents found these activities effective for strengthening the collaboration among actors. Due to the monetary size of the projects, the costs of performing these activities were not considered unreasonably high.

Table 1: Summary of the four dimensions of collaboration in Projects A-D

(Abbreviations: CC = construction contractor, EC = Electrical contractor, ES = Electrical supplier, ESC = Electrical subcontractor, MS = Mechanical supplier, SC = subcontractor).

	Project A	Project B	Project C	Project D
Width	Two partnering teams were established, 1) CC and two consultants and 2) ES, EC and one consultant. No SCs were formally involved.	Three partnering teams: 1) MS1, MS2 and CC1, 2) CC1 and one consultant, and 3) CC2 and one consultant. No SCs were formally involved.	Partnering team included CC and 3 SCs. CC and the largest SC shared gain/pain share agreement.	Partnering team included CC, MS, ES, two consultants and one SC. Compared to Project A and B the main partners tried to involve SCs more.
Depth	Involvement of high hierarchical levels assured top management commitment. Blue collar workers and end-users were not involved.	Similar to Project A.	Involvement of high hierarchical levels assured top management commitment. End-users participated in workshops. Blue collar workers were involved through special workshops and bonus payments if weekly production reached certain levels.	Involvement of high hierarchical levels assured top management commitment. End-users participated in partnering workshops. Blue collar workers were not involved.
Duration	Only MS was involved (as a consultant) in the feasibility stage. CC was procured and involved soon after the investment decision, but only 1.5 months of the design stage elapsed before construction start. ES was procured shortly after construction start. Partners collaborated well in concurrent engineering. Some key SCs were procured rather late. Key consultants were involved to the end of the project.	CC & MS were procured early in the feasibility stage. In the MS contract there was also an option for a contract in Project D. Collaboration was close with MS but strained with CC due to lack of human resources dedicated to this relation. Start workshop was held too late (after construction start). Relationships got off on the wrong foot, which was difficult to correct during the remainder of the project. EC was procured after construction start.	The client performed the design work regarding the placement of tunnels. Consultants are involved to some degree in the design of underground facilities. Since the involvement of contractors were not needed in the design work they were procured after most of the design work was finished. CC and three SCs were procured fairly simultaneously to plan construction work jointly. CC was contracted for one year but with an option of continuance for one additional year.	CC, MS and ES were procured as consultants early in the feasibility stage. Collaboration was close among all partners in concurrent engineering although they were a bit unfamiliar with contributing to design work. Due to the early involvement of partners on a consultant basis 2/3 of the design work was finished before target prices and contracts for the construction stage were agreed. MS was contracted as a continuance of a similar delivery as part of Project B.
Intensity	CC-evaluation: Price 22%, Soft parameters 78%	Similar to Project A for CC but the focus on price was higher for EC. Collaboration was strained with CC due to tough price negotiations when setting the target price.	CC-evaluation: Price 33%, Soft parameters 67%	Favorable risk analyses and earlier positive experiences made the client choose these three suppliers.
	CC, MS & ES had similar compensation schemes: fixed price for indirect costs and open book reimbursement for direct costs including 50/50 gain-share/ pain-share in each contract. Opportunities for bonuses (€ 1.5 M ~ 0.5% of total value) connected to work environment, time & collaboration.	Compensation was similar to Project A for CC and MS. Fixed price for EC. Bonus opportunities (~ 1% of total value) were similar to Project A.	CC and one SC had similar compensation schemes: fixed price for indirect costs and open book reimbursement for direct costs including 45/45/10 gain-share/ pain-share on the total cost performance. Bonus opportunities (€ 0.4M ~ 2% of total value) connected to work environment & time.	Similar compensation schemes as Project A. Bonus opportunities (€ 2M ~ 5% of total value) connected to work environment and time.
	Start workshop, joint IT-tools, joint objectives, partnering questionnaire, follow-up workshops, teambuilding, facilitator, conflict resolution.	Collaborative tools were similar to Project A, but also included a joint project office. Joint IT-tools were not used to the same high extent as in Project A.	Similar to Project B.	Similar to Project A but also included a joint project office and the work planning method Last Planner.
Project results	Results regarding costs, time and quality were satisfactory. Cooperation was very good within contract relationships but slightly less good between contracts.	Slight cost and time overruns due to increased scope and change orders. Quality was satisfactory. Cooperation among partners was not satisfactory considering the partnering arrangement.	Results regarding costs, time and quality were satisfactory. Costs were reduced with 10% compared to preceding year when partnering was not used. Cooperation was very good both within and between contracts.	Results regarding costs, time and quality were very good. Cooperation was very good both within and between contracts.

DISCUSSION

Due to the challenging characteristics of all four case projects (i.e. high complexity, uncertainty and time pressure) the explicit partnering strategies seem suitable (Eriksson, 2008b). In all four projects partnering involved more than just collaboration between client and main contractor. Hence, collaboration was a bit broader in all projects than what is often described in literature (Bresnen & Marshall, 2000a; Humphreys et al., 2003). However, dividing key actors that are interdependent of each other into different partnering teams is not very beneficial from a collaborative perspective. It diminished wide collaboration among many key actors and across contracts. The case results indicate that establishing a wide partnering team in which main contractor and a selection of key suppliers, consultants and subcontractors participate facilitate a greater width of collaboration. Such wide partnering teams require more careful planning of workshops and meetings since too many people at each meeting is counteractive. Fewer people from each company can therefore participate in general workshops where all partners are represented. In more specific meetings, in which only a few partners participate, more people from each company can be involved. This great width of collaboration may be very important in complex engineering projects in which many interdependent actors need to coordinate their activities in order to jointly design, assembly and install the end product.

Top management commitment was established by the participation of higher hierarchical levels in partnering workshops. Similar to previous research this was considered beneficial (Bayliss et al., 2004; Akintoye & Main, 2007). In Projects A and B neither end-users nor blue collar workers were participating in partnering activities, which was perceived as a weakness. This was therefore changed to Projects C and D, which showed that increased depth of collaboration may be beneficial. However, the involvement of end-users and blue collar workers was not easily obtained since these types of actors are not accustomed to the partnering arrangement.

The duration of collaboration was rather long in all four projects. In line with findings in some previous literature (Gil et al., 2008; Eriksson, 2010a), early involvement of key contractors/suppliers in concurrent engineering was perceived critical for collaboration and also for project results in Projects A, B, and D. It is, however, important that the client has the human resources to engage in collaborative activities and not leave partners working on their own without support. In Project C, longer duration was instead achieved through a long-term contract, which was considered vital for collaboration. A similar approach in Project B and D produced mixed results. In Project B the client was satisfied with the collaboration and performance of the mechanical supplier, who therefore got the chance to supply a similar product in Project D. In this subsequent project the client was not satisfied with the supplier who initially acted a bit lazy and uncommitted. From a game theoretic perspective, this can be explained by rationality; the supplier was more committed to collaboration in Project B due to a possible chance of continuance, which was not apparent in Project D (Eriksson, 2007). Prior partnering studies have shown that such possibilities for future work serve as a vital mechanism for increased collaboration (Bresnen & Marshall, 2000b; Eriksson, 2008b). This reflection shows that designing option-based contracts is a complex task; they should provide the supplier with a chance of long-term continuance if performance standards are met.

The intensity of collaboration was rather high in all four projects due to the use of cooperative procurement procedures. The empirical results show the importance of selecting partners on basis of multiple criteria rather than lowest price. Tough price negotiations with one partner in Project B, resulted in strained relationships that were difficult to improve during the reminder of the project. Incentive-based payment was utlised in all four projects and connected not only to economic performance but to work environment, collaboration and time too through bonuses and mile stones. In addition, the extensive use of collaborative tools increased the intensity of collaboration among the partners. These findings support earlier research that endorses the importance of cooperative procurement procedures for collaboration to emerge (Bresnen & Marshall, 2002; Clegg et al., 2002; Crespin-Mazet & Ghauri, 2007).

The four dimensions of collaboration can be illustrated in a figure by letting the three dimensions of width, depth, and duration (length) form a box (i.e. the greater the width, depth, and duration, the larger the box) and letting the intensity represent the content of the box (i.e. the greater the intensity the more content). The empirical results presented in this paper have shown how a client can actively go about to implement partnering in ways to shape the size of the box and its content.

CONCLUSIONS

Previous research has argued for more intense collaboration in construction projects and that key actors should be involved earlier in order to start collaboration already during design activities. Furthermore, many authors mean that partnering should not be arranged only with client and main contractor, since other key actors play important roles too. In addition, lower hierarchical levels, at which the actual on site work takes place, should be involved in order to enhance coordination of work tasks. In this paper it has been shown how collaboration can be divided into four dimensions in order to get a more detailed yet holistic picture of how partnering can be implemented.

There are some general reflections that can be made on the basis of the empirical results. The case study findings show that compared to what is normally described in prior partnering literature, a greater *width* of collaboration is required in complex engineering projects since there are many interdependent actors that need to coordinate their activities. A greater *depth* of collaboration is important when end-user inputs are vital for a customized design and when blue collar workers are working continuously for a long time on the site. When contractor/supplier input is vital in the design stage in order to improve buildability and when time pressure requires parallel design and construction, a longer *duration* of collaboration through early involvement in concurrent engineering is suitable. When work is similar across projects/processes a longer duration of collaboration through long-term contracts or strategic partnering is viable. A higher *intensity* of collaboration is required when project characteristics are challenging (i.e. high complexity, uncertainty and time pressure), which makes it more difficult but also more important to obtain coordination and joint problem-solving among various partners.

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REFERENCES

Akintoye, A., McIntosh, G., & Fitzgerald, E. (2000). A Survey of Supply Chain Collaboration and Management in the UK Construction Industry. *European Journal of Purchasing & Supply Management,* 6 (3-4), 159-68.

Akintoye, A. & Main, J. (2007). Collaborative Relationships in Construction: The UK Contractors' Perception. *Engineering, Construction and Architectural Management,* 14 (6), 597-617.

Bayliss, R., Cheung, S., Suen, H., & Wong, S.-P. (2004). Effective Partnering Tools in Construction: A Case Study on MTRC TKE Contract in Hong Kong. *International Journal of Project Management,* 22 (3), 253-63.

Bresnen, M. & Marshall, N. (2000a). Partnering in Construction: A Critical Review of Issues, Problems and Dilemmas. *Construction Management and Economics,* 18 (2), 229-37.

Bresnen, M. & Marshall, N. (2000b). Motivation, Commitment and the Use of Incentives in Partnerships and Alliances. *Construction Management and Economics,* 18 (5), 587-98.

Bresnen, M. & Marshall, N. (2000c). Building Partnerships: Case Studies of Client-Contractor Collaboration in the UK Construction Industry. *Construction Management and Economics,* 18 (7), 819-32.

Bresnen, M. & Marshall, N. (2002). The Engineering or Evolution of Cooperation? A Tale of Two Partnering Projects. *International Journal of Project Management,* 20 (7), 497-505.

Bresnen, M. (2007). Deconstructing Partnering in Project-Based Organisation: Seven Pillars, Seven Paradoxes and Seven Deadly Sins. *International Journal of Project Management,* 25 (4), 365-74.

Bygballe, L., Jahre, M., & Swärd, A. (2010). Partnering Relationships in Construction: A Literature Review. *Journal of Purchasing & Supply Management,* In Press

Chan, A., Chan, D., & Ho, K. (2003a). An Empirical Study of the Benefits of Construction Partnering in Hong Kong. *Construction Management and Economics,* 21 (5), 523-33.

Chan, A., Chan, D., & Ho, K. (2003b). Partnering in Construction: Critical Study of Problems for Implementation. *Journal of Management in Engineering,* 19 (3), 126-35.

Chan, A., Chan, D., Fan, L., Lam, P., & Yeung, J. (2006). Partnering for Construction Excellence - A Reality or Myth? *Building & Environment,* 41 1924-33.

Cheung, S., Ng, T., Wong, S.-P., & Suen, H. (2003). Behavioral Aspects in Construction Partnering. *International Journal of Project Management,* 21 (5), 333-43.

Clegg, S., Pitsis, T., Rura-Polley, T., & Marosszeky, M. (2002). Governmentality Matters: Designing an Alliance Culture of Inter-organizational Collaboration for Managing Projects. *Organization Studies,* 23 (3), 317-37.

Crespin-Mazet, F. & Ghauri, P. (2007). Co-Development as a Marketing Strategy in the Construction Industry. *Industrial Marketing Management*, 36 (2), 158-72.

Dubois, A. & Gadde, L.-E. (2000). Supply Strategy and Network Effects - Purchasing Behaviour in the Construction Industry. *European Journal of Purchasing & Supply Management*, 6 (3-4), 207-15.

Eccles, R. (1981). Bureaucratic versus Craft Administration: The Relationships of Market Structure to the Construction Firm. *Administrative Science Quarterly,* 26 (3), 449-69.

Eisenhardt, K. (1989). Building Theories from Case Study Research. *The Academy of Management Review,* 14 (4), 532-50.

Eriksson, P. E. (2007). Cooperation and Partnering in Facilities Construction - Empirical Application of Prisoner's Dilemma. *Facilities*, 25 (1/2), 7-19.

Eriksson, P. E. (2008a). Procurement Effects on Coopetition in Client-Contractor Relationships. *Journal of Construction Engineering and Management*, 134 (2), 103-11.

Eriksson, P. E. (2008b). Achieving Suitable Coopetition in Buyer-Supplier Relationships: The Case of AstraZeneca. *Journal of Business to Business Marketing*, 15 (4), 425-54.

Eriksson, P. E., Nilsson, T., & Atkin, B. (2008). Client Perceptions of Barriers to Partnering. *Engineering, Construction and Architectural Management*, 15 (6), 527-39.

Eriksson, P. E. (2010a). Improving Construction Supply Chain Collaboration and Performance: A Lean Construction Pilot Project. *Supply Chain Management: An International Journal*, 15 (5), 394-403.

Eriksson, P. E. (2010b). Partnering: What is it, When should it be used and How should it be implemented? *Construction Management and Economics*, 28 (9), 905-17.

Gil, N., Beckman, S., & Tommelein, I. (2008). Upstream Problem Solving under Uncertainty and Ambiguity: Evidence from Airport Expansion Project. *IEEE Transactions on Engineering Management*, 55 (3), 508-22.

Gil, N. (2009). Developing Cooperative Project Client-Supplier Relationships: How Much to Expect from Relational Contracts? *California Management Review*, 51 (2), 144-69.

Glagola, C. & Sheedy, W. (2002). Partnering on Defense Contracts. *Journal of Construction Engineering and Management,* 128 (2), 127-38.

Gransberg, D., Dillon, W., Reynolds, L., & Boyd, J. (1999). Quantitative Analysis of Partnered Project Performance. *Journal of Construction Engineering and Management,* 125 (3), 161-66.

Humphreys, P., Matthews, J., & Kumaraswamy, M. (2003). Pre-Construction Partnering: from Adversarial to Collaborative Relationships. *Supply Chain Management: An International Journal*, 8 (2), 166-78.

Kadefors, A. (2004). Trust in Project Relationships - Inside the Black Box. *International Journal of Project Management*, 22 (3), 175-82.

Kaluarachchi, Y. & Jones, K. (2007). Monitoring of a Strategic Partnering Process: the Amphion Experience. *Construction Management and Economics,* 25 (10), 1053-61.

Larson, E. (1997). Partnering on construction projects: A study of the relationships between partnering activities and project success. *IEEE Transactions on Engineering Management,* 44 (2), 188-95.

Lui, S. & Ngo, H.-y. (2004). The Role of Trust and Contractual Safeguards on Cooperation in Non-Equity Alliances. *Journal of Management,* 30 (4), 471-85.

Miller, C., Packham, G., & Thomas, B. (2002). Harmonization between Main Contractors and Subcontractors: A Prerequisite for Lean Construction? *Journal of Construction Research,* 3 (1), 67-82.

Ng, T., Rose, T., Mak, M., & Chen, S. E. (2002). Problematic Issues Associated with Project Partnering - The Contractor Perspective. *International Journal of Project Management,* 20 (6), 437-49.

Packham, G., Thomas, B., & Miller, C. (2003). Partnering in the House Building Sector: A Subcontractor's View. *International Journal of Project Management,* 21 (5), 327-32.

Rahman, M. & Kumaraswamy, M. (2004). Contracting Relationship Trends and Transitions. *Journal of Management in Engineering,* 20 (4), 147-61.

Rönnberg-Sjödin, D., Eriksson, P. E., & Frishammar, J. (2010). Open Innovation in Process Industries: A Lifecycle Perspective on Development of Process Equipment. *International Journal of Technology Management,* (In Press),

Saad, M., Jones, M., & James, P. (2002). A Review of the Progress towards the Adoption of Supply Chain Management (SCM) Relationships in Construction. *European Journal of Purchasing & Supply Management*, 8 (3), 173-83.

Skaates, M. A., Tikkanen, H., & Lindblom, J. (2002). Relationships and Project Marketing Success. *Journal of Business & Industrial Marketing,* 17 (5), 389-406.

Wood, G. & Ellis, R. (2005). Main Contractor Experiences of Partnering Relationships on UK Construction Projects. *Construction Management and Economics,* 23 (3), 317-25.

Yin, R. (2003). *Case study research, Design and Methods.* London: Sage Publications.

PARTNERING, LEAN CONSTRUCTION AND HEALTH AND SAFETY WORK ON THE CONSTRUCTION SITE: CO-PLAYERS OR OPPONENTS?

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Each new construction project is organised with new clients, consultants and contractors every time. Planning and coordinating the construction process and the specific health and safety work on the construction site must therefore also be organised each time. In recent years, partnering and Lean Construction have been introduced as new forms of cooperation between the actors in construction. Simultaneously, new regulations have been implemented that place the responsibility for health and safety conditions on clients. Partnering and Lean Construction were studied with a focus on the importance of, and interaction with, health and safety on site. Production as well as health and safety are often perceived as two separate areas with different key actors and they are handled as two different management areas with their own embedded management problems. This despite, the fact that it has long been known that health and safety is dependent on the organisation and execution of production and that a familiar theme in the management of safety is to avoid a sidecar mode of production. The study applied theories on construction management and construction safety management. The research methods were based on trade analysis and studies of 5 building projects on site. The trade analysis was performed by interviewing focus groups. The construction sites were observed over a six-month period by applying the methods: Observation, documentation and interviews. It was concluded that 1) synergy between partnering and Lean Construction, and health and safety work can be achieved, 2) there has to be a driver to facilitate the interplay between the management areas, 3) all the actors can drive the process, 4) as drivers they have to handle context-dependent dilemmas.

KEYWORDS: Partnering, Lean Construction, Health & safety, Management, Construction site

INTRODUCTION

Since the 1940s, the leadership of the construction industry has been characterised by a planning rationality that has been based on an understanding of the construction process as a sequential phase model. Within this rationality, the various parties in construction were allocated permanent roles and responsibilities, and the relations between the parties were regulated by contracts. The interaction between the parties was taken for granted and you did not question the "social order". With the new partnership models, including partnering and Lean Construction, which has emerged as a reaction to too many problems in construction (high number of conflicts, etc.), the structures and standards have been challenged, and with the new partnerships the conditions for the new social order are therefore set to be renegotiated between the parties (Gottlieb, 2010).

The Sidecar Effect of health and safety (H&S) work has long been a familiar phenomenon (*cf.* Jensen, 2002: 204). Sidecar location characterises a situation where safety is disconnected from the core performance and function in an isolated system – a situation that for years has been criticised for isolating the H&S work. By linking H&S work with the core contributions on site, H&S work can move away from the location as "sidecar".

This paper explores implications of bringing H&S work in play together with the new forms of partnerships. Three important lessons learned from the development project were:

- That the synergy between new forms of partnerships and H&S work on construction sites required that both management areas were prioritised.
- That to exploit the synergy to support the use of new forms of partnerships and H&S work, it require the development of routines for interaction between production and H&S work.
- That there were a number of dilemmas that the various actors had to react to when they wanted to engage in the process.

The paper begins with a theoretical introduction to the new forms of cooperation and the work environment concept that were applied in the analysis. Construction projects are project-organised, which places special demands on the management of the construction process. Managing a construction project depends on how the parties interpret the construction process. The theoretical review therefore finishes with a description of the two dominant perspectives indicating two different ways of understanding the construction process.

Following the theoretical review, the methodological approach and its implications for the results will be discussed. Finally the empirical results of the study will be presented with a focus on the different actors in construction that can act as drivers for interaction between the new forms of cooperation and the work environment on site. There is a particular emphasis on describing the dilemmas that the actors faced due to the construction project's specific conditions in which new actors will meet each time a construction project is established.

THE THEREOTICAL FRAMEWORK

Forms of cooperation as new partnerships

In the past 10-15 years, attention has been paid to human resources and organisational potential (*cf.* Dainty *et al.*, 2007). The ongoing unfavourable criticism of low productivity, a high number of failures, varying quality and cost overruns has led to the development of new concepts of cooperation with the aim of promoting learning and innovation through improved dialogue and cooperation between the stakeholders.

The objective of partnering is to increase productivity and quality by establishing common objectives between the parties in each construction project (Nyström, 2005). The key actors are, at the very least, client, consultant and contractor. This means that what makes partnering special is an early involvement of the contractor in the cooperation. Partnering is about creating a transparent business environment by establishing a partnership based on dialogue, trust and transparency and by creating an economic structure that supports the fact that the parties have common economic interests.

The purpose of Lean Construction is to optimise construction processes on site. Application of Lean Construction in Denmark is primarily related to the use of the "Last Planner System" which is a planning tool. The key actors are consultants and contractors, including construction managers and craftsmen. Today several sites use the Last Planner System to coordinate and plan the construction process.

Teams, autonomous groups, self-managing groups are all designations that cover roughly the same i.e. that tasks previously handled by managers are assigned to a group of employees. The purpose of autonomous groups is often to place responsibility and coordinating tasks with or as close to the performance of work as possible. It is debatable whether autonomous groups are new in construction or whether they have always existed with gang culture. The area has not earlier received a particularly much attention, but autonomous groups are beginning to emerge in association with Lean Construction, since experience suggests that the essential conditions for the use of Lean Construction involve the transfer of new skills and responsibilities to the craftsmen / gangs.

Many companies work with elements from several different forms or concepts of cooperation (e.g. Lean and Partnering) at the same time. When partnering is used as cooperation form between parties in a construction project the cooperation will be written into a contract. The application of Lean Construction can either be written into a contract, which will be the case if the use of Lean Construction is prompted by client demands, or be implemented in practice by the contractor. The application of autonomous groups and the degree of self-management are now embedded at the level of the individual contractor rather than as a concept that a whole site is organised around.

The H&S concept

The study was based on a working concept and on an understanding of H&S on the construction site as a result of:

- The physical work environment – i.e. the work environment impacts that the specific performance of the work could result in
- H&S work – i.e. systematic activities undertaken to understand and improve the work environment, for example safety meetings, work place assessment, Last Planner System and safety coordination
- The local H&S awareness (H&S culture) that determined what was locally accepted as negative influences at work, and what remedial and preventive measures, were given priority (Turner, 1991; Pidgeon, 1998).

On the construction site the substantive work was partly related to the individual craft-specific work processes and associated risks, and to the risks that might occur when the many disciplines working in parallel influenced each other's work environments.

H&S work will partly consist of implementing the above statutory systematic activities but may also include voluntary activities such systematic work environment management, audits, tool-box meetings, etc.

Safety culture plays a significant role on the construction site. On-site construction work takes place in physical environments that are constantly changing as the construction progresses. The work environment is therefore dependent on individual employees being able to assess the safety and exercise a high degree of self-control; a positive safety culture may help to guide employees in their daily safety practices on site (Rowlinson, 2004).

As for the local working understanding / safety culture there could be several (competing) local understandings present simultaneously on the construction site. This meant that there was no mutual agreement on whether the construction site working environment needed improvement or was at an acceptable standard.

Work efforts have long been dominated by a mindset of prevention through better planning partly reflected in the regulation of H&S work on the construction site. It has long been known that a good work environment on a construction site is dependent on both efficient H&S work and a positive safety culture. The problem with the safety culture so far has been to define and operationalize the concept in a way that facilitates its use as a tool in bettering the work environment on the constructions site.

The existing cultures on site may both support and complicate the use of new forms of cooperation and H&S work. At the same time the use of new forms of cooperation and H&S work may change culture on site. Good interaction between the use of new forms of cooperation and H&S work therefore necessitates that different parties are aware of the existing cultures, how cultures are affected across the cooperation and work environment and what impact the development of cultures has on future cooperation and work environment.

Management in construction

A key hypothesis in this study was that if both the H&S work and the safety culture must be supported in the developing and maintaining of a good work environment, this would make demands to the type management.

Strengthening the influence of the various employees on their own work (empowerment) is often discussed as a management strategy for the management of complex products and processes, many actors, fragmented processes and tasks, etc., which is precisely what characterise the construction sector (Dainty et al., 2002). The relevance of the strategy is further enhanced when using the new forms of cooperation, where parts of the contractual relationship between construction partners are replaced by partnerships with the expectation of cooperation and reciprocity. This relationship is between client, consultants and contractors but also between construction management and craftsmen.

Managing a construction project depends on how parties in a construction project interpret the construction process. This section introduces two dominant perspectives that indicate two different ways of understanding the construction process.

The first perspective was based on the phase model. Phase model of a construction project has long existed as an understanding of how a construction project evolves in phases and that the previous phases determine the subsequent phases. In this understanding the execution phase is a phase where design and planning is implemented as a plan. This understanding helps to maintain an understanding of the construction phase as a phase, the sole objective of which is to follow an existing plan. Managerial challenges within this perspective will often be about developing better planning models.

The second perspective was based on an understanding that a site will be constantly changing. As construction progresses, the physical surroundings are constantly changing. This means that construction management and craftsmen during the construction process must always be ready to respond quickly to changes in the environment. In addition to building development, changes may be due to changes in terms for example design changes, weather conditions, unexpected events such as pollution, etc. Managerial challenges in this perspective is the handling of the large uncertainties associated with the process and to support the employees themselves are able to constantly assess and react in the situation on site.

On construction sites you will often find combinations of the two management models and the theoretical issue of this paper was not whether one or the other model was right, but where the appropriate interface was between the two models.

OBJECTIVES AND METHOD

Objectives

The aim of the project was to investigate:

1. What kind of impact would new concepts of partnerships have on H&S work in construction?
2. Could the development and implementation of the new concepts be planned in ways that would also promote good H&S conditions?
3. What role could H&S play in the readjustment of construction?

Research methods

The project was a qualitative development project designed as an iterative sequence, in which each phase is a precondition for the next phase, with ongoing adjustments and corrections of the field of study, methods and results. The project and method used consisted of the following main phases:

1. Preparation, gathering and systematisation of existing experience with the implementation and utilisation of new concepts of cooperation (Literature study)
2. Gathering of experience of new cooperation concepts and H&S at the construction industry level (Focus group interviews with different actors in the construction industry)
3. Gathering of examples of practice with new cooperation concepts and H&S on the construction-site level (Interviews with different actors on site, observations and data collection in five ongoing construction projects)
4. Intervention on construction sites; integration of H&S work in the new concepts of cooperation (Test on five construction project over a one-year period)
5. Analysis of the experiences gathered and development of a guideline of recommendations.

RESEARCH RESULTS

Synergy between H&S and new forms of cooperation

H&S work and Partnering

H&S work could exploit that partnering established a common forum already in the design phase. This created the possibility that parties could jointly discuss - not only technical construction issues, but also the work environment - opportunities and problems, so that the project was planned to get the most effective and safe project implementation.

The early dialogue, the setting of common goals and the ensuing dialogue engendered by common objectives were key elements in the discussion of how partnering could contribute to a common focus on H&S and create new opportunities in the area.

Conversely, H&S work activities and H&S actors could contribute to a better planning in a partnering project, so it could proceed without unnecessary stops due to unforeseen H&S problems. H&S actors will have an eye for how planned processes might be used more flexibly, for example by incorporating means to facilitate the work or where for reasons of the work environment it would be necessary to change / move the planned processes, so that the impacts were minimized. H&S stakeholders could also point out how a process might be planned more appropriately, so that workers were exposed to less noise, less vibration, avoided the use of filtering respirators, etc. and thus not be subject to the time limits that otherwise apply to for how long the work can be performed according to workplace legislation.

H&S work and Lean Construction

In connection with the systematic H&S work working conditions will often be identified where solutions should be found. In the process planning, solutions could often be found to H&S conditions and the solutions could be operationalized. Some of the solutions would also help to improve the production process. Lean Construction and the formal H&S work could support each other. Experience suggested that for example input from the Last Plan System and work place assessment in the early process planning could prevent poor working posture when handling building materials by early planning of scaffolding, and improved logistics. Experience suggested that input from the current H&S work (safety rounds, safety meetings, etc.) to Last Plan System meetings, could support for example clean-up that fences were in order and coordination of the different trade groups' work. In that sense, using the Last Planner System could realise new ways to integrate safety aspects as early as at the planning and coordination stages of production.

Partnerships and conflicting interests

Work environment efforts were organised on the basis of an A and B side, i. e. the premise was that there might be conflicts of interest between the A and B side in relation to working conditions. Partnerships provided for an understanding of common interests between various parties and it could mean that the dual relationship stepped into the background throughout the organisation among both managers and workers.

Depending on management culture and gang culture, observation showed that different relationships could develop between construction management and craftsmen in connection with the implementation of Lean Construction. Two examples were:

- a negotiation culture characterised by "us and them" with focus on control

– a culture of partnership characterised by "us" with focus on self-management

The relationship between construction management and craftsmen influenced the culture that was developed and maintained on site and might also have had a spill-over effect on construction-site safety culture.

Negotiating culture could inhibit the solution of health problems when productivity and good working solutions converged but could also underpin a discussion of working conditions when the areas were opposed to each other.

Partnerships can increase productivity and good solutions for the work environment when the areas converged, but inhibit the solution of safety problems when the areas were opposed to each other.

One should therefore be aware whether there are safety aspects that could usefully be resolved within the community when negotiating culture is dominant and, conversely, whether there are safety issues that might disappear when the partnership culture is dominant.

All Actors can drive the process

In the following the relevant actors are presented.

Client requirement and craftsmen responses

In Denmark, clients are assigned greater responsibility for H&S on construction sites through regulation, including a requirement to appoint a safety coordinator with the function of coordinating the crossover H&S work between the various trade groups on site. This has led to several clients having started to formulate demands to contractors' work environment.

Despite the fact that production and the work environment usually were handled as two separate management areas, the craftsmen often perceive production and the work environment as two sides of same coin. It was therefore appropriate to create space for managing the work environment related to the partnership concepts. Several craftsmen in the construction projects expressed it like this: "When you perform an activity, you consider which method should be used to achieve a good result and the impact of the methods on H&S”. When there was a "positive safety culture", it might help to promote that considerations of safety were taken seriously and given priority in the craftsmen’s work behaviour and, conversely, a "negative safety culture” helped to promote a work behaviour that took chances.

The separation between production and the work environment, which existed in the organisation of the sites and the tools to address the areas, was not necessarily found among the craftsmen. This could have implications for how craftsmen experienced requirements for the work environment. Requirements might be perceived as the regulation of behaviour. Depending on the context, work requirements could serve as drivers for the development of safer behaviour, but they could also become barriers.

If the craftsmen did not see a purpose in certain work environment requirements, the craftsmen might perceive requirements as rules that make life more difficult and in the worst cases they could make the workflow more risky. At the same time very restrictive requirements that craftsmen did not see the justification of could result in a perception by the craftsmen that they were not being respected. This could lead to backlash, where the craftsmen disclaimed responsibility, since they felt that they were not consulted.

It could therefore be important in relation to the work environment requirements to consider:

- Whether the craftsmen on site are competent or whether they are characterised by for example unskilled labour, lack of experience, influenced by different standards than traditional Danish ones?
- Whether the safety culture is positive or negative?
- How the craftsmen perceive the requirements; whether the requirements are perceived as reasonable and legitimate or not?
- What the requirements are and how they should be disseminated to support the development of an appropriate work-behaviour on the actual site?

Lean Construction supports the craftsmen' joint coordination and planning across the trade groups. Since working conditions are perceived as an integral part of planning, it will be perceived by many as "natural" to include prevention of safety problems that can arise across the trade groups in the joint coordination and planning.

If working conditions on the construction site across the trade groups must be prevented, it would therefore be important to include craftsmen in the dialogue about how working conditions across the trade groups’ activities might best ensure that their skills and knowledge of work processes and work environment could incorporated in designing the construction site safety conditions.

Safety coordinator

The contractors' use of Lean Construction and the clients' use of a safety coordinator were intended to optimise and improve the interfaces between contractors as a way to achieve a better production flow and a better work environment. The building process and work environment on construction sites are dependent on contractors knowing their subjects and their work environment, including how they manage workflows responsibly in terms of the work environment. On the one hand the planning of construction processes and coordination of H&S work on construction sites were about coordinating the different disciplines working on site at the same time, and on the other hand about respect and support of the trade groups’ own efforts. If the safety coordinator was unaware of the interface between the contractors' employer liability and the responsibility of the client, it could create confusion about the roles and responsibilities of those involved.

Construction managers were often safety coordinators in connection with the execution of total and head enterprises, while consultants were often safety coordinators in trade contracts. When the safety coordinator service for example in relation with major construction projects was undertaken by independent consultants, the service was defined as special services with its own budget. If the safety coordinator service was performed in parallel with other consultancy services or construction services, it would often be a part of the other services and not made independent as a special service with an autonomous budget. It might be considered whether the visibility of the safety coordinator service at the same time could highlight the client's priority of the task and support the prioritisation and legitimisation of time spent on executing the task for both consultants and construction managers, when construction projects were pressed on time schedule.

Construction managers

Implementation of Lean Construction by the contractors reflected a desire for greater involvement of craftsmen in the ongoing planning of the construction site as a way to improve planning and strengthen coordination between the contractors. This might challenge the existing construction manager that must take on a new role in the division of labour between the craftsmen and construction managers.

When companies chose to focus on concepts that supported and enhanced the employees' own resources as management strategy, it was rarely easy. Typical barriers might include (Forman et al, 2001):

- Disaffection of the middle managers' role in the new organisation due to an unclear definition of the role.
- Lack of provision of new skills of middle managers that would be necessary if middle managers were to perform their new role.

From several sides it was stressed that these barriers could be further emphasised in the construction sector, unlike other industries because of distance, both geographically and in local understandings between the company and the construction site (Bryman, 2005).

Construction managers played a central role in the interaction between production and the work environment. In connection with the implementation and use of Lean Construction and prioritising the work environment, it could therefore be necessary for the construction manager to define, develop and sustain a construction leadership that would be able meet the new challenges, for example:

- Handle the oversight and management of plans
- Can delegate responsibility and influence to the craftsmen, and be process manager for meetings etc.
- Can help with solutions to problems that go beyond craftsmen' competence when it is needed
- Have an eye for the need for informal coordination between meetings and the support of craftsmen when needed
- Takes H&S seriously

Additional challenges for the construction manager were that each project required balancing of the relationship between management based on "planning, direction and control" and "process management". Plans, management and control could promote the production, when craftsmen were not competent, but inhibit production when craftsmen were competent.

There could be several ways for the contractor to support the process. Lessons learnt from a construction site showed that construction managers with a background in the craft could be good facilitators in the process because they knew both the world of craftsmen and the world of construction management. This role could be prioritised by the contractor if he started to make the role visible and give it value. Lessons learnt from a second site showed that a clear division between construction managers, foremen and craftsmen could facilitate the process. On the construction site the foremen had the responsibility for using the Last Planner System, and the construction manager only entered the process when it was necessary for example in relation to major changes.

The contractor’s department for the work environment

At several medium-sized and large contractors, it was common to have staff functions within the company. Several contractors employed both H&S workers and employees working with the development and introduction of new production concepts, including Lean Construction. Staff functions were the link between the company and the construction projects.

Staff functions typically had three functions in relation to the actions they performed:

- Development of frameworks / concepts for construction projects.
- Resource support for construction projects
- Compiling of lessons learned from construction projects and ongoing evaluation in relation to the given area, including potential changes.

In connection with implementation of Lean Construction, it was relevant to consider how the interaction between the contractor's Lean Construction concept and H&S work should be. By coordination of procedures in the ongoing planning of construction processes and in the safety management system, activities could be coordinated already in the early planning and thus ensure that both the production needs and work environment were considered.

Documentation was an important element of safety management systems. Increased demand for documentation was further strengthened by external requirements to the documentation of its safety efforts at the site from both the Labour Inspectorate and the client. Documentation might increase oversight and provide a basis for new strategies by the contractor and thus help to solve H&S problems, but at the same time increased demand for documentation from the construction sites could take time from problem solving of H&S conditions on site. Departments of H&S must therefore be mindful of this balance.

When the demand for documentation increased, there was a tendency that the interaction between the H&S department and the construction managers was enhanced at the expense of the interaction with the H&S organisation on site. In this connection it could be relevant to distinguish between the contractor's safety organisation, which was fixed, and the site safety organisation, which was temporary, as it was established and only acting during the execution phase. This meant that for every new construction project, cooperation between the department of H&S and the H&S organisation on the construction site had to be established. In the interplay between the construction site's H&S work and Lean Construction activities, the work environment could be incorporated into planning through cooperation between site managers, H&S organisation and the safety coordinator. There might therefore be a particular challenge for the department of H&S to support and retain a well-functioning H&S organisation on site. A successful H&S organisation on site may contributed to qualifying the H&S work on site and provided important input to Lean Construction activities, and at the same time a well-functioning H&S organisation could help develop local understanding of the work environment on site.

Safety organisation

The safety organisation has one function only on construction sites and that is to keep the focus on H&S and undertake the systematic H&S work with the construction management and the safety coordinator. Hvid (2003) indicates that in the development of partnerships those aspects of the work environment where there convergence is promoted, while other H&S issues risk being forgotten. A challenge for the safety organisation is, on the one hand, to maintain the H&S work with focus on working conditions and, on the other hand, to exploit the potential of Lean Construction to promote the work environment. The safety organisation should therefore consider the H&S issues that could usefully be addressed and resolved under the auspices of Lean Construction and the H&S problems that have to be addressed in other connections for example the contractor's department of H&S.

CONCLUSIONS

The results showed that synergy can be achieved between partnering and Lean Construction, and H&S work. There has to be a driver to facilitate the interplay between management areas, and it seemed that all the actors could drive the process. Because construction projects are project-organised, the context, the actors and the actors' interaction will be new each time. This means that every time the actors want to drive the interplay between new partnerships models and H&S, they cannot use routines but have to handle dilemmas which are context-dependent.

The dilemmas for the different actors shown in this paper were:

Client: Client demands can act as drivers, but they can also be barriers for developing safety behaviour on site

Safety coordinator: Coordination may visualise simplicity/interaction when interfaces are clear but may cause confusion when interfaces are pressed

Construction manager: Plans, management and control can promote the production, when craftsmen are not competent, but inhibit production when craftsmen are competent

Department of H&S: Documentation may increase oversight and provide a basis for new strategies by the contractor and thus help to solve H&S problems but at the same time increased demand for documentation from the construction sites can take time from problem solving of H&S conditions on site.

Safety organisation: In the development of partnerships those converging aspects of H&S are promoted, while other H&S issues risk to be forgotten.

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REFERENCES

Bryman, A, Dainty, A; Price, A, Soetanto, R and King, N (2005) Employee perceptions of empowerment, *Employee Relations*, **27**(4) 354-368.

Dainty, A.R.J., Bryman, A and Price. A.D.F. (2002) Empowerment within the UK construction sector, *Leadership & Organization Development Journal*, **23**(6) 333-342.

Dainty, A., Green, S. and Bagilhole, B. (2007) People and culture in construction. Contexts and challenges, in: Dainty, A., Green, S. and Bagilhole, B. (eds.) *People and culture in construction. A reader*, Oxon: Taylor & Francis, 3-25.

Forman, M and Joergensen, MS (2001) The social shaping of the Participation of Employees in Environmental Work within Enterprises - Experiences from a Danish Context. *Technology Analysis & Strategic Management*, **13**(1), 71-90.

Green, S.D. (1999) The Dark Side of Lean Construction: Exploitation and Ideology. *Proceedings IGLC-7, 26-28 July 1999*, University of California, Berkeley, CA, USA 21-32.

Gottlieb, S. C. (2010) *The constitution of partnering, a Foucauldian analysis of dispositives, space, and order in Danish construction*. Denmark. DTU Management Engineering,

Holt G D, Love, P E D and Jawahar Nesan, L (2000) Employee empowerment in construction: an implementation model for process improvement, *Team Performance Management: An international Journal*, **6**(3/4) 47-51.

Howell G and Ballard G (1999) Bringing Light to the Dark side of Lean Construction, *Proceedings IGLC-7, 26-28 July 1999*, University of California, Berkeley, CA, USA 33-38.

Hvid, H.S. (2003) Dilemmaer knyttet til medarbejderdeltagelse i partnerskaber, *Tidsskrift for Arbejdsliv*, **5**(2), 7-26

Jensen, P.L. (2002) Assessing Assessment: The Danish Experience of Worker Participation in Risk Assessment, *Economic and Industrial Democracy*, **23**, 201-227.

Kreiner, K (2002) Tacit knowledge management: the role of artifacts, *Journal of Knowledge Management*, **6**(2), 112-123.

Lingard, H and Rowlinson, S (2005) *Occupational health and safety in construction project management*. London: Spon Press

Nyström, J. (2005) The definition of partnering as a Wittgenstein family resemblance concept, *Construction Management & Economics*, **23**(5), 473-481.

Peckitt, S J, Glendon, A I and Booth, R T (2004) Societal influences on safety culture in the construction industry. In: S. Rowlinson (eds) *Construction safety management systems*. London: Spon Press.

Pidgeon, N. (1998). Safety culture: key theoretical issues. *Work and Stress* **12**(3).

Rowlinson, S (2004) Overview of Construction Site Safety Issues. In: S. Rowlinson (eds) *Construction safety management systems*. London: Spon Press

Turner, B.A. (1991): The development of a safety culture. *Chemistry and Industry*, 1 April 1991.

REVISITING BOUNDARY OBJECTS: ERP AND BIM SYSTEMS AS MULTI-COMMUNITY ARTEFACTS

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This paper revisits the early conceptions of boundary objects, with a view to unpacking the multiple ways in which boundary objects are constructed, shaped and deployed in practice across multiple communities within construction contexts. This is significant given both the role of technologies in transforming practice within the sector, and the ways they affect and are shaped by traditional practices and institutional conventions. We do this through analysing and comparing two different empirical cases – the implementation of an Enterprise Resource Planning system (ERP) in a large engineering consultancy and the use of Building Information Modelling (BIM) to coordinate the design and construction of two large hospitals in central London. Both BIM and ERP have complicated and on-going histories, and involve the inclusion of many different groups and actors, as well as a plethora of objects in circulation between them. They therefore make useful sites within which to problematise and explore the dynamics and implications of boundary objects.

KEYWORDS: boundary object; ERP; BIM; community

INTRODUCTION

From its inception in the work of Star and Griesemer (1989) the term ‘boundary object’ has become widely used across a range of disciplines to explore issues of knowledge generation, sharing and transformation and the role of artefacts and technologies across epistemologically distinct groups (e.g. Wenger 1998, Carlile 2002, 2004, 2005). However this series of appropriations has led to criticisms that the term has become overly ‘managerial’ and unitary in use, focussing on the benefits of the production of objects which are able to harmonise the interactions between diverse groups, and enable largely unproblematic knowledge transfer. This has been at the expense of understanding the power implications inherent in such transactions (Contu & Willmott 2004, Oswick & Robertson 2009) and the effects of power on the production and transformation of boundary objects themselves. Theoretical suspicion and empirical evidence has led some scholars to reject the efficacy of boundary objects in situations where spatial or epistemological distance is coupled with a lack of other mechanisms of interaction (Sapsed and Salter 2004).

There is a further tension within the dynamics of boundary objects – that through their mutual production and operation, tensions are resolved and a point of closure is achieved where stable objects can facilitate straight-forward exchange. But other literature on the construction and shaping of artefacts points towards coercion, multiple interests and proliferation, continual flux as well as closure – indeed Star and Griesemer’s original conceptions draws on

Callon’s model of interessement. In addition, artefacts can have complex and highly contextualised biographies, extending considerably back (and forward) in time and following circuitous paths and trajectories. The production of boundary objects is arguably grounded in history just as much as in the necessity of interaction between groups around a particular problem or activity.

This paper revisits the early conceptions of boundary objects, with a view to unpacking the multiple ways in which boundary objects are constructed, shaped and deployed in practice. We do this by concentrating on the analytical distinctions proposed by Star and Greisemer, and the appropriation of this typology by Wenger (1991) and Carlile (2002). We are then equipped with an expanded analytical typology of boundary objects which we discuss in relation to two different empirical cases – the implementation of an Enterprise Resource Planning system (ERP) in a large engineering consultancy and the use of Building Information Modelling (BIM) to coordinate the design and construction of two large hospitals in central London. Both BIM and ERP have complicated and on-going histories, and involve the inclusion of many different groups and actors, as well as a plethora of objects in circulation between them. They therefore make useful sites within which to problematise and explore the biographies and implications of boundary objects as dynamic and on-going artefacts.

TYPOLOGIES OF BOUNDARY OBJECTS

The common definition of boundary objects as provided by Star and Griesemer (1989) states that they are "both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites" (Star & Griesemer, 1989: 393). They are objects which can support or be consistent with multiple interests and which can, in some way ‘stay the same’ across different groups or sites. In effect, they perform a balancing act where they remain ‘interpretively flexible’ enough to be appropriated into and be useful in local contexts or specific groups, but retain enough robustness to resist being transformed (or translated) completely within that context and hence lose their utility outside of that. They move along a narrow path with ‘going native’ on one side, and the enforced constraint on the other. The former is a failure of translation between the groups as the object moves between them, the latter fails to represent multiple interests.

Star and Griesemer go on to develop four types of boundary object from their empirical analysis. These are specifically mobilised as analytical categories, rather than as distinct artefacts - “this is not an exhaustive list and are analytical distinctions in the sense that we are really dealing with systems of boundary objects, themselves heterogeneous”. They are (in italics): *Repositories* – Ordered piles of objects indexed in a standardized fashion (e.g. a library of a museum). Individuals can borrow from the pile without having to directly negotiate differences in purpose. *Ideal type* – An abstract diagram, atlas or other description that does not accurately describe the details of any one locality or thing. It is abstracted from all domains and may be fairly vague. Is a ‘good enough’ roadmap for all parties. *Co-incident* boundaries – Common objects which have the same boundaries but different internal contents. Work in different sites and with different perspectives can be conducted autonomously while sharing a common referent. The advantage is the resolution of different goals. *Standardized forms* – These are objects devised as methods of common communication across dispersed work groups. Results in standardized indexes and ‘immutable mobiles’ which can be transported over long distances and convey unchanging information. The advantages are that local uncertainties are deleted. There are two things of note here. Firstly, there are strong elements of standardization and stability of format across these objects – the indexing of the repository, the structure of standardized forms, the level of abstraction of the ideal type, the stability of co-incident boundaries. In practice, this level of stability is what allows the objects to both travel between groups, and to have meaning in different sites but retain an inter-group shape or identity. Secondly, and perhaps in contrast to some later accounts of boundary objects, they all serve to mask or obscure (rather than necessarily resolve) cross boundary controversies and differences – the vagueness of the ideal type, the insensitivity of both the repository and co-incident boundaries to their actual contents, the deletion of uncertainties through selective incorporation of some things and not others on standardized forms. Although the co-incident boundary is stated as able to reconcile goals, its function is to allow groups to work autonomously, and it is difficult to see how this produces reconciliation. The examples given avoid rather than reconcile. These objects serve to produce and maintain boundaries, not break them down, and provide limited or constraint methods of interacting across boundaries. It is, then, unsurprising that the boundary object is offered as only a partial explanation grounded in a specific case. In a now well worn quote, Star and Griesemer state that "the production of boundary objects is one means of satisfying these potentially conflicting sets of concerns. Other means include imperialist imposition of representations, coercion, silencing and fragmentation" (Star and Griesemer, 1989: 520). All of these 'other means' (perhaps with the exception of fragmentation) do suggest the resolution of concerns, but through the wielding of power and the imposition of control. Fragmentation suggests an impasse with no party able to exert enough power over others.

Wenger (1991) proposes boundary objects functioning to bridge the boundaries between different groups or communities. He imagines "the office replete with boundary objects that connects its function with a wide range of communities of practice and constituencies without a specific shared practice. One could picture the claims processing office as a walled computation center, with parades of carefully crafted boundary objects being shipped in and out , in and out" (Wenger, 1998: 107). These objects are boundary drawing, as well as crossing – in Wenger's example maintaining the specialist functions of the claims office whilst allowing it to participate in the wider organisational processes. The objects 'both connect and disconnect'. Wenger also draws on Star and Greisemer's typology to drill down into the different ways boundary objects function, albeit in a somewhat ambiguous and inconsistent way. Although he states he is following S&Gs typology, what he proposes is quite different in some aspects. He proposes the following as four characteristics of boundary objects: *Modularity*: each perspective can attend to one specific portion of the boundary object (e.g. a newspaper is a heterogeneous collection of articles that has something for each reader). *Abstraction*: All perspectives are served at once by deletion of features that are specific to each perspective (e.g. a map abstracts from the terrain only certain features such as distance and elevation). *Accommodation*: The boundary object lends itself to various activities (e.g. the office building can accommodate the various practices of its tenants, its caretakers, its owners, and so forth). *Standardization*: The information contained in a boundary object is in a prespecified form so that each constituency knows how to deal with it locally (for example, a questionnaire that specifies how to provide some information by answering certain questions). The recognition of the boundary object as maintaining as well as spanning boundaries is both consistent with Star and Greisemer, and potentially important in understanding the functioning of boundary objects beyond reconciliation, as is the explicit acknowledgement of abstraction and deletion of controversy and difference. The change from co-incident boundaries to accommodation is also significant. Rather than possess a shared boundary with different activities occurring in parallel within it, accommodation might suggest the appropriation of objects within specific bounded groups or contexts. It is less about shared boundaries and more about transformation within contexts. Arguably, Star and Greisemer's typology does not have a 'type' which explicitly recognises this adaptation, although their general definition of boundary objects as 'plastic enough to adapt to local needs' does suggest that objects are at least partly shaped and configured within local settings. Accommodation perhaps contrasts with Wenger's own definition of the boundary object, which is slightly differently to S&G: "when a boundary object serves multiple constituencies, each has only partial control over the interpretation of the object" (Wenger, 1998: 108). This is not quite the same and Star and Greisemer's definition where the boundary object actively translates or transforms interests and knowledge as it moves across epistemological boundaries. Rather Wenger seems to suggest that the boundary object is relatively fixed, but can be interpreted differently (rather than transformed or translated) in different settings.

The final proponent of the boundary object to discuss here is Carlile. Like Wenger he takes the original typology and re-interprets it: *Repositories* supply a common reference point of data, measures, or labels across functions that provide shared definitions and values for solving problems. Repositories function advantageously as a shared resource from which to compare across different functional settings. *Standardized forms and methods* provide a shared format for solving problems across different functional settings. Forms come in a mutually understood structure and language that makes defining and categorising differences and potential consequences mare shareable and less problematic across different settings. *Objects or models* are simple or complex representations that can be observed and then used across different functional settings. Objects or models depict or demonstrate current or the possible "form fit and function" of the differences and dependencies identified at the boundary. *Maps of boundaries* represent the dependencies and boundaries that exist between different groups of functions at a more systemic level. Maps help clarify the dependencies between different cross-functional problem-solving efforts that share resources, deliverables and deadlines. (Carlile, 2002: 451). Carlile goes on to conflate objects and maps of boundaries, and proposes a three tier framework associating different objects with different boundaries. Syntactic boundaries are the simplest, where a shared grammar between groups allows unproblematic transfer through repositories. Semantic boundaries involve differences of interpretation across the boundary; the development of standardized forms and methods allows translation of these differences between groups. Pragmatic boundaries are the most complex, where novelty or incommensurate and contextual knowledge within different groups has to be transformed. The joint development of models or prototypes is given as an example boundary object which produces new cross-boundary knowledge, but also transforms the 'old knowledge' located within specific groups. Again there are some central issues here. The first is that the framework is oriented to resolving problems and lack of understanding across groups, and this is different to the former descriptions where maintenance of boundaries and deletion of controversy is key. The resolution of cross-boundary problems at the pragmatic level is to co-create mutually intelligible knowledge, and unlike both Star and Greisemer, and Wenger there is little recognition of the boundary object as maintaining, as well as crossing boundaries. Instead, there is a strong sense of moving through the boundaries to reach unproblematic transfer; both the production of new knowledge at the pragmatic level and of standardized forms and methods at the semantic result in shared syntax and the resolution of differences. Putting these three versions of the typology gives us table 1.

Table 1: Typologies of boundary objects

Star and Griesemer 1989	Wenger 1998	Carlile 2002
Repository	Modularity	Repository
Ideal Type	Abstraction	Objects or models
Co-incident boundaries	Accommodation	Maps of boundaries
Standardized forms	Standardization	Standardized forms

As described above, there is some consistency across these typologies. The centrality of standardisation is shared, showing the importance of consistent ways of representing knowledge across different groups, which remain immutable as they circulate – using for example standardised forms, no group can impose a specific epistemological framework or interpretation on another. The use of systems of ordering, whereby different groups can draw on information regardless of 'internal' intentions or uses is also consistent – whether described as a shared repository or a modular structure organising pooled information. A related type of boundary object is the ideal type or abstraction, where controversy or differing interests between groups is deleted or abstracted away, leaving only those aspects which are mutually understood or accepted between groups. The map is the common example of this type of object. Carlile's concept of objects or models is, however, different, with a focus on the transformation of knowledge across boundaries over time, rather than the deletion of those aspects which are not shared between communities. In this sense it integrates across boundaries, rather than maintain them, and the distinctiveness of the knowledge within each group. Co-incident boundaries involve parallel activities within the same domain; maps of boundaries instead are representations of a set of different boundaries across which objects might circulate. Accommodation is also unique in describing the way objects can have the flexibility to maintain different sets of interests and groups. In one sense this is the opposite of processes of deletion, but does capture the more general definition given by Star and Bowker of boundary objects as 'plastic enough' or interpretively flexible across communities.

This leaves us with six potential types of boundary object, or type of process they mediate to take forward: standardisation (both at the level of objects such as forms, and of organising multiple objects through repositories or other modular structures); abstraction (including ideal types); objects or models (with a focus on learning and transformation across groups); co-incident boundaries; maps of boundaries and accommodation. We now present a brief overview of the development of ERP and BIM systems, and introduce the contexts of our cases (see also Harty 2008; Koch, 2007), before rehearsing some brief examples from each case illustrating the circulation of boundary objects in some of the ways identified above.

We then use this to outline some of the tensions around the way boundary objects circulate and operate in our cases, through a discussion of standardisation through abstraction / deletion and accommodation. We argue that the centre of a definition of boundary objects should be fluidity – not in terms of interpretive flexibility, but rather that that the boundary object itself is a temporal transition between disconnections across groups towards integration. One outcome of this process is the transformation of the boundary object to something more coherently accepted and 'naturalised' between communities. Another is that it becomes redundant as consistency cross groups is established. Finally we argue that boundary objects cannot be studied in isolation, but rather as webs multiple objects, including boundary objects interacting across boundaries in practice.

OPENING THE BLACK BOX: SAP ERP AT CONSULTCO

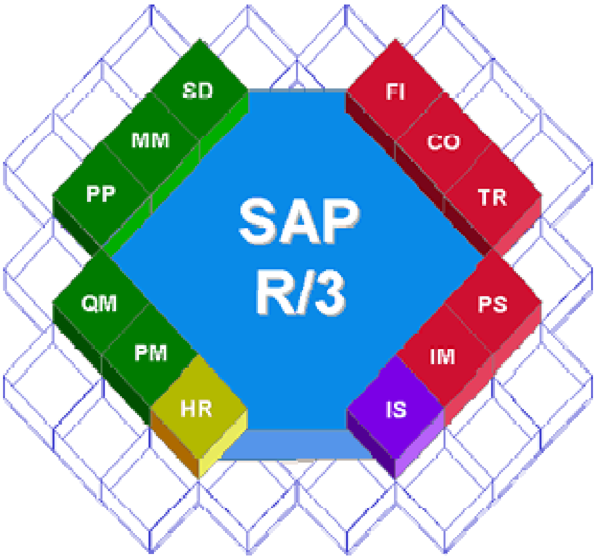
Software Applications and Products, SAP is a global software vendor originating from Germany. SAP ERP (Enterprise Resource Planning) is a software suite covering a number of classical enterprise functions such as finance, accounting, purchasing, production planning, material management and more. SAP ERP emerges from a system called R/3, which SAP marketed for the first time in 1993 and the last time in 2008. SAP developed a series of R/3 releases from 1993 until 2008. R/3 main releases includes 2.2, 3.0, 3.1, 4.0, 4.5, 4.6 and 4.7 (SAP 2010). Consultco implemented SAP R/3 from 1996-1999. An upgrade of R/3 from version 3.1 to 4.6 was realized in the autumn of 2000. This upgrade was necessary to keep up with the SAP development of R/3. Consultco later migrated to SAP ERP. SAP started to substitute R/3 with another, webbased product called mySAP by 2003. MySAP was in turn substituted by SAP ERP in 2006. At Consultco the present IT architecture (boundary infrastructure) consists of nine integrated applications/systems, where SAP ERP is just one of the systems (see also Koch 2007). Other systems being for example CAD (Bentley Microstations) and intranet.

In Consultco the relevant social groups are different than “normally” around ERP. As it is a consulting engineering group, most employees are engineers and other academics working on projects. These are the relevant social groups, project managers, project members, business unit managers, accountants, controllers, financial managers, CEO. Consultco have implemented the following main modules: finance (FI), sales (SD), project management (PM) and human resource (HR). At the sub-module level, the following choices are characteristic. Within Human Resources, the cross application time sheet module (CATS) is crucial in this configuration. All 1500 employees use this module on a daily basis. Also travel administration is important. To support financial reporting on projects, the special ledger sub-module (FI-SL) was configured. Also elements of the industry package for service providers were implemented. Configuration of user profiles and training was carried out in a relatively traditional way. This implied an ordering of access elements in 200 activity groups. These are mixed for the individual user according to user groups. For example, employees have two central profiles for CATS and travel respectively, and each department needs to have a specific activity group. Other important meta-groups of user profiles include those for line managers and financial management. Consult Co has made a number of smaller upgrades and developments. In 2001 a major configuration and programming for intellectual capital accounting was implemented, an application still in use. Although the original belief in 1995 was that an integrated architecture with a few systems could be realized, the IT architecture is still combined by a number of systems. External co-operation in the construction area, for example, means that the company needs to be able to tackle different system interfaces in almost every new project. Moreover, intranet, projectweb, project management and computer- aided design continue to be areas where others can deliver better systems than SAP. The present best-of-breed architecture consists of nine integrated applications/systems.

Two major companies were merged into the company structure, which meant developing two different IT-integration approaches. In the first merger the user profiles were enlarged, accounts, etc. in a full embankment of SAP functionality, which collided with organizational practices in the acquired company. The other merger was much more cautious in recognizing the existing ERP-system in use in the acquired company, and using single projects as probes for the integration. In 2008 a major renewal and extension of the enterprise portal and intranet was carried out. This extended the previous headquarters based portal into a general coverage of the corporation’s global network. The enterprise portal if also more closely integrated with

SAP ERP that previously. By 2009 the SAP development of SAP ERP is forcing Consultco to consider migration to a new platform, following the development into web-based technologies first provided and later required by SAP (R/3 v. 4.6 is phased out).

Fig 1: the SAP R/3 Diamond

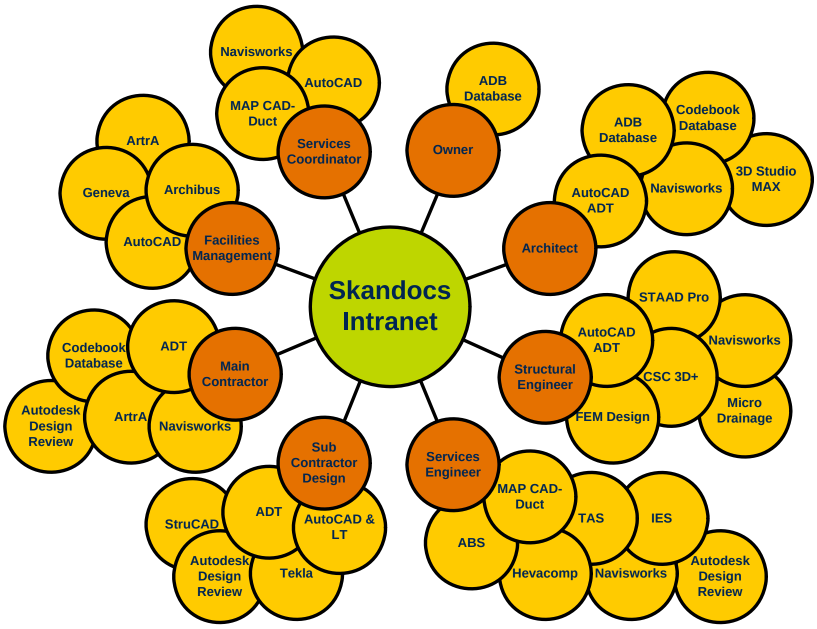


OPENING THE BLACK BOX: BIM FOR BUILDING HOSPITALS

Currently, Building Information Modelling (BIM) technologies are being heralded as able to provide this increased integration by combining CAD designs across different disciplines, document management systems, scheduling packages, supplier component information with software to represent this information of multiple ways. The business case for their adoption in terms of saving rework and avoiding costly errors is highly persuasive. The benefits of a complete and accurate source of design and construction information are also being extended into the operation and maintenance of these facilities. The research from which the description below is taken is following the development and implementation of a BIM system on a large construction project with a total value of approximately £1 billion. The project involves the construction of two new 'state-of-the-art' hospitals on separate but existing hospital sites in Central London covering a built area of 270,000 m2. In total the hospitals will hold over 1200 beds and employ 7000 staff (see also Huberman and Throssell, 2008).

The research concentrates on the interactions between the main contractor, architect, services engineers, services coordinators, trade contractors, facility managers and software providers. Within each of these groups are a variety of actors, functions, and IT artefacts. For the project, BIM represents the bringing together of these groups and tools into an integrated (socio) technical system with the purpose of collecting and coordinating all of the information produced when designing, building and operating the hospital – design information from different disciplines, construction and planning information, manufacture and supply information, operation information and so on, and being able to represent this information in formats which are appropriate for each group. As an artefact, or collection of artefacts BIM as utilised on this project consists of applications for designing and representing elements of the building, and for planning and organising the construction process. These artefacts are located within specific groups; e.g. ADT within the architectural practice, CAD-Duct and Hevacomp within the services engineers, 3D+ within the structural engineer, primavera with the main contractor – these are represented in fig 2. Alongside these are visualization tools designed to take the models from these various design applications and merge or coordinate them into aggregated views. The main one used is Navisworks and can used to check spatial coordination, or to run simulations over time of future erection of parts of the building. A further layer is added with a customised database – in this case Artra - which, depending on specific activities, can both extract information embedded in some design models, and export information into other formats such as material take-offs, schedules, or room data sheets. A bespoke EDMS system, linked to the database, stores these files and documents from the various artefacts.

Figure 2: The hospital BIM system



Between Artra, Navisworks and the EDMS system, bespoke views of the information can be produced which, for instance, show a 3D representation of a floor of the hospital highlighting specific aspects (for instance a particular type of door), a 2D plan showing the same, and a set of specifications for that door.

DISCUSSION: BOUNDARY OBJECTS IN SAP ERP AND BIM

Both cases involve complex IT systems, being developed and used in complex contexts. ERP is, however, a more coherently developed suite of applications than BIM and has had a longer trajectory of development and stabilisation than BIM. Given this, it is difficult to make broad comparisons across both systems, but we are able to draw out some of the ways various objects circulate across the communities that these systems encompass.

SAP ERP is more overtly modular in structure. This enables specific groups to interact – for instance the accounting department can mediate with project managers around the financial functions. This modularity is coupled through a number of interfaces among the grid of modules and an underlying database system. Through this boundary spanning is enabled, not only in single sub domains but across domains, for example enabling hours spent on registration to generate corrections on project management. However, data exchange is also inhibited by the modular structure – by the specific constraints of the different interfaces – in effect a type of 'standardised form'.

In contrast, the BIM system is a collection of (more or less) inter-operable artefacts, rather than a single artefact with a modular structure. The database at the centre of the BIM system can be seen as a repository with standard rules for what can be extracted, but the challenge was actually in deciding what to actually put into the database, and how to structure it. This may be a function of the relative novelty of the system compared to SAP ERP. The information within the BIM system is, partly at least, structured around the concept of 'intelligent objects'. These are components within a database with a format where various bits of information can be attached to them. The emphasis is being able to transfer the 'intelligence' (or these bits of information) as the component moves between applications (from CAD software, to database, to viewing software, etc). It does not matter at system level what that information is, or which groups it is useful to. This is again an instance of a standardised form, also with constraints around what can be represented, and how to represent it within the confines of the structure of the 'intelligent object'.

Perhaps more interesting is the evidence around standardisation as a process which involves extensive accommodation. SAP ERP contains a large number of predefined generic business processes, which are then configured to accommodate Consultco's own specific processes. This accommodation involves setting of parameters (configuration) adding new software, adding extra software code and more. This process of standardising the system goes through initial negotiations and stabilisation into a rather mechanistic transfer between social groups/communities. This follows a scheme parallel to Carlile (2002) argument of pragmatic, semantic and syntactic types of transfer of knowledge. Standardisation should thus be viewed as a process – a gradual development and refinement of formats, what to exchange, how to represent. It is also a multi-community process – many groups, actors and artefacts are involved.

In the case of BIM, similar accommodation was made to incorporate the ArtrA database into the assemblage of other packages. There was extensive, on-going interaction between the Artra programmers and project-based groups to tailor the software to work with the visualisation and viewing tools used within the BIM system. We can even see the programmer as an accommodating boundary object (although Wenger would probably call this brokerage). As a relatively small organisation with a small client base, this level of accommodation is desirable as it established an interface with larger BIM systems and with a major client – so this is a feature of the biography of Artra and where it is in its development history at this particular time. But the outcome was to stabilise, to standardise the way ArtrA was set up to allow many groups and many users to both enter and extract standardized and configured information. Again, it is a process accommodation (of the ArtrA software) leading to increased standardisation.

This points towards various boundary objects (potentially including actors as well as artefacts) circulating to increase levels of standardisation across disparate groups, and to provide artefacts (forms, user interfaces, data objects) which are consistent but allow groups to include or access information specifically relevant to them. But accommodation is only one type of process. In both cases, various objects also circulate as abstractions or ideal types. Clear examples are the representations in figs 1 and 2 above. For both ERP and BIM, these representations were widely circulated to represent the ways that the systems were integrated. Both figures have a core at the centre (the SAP database or document intranet) with other objects arranged around it. They represent the systems as a stable set of interconnected artefacts, with the effect of abstracting away or deleting all of the controversies and ambiguities which were playing out in practice.

For example, SAP ERP looks strongly organised and ordered and suggests it is a software suite operating on at least largely similar techniques throughout the modules. However, it is the case that most transactions occur within the modules rather than across them. For instance 700 – 800 project managers in Consultco specifically use the project control module for project management accounting, and 60 – 70 line managers use the system specifically for financial management. There are exceptions, such as the CATS (Cross Application Time Sheet) module which extends across the whole organisation (and 1500 users) but in the main system using tends to be module specific with modules not fully integrated but rather interlinked to a certain extent. The integration of SAP with other organisational IT systems was also a challenge. Although the original belief in 1995 was that an integrated architecture with a few systems could be realized, the IT architecture is still comprised of a number of systems. External co-operation in the construction area, for example, means that the company needs to be able to tackle different system interfaces in almost every new project. Moreover, intranet, projectweb, project management and computer- aided design continue to be areas where others can deliver better systems than SAP. The figure abstracts away these difficulties. Similarly, the configuration of user profiles involved extensive deletion and “compartmentalization” where different user profiles had limited access within the software functionality.

The BIM case likewise shows most BIM activity occurs with specific groups using specific application, but fig 2 abstracts away issues of both technical integration and interoperability across these artefacts. In practice, on the project there were constant debates and negotiations over what information should be distributed across and shared between different groups. Discussions about who had ownership and responsibility (i.e. risk) for different information were prevalent, as were issues of resistance to abandoning or tailoring existing systems (or at least suites of different applications) being used within the specific organisations involved. The figure was repeatedly used in presentations and meetings between groups (by the team within the main contractor who were leading the development of the BIM system) to show how ‘straightforward’ integration of the various artefacts would be. It became a standard, and standardized, representation of a model of BIM which deleted the difficult and challenging parts of the context – a boundary object attempting to circulate an ‘ideal type’ set of unproblematic relations between both groups and a diverse range of artefacts.

The terms BIM and ERP themselves can be seen as playing a similar role; on the one hand the terms represent a collection of boundary objects which attempt to integrate numerous groups and artefacts into a coherent system. On the other hand, they are themselves an abstraction which smoothes over these distinctions and divisions to allow groups to coalesce around a vague and ambiguously defined set of objects. Multiple and shifting definitions lie underneath this – certainly in the case of BIM there was little agreement across the project as to what it means, with definitions ranging from narrow (sets of inter-operable tools) to broad (a new business strategy for delivery construction projects. This level of abstraction was significant in allowing various actors and groups to talk about ‘BIM’ in a way which implied coherence, and to have agreement that ‘BIM’ was an important part of the project, even if on further interrogation particular interpretations differed widely. Furthermore, the ability to have these interactions around ‘BIM’ (as an abstract representation) did enable in some cases (but not in others) a gradual convergence around engaging with the system. For instance, ‘BIM’ was described as something which could provide coordinated information for on-site managers to use, rather than relying on traditional paper documents. There were many problem deleted from this description – getting reliable IT on building sites, smaller formats of screens compared to paper, tailoring software to collect data on site and so on. However, it was enough to get site managers interested and participating in working through these problems to make the use of the BIM data on site actually happen. This would seem to be an important function of boundary objects in this case, and can be linked with the idea of objects or models as devices through which learning and transformation between groups occurs. Somewhat counter-intuitively, we could argue here that the process of abstraction served as a starting point for a process of transforming knowledge across group.

The final parts of the typology to discuss are co-incident boundaries and maps of boundaries. In both cases we did not see the former – the idea that the boundaries were the same, but the activities and use of objects within were different. Perhaps because of the complexity of both contexts and the extent of existing systems within them with which ERP and BIM had to engage, specific boundaries partially overlapped, but did not neatly contain multiple communities. For the latter, we might argue that the two figures discussed act as maps of boundaries, but because of their abstract nature they were not accurate representations of real interdependencies. Both of these forms of boundary object require further empirical exploration.

CONCLUSIONS

This paper aimed at revisiting the basic concepts of Star and Griesemer’s boundary object analysis. We hoped to have demonstrated the richness and ability of these concepts in understanding multi-community interactions involving artefacts. This is not thought of as an extension of the Star & Griesemer argument but rather a comment to later and recent contributions where boundary objects have been unduly simplified.

From our initial analysis, we can draw a number of conclusions. The first is that we do see various forms of objects circulating between, and being employed by, different communities in different ways. The multi-community boundary object as ‘plastic enough’ yet ‘robust enough’ is evident, whether as an abstracted definition of BIM or a collection of user profiles. But we see these not in isolation, but as a complex network of objects and communities. The second is the complexity and dynamics of these objects, and the various processes which they mediate. Standardisation is a key feature, but this can be achieved through processes of deletion or abstraction, and / or extensive accommodation. Through these processes, the boundary objects themselves are transformed - for example ArtrA or the tailoring of the ERP system to organisation specific activities. Boundary objects both enable interaction and actively ‘push’ communities as they develop, whether through configuration, through standardizing process, or through introducing new opportunities from elsewhere, such as the use of BIM on site. A key aspect which is perhaps missing from some of the later literature around boundary objects is the outcomes of these processes, and the ‘life-cycle’ of the boundary object. Bowker and Star (1999) discuss the concept of ‘naturalisation’, where an object stops being on the boundary and becomes accepted as part of a community, or communities: “Some objects become naturalised in more than one world. They are not then boundary objects, but rather they become standards within and across [these] multiple worlds” (Bowker and Star, 1999: 312). So one outcome of the ‘biography’ of a boundary object is that it eventually becomes something else – something standardised and accepted across communities without controversy or the need for interpretive flexibility. But they suggest another alternative – the continual habitation of the borderlands between and across communities – a ‘monster’ which refuses the overtures of naturalisation. They argue that boundary object arise when different communities interact as “working arrangements that resolve anomalies of naturalization”. The processes of abstraction, of accommodation, of mapping (or recognizing) dependencies become the primary construction of boundary objects, which occur to both mitigate against, and perhaps move towards, naturalisation, standardisation and the integration of those communities. As we look at the case studies, we see a complex web of objects circulating, communities transforming, standards emerging, with BIM and ERP at different stages of a journey. But these are processes of ordering, of achieving stable regimes of both boundary and naturalised objects. What is clear is the utility of the concept, and the potential for further mapping of the dynamics and biographies of boundary objects in complex sets of interactions.

REFERENCES

Bowker, G.S. and Star, S.L. (1999). *Sorting Things Out: Classification and Its Consequences*. MIT Press, Cambridge, MA.

Carlile P.R. (2002). A Pragmatic View of Knowledge and Boundaries: Boundary Objects in New Product Development. *Organization Science*. **13** (4), 442-455.

Carlile, P. R. (2004). Transferring, Translating and Transforming: An Integrative Framework for Managing Knowledge across Boundaries, *Journal of Information Technology*, **16**, 73-81.

Carlile P.R. (2005). Using Artifacts to Interpret and Negotiate Knowledge across Domains. In Rafaeli, A. & Pratt, M. (Eds.), *Artifacts and Organizations* Lawrence Erlbaum. New York.

Contu A. & Willmott H (2003). Re-Embedding Situatedness The Importance of Power Relations in Learning Theory. *Organization Science*. **14** (3), 283-296

Harty, C. (2008). Implementing innovation in construction: Contexts, relative boundedness and actor-network theory *Construction Management and Economics*, 26: 1029-1041

Huberman, M. And Throssell, D. (2008). Collaboration through building information modelling. *Space craft: Developments in architectural computing*. D. Littlefield. London, RIBA.

Koch C. (2007). ERP –a moving target. *International Journal of Business Information Systems (IJBIS)*. Vol. **2** (4), 426-443.

Oswick C. & M. Robertson (2005). Boundary Objects Reconsidered: from Bridges and Anchors to Barricades and Mazes. *Journal of Change Management*, **9** (2), 179-193.

Sapsed, J. and Salter, A. (2004). Postcards from the Edge: Local Communities, Global Programs and Boundary Objects. *Organization Studies* 25: 1515-1534.

Star, S. L. & Griesemer, J. R. (1989). Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39", *Social Studies of Science*, **19**, 387-420.

Wenger, E. (1998). *Communities of practice.* Cambridge University Press, Cambridge.

DEVELOPING AND IMPLEMENTING CORPORATE CORE VALUES IN A CONSULTANCY COMPANY

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Culture in organizations is a subtle governing framework which can either help or damage an organization. It is becoming increasingly more common for organizations to create core values that define how the company views itself and wants to be viewed by the society, in attempt to create a strong company identity and an inherent corporate culture that increases commitment and performance. However to successfully implement core values in a company there are a few factors that are crucial for a positive result, e.g. acceptance and clarity of the values. This paper studies how the core value development and implementation process has progressed for a large consultancy company in the construction industry with the aid of interviews with three different employees in different positions in the company. Comparing the findings from interviews with the theoretical framework of organizational culture and core values the paper concludes that the company could do more to address the factors for successful implementation of core values.

KEYWORDS: organizational culture, core values, consultancy company

INTRODUCTION

The analysed company have stated how they should conduct their work in order to gain a unified organizational culture and thereby also form a company image that represents how they want to be seen by customers. To achieve this, the company formulated four core values which they hope will direct the company toward common goals and to modernize their image. A common metaphor used in the paper to illustrate their current image is a comparison with a navy blue Volvo meaning that they are considered the safe, rather boring and traditional choice.

Organizational culture can be divided into artefacts which are observable, espoused values which people have emotional interest in, and basic assumptions that are the essence of culture (Clegg et al., 2008). Culture in an organization is often hidden and unconscious; it consists of the deep, basic assumptions and beliefs shared by an organizations members. Therefore, understanding organizational culture is important in order to investigate members' behaviour patterns, since the culture works as a governing framework for the organization (Ankrah and Langford, 2005).

With the aim to reach more unified thinking and shared values, the deliberate forming of corporate core values has become increasingly more common amongst large organizations (Osborne, 1991). The purpose of the values is to govern decision making and actions of all members in the organisation, i.e. create a sense of corporate morality that the organizational members work by. A strong organizational culture with shared values can lead to a strong company identity that can stabilise the social system and increase commitment amongst employees (French et al., 2008).

In the implementation process of corporate core values there are a number of factors that are crucial in order to succeed with the implementation (Osborne, 1991). Firstly the core values must be accepted throughout the entire organization and the key employees should share the articulated beliefs. Secondly the core values should be integrated in everyday activities in the organisation. Lastly, in order for the first two factors to affect the core values, they should be communicated well and clearly formulated and articulated in the organisation.

This conference paper is a case study which aims to address how development and implementation of corporate core values are made in a consultancy company within the construction industry. The case presented a unique opportunity to investigate the process of development and implementation of core values, due to the changes and circumstances the company experienced after the development of the core values: the growth of the company and the recession.

CASE DESCRIPTION

The company in this study is an engineering consulting firm which operates in the construction industry, with around 300 employees that mainly work in Sweden. The company was founded 1952 and is thus a well established company on the Swedish market. Its main areas of expertise are HVAC, energy and environment, control and monitoring, fire safety and technical administration. These areas form the basis of how the business is organized: they form five subsidiary companies. Together with the main company, which consists only of the director of business and director of staff, they form the entire business. Furthermore they have some other offices, or rather subsidiaries, in Swedish cities depending on acquisitions and geographical relocations of employees.

Recently, the company has implemented a number of core values, to attain a clear and homogeneous organizational culture and thereby guide their employees'. The attempt has been made due to the rapid growth that has taken place during the last few years; they have acquired a new company and expanded geographically with many new offices.

Due to the growth of the company and the recession that began in autumn 2008, the case presents an interesting perspective on how the company implemented and developed their core values during these challenging times for the company. Thus the paper's main focus is to try to establish how corporate core values are developed and implemented in a consultancy company.

METHOD

To collect information needed for this qualitative research, three interviews were made at a consultancy company in the construction industry during the autumn of 2010 in Gothenburg, Sweden. All interviewees had different positions within the company; The CEO of one of the subsidiary companies, a project administrator and a head of department. All interviews took place at the company office in Gothenburg where semi-structured interviews, lasting for approximately 50 minutes each, were conducted. These interviews focused on the process of developing and implementing the core values in the company and the perceived effects afterwards; e.g. how did the core values affect the structure and expansion of the company.

In order to get a fuller understanding of organizational culture and core values, the paper is also based on a literature study. Finally, the information collected from interviews were analyzed and compared to theories found in literature that are presented in the theoretical frame of reference part.

THEORETICAL FRAME OF REFERENCE

In order to understand how core values might affect an organization and its surroundings, it is important to be familiar with the concept of organizational culture. Therefore the literature review contains basic information about organizational culture, as well as theory about the creation and implementation of core values.

Organizational Culture

The first area, organizational culture, can be defined as *"the system of shared values and beliefs that develops within an organization and guides the behavior of its members"* (French et al., 2008). Culture is not always clear or visible but instead something that lies hidden in people's unconsciousness (Clegg et al., 2008). The concept of culture being applied to organizations and businesses is a relatively new phenomenon within organizational theory, and some of the most significant contributions, such as research from Schein, and Peters and Waterman were published in the 1980´s (French, 2008).

Previously, culture studies were made mainly in the fields of anthropology and sociology (French et al., 2008). Organizational climate studies in the 1970´s were to some extent the origin of a major interest in organizational culture. Along with globalization, it has become even more important to understand organizational culture within construction management as well as in any field of business (Liu, 2006). This is because behavior in an organizations differs between countries, as described in Hofstede's cultural dimensions (Hofstede, 2009).

Organizations can be viewed as subsystems within society, who possess their own features that create a certain culture (Liu, 2006). Therefore it is of utmost importance to understand the fundamentals in organizational culture since they can be a link to competitive advantage, employee commitment and performance (French et al., 2008). However, when a company faces a change, cultural barriers can arise for both managers and employees (Rowlinson, 2001).

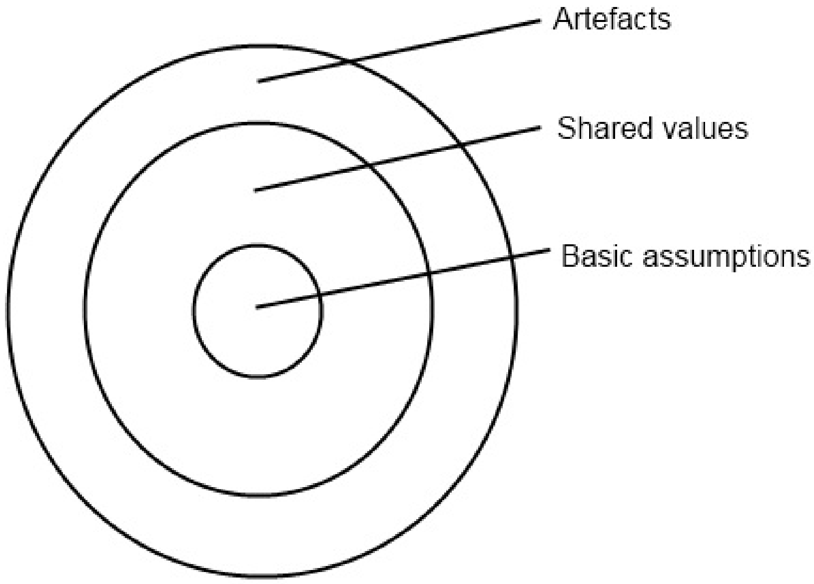
According to Carpenter et al., (2010), researchers have seen a link between organizational culture and company performance; there are indications of success that encompasses revenues, sales, volume, market share and stock prices. The culture also needs to fit with the demands of the company's environment. It must not be taken for granted that culture only benefits the performance. In an architect office, for example, the inherent culture promotes out-of-the-box thinking, as opposed to a contractor where production and effectiveness is of most concern. Having the "right" culture for a company can increase the performance and vice versa if a company has a "wrong" culture (Carpenter et al., 2010). However, there are different definitions of organizational culture in literature. For instance, one anthropological perspective indicates that culture is the way behavior is expressed in an organization. Another view often points out culture as non-visible and hidden in the mind of the members (Liu, 2006).

As stated by Carpenter et al., (2010), culture is a more effective than rules and regulations in controlling and managing people in an organization. For instance in relation to customers, rules and regulations are more distinct and hard to implement for unique problems. If a company faces a lot of unique problems it is better for the employees to recognize priorities than certain rules.

Levels of Culture

Explaining and changing organizational culture is difficult since there are often many different cultures within an organization. Another aspect is that the existing culture might not be easy to amend. Schein defines organizational culture by differentiating between three levels of culture (See Figure 1). Level one is dealing with artifacts, which means such things as physical structure of buildings and their architecture, uniforms and interior design. It is easy to observe this level but it does not reveal the organizational culture. Level two represents espoused values, and refers to non-visible aspects of culture which embrace the norms and beliefs when employees talk about organizational issues. A mission statement, which clarifies the purpose of a company, is a part of this level. The core of culture is basic assumptions, seen as level three. This is the most important level that outlines the beliefs and norms of the organizational members, and guides activities without being clearly expressed (Schein, 1997).

Figure 1: Levels of culture according to Schein. Source: Schein (1997)



A common way of understanding organizational culture is to first observe artifacts such as its physical environment, employee communication, company policies and other observable characteristics. Nevertheless, just looking at these aspects will not give a clear picture of a company's culture, since the major part of what makes up a culture is below employee's degree of awareness. By observing how employees communicate and which choices they make can help to expose the values and assumption in the organization (Carpenter et al., 2010).

Organization Values

As Schein explained culture, there are three different levels of culture where only parts of the organizational culture are visible. Therefore it is important to look deeper into the organisation than just the observable aspects to be able to fully understand its culture. This is where the shared values come into play, hence many studies and researchers points out shared values as an important part of an organizational culture. First of all, shared values can help turn routine activities into valuable and important actions. Furthermore, it ties the organization to the important values of society and may provide a distinguishing source of competitive advantage to other companies (French et al., 2008).

Core Values

According to Lawrence et al., (1989) the corporate core values…

"…have long been referred to as the central dimension of an organization's culture and have been recognized as powerful influences differentiating one firm from another".

The link between organizational culture, shared values and performance are complex and it is not obvious that a strong culture automatically will lead to good performance (Clegg et al., 2008). Anyway, it has become increasingly common that companies choose to form a number of core values, in attempts to obtain shared values and a more unified thinking in the organization. The purpose is to try to connect actions and values in order to make sense of the actions.

In an ideal world, members see that their actions are not only workable but also correct, right and important. Companies that succeed in achieving shared values can benefit in a number of ways. To begin with, unique shared values can lead to a strong corporate identity. Further, it can strengthen the commitment among employees in the organization and make the social system more stable (French et al., 2008). By Rowlinson (2001), commitment is essential for making a change process within an organization effective and rapid. It could also reduce the need for formal and bureaucratic controls. However, outcomes from achieving a strong organizational culture are not only positive. A strong culture can reinforce a view of the company and its environment, which may not be in the best interest of the organization. Moreover, organizations with strong cultures tend to be inert and slow in adapting to changing environment. Sometimes quick changes might be needed, and if so, this could be crucial for companies with strong cultures (French et al., 2008).

Implementing Core Values

When implementing corporate core values, there are a number of things that need to be considered if the impact shall have positive results for the organization. Initially, core values must gain acceptance throughout the whole organization, and the most important factor is that key employees share the articulated beliefs. It is also crucial that the core values are clearly articulated, successfully communicated and integrated in the organizations everyday activities (Osborne, 1991).

The value statement shall clarify the company's intentions and thereby maximize the employees' effectiveness. In the creation process, the owner's preferences will of course be essential to the outcome but nevertheless, it is important to gain consensus among key managers. Owners and key managers should be like partners in the creation process and together work out a set of basic beliefs. If core values are to be accepted in the company the participation and communication with senior employees is fundamental (Osborne, 1991).

The core value's capacity to influence an organization's culture and members' behaviour is to a large extent determined by their clarity, so that executives' intentions must fit together with employees' perceptions. An easy way of testing the core values is to request employees to rewrite the statements in their own words. If there are any ambiguities in this phase it could be corrected before final publication. However, words alone are not enough to put the core values into practice. If the statements shall pay off it is essential to link them together with actions, attitudes and behaviours. The integration of the values is the most important thing rather than their elegance and novelty. Managers can do this by linking core values to the employee review and reward process (Osborne, 1991).

When a statement of core values is composed properly, it can create a guiding compass for the organization, which leads it towards meaningful and approved behaviour (Osborne, 1991).

RESULTS FROM INTERVIEWS

Organizational Culture

There are different approaches that can be used improve an organization's culture. One of the interviewees explained that the company has long been seen as a boring, navy blue Volvo. However, this is a picture they have been trying to change during recent years. Further, the interviewee explains why the company is seen as out-of-date. It may be because of the fact that the company does not have same economical resources for marketing as large companies listed on the stock market do.

Even as the company grows, the company management want to keep the advantages of a small company but also obtain the positive parts of being a big company. As an attempt to achieve this, the company organize a trip annually for all employees in order to encourage cohesiveness and a pleasant culture. When the analyzed company acquired a smaller consultancy company, they did not interfere with the existing culture of the acquired consultancy company too much in order to avoid disturbing a functioning organization. This resulted in a distance within the merged company that persisted over a long period of time. Not until about three years after the acquisition did the smaller company change their name to the same as the main company. One interviewee claimed that a challenge for the merged company is to reduce this distance and that is an ongoing process.

Corporate Core Values

The analysed company wished to change how customers and employees viewed the organization as well as improving the way of working. Therefore a process started about three years ago to create core values shared by everyone in the organisation. Previously they did not have any formally stated values. The reason why the company chose to develop these values was the significant growth in terms of employees they had experienced previous years. New offices had been established at different locations around Sweden and another consultancy company had been acquired by the company. The company supervision therefore sensed a need for unifying all employees in order to make everybody work in the same way.

When the creation process was initiated, all partners of the company gathered for meetings and discussed what is important in the organisation. Many suggestions for values were discussed, and an external consultant was hired to help formulate these. The other employees were not involved in the actual creation process but were later engaged in different workshops when implementing the values, and putting them in a context. It was important that these values would be easy for all employees to understand. The partners agreed upon four words that became the four core values of the company; these are *Holistic, Commitment, New Thinking* and *Expertise*.

After the development of the four values, the company received external help to create a book called “The Book of Culture”. This book is provided for all employees within the organisation and contains information about values, vision, strategies and business concept. It was said during the interviews that it is important to work with the values regularly so that they will not be forgotten. Along with workshops, the company carried out performance reviews with employees who had been working on implementing the values since the process started. Hence, all employees ought to know about the values and the meaning behind them. However, according to one of the interviewees, the recession had caused the company to focus on surviving instead of prioritising time for working with the values. The four core values are defined in “the book of culture” and the meaning of each word is described as follows:

- Holistic stands for providing long-term and value adding solutions. The customer’s needs and expectations should be in focus.
- Commitment is defined as availability, concern for the customer and aim for wider range of costumer.

- New Thinking represents focus on quality, environment, energy, being ahead of the development and always think about the future.
- Expertise includes knowledge, developing competence and exchange of experience.

According to the interviewees, the employees interpret these values differently (See Table 1). Concerning *Holistic*, all interviewed agreed with what was stated in the book. However there were some additional interpretations: one interviewee mentioned the importance of internal respect and needs employees may have. It was also mentioned not just to think about one's own part but to consider the whole construction site. Even for *Commitment* there were some complementary views. For example, one interviewee thought that commitment includes being seen in different magazines and to be known to other organizations. Moreover, the possibility to advance in the organization is also seen to be included in the meaning of commitment. Regarding *New Thinking*, the most important issue for those interviewed was to be ahead of development within technology. Another interviewee also mentioned energy and environment as significant factors of new thinking, which is in line with what is stated in "The Book of Culture". Considering *Expertise*, the interviewed persons more or less agreed with the book, for instance exchange of experience. However they emphasized the various areas of expertise within the company.

Table 1: Interpretations of the four core values.

	The book of culture	**CEO of one of the subsidiary companies**	**Project administrator**	**Head of department**
Holistic	Provides long-term and value adding solutions. The customers' needs and expectations should be in focus	See the whole picture, customer focus; consider other actors involved in a project.	Customer focus, see their problems.	Respect, customer focus, see the whole picture, and collaborate.
Commitment	Availability, concern for the customer and aim for wider range of customer	Do more than what is expected, be active.	Be committed to the customer, keep them updated, and be available for the customer.	Be seen in different magazines and to be known to other organizations, possibility to advance in the organization.
New Thinking	Focus on quality, environment, energy, being ahead of the development and always think about the future.	Be at the forefront of technology, not doing as always has been done.	Be updated within technology and in the business, new ideas.	Adopt new technology, especially environment and energy.
Expertise	Knowledge, developing competence and exchange of experience.	Take advantage of experiences within the company.	Diverse departments within the company, keep a high level of knowledge.	Knowledge in many different areas.

Opinions among the interviewees differ on how much these values are affecting the daily working life in terms of implementing them in their thinking. The CEO of the subsidiary company thinks about the core values regularly in his work, while the head of department does not, believing that each department manager is responsible for making sure the values are linked to everyday work. In the end, the values are compiled to build a wide range of customers. However, one employee stressed the importance of that these values should not just be words but ought to be involved in all projects. All interviewed agreed that the company has to continue working with the values so that they become a natural part of the organizational culture.

DISCUSSION AND CONCLUSIONS

All of the respondent people seemed to be aware of the four core values and their purpose. This probably has to do with the implementation that has been going on in the company, where the employees have participated in workshops about the core values and the desired culture. According to Osborne (1991) acceptance among employees, especially key managers, is important to get positive outcomes from the creation of core values. To be able to get acceptance, a prerequisite must be that people first of all understand the purpose of the values which ought to be the case according to what the respondent said. What could have improved the acceptance further is to involve the employees at lower levels earlier during the formulation of the values. What is important to consider is that two of the three interviewed persons were partners and therefore participated in the actual process of creating the values. It is possible that the result would have been different if other employees who did not participate in the creation of the values had answered these questions.

A factor that Osborne (1991) points out is the clarity of the core values. Since the core values of the company have been stated in “The book of culture” it clarifies the meaning of the values even more for the employees. During the creation phase the company engaged a consultant to help them with the wording. This has contributed to more clarity. An advantage with this is that an external consultant can be objective, and have a different point of view in order to help the company become more modern. However, a potential risk might be that the company’s current culture to a great extent is being neglected when an external consultant is engaged.

One of the objectives with the creation of core values was to change the perception of the company as a conservative old-fashioned company. A metaphor that came up was that customers see the company as an “old navy-blue Volvo”. A thing that might have been forgotten is that there can be benefits in this comparison, not least since they want to be the obvious choice for their customers. This could create a feeling of security among the company’s potential customers.

According to French et al., (2008) one of the important factors is to link actions to values in order to create meaning of the actions. In this way a strong and unifying culture with shared values can be reached. Opinions were ambiguous whether the company had connected the core values to everyday activities on a regular basis or not. One of the partners explained that they had a connection between the core values and activities, e.g. during performance reviews. Contradictorily, another partner thought that the core values had been neglected during the recession since the company was only focusing on surviving. The responsibility for linking values to everyday work tends to rest with each department manager and received indications show that the values are implemented differently. This might be due to the different types of culture in each specific department. How the core values are implemented seems to depend largely on how each director chose to work with values. Concerning this matter, it is important for the group executive board to be clear about how important it is that the core values permeate the daily work.

For further research within this field, a larger sample of interviewees within different levels of the hierarchy would give a result that better represents the entire organization.

REFERENCES

Ankrah N. A. & Langford D. A. (2005) Architects and contractors: a comparative study of organizational cultures, *Construction Management and Economics*, 23(6), 595-607.

Carpenter M., Bauer T. & Erdoga B. (2009) *Principles of management.* San Francisco: Creative Commons.

Clegg S., Kornberger M. & Pitsis T. (2008) *Managing organizations* England: Sage Publications

French R., Rayner C., Rees Gary., & Rumbles S. (2008) *Organizational behavior* England: Wiley & sons

Hofstede, G. (2009), *Cultural Dimensions*, Webpage accessed 18-12-2010 at: http://www.geert-hofstede.com/hofstede_east_africa.shtml

Liu A, Shuibo Z, & Meiyung L. (2006) A framework for assessing organizational culture of Chinese construction enterprises, *Engineering, Construction and Architectural Management* 13(4), 327-342.

Osborne, R. (1991) Core value statements: the corporate compass. *Business Horizons*, 34(4), 28-34.

Rowlinson S. (2001) Matrix organizational structure, culture and commitment: a Hong Kong public sector case study of change, *Construction Management and Economics,* 19, 669–673.

Schein E. (1997) *Organizational Culture and Leadership*. San Francisco: Jossey-Bass.

Shelby D. Hunt, Van R. Wood, & Lawrence B. Chonko (1989) Corporate Ethical Values and Organizational Commitment in Marketing, *The Journal of Marketing*, 53, 79-90.

USE OF COGNITIVE MAPPING IN THE DIAGNOSIS OF TOLERANCE FAILURE

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The management of construction tolerances is a necessary and routine part of the construction activity and is normally brought to our attention only when failures are reported. In a study of tolerance management, the authors found widespread evidence of the same failures and the reasons for them. There seems to be no shortage of experience of the effects of failures in tolerances or of knowledge about how to avoid them. The situation is frustrating for all involved, especially the owner, end-users, designers and operatives. In questioning practitioner experts in this field, the authors identified a misalignment in the perception of 'problem, cause and effect'. In workshops involving experts from various construction backgrounds, the issue of tolerance management and, in particular, failures and their causes were examined. The experts were introduced to the concept of fault diagnosis using backwards-chaining 'cause and effect' analysis. Experts were then asked to undertake several analyses of their own of preselected failures using a cognitive mapping tool. The purpose of the study is to see how useful the method is among the experts and later be able to identify the root causes to the issues of tolerance management. The preliminary results showed that the experts were initially reluctant to break with discussing the effects and what they saw as the solutions, but gradually began to trace the causes backwards until they believed they had identified the root causes. The results show a possibility to reach beyond the obvious problems and therefore as a consequence be able to find a new approach in the following steps of the research process. This is a proven working method for research problems where the interaction with partners in the industry is of great importance.

KEYWORDS: Cognitive mapping, construction tolerances, failure

INTRODUCTION

This paper discusses a method put in practise for creating an understanding of the problems of tolerance management present in the construction industry. Complications due to misfits lead to delays, increased costs and lack of estimated performance. The problem has long existed and there is a need for a new approach and a new method for dealing with these complications. The difficulties to gather relevant data cause problems in the research process. The method denoted cognitive mapping is used as a general concept for investigating the root causes to previous identified problems.

There are a variety of standards, rules and regulations for how tolerances for various building components are determined. The fact is that there are many different values of tolerances, in the industry, resulting the emergence of problems. There are also different standards and regulations for different materials (Holm et. al. 1987, Meacham 2010). Which level of performance accuracy is required and what are the responsibilities to maintain the acceptable level of construction quality? Performance approaches have for several years been identified in building regulations, design and in various construction documents. Without adequate controls, education and feedback in the process, it is possible for problems to go unnoticed and to outpace solutions (Meacham 2010). Many times the meetings between different materials, construction nodes, can be complicated. It depends on the material behaviour, design, the manufacturer and the construction itself but there are also implications throughout the lifecycle of a building. Many problems that occur on the construction sites are mostly caused by the joints and connections between different building components. It is common that failures due to lack of tolerance management are adjusted on-sites (Landin and Kämpe 2007). Interface management within the construction process continue to cause problems. Therefore there is a need to understand the problems as early as possible in the process. Interface management for different components should be identified and verified to determine how they affect the entire project. This requires an understanding of the project structure among all participants (Pavitt and Gibb 2003, Yan et. al. 2009).

Specifications of construction tolerances on component dimensions can have impact on the quality, cost, and performance of the product. But a component cannot be manufactured exactly to nominal dimensions due to variations in human behaviour, materials and machines (Kumar et al. 2007). To eliminate this kind of problem the root causes need to be determined in the construction process. Is it possible to examine whether there exist tolerance abnormalities which are more frequent, or more expensive than others? When a tolerance deviation occur, it is also important to determine at which stage the construction process deviation occurs. Tolerances are divided into manufacturing tolerance, measuring on-site tolerance and assembly of a complex site tolerance (Holm et. al. 1987).

Occasionally, the failures have serious consequences, such as following a structural collapse. The causes are often quickly detected and more often than not are found to be rooted in a recognised problem. Despite considerable experience of failures due to poor definition of tolerances and the means for overcoming them, problems recur causing further damage and distress. Not all failures are as pronounced as a structural collapse and most tend to be accepted as ‘what might be expected in the course of construction work’. Evidence of such acceptance is to be found in innumerable examples of the same problem recurring. The steps that should have been taken to avoid them were known, yet they were not and the failure occurred. Furthermore most of the problems could have been solved already at the planning stage (Landin and Kämpe 2007). The resolution of the problems is in finding ways to ensure that the same mistakes are not repeated. It is not new for the industry that the cost of deviation is multiplied, the later in the construction process the deviation is discovered and can be addressed (Love and Irani 2003). Reference is generally made to the problem as the manifestation of a failure rather than the root cause. For owners and end-users, what is actually observed is the problem; but for designers and operatives it is the effect of a problem elsewhere. Cataloguing failures is common and the authors have been acquainted with many. There is no shortage of material describing and illustrating the consequences of failures. It is not always easy to understand where issues or problems may arise. Hence, there is a potential for improvement of the management of construction tolerances.

Background

The management of precision is one of the key foundations to the industrialized construction. Regular and accurate measurements are required to yield an effective production. Strategies concerning the technical approach to be taken in efforts to achieve greater industrialisation are directed increasingly at developing robust and standardised processes and procedures for the manufacture of products of different types, regardless of whether production takes place on-site or in a factory (Winch 2003, Johnsson and Meiling 2009). The precision in the construction industry does not mean zero tolerance for deviations, rather that the final product must meet the requirements and does not hinder the production process. It must also be possible to carry out the construction. All dimensions and part of dimensions of a building are interdependent. To achieve the coordination between function, safety and aesthetics, these parts need to be synchronised. More building components are constructed with traditional industrial technology and repetition of precast products for mass production.

The construction industry has a tendency to use audits only for correcting defects and not so much for further analysis. To get a better quality in construction, the defects should be linked to an improvement strategy (Johnsson and Meiling 2009).

The construction industry requires dimensional space dependent among others on the suitability and smoothness of different materials. Some materials do not have the ability to retain their qualities over time. The tolerances are degrees of accuracy and are also dimension describing a building element within certain limits (Ballast 2007). Tolerance levels are difficult to apply to different components within a building project as a whole. There are tolerance requirements dealing primary with concrete, steel, wood and glass. This can complicate the planning of how assembling material to another or joining of materials in the best way (Landin and Kämpe 2007). Tolerances are of significant meaning for managing quality. The management of tolerances became an important issue early on when the need for product efficiency increases. Recently the tolerance systems have also increased in importance as to gain customer satisfaction and also to avoid disputes to achieve production. The building must achieve the customer satisfaction by stated requirements of aesthetics, function and safety (Forsythe 2006).

With today's advanced technology, in terms of Computer Aided Design (CAD) and Building Information Model (BIM) development, there are great opportunities to minimize production tolerances and deviations, already during the design and manufacturing. BIM is a way to manage information produced during the design and construction process and a number of benefits and challenges have been identified. But due to incompatibilities among systems in the industry, technical obstacles have prevented integrated BIM. Many times the expected benefits of technological innovations do not guarantee the transfer and diffusion completely. To implement BIM in construction projects, some participants in the industry say it requires a cultural change in the industry. It says also that the applications requiring a more long term perspective in the production process (Linderoth 2010).

Tolerances are an important area in the building industry because tolerance management is important in different stages of the development of a product, stages like design, manufacturing, assembly and quality control. In the building process the tolerance transfer needs to be required. There are tolerance techniques as tolerance charting which is used in manufacturing industries. In order to set the tolerance accumulation, tolerance charting needs a dimensional chain describing method. The techniques of tolerance transfer make it possible to establish the inequalities of tolerance accumulation in a final dimension scheme of the product (Conzalez Contreras and Rosado 2006). But this requires that different parts in the construction process have good coordination and that the companies in the industry use the same system to coordinate all dimensional parts which is novel.

There are several different frameworks that are used to determine tolerances. Sometimes even the companies have their own, internal tolerances that they use. In addition, there are tolerance standards from older versions that are still used in the industry. The building industry consists of complex projects that are multi-organisational and required range of expertise. When the projects become increasingly complex and the traditional project management becomes inadequate, the methodological approaches must allow for a more detailed insight into the processes involved (Edkins et. al. 2007). The traditional project management must take into account the metrics of quality, cost, designs and time, which all are affected by the accuracy and precision in the building process. To get a better tolerance management in the process the issues need to be understood at a deep level among the experts in the industry why this research management tool, cognitive mapping, has been used. The current phase of the research involves a series of mapping sessions with individual experts using further examples.

METHODOLOGY

The study follows an inductive approach investigating tolerance failures. The method is a qualitative data analysis that strategically identifies the different causes which are dependant to each other. The participants are carefully selected people in the industry who have experienced the problem about the management of construction tolerances. The method denoted cognitive mapping is used as a general concept for investigating the root causes to previous identified problems. The aim of this method is to gather knowledge and views among the participants in the industry through workshops. Analysis over the causes which the participants raised can then be made. Furthermore correlation among the root causes can later be established and possible solutions to the problem can be found. This study focuses mostly on the use of cognitive mapping and not so much on possible solutions to the problem of tolerance management itself.

Cognitive mapping

The use of cognitive mapping has been a growing area of interest among the scientists. The technique or the method cognitive mapping has also been used and developed over a period of time. It has also been demonstrated its use for researcher working on a variety of different tasks. Mostly the technique have been used to structure messy or complex data for problem solving, managing large amount of qualitative data and assisting interview process. Cognitive mapping have been used for a variety of purposes but the concept “problem” of some sort usually forms the focus of the work. The technique is used to structure, analyse and make sense of accounts of problem. The process promotes the analysis, questioning and understanding of the data (Ackerman et. al. 1992 and Edkins et. al. 2007).

Cognitive mapping builds upon personal construct theory (Kelly 1963) and that of the repertory grid technique (Fransella et. al. 2004). According to the theory, individuals or groups, acquires codes and information about the relative locations and attributes of phenomena in their everyday environment (Downs 1973, Edkins et. al. 2007). This information is categorized as constructs representing the sum of perception of a specific phenomenon. Cognitive mapping may be defined as a process composed of a series of psychological transformations which is used to elicit those construct in a systematic manner. Therefore; the cognitive mapping techniques are used to identify the participants’ beliefs about a particular area or topic and to depict these diagrammatically. Cognitive mapping is an umbrella term for causal mapping, semantic mapping, and concept mapping, all encompassed by the term cognitive mapping, referring to mental models or schemata of an specific object, event or process. Different types of cognitive maps and mapping are defined with some latitude and overlap, depending upon preference and context. Cognitive mapping results in graphical structures to make sense of information but it also gives a structure of knowledge (Tolman 1948). The method of cognitive mapping is a structured process, focused on a topic or construct of interest, involving input from one or more participants, that produces an interpretable pictorial view of their ideas and concepts and how these are interrelated. As a result of this method a graphical representation will be presented. Within the graphical representation there are nodes (points or boxes) represent concept and links (arrows or lines) represent the relationships between the concepts. The concepts, and sometimes the links, are labelled differently on the map. The links between the concepts can be one-way, two-way, or non-directional. The concepts and the links may be categorized, and the map may show temporal or causal relationships between the concepts (Novak and Cañas 2008). It is then easier to see the overall structure and how each concept and causal relationships relate to each other.

By producing a representation of how the participants think about a particular problem or situation the method can act as a valuable technique for helping the researcher and the experts themselves to develop a solution to problem. The ability to structure, organise and analyse data and visualize this with graphical representations enable both the researcher and the experts/participants together to perceive their own mental models of the phenomena being studied. Thus cognitive mapping not only provide clarity for the researcher but it does also makes the experts aware of occurring schemata and enables them to react and find a suitable direction forward. This allows for cognitive mapping, in addition to being a data collection tool, to act as an action science (Argyris et. al. 1990) catalyst.

The graphical representation can be designed differently. Hierarchical structure depends upon the context and perspective from which one approaches the map. By analyzing the concepts on the top of the map the researcher are able to compare emergent value systems within the map as well as between different maps. Those value systems describe problem areas or specific goals from which the rest of the concepts in the map stem. Furthermore concepts can be categorized by its centrality. This allows for the identification of concepts being cognitively central to other surrounding concepts. Identifying those concepts is essential for exploring possible options towards change. By analysing the different clusters in the map it gives indications of where the nub of the issues may lie. It facilitates the examination of emergent topics and themes within the map causing the investigated problem (Eden and Ackermann 1998). In the hierarchical map there can be circularity or loops, which destroys the hierarchical structure of the map and make it harder to analyse the topic concept. It is sometimes difficult to determine what cause is and what effect is (Eden et. al. 1992). A thorough analysis will also permit the researcher to identify potent constructs. Those constructs typically affects more than one value system, or influence more than one cluster. Those constructs usually appear in the bottom of a hierarchical map, hitting the top concepts through many pathways throughout the hierarchy (Eden and Ackermann 1998). Identifying those constructs is essential to identify root causes, and to allow for the prioritizing of which concepts to deal with in order to create maximum change to the core problem. The analysing part should also show which details need to be more considered and which concepts need to be more developed. Through the process of explaining the ideas of how the concepts fit together the participants begin to get a better understanding of the problem and allows for the construction of a more detailed map (Ackerman et.al. 1992).

RESULTS AND ANALYSIS OF THE WORKSHOPS

In a workshop involving experts from various construction backgrounds, the issues of tolerance management and, in particular, failures and their causes were examined. The experts were introduced to the concept of fault diagnosis using backwards-chaining 'cause and effect' analysis. Examples of how this might be applied to tolerance failures in construction were shown. Experts were then asked to undertake several analyses of their own of preselected failures using a cognitive mapping tool. The preselected failures were about shortcomings or problems about the tolerance management in the building industry. Four workshops have been conducted. In each performed workshop, the experts draw a map of their analysis over the problem area. After some time there was a well conceived map. During the workshops the participants were divided into groups of 3-4 people in each group. This size of the group is considered to be good because everyone should be heard and at the same time be able to comment on each other's ideas. It requires a certain number of participants to perform a well developed map over the common problem. Too few participants may not consider everything within the issue area and there is then a risk of missing essential parts. Too many people in one group leads to that someone may not be heard and become a spectator. In the performed workshops, the participants were able to see their ideas in context of others. Using this technique in group made the individuals' thoughts captured in a common map. The ideas are also presented anonymously for the individual when the developed map is finished.

During the workshops, it was noted that the participants found it difficult to both use the guidelines to create a map and at the same time discuss the problem with the others in the group. Sometimes the participants gave up with the mapping and making straightforward notes which is not beneficial to the cognitive mapping. The participants went back to cognitive mapping exercise when they were guided by the facilitators. The guidance is important during the performance why there were facilitators during the whole workshop. When the facilitators noticed that the participants start to go wrong, their task was to lead them on the right path again without affecting their views or thoughts about the problem. The authors of this paper had their role as facilitators during the workshops. This kind of method and mentoring went well for the development of the mapping and how the participants worked throughout the exercises.

As results from the different workshops there are a numbers of maps representing different problems and the participants' thoughts about these problems. The results from the method cognitive mapping can be analyzed in different ways. The groups were free to choose their own problems they wanted to analyze because this practise should also be a direct benefit for them. But still it is important that the main problems consider the area of tolerance management.

The maps offer an explicit statement of a phenomenon and have already proven to be useful in discussions with the experts, but also amongst the experts themselves. Moreover, the maps represent a shared understanding of what happens and can highlight where attention to root causes needs to be directed. The different maps give different views of the problem and can also be merge in different ways. By examining the different maps, some common concepts can be found. Concepts in these cases are causes to the main problem. The analysing of the maps will continue to find different clusters containing various sub-areas of the problem. It will also highlight similar root causes to the problem. By finding these causes possible solutions to the problem can be identified.

CONCLUSIONS

Different topics of analysis detailed above have been presented in the preliminary analysis of this paper. The current study is not extensive enough to make any final conclusions whether the analysis reach the expectations. This is only a part of the process to establish the validity of cognitive mapping in this research field. On a general note some limitations should be pointed out. The methodology suggested above allows for an epistemological approach studying different phenomena in its current context. Every effort in generalizability would not be conductive using the suggestions in this paper. Even so; it might be possible to use quantitative methods in corporation with variants of cognitive mapping in order to adhere to a more positivistic approach e.g. by using neural networks in order to quantify the maps.

With this said; the result show a possibility to reach beyond the obvious problems and therefore as a consequence be able to find a new approach in the following steps of the research process. This is a proven working method for research problems where the interaction with partners in the industry is of great importance. When the workshops were conducted, the basic approach was deemed to be sufficiently validated by these actions. The preliminary results showed that the experts were initially reluctant to break with discussing the effects and what they saw as the solutions, but gradually began to trace the causes backwards until they believed they had identified the root causes.

The resultant maps will be compared and merged and a qualitative analysis will be performed to determine if certain concepts are implicated in more than one type of failure and, if so, their relative influence. The maps offer an explicit statement of a phenomenon and have already proven to be useful in discussions with the experts, but also amongst the experts themselves. Moreover, the maps represent a shared understanding of what happens and can highlight where attention to root causes needs to be directed. When even more workshops have been performed, a pattern can be read from the common maps and further analysis can be done to find the final root causes of the problem.

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REFERENCES

Ackerman, F., Eden, C. and Cropper, S. (1992). Getting started with cognitive mapping, Young OR Conference, University of Warwick.

Argyris C., Putnam, R. and Smith, D. M. (1990). Action science, Jossey-bass, San Francisco.

Ballast, D. (2007). *Initiative on Dimensional Tolerances in Construction Surface Compliance Design Issues*, United States Access Board, webpage accessed 20-01-2011 at http://www.access-board.gov/research/tolerances/design.htm/

Conzalez Contreras, F. and Rosado, P. (2006). An alternative method to tolerance transfer for parts with 2D blueprint, *International Journal for Production Research*, **45** (22), 5309-5328

Downs, R.M. and Stea, D. (1973). *Cognitive maps and spatial behaviour: process and products*. Editors: Downs R.M. and Stea D, Chicago: Image and Environment, Aldine, IL (1973), 8–26.

Eden, C., Ackermann, F. and Cropper, S. (1992). The analysis of cause maps, *Journal of Management Studies*, **29** (3), 309-325

Eden, C. and Ackermann, F. (1998). *Analysing and comparing idographic casual maps.* In: EDEN, C. & SPENDER, J. C. (eds.) London: Managerial and organizational cognition : theory, methods and research. Sage.

Edkins, A. J., Kural, E., Maytorena-Sanchez, E. and Rintala, K. (2007). The application of cognitive mapping methodologies in project management research, *International Journal of Project Management*, **25** (8), 762-772

Fransella, F., Bell, R. and Bannister, D. (2004). *A manual for repertory grid technique*, Wiley: Chichester.

Forsythe, P. (2006). Consumer-perceived appearance tolerance in construction quality management, *Engineering Construction and Architectural Management*, **13**(3), 307-319

Holm, H., Lindberg, Å. and Lorentsen, M. (1987). *Projektera och bygga med toleranser* [Design and build with tolerances], Stockholm: AB Svenska Byggtjänst.

Johnsson, H. and Meiling, J. H. (2009). Defects in offsite construction: timber module prefabrication, *Construction Management and Economics*, **27** (7), 667-681

Kelly, G. A. (1963), *A theory of personality: the psychology of personal constructs*, New York: Norton.

Kumar, M. S., Kannan, S. M. and Jayabalan, V. (2007). Construction of closed-form equations and graphical representation for optimal tolerance allocation, *International Journal of Production Research*, **45** (6), 1449-1468

Landin, A. and Kämpe, P. (2007). Industrializing the construction sector through innovation – Tolerance Dilemma, Conference CIB 2007- 387, Cape Town, South Africa.

Linderoth, H. C. J. (2010). Understanding adoption and use of BIM as the creation of actor networks, *Automation in Construction*, **19** (1), 66–72

Love, P. E D. and Irani, Z. (2003). A project management quality cost information system for the construction. *Information and Management*, **40** (7), 649-661

Meacham, B. J. (2010). Accommodating innovation in building regulation: lessons and challenges, *Building Research and Information*, **38** (6), 686-698

Novak, J. D. and Cañas, A. J. (2008). The Theory Underlying Concept Maps and How to Construct and Use Them, Technical Report IHMC CmapTools 2006-01 Rev 2008-01, Florida

Pavitt, T. C. and Gibb, A. G. F. (2003). Interface Management within Construction: In particular Building Facade, *Journal of Construction Engineering*, **129** (1), 8-16

Tolman, E. (1948) Cognitive maps in rats and men. Psychological Review **55**(4), 189-208, American psychological association

Yan, C., Ruifeng, X. and Liqun, W. (2009). Geometric Tolerances Information Modeling for Integrated Manufacturing Processes, WASE International Conference on Information Engineering, Hangzhou Dizn University.

Winch, G. (2003). Models of manufacturing and the construction process: the genesis of re-engineering construction, *Building Research and Information*, **31** (2), 107-118

INDICATORS FOR BUILDING PROCESS WITHOUT FINAL DEFECTS – METHODOLOGY AND THEORETICAL FOUNDATION

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This article introduces the preliminary data analysis, as well as the underlying theories and methods for identifying the indicators for building process without final defects. Since 2004, the Benchmark Centre for the Danish Construction Sector (BEC) has collected information about legal defects in connection with Danish construction enterprises that have been handed over. The project aims to utilise the knowledge potential available in BEC´s database in order to locate key performance indicators of construction failures and defects. The empirical data from BEC is applied in a more academic context than has been the case until now. The idea is to survey which indicators differentiate good construction and processes of construction from bad ones. The method is a retrospective analysis, which is based on data on the handing over. The data used has been partly that which BEC has already collected and partly additional focused data collected through interviews and electronic questionnaires directed to developers, designers and contractors. The first results from the data collection will be available in spring 2011 and will be able to indicate the differences between construction without or with only a few defects and construction that is handed over with many and serious defects.

KEYWORDS: Failure and defects, Construction, Best practices, Indicators

INTRODUCTION

The Benchmark Centre for the Danish Construction Sector (BEC) is a business foundation established by a broad circle of parties from the construction sector in order to promote quality and efficiency. The Centre's function is to collect and organize information and evaluations from the parties involved in construction projects. The collected data is used to calculate key performance indicators. The type of defects, deficiencies and failures registered in BEC are of a legal nature, i.e. the discrepancies registered by the client following delivery, also where there is a lack of correspondence between what has been delivered and what was agreed upon by the customer and the supplier (the client and the contractor).

All governmental buildings and all publicly utilised buildings will be evaluated; all other buildings may be evaluated by BEC. The motivation for being evaluated is that the public contractors begin to pay regard to evaluations in their tenders. January 2011, BEC has collected data for approximately 2,200 completed construction projects within the period from 2004-2010 and is thus the largest Danish register over evaluated buildings. Information is submitted by the building owner and the contract manager, respectively, where it is made certain that the two parties agree upon the details. In this way, a high degree of validity and reliability are ensured in the given details.

BEC's data provides the basis for identifying construction projects delivered with few legal discrepancies and those with many. The project *Indicators of construction without failures and defects* investigates what differentiates these construction projects, with the aim of identifying the indicators that lead to few discrepancies. Indicators, refers to the characteristics of a building project that can have direct influence on the discrepancies found, even though they do not directly explain their causes. Such indicators can be the way bids are made, organization, experience, coordination, form of cooperation etc. In order to ensure the quality of the finished construction project, a large share of the responsibility is placed on the client. Guidelines stipulate that the client shall provide a program proposal, that the program and the project express satisfactory use, value and architectural appearance, a sound technical construction design, durability, consideration for the environment, energy consumption and ecology, and a realistic plant and operations economy (Business and Housing Administration 2003).

There are many different causes of defects and discrepancies, and they can be found throughout the construction project's value chain. Some sources have sought to systematize some of the most important types of causes, in relation to both interested parties and processes (Jørgensen2009). Explanations of causes related to the involved parties' attitudes and actions are characterized by 1) lack of communication and coordination (Josephson 1994, Apelgren et al. 2005, Nielsen et al. 2004), 2) lack of knowledge and experience (Josephson 1994, Nielsen et al. 2004), and 3) engagement, stress and time pressure (Josephson 1994, Nielsen et al. 2004). But other sources point to other problems with defects in project materials, defects in building products, poor planning, and poor execution of work (Nielsen 2004). Explanations of causes related to building processes include deficiencies in the client's project plan, which should define the concept, the quality level, and demands for the project; the client's strategy in relation to quality level, and the relationship between the level of ambition and the resources for ensuring the technical construction quality are some of the elements involved (Henriksen & Hansen 2006). Other sources emphasize deficiencies and errors in project design and on the part of suppliers and defects in supplies, deficiencies in planning the execution of the work and contractors' leadership, deficiencies in organizing the work and carrying it out, and in management of delays and shifts between operations (Josephson 1994, Nielsen et al. 2004, Apelgren et al. 2005). Case histories from building processes paint an extremely clear picture of the complexity of construction projects and of how small factors and different ways of understanding situations can often lead to unfortunate and undesirable consequences (Kreiner 2005, Jørgensen2009). The factors that various researchers in building processes have found to be problematic are factors for which it is relevant to investigate whether they are indicators for a successful construction project or not. This leads to the following hypotheses:

- BEC´s data for registered legal deficiencies at delivery of a construction project provide an indication of whether a construction project and process have been good or bad; thus, such indicators can actually be used to tell us something about the quality and robustness of a given construction project.

- It is possible to find generic differences in construction projects and building processes, which can be identified by the level of legal deficiencies at delivery.

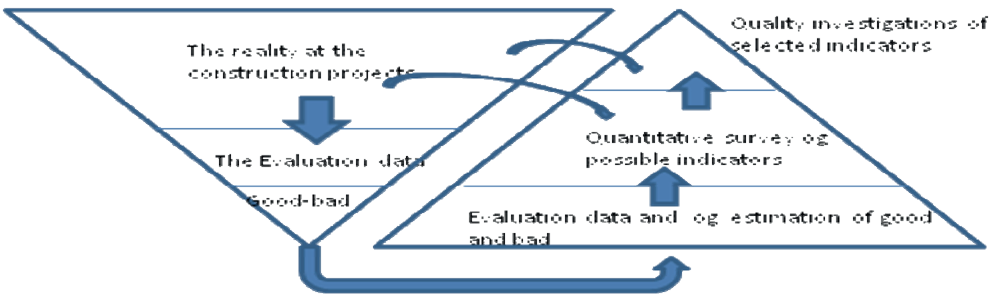
- The indicators that have been found to influence robustness in safety and risk research are also relevant for robustness in relation to quality.

- It is possible to recreate and rediscover such indicators in a retrospective investigation in which the empirical data must be based on interviews and historical statistical data.

METHODOLOGICAL CONSIDERATIONS

The data that exists is data from evaluated construction projects, which either are the state or non-profit construction projects that are obliged to be evaluated, as well as the municipal or voluntary evaluations, where either the builder or the contractor have deemed it an advantage to have the project evaluated. Roughly 2% of construction projects within the period 2004-2010 were evaluated, but primarily among the larger construction projects. One can regard the existing data as an extract of the practical reality the individual construction project represents and that from this extract it results in an evaluation of the contractor good-bad. One method of mapping indicators can be 1) to take a point of departure in the evaluated data and the opportunities this data provides for the evaluation of good-bad, 2) to conduct a quantitative investigation with the aid of a questionnaire to the many evaluated interested parties, who can map out a part of the practical reality and who can point out themes, which can function as indicators and 3) to supplement with targeted qualitative studies of the themes, which the quantitative study points out as relevant for the project's purpose. The combination of the collection and analysis of quantifiable data and subsequent supplementary qualitative investigations is regarded as being strong (Robson et al). The method for data generation can be illustrated as shown in figure 1.

Figure 1: The method for establishing data



The methodological questions to be answered in this article are:

- On the basis of BEC's data, how can we define which construction projects are good and which are bad?

- Which indicators shall be included when identifying the indicators of construction projects that are defect-free?

- What theoretical foundation and methodological procedures can be used to identify these indicators?

The first question involves considerations about how much can be achieved using the existing BEC data with respect to differentiating good construction projects from bad. This must be answered through an analysis of BEC's data for construction projects during the period 2004-2010, where on the basis of the existing data, the frequency of the occurrence and seriousness of the defects in each project is weighted in relation to the others. Through this process, the data for each construction project is used to calculate a value that can function as a basis for comparison, making it possible to differentiate construction projects with few defects from those with many, without however determining whether they are good or bad. The second question investigates what the literature considers as influences on the good building process. This will primarily be investigated by studying the more recent sources of literature in order to contribute to identifying indicator themes and produce a model that links the hypotheses and the existing BEC data. The third question considers the method to be used for collecting knowledge about indicators. Both a quantitative and qualitative analysis are planned to make it possible to identify indicators in both breadth and depth. A qualitative analysis will also make it possible to verify and explain the results that can be deduced from the quantitative analysis. It is also necessary to determine how to proceed from identifying the possible indicators found in the literature to a procedure for formulating questions in a quantitative questionnaire survey.

GOOD AND BAD ENTERPRISES

BEC calculates defects as the number of concrete defects and not as types of defects. Defects in the period 2004-2009 are classified into four categories:

- A0, cosmetic defects, i.e. defects with no or insignificant technical construction significance.

- A1, less serious defects, i.e. defects with little technical construction significance; defects without influence on the construction or function of the parts of the construction project.

- A2&A3 serious and critical defects, i.e. defects with some or significant technical construction significance; defects that influence the construction or function of parts of the construction project.

BEC calculates key performance indicators for defects as the number of defects in relation to the value of the contracts calculated in million DKK at the 2004 price level.

BEC has collected data since 2004, partly from building contracts financed by the state and partly from construction projects that volunteer for evaluation. This applies both to municipal and private projects, in addition to housing associations.

The database provides information about the reported defects per one million DKK contract sum for the years 2004-2010. Table 1 shows the average number of defects per one million DKK contract sum for the three categories of defect seriousness in the period 2004-2010. In addition, the relationship is stated between these average values, which constitute a set of preferred numbers, that is to say, the figure that the average value for each seriousness category shall be added by in order to correspond to the average value for A0. These preferred numbers are subsequently used as an adjusted weighting factor, where e.g. A2-A3 defect becomes weighted 50 times more than A0 defect. This is a purely technical weighting statement, which shall subsequently be investigated with regard to whether they can contribute to a reliable division of the evaluated businesses in the good and less good based upon the presence of errors and defects upon delivery.

Table 1: The relationship between the four seriousness categories' values for the number of defects per one million DKK contract sum for the period 2004-2009, together with proposed weighting factors for the four seriousness categories.

Seriousness category	Average no. of defects pr 1 mill. contract sum	Relation between seriousness categories	Weighting factor seriousness categories
A0	4.647189	1	1
A1	1.294525	4	5
A2-A3	0.090574	51	50

The average construction contract will thus have the number of defects shown in table 1, which leads to the following calculation:

$$4.6 \text{ x } 1 + 1.3 \text{ x } 5 + 0.09 \text{ x } 50 = 15{,}6520.55 \Longrightarrow 15$$

The value 15 is the weighted average value of the number of defects per one million DKK contract sum, taking into account both the number and seriousness of the defects.

The weighting factors and the average of the values can be used to group the registered construction contracts as good below the average and bad above the average.

For each construction contract registered with BEC, a calculation is made of the seriousness factor norm AN:

$$\frac{\text{A0 x 1 + A1 x 5 + A2-A3 x 50}}{\text{Construction sum}} \text{ x DKK 1 million}$$

If the value 15 is considered the average value, the construction contracts can now be divided into five groups, based on the following values for the Seriousness Factor Norm:

Gr. 1: contracts with value equal or above 0 but less than 5

Gr. 2: contracts with value equal or above5 but less than 15

Gr. 3: contracts with value equal or above 15 but less than 30

Gr. 4: contracts with value equal or above 30 but less than 50

Gr. 5: contracts with value equal or above 50

BEC registered more than 800 construction projects in the period 2004-2010 for which the whole construction project was evaluated. They are distributed among the five groups as shown in table 2.

Table 2: The number of evaluated construction projects in the period 2004-2009, on the basis of each project's seriousness factor norm.

Group 1	Group 2	Group 3	Group 4	Group 5
428	156	96	57	69

The subsequent phases of the investigation must show whether such a grouping of construction projects is valid with respect to the hypotheses for which other indicators might have significance for the resulting quality of construction projects.

INDICATORS FOR THE BUILDING PROCESS

The types of indicators sought are partly those that can support the hypotheses and partly those the literature indicates as significant to the good building process. Figure 2 presents a model in which the relationship between BEC's basis data and the hypotheses themes are filled in with the indicator themes that according to the literature sources are characteristic of the good building process. In addition to the information on defects, BEC's evaluations comprise a registration of discrepancies between planned and actual timeframes, deadline extensions, time for correcting defects, the client's satisfaction with the building process, and information about eventual work accidents. There is also some factual information both about the client and the contractor, the type of construction, type of contract, the building project's price, the construction time, the building area (m2) and some information on resources. It is to supplement all this information that further knowledge is sought regarding the construction projects.

Economy and time schedule

An important prerequisite for being able to estimate costs in the initial phases is knowledge about potential and possible solutions, as well as what they cost and how quickly they can be realized (Winch 2010). The ongoing management and follow-up of the economy for a construction project is essential for a successful result (Chapman et al. 2010). Economy and time schedules are central elements in a building process, where insufficient economic resources will lead to the problems cited above, and an insufficient timeframe will lead to a forced building process, which will especially cause pressure in the last phases of the process. Other relevant factors regarding economy are the use of incentives and bonuses in order to reward firms or interested parties for work well done (CIB920). Experiences with open accounts, where firms present their internal project accounts, have also proved to create greater trust between the parties involved in the project. This principle is, for example, applied in partnering projects. Some of the traditional problems in the building process are 1) that the client often chooses to go after the lowest price; 2) that the requirements for the construction project are not sufficiently precise; 3) that there is little focus on the business aspects of the case; and 4) that competition often leads to underbidding. These problems together lead to poor project planning and implementation, poor build ability, deficient specifications that prevent adjustments and development, resistance toward using experts and to finding weaknesses and areas of risk. If these are also supplemented with poor planning and lack of management experience, then this creates problems for the project (Winch 2010).

A clear division of responsibilities can minimize the risk of unexpected occurrences (Szentes 2010) and also help the interested parties focus on their own main tasks. It is therefore important that the project has a well-functioning project management group with clear goals and agenda (Szentes 2010).

Co-ordination and communication

Precisely because construction projects have many different stakeholders and interested parties, increasing difficulties will arise if special management and organization are not ensured to avoid such problems as difficult paths of communication, lack of mutual understanding, unpredictable building site conditions, unclear frameworks for the quality of the work done, and incomplete deliveries by suppliers (Loushine 2006). There are therefore good reasons to focus on coordination, communication and cooperation. Lack of design and integration of quality in the building process create in turn a general lack of focus on quality and customer value, poor contracts, and poor understanding of why it is difficult to carry out a construction project (Leong & Tilley 2008). This leads to the question of co-operation forms and culture, which also include awareness of the quality expected by the client.

Planning, management and quality

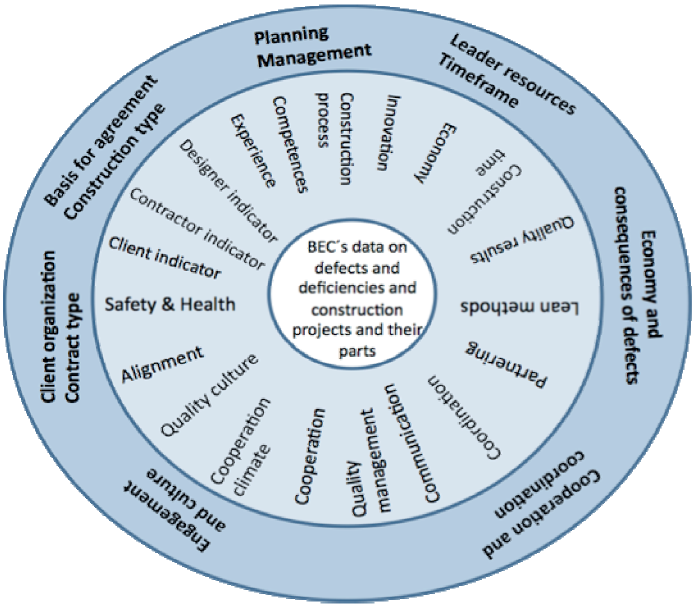
The project leader's style of leadership in the form of commitment and involvement are central factors (Yang et al. 2010, Misumi 1985), as is the ability to develop coherence and realistic plans (Chua et al. 1999, Winch 2010), since well-functioning planning practices are of central importance in realizing the construction project. Since not all aspects of a construction project are always planned, however, much time is used for problem solving (Winch 2010, Thuesen 2006). A central element in planning practices involves the use of instruments that can optimize the project's design aspects in order to achieve a balance between quality, economy and time, as well as such concrete planning instruments as project plans, cyclograms etc. After developing plans, the ongoing management and follow-up of these plans is essential (Winch 2010, Szentes 2010). This entails continual monitoring of the project's status in order to identify discrepancies in relation to the plan (Szentes 2010). In addition, there are several management factors that affect quality, such as requirements for the level of quality and quality control, time and resource planning, monitoring and control of deliveries etc. (Jørgensen 2009). Cooperation processes are of central importance for a project's realization (Winch 2010, Szentes 2010). An important aspect of the co-operative effort is the ability to formulate common goals and continually follow them up, as seen for example in partnering projects. It is also important to celebrate a project's achieved successes, with flag days etc. (Szentes 2010).

The interested party's competences and experiences

The project's access to the right competences is important to the project's success. Lacking competences on the part of the designers as well as the contractors are judged to be important causes of problems in construction projects (BEC 2008). Project management competences are also seen to be a critical success factor (Szentes 2010). These include the ability to facilitate open communication and cooperation in order to formulate common goals. One of the greatest challenges in this context is the ability to attract qualified workers (Chapman et al. 2010). Experience is another important project resource. Experience is often borne by individuals (Thuesen 2006), but it is possible to differentiate between general experience, experience from similar projects, and mutual knowledge in relation to each other. Experience and competence are important in choosing partners for a project (Hardeman & Vlist 2010), but they are rarely given higher priority than the lowest price. It is important to know what things cost, what the possibilities are for realizing the project, and how long it will take (Winch 2010).

Figure 2 shows the hypotheses, themes and the indicators they contain. The indicators are based on and supplement the central information from BEC's evaluations of the registered construction projects.

Figure 2: BEC's indicators



Working environment and new technology

Finally, new technology and innovation have great significance in realizing the project (Wadugodapitiya et al. 2010, Chapman et al. 2010). In this context, the working climate is important (Wadugodapitiya et al. 2010), including such factors as employee satisfaction, working hours and stress conditions, absence due to illness, and the overall working environment. It is quite clear that this can be seen in connection with how the quality culture functions.

Quality culture

One of the relevant places to find inspiration regarding how quality culture can be identified is in the experiences of Construction Industry Institute (CII), Texas University, where they continually carry out benchmarking for large American construction projects. At CII, they find that quality culture can be identified on the basis of information from the use of some system tools such as lean construction, partnering, TQM, SCM, team building, cooperation, quality control systems and requirements, and safety work. CII also finds that the characteristics of the quality culture are a question of competences within the area of quality with regard to which conditions determine choice of partners, whether foreign labour is used, and such simple conditions as access and waste disposal; but knowledge sharing and trust between and involvement of the craftsmen are also necessary. These many sources and perspectives must be integrated into the themes to be investigated further in the research, and not least in the questions that form the basis for the project's empirical part.

PROCEDURE FOR THE INVESTIGATION

Identifying the indicators for the good building process and their significance for the scope and seriousness of defects at delivery should be able to be accomplished through combining a quantitative survey with a subsequent qualitative investigation, where the results from the quantitative survey are investigated in depth. This will make it possible both to carry out a study with statistic analyses of indicators, and a case-oriented description of how the same indicators function and are related to concrete construction projects. The quantitative survey, for reasons of time, will be a retrospective study of finished and evaluated construction projects. In order to ensure that respondents can remember the building process, the survey will only include projects completed within the last three years. Thus, the empirical study includes only evaluated construction projects from the years 2007-2010, as per October 1, 2010. A prerequisite for the investigation is that those to be included in the quantitative survey are the same persons that contributed to BEC's evaluation, i.e. the client and the contractor's project leader. Thus, neither designers, employees nor sub-contractors are involved in the quantitative survey. On the other hand, it is possible to pose questions to both client and the contractor about their mutual understanding of the same conditions, which makes it possible to differentiate answers to subjective questions and compare their conceptions of the building process. All the indicators proposed for the good building process show that many questions are related to more than one of the indicator themes. It will therefore be relevant to differentiate between the structure of the questionnaire and the structure of the subsequent analysis. The reasons for this are:

- The questionnaire must be structured so that a question is only asked once and that the order makes sense to the respondent.
- The analyses will benefit from being structured across the structure of the questionnaire.
- It is necessary to ensure that the questionnaire does not exceed 80-90 questions.

The type of contract must also be taken into consideration, since the roles of both the client and the contractor vary for different types of contracts. This means that the questions must be targeted to clients and contractors respectively, depending on whether the project is a turnkey contract, general contract, or individual trade contract/prime contract etc.

The questions are primarily positively formulated, and the answers have a truth weight between 1-10. Simple, clear yes/no questions will also be formulated. The aim is to be able to calculate scores for various indicator subjects on the basis of a series of questions, and to analyze across the questions. Thus, the questions are formulated so that they cover the themes shown below, while the analyses will go across this structure and collect the answers that can tell something about the indicator subjects shown in figure 2. The structure for the questionnaire is demonstrated in table 4.

A total of 90 questions are formulated targeting the client or the contractor. Questions to the client and contractor are also formulated in three versions each, for different types of contracts – i.e. a set of questionnaires for turnkey contracts, general contracts, and individual trade/prime contracts. The reason for this is that responsibilities, roles and influence differ for both client and contractor for the different types of contracts. The questionnaires were tested by selected contractors and clients before use.

Table 3 below illustrates the headlines and contents of the question asked in the survey

Table 3: Headlines and contents of the question asked in the survey

Economy	BEC´s data on economy are supplemented with: Economic Planning Economy management Consequences of economy Incentives and bonuses
Construction time	BEC´s data on construction time and deadlines etc. are supplemented with: Construction time requirements Time planning and time consumption Time consumption for project phases
Value and priorities	Project's priorities Basis for selecting partners
Quality	Planning quality Producing quality Quality result
Competences	Leadership competences Survey of the parties' competences
Co-operation	Co-operation climate Co-operation forms and agreements Involvement across the parties Methods for strengthening cooperation
Co-ordination and planning	Managing project changes Meetings and meeting structure Planning methods Production process
Working environment	Safety work implementation Safety conditions on the building site
Risks, complexity and innovation	Construction project's complexity Innovative methods Important risks

The questionnaire has been disseminated to more than 800 interested parties with a response rate of 25%. On the basis of the results from this quantitative survey the plan is subsequently to carry out a qualitative investigation. The aim here is to gain a deeper understanding of the factors that the analysis from the questionnaire finds to be indicators for the good and bad construction projects, respectively. The focus here will primarily be on more recent construction projects, some of which are as yet not completed, and where it is possible for other interested parties to be involved than those who were able to participate in the quantitative study. The aim is to end with a result that shows which indicators affect the range and seriousness of the defects found after project delivery, and describe the best practice in these areas.

DISCUSSIONS AND CONCLUDING REMARKS

The article presents proposals for how to identify indicators for the good building process, which is characterized by delivery on time and without defects. The point of departure is evaluations of construction projects during the period 2004-2009, carried out by Benchmark Centre for the Danish Construction Sector. The method is to collect supplementary information based on a quantitative survey and a qualitative investigation regarding indicators, in order to discover whether they contribute to building processes that lead to no or only few defects at delivery. The article describes this method; however, the results from the survey are not yet available. The method's use of BEC's data of evaluated construction projects can be discussed, as well as the considerations about the method for collecting and analyzing indicators. BEC collects data to be used to make character ratings for contractors that have carried out construction projects; therefore, the results of the evaluations have great significance for these contractors and can easily influence their actions. This is of course the intention, but it can also have its disadvantages. Adhering to time schedules can for example be pressed to a disadvantage for construction quality, and defects can be hidden or patched. The number of defects and deficiencies, especially the less serious defects, can very well vary according to who conducts the evaluations – for example, if the client is very critical. Thus, the same defects are not necessarily registered in the same way. Dividing the construction projects into five groups, ranging from no defects to many serious defects, can also be subject to question. Can the groups be used to characterize the good and bad building processes? Investigating this question is considered an important element of the analysis. The use of a retrospective investigation, where the client and the contractor must recall a project that has been delivered, can also be questioned. Can they remember the process and do they know very much about what actually went on? There is also a big risk that the answering percentage will be low, i.e. that they are not motivated or do not have time to participate. On the other hand, just this possibility can provide information about many projects in a short time, where the answering percentage and an analysis of non-participation are important aspects. There are also limitations in only being able to ask clients and project leaders, since they do not necessarily have full insight into the whole building process and the involved parties, but again it is a question of the possibilities to gather knowledge from many construction projects. The analysis must take into consideration who has been asked and on what basis. It is the analysis of the many answers to central questions that will be interesting. It is also possible to set the answers in relation to a quality result regarding delivered defects, adherence to time schedules and economy. The subsequent qualitative investigation will therefore be necessary to qualify and pinpoint the significance of the quantitative conclusions. It will also make it possible to triangulate the survey. The first results of the quantitative survey will be presented in spring 2011 and will be included in the presentation material at the conference.

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REFERENCES

Apelgren, S., Richter, A., Kock, C. (2005), ”*Snublesten i byggeriet*” [Stumbling stones in construction], BYG-DTU

BEC, (2008), ”*Byggeriets produktivitet – en tværsnitsanalyse fra 2004-2007*” [The construction sector's productivity – analysis of a cross-section from 2004-2007], The Benchmark Centre for the Danish Construction Sector

Chapman, R.E., Butry, D.T., Huang, A.L. (2010), *Measuring and Improving U.S. Construction Productivity*, Proceedings CIB2010, CIB562

Chua, Kog and Loh (1999), *Critical Success Factors for Different Project Objectives*, Journal of Construction Engineering and Management, Volume 125, Issue 3, pp. 142-150

Business and Housing Administration [Erhvervs og Boligstyrelsen] (2003), ”*Kvalitetssikring i byggeriet – vejledning*” [Ensuring quality in construction – guidelines], Schultz Grafisk

Hardeman, S., Van der Vlist, A. (2010), ”Public Procurements´ Qualification Requirements: The case of Dutch Civil Work Procurements”, Proceedings CIB2010, CIB766

Henriksen, K.R, Hansen, E.J. (2006), ”*Kvalitet og byggefejl*” [Quality and construction defects], SBI

Josephson, P.E. (1994), ”*Orsaker till fel i byggandet*” [Causes of defects in construction], Chalmers University

Jørgensen, K., (2009), ”Failures and Defects in the Building Process – Applying the bow-tie Approach”, Proceedings, CIB 2009

Kreiner, K. (2005) ”*Læringssvigt i byggeriet*” [Learning breakdown in construction], CBS

Leong, M.S., Tilley, P.A. (2008), *Lean Strategy to Performance Measurement – Reducing Waste by Measuring* 'Next' Customer Needs”, Proceedings, IGLC-16

Loushine, T.W., Hoonakker, P.L.T., Carayon, P., Smith, M.J. (2006), "*Quality and Safety Management in Construction*", Total Quality Management, vol. 17, no 9, 1171-1212,

Migliaccio, G.C., Bogus, S.M., Chen, A. (2010), "*Relationship between Design-Build Procurement Duration and Project Success*", Proceedings, CIB2010, CIB920

Misumi, J. (1985), "The behavioral science of leadership: An interdisciplinary Japanese research program", University of Michigan Press (Ann Arbor)

Nielsen, A.S., Kristensen, E.L. (2002), "*Lean Construction – En redegørelse for det amerikanske produktionskoncept*" [- a report on the American production concept], Thesis, Aalborg University

Robson L.S., Shannon H.S., Goldenhar L.M., Hale A.R., 2001, " *Guide to Evaluating the Effectiviess of Stragies for Preventing Work Injuries*", DHHS (NIOSH) publication no. 2001-119

Szentes, H. (2010), ”*Success Factors in Large Construction Projects*”, Proceedings, CIB2010, CIB1419

Thuesen, C. (2006), "*Anvendelse af den rette viden – et studie af byggeriets kulturelle organisering*" [Applying the right knowledge – a study of construction's cultural organization], Byg-DTU

Wadugodapitiya, R.R.M.M.K., Sandanayake, Y.G., Thurairajah, N. (2010), "*Building Project Performance Evaluation Model*", Proceedings, CIB2010, CIB967

Winch G.M. 2010, "*Managing Construction Projects*", second edition, Wiley-Blackwell

Yang, J., Liu, A., Fellows, R. (2010), "Team Morale and Leadership Styles of Project Managers in China Construction Projects", Proceedings, CIB2010, CIB779

DESIGNING CLEAN

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Consulting Engineers and Architects riding on the climate mitigation wave, are currently experimenting with the concept of "Integrated Design Process" (IDP). This paper views "Integrated Design Process" along with other management or organisational concepts, seeing them as less of systematic knowledge and more of a symbolic device for enabling change. The paper acknowledges a number of international variants, but concentrates on three variants present in Denmark: an architect and engineering variant of IDP and an Integrated Design Organization. The differences between the concepts include perception of main actors, the role of information technology, the relation to lean, and forms of collaboration. Furthermore the focus of the variants differ (industry, organizational or project level).The paper discusses case studies of four teams of engineers and architects. It is argued that there exists (only) several ambiguous concepts of IDP, none well defined, and the architects and engineer struggle with the concepts even when directly involved. Precarious and negotiated consensus has to be created. The various players agree that an increased interdisciplinary interaction in the design team is necessary in order to comply with the increased complexity of sustainable building design. This tendency changes the traditional roles and responsibilities in the design process.

KEYWORDS: Integrated design processes, sustainable building, Denmark, negotiated concepts

INTRODUCTION

Energy consumptions in buildings are one out of four main issues in the current climate transition towards a non fossil economy (The Danish Climate Commission 2010). Designing clean buildings has become part of the rush, and hype created around this societal and global agenda, call it LEED, BREEAM, Active houses, Passive houses, zero carbon, GreenBuilding, cleantech (Pernick & Wilder 2008) or the like. Designing clean buildings involves meeting the elevated European directive's demands, a task that several studies shows is not simple for the professional service providers, the architects and the consulting engineers (Marsh et al 2010, Hojem & Lagesen 2011). Part of the complication lies with the cacophony of competing concepts for climate change mitigation in building. Clients (and regulators) ask for more, or something, else than just following building regulations, and finding the right synthesis of design criteria becomes a renewed challenge.

One of the central impacts of the need of designing clean buildings is that energy consumption concerns and energy related requirements pushes themselves "upwards" in the design process to the early conceptualization phase. Therefore in this paper the focus is on cases of what would previously have been called programming and would often be organized as “architects competitions”, but with the introduction of integrated design (and energy calculations) also involves engineering consultants and for other reasons even contractors. What is in play in other words is a fundamental reorganization of previous linear and “over the wall” fragmented design processes (Brunsgaard et al 2009). Integrated Design Process (IDP) is here understood as a management and organisational concept. Concepts travel globally, across countries and sectors (Czarniawska & Sevon 1996). This is also the case with IDP, and the international variants are identified. Here the interest is the appropriation in a Danish context, and it is assumed that local actors would translate and transform any such organisational and managerial concept, rather than merely mimicking it. The preference in the theoretical framework is therefore given to Danish contributors, identifying three variants.

The aim of this paper is to analyse how Danish architectural and engineering companies interact with the concept of “integrated design processes” as part of their transition into delivering professional services of sustainable buildings. The paper’s empirical material encompass two building projects both aiming at going beyond the EU-requirements for energy consumption. At each of the two projects, two competing project teams, were interviewed addressing architects and consulting engineers. And also referring to clients and contractors representatives. Here two teams responses are described to illustrate the process and all four teams responses are encalculated in the analysis .

METHOD

The theoretical approach taken is multidisciplinary, with interpretive sociology as a central position. The paper open with identifying internationally present versions of IDP, as a background for characterizing three versions of integrated design present in Denmark. This part of the paper built on desk and a selective literature study, both identifying research based and more popular versions of the concept (Koch et al 2003). The paper’s empirical part builds on case studies of four teams participating in a competition on two building projects with high profile energy demands. The cases were developed in a master thesis (Haubjerg, 2010). The choice of cases was done with point of the departure of a collaboration of Haubjerg with a consulting engineering company active in a (completely) informal network of architectural, engineering and construction firms heading in the direction of using integrated design and sustainable buildings. The two design competitions of building with energy requirements, each with two teams are covered by interviews of one engineer, and one architect from each team supplemented with two interviews with clients representatives. A desk study was used to complement on knowledge about the two competitions. The names of the two competitions “Zero Carbon” and “Mountainview” are fictions. Below the process is focusing on the two teams of Mountainview, to be understood as examples. The analysis cover all four teams.

THEORY: READING “INTEGRATED DESIGN PROCESS (IDP)” AS MANAGEMENT CONCEPTS

Thinking of IDP as a management concept, implies that the concept is thought of as a loosely bundle set of ideas, visions, processual and content tools, exemplary cases and results (Koch et al. 2003). This stands in contrast to a belief that concepts used in enterprises would be founded on scientific systematic knowledge, and encompass well defined and explicit tools (Czarniawska & Sevon 1996). When an enterprise or group uses a concept, it would aim at directed change, realized through symbolic, learning or political processes (Koch et al. 2003). The local context would moreover shape the concept in a characteristic way.

Integrated Design Processes

Concepts of integrated design have been around for some time and are present both in academic literature and in companies' branding of competences etc. The focus on integrated design (without processes) is for example presented by Moe (2008). He understand integrated design as what architects do, when they incorporate the energy, site, climatic, formal, construction, programmatic, regulatory, economic, and social aspects of a project as primary parameters for design. Moe's concepts are clearly aimed at mitigating climate change, through creating sustainable buildings. One example given is the reduction of use of traditional power operated convectors in heating (Moe 2008:7). He moreover characterizes some recent changes in architecture as drivers for integrated design (ibid p7): '…new extended understanding of composition, a broadened understanding of the context and the multivariate assemblage of factors and forces that compose buildings. The composition as a confluence of two salient aspects; the energy milieu of every building site and the social construction of architecture'. Moe places the architect in a central role, albeit in another shape than previously (ibid. p8): '… [building] project shifts the power of authorship beyond the twentieth century myth of the singular architect to thoroughly collaborative team structures… Social integration precedes technical integration. All technology is social before it is technical. The role of the architect shifts from individual master to strategic organizer of manifold, often disparate forms of knowledges and processes'. Where Moe and also Zimmerman (2006) places most of the competences and processes of integrative design amongst architects, Löhnert et al (2002) in their internationally based task force of the International Energy Agency (IEA) presents a comprehensive model for IDP, providing roles for a series of actors and a phase model encompassing iteration. Four phases are proposed basic predesign, concept design and design development (Löhnert et al 2002:39). The committed client and a core team of architects and engineers supplemented with further experts is a core organisational idea. It is claimed that energy design become integrated with architectural design rather than being an external add on. Brunsgaard (2009) claims that the weaknesses of the IEA model is too little focus on architectural quality, and underestimation of cooperation challenges between engineers and architects. Another similar comprehensive IDP concept with clear energy design focus is Keeler and Burke (2009).

The third example of a integrated design process concept is the International council for Research and Innovation in Construction's (CIB), publication on 'Integrated Design and Delivery Solutions' (CIB 2009). Here integrated design is defined as "Integrated Design and Delivery Solutions use collaborative work processes and enhanced skills, with integrated data, information, and knowledge management to minimize structural and process inefficiencies and to enhance the value delivered during design, build, and operation, and across projects." (CIB 2009:3). The CIB concept combines collaboration, enhanced skills and IT- tools such as Building information Models and knowledge management with process elements from lean (design) (CIB 2009). Apart from the comprehensive process scope, there is also a clear industry transformation focus in the CIB model, it is processes, technology and people of the sector that need to change (CIB 2009: 14).

Summarising, the international variants there are differences is emphasis on which players are to "carry" the integrated design, what role technology and process methods should play and whether the concept is seen as a project approach or an industry approach.

Danish variants of IDP

On the international background, the interest now turns to de present variants in a Danish context. Here one can identify three variants of IDP, an architectural-oriented Hansen & Knudstrup 2007), an engineering-oriented (Svendsen & Petersen 2007) and an organisational

(Bendixen 2007). All three variant are embedded in more than one player in Denmark, both encompassing industry companies and universities. The *architectural oriented variant* is developed at the Department of Architecture and Design at Aalborg University, Denmark (Hansen & Knudstrup, 2005). It is based on a holistic architectural approach and advocates a close collaboration between architects and engineers, where the building is designed through an interdisciplinary approach. The approach is based on a common language between the architects and engineers. Hence, they must carry an interdisciplinary profile which incorporates skills from both professions. One of the fundamental tools in this approach is a comprehensive parametric analysis that allows the engineers to be more proactive in the design phase. The approach operates with four phases: Analysis, Sketching, Synthesis and Presentation. Joint decision making and corporation between all professions in all phases should be exercised. The architectural variant argues that engineers and architects should adapt their competences to each other and thereby create a common language from which they can design the building jointly. The *engineering oriented variant* is developed by Petersen & Svendsen (2007) at the Technical University of Denmark (DTU). It is based on designing rooms before buildings in a "space of solutions" where each room is analyzed in accordance to predefined goals regarding energy performance and indoor environment by the engineers. The architect can then design the building by combining the rooms in various ways based on the performance of the rooms (Petersen &Svendsen 2007, 2010). It is thereby possible to design various buildings that automatically fulfill the predefined performance goals. This approach decreases the trial and error design element, and claims to base the design on conscious decisions. The space of solutions is not intended to control the design but set the boundary condition. The approach is based on the assumption that indoor environment differ from room to room according to the specific orientation and internal load etc., hence, it is argued that it makes no sense to analyze indoor climate on building level in the design phase. The approach is less depended on joint decision making than the AAU method above as the engineers and architects can work more individually (Petersen & Svendsen, 2008). The Petersen & Svendsen (2007) approach focuses on the strengths of the different professions' skills and utilizes them in different phases in the design process. According to Petersen & Svendsen (2007, 2010), integrated design involves four stages with particular roles (in paranthesis):

1. Establishing design goals (building owner and design facilitator (DF))
2. Establishing design proposals for rooms and sections (building owner and DF)
3. Generating proposals for rooms and sections (architects, experts, DF)
4. Selection and optimization of final building design (building owner, DF, experts)

The design facilitator is a role that Petersen & Svendsen (2007) share with the IEA concept discussed above. Also Petersen & Svendsen advocate the use of a specific IT-tool for handling the data on rooms in the building, 'iDbuild' (Petersen & Svendsen 2010). This is a building simulation tool developed by Petersen & Svendsen for generating design advice for a goal-oriented design processes (see Petersen & Svendsen 2010). According to Petersen & Svendsen (2010), it relies on the power of building simulation tools in design. And with the intention to push performance evaluations into the early phase in the building design process to reduce costs. Brunsgaard et al (2009) analyse seven cases of use of IDP in an set of passive house projects. They find that most of the cases position themselves within the "extremes" of the engineering and architectural variants, wheras two adopt a more traditional design process (Brunsgaard et al. 2009:4). IDP causes different problems within the consortiums (Brunsgaard et al 2009):

- Unclear boundaries compared to a traditional design process. Who does what and when?
- Different understanding of the same decision
- The design teams focused so much on the technical aspects that they forgot the architectural qualities
- So binding constraints that the architect was not able to design good architecture
- The engineer felt too constrained because the architectural aspects were too fixed.

It follows that changes in the traditional design approach engender new ways to work as a team. Unclear roles and goals, ineffective communication, increased constraints and unfamiliarity with each others' processes prevailed in the cases - issues which emphasize the utilization of IDP. However, it should be noticed that these experiences are based on an entire project process and not the competition phase alone.

Integrated Design Organization

Bendixen (2007) studied a consultancy engineering company who in a period, roughly 2004-2006, organised an internal grouping of 15 employees, around an integrated design concept of the building envelope. The organisation occurred as part of larger restructuring of the company's organisation. The group encompassed facade engineering, structural engineering, indoor climate and building physics engineering competences including experiences with more concepts and issues, such as natural ventilation, passive houses, molds. The formation of the Building Envelope Group was sanctioned by management and marketed externally. The groups providing specialist services were supposed to sell their services both internally to standard projects and externally as an independent service. The group leader adopted integrated design as the central unifying idea. The group leader regarded the group as an opportunity for interactive creations of new services and project solutions through mutual inspiration and integration of different engineering competencies, and involvement at an early stage in projects. Upon formation, the group and its manager started looking for a major project to act as trailblazer for their concepts. Meanwhile only a few members worked on the same project, whereas most worked on many small one-man projects or providing a few hours of assistance to other projects. The expert engineers were highly self-sufficient as they had a more or less continuous portfolio of projects with core clients and/or through their internal and external networks. Many members of the group had more than ten projects running at the same time. Most time was spent desk working or at meetings and sometimes people with similar engineering expertise approach each other for advice or discussion. The group leader took initiatives to consolidate the group and promote its overall objectives arranging various workshops. A reconstruction project involving more members of the group was considered as the trailblazer project. And eventually after roughly six month a project with the potential for realising the group's ideas came along. The process in this project encompassed interacting with a client, other engineering consultancies and with architects. However the project failed to materialise as the client withdraw. After a further period of a "many project" portfolio the group ceased to exist. Not so much due to requirements to adhere to strict procedures of project economy (Koch 2004). On the contrary the formation and development of the initiative has been quite "organic" and voluntary. It was particularly 'small projects, large in number' that drained the initiative. The company later mobilised integrated design in other contexts drawing on the experiences made in the group.

Summarizing three variants of IDP have been discussed in a Danish context, illuminating different emphasis on architectural and/or engineering competences and approaches to processes (see also Löhner et al 2003), with different emphasis project versus organisation and little emphasis on IT or lean principles. The two "profession variants" alludes to the buildings sectors difficulties in creating common (mental) spaces for collaboration, and the organisation example underlines that IDP-projects does not occur as “islandic” vacuums but should be viewed as linked to the development of the project based companies in the sector.

CASES: TWO BUILDING PROJECTS AND FOUR TEAMS DOING IDP

We now turn to the empirical material developed in Haubjerg (2010). In the following the two building projects and their energy ambitions is first described, followed by a description of the process of two of the teams, and the analysis of all four teams.

Zero Carbon

Project Zero Carbon concerned a medium sized building (5,000+ m^2). The client’s requirements to the building’s energy performance were tighter than what is required in the Danish building regulations (and EU regulation) and the client was focusing on facilitating IDP. The client arranged an invited project competition for five selected parties with duration of roughly 3 months. The client was represented by 3 partners: a contractor, the municipality, and a consultant. After awarding the winning team, the project carried on as a traditional design build contract in collaboration with the contractor as the main contractual reference point for the architects and engineers. Out of the five prequalified teams, two project groups were chosen as cases in which one of them was the winning team. The project teams consisted of a main architect, a main consulting engineer, and various sub consultants and specialists. The interviewees were the main architect and the main engineer from both teams and the client consultant. A client consultant was instrumental in developing the demands for sustainability of the building and the use of integrated design. For this consultant sustainability should be realized through a client drive and close collaborated of some form in the completion teams were viewed as crucial. The energy ambition was formulated as ” a concept where a synthesis of form, materials and technique, creates as building which on a yearly basis is 100% energy neutral” (web material). The ambition’s scope is energy consumption by heating and ventilations as defined in the building regulation, but also the individual consumption by lightning and use of household utilities. Life Cycle analysis of material and surface treatments is mentioned, as well as noise from the sourrindings and installations and acoustics. Upon finalizing the competition the winning project was characterized as “actively energy producing, energy neutral multi story dwelling, with an comprehensive focus of health, perfect indoor climate and quality of life” (web material). The client’s consultant emphasis on the holism in design, and an integration in the process also implied looking for integration in the bids. During the evaluation of the bid the client consultant observed that some teams had not worked close enough together to assure consensus within the material handed in (client consultant Zero Carbon).

Mountainview

Project Mountainview concerns a large scale building project (30.000 + m^2). The client invited selected companies to a Design/Build competition with duration of approximately 3 months. The client is represented by 3 partners which all are future users of the building. The project’s requirements concerning energy performance was also tighter than required in the regulations though there were no specific initiatives regarding facilitating IDP. Like in project zero carbon, two of the prequalified teams were chosen. When the interviews were conducted the client competition committee was still deliberating. The project teams consisted of the Design/Build contractor, a main architect, a main consulting engineer, and various sub contractors, consultants, and specialists. The interviewees were the main architect and the main engineer from both teams and a contractor from one of the team. Furthermore, one of the clients was also interviewed. The client, is this case the owner of the property, collaborated with the two other partners. The client announced the competition, first as a prequalification round and then asking five selected teams to develop a proposal. Each project team could involve other consultants in order to secure the quality of the proposal, which the two studied teams did. When the winner was awarded, the proposal is contracted with the design/build contractor, which in turn hires sub contractors. The energy ambition had, similar to Zero Carbon two dimensions. First the building should be able to obtain a class 1 level compliant with EPCB (2003), which at the time of announcement equaled 50% of the present day Danish Building regulation. Secondly the occupants of the building should be actively involved in reducing the behavior oriented energy consumption. The Mountainview client asked for the use of integrated energy design (EID), using a design process focused on climate appropriated design, user appropriated design and a planning of internal functions with a view to optimizing energy consumption.

The process of team 1, Mountainview

As the client demanded the project teams to use integrated energy design, this was part of the ex ante requirements and the adoption beyond debate. This was interpreted as an advantage:

'…it is an advantage that the client clearly states what he wants and can relate to that. It is easier to decode their requirements. ... And then the project teams do not need to interpret that much as they can see the level of ambition and what is expected.' (Engineer team 1)

'When we got the program we evaluated the winning parameters… And one can easily see that Integrated Energy Design, among other things, is of great importance. And we do adopt that, because it is an important part of this process and the contractor paid it a lot of attention, hence, and it was something we discussed every time' (Architect team 1)

Whereas in contrast to EID, the architect saw IDP as more of an engineer's concept:

'The engineer had a method/process they adopt into a project: first we do this, and then we do that. And of course we looked into that, but we're at a point where many strings need to be tied together, so IDP is only a part of the many processes we are trying to coordinate. It's not a model that we are familiar with, so I cannot really tell how it worked out' (Architect team 1)

So where the engineer maps EID to IDP, the architect distinguished between them. The established project organisation scheduled a number of deadline and meetings. But according to the engineering consultant, things got more fluid, and there it was a strength that the architects firm managed to keep a partner (high level manager) onboard in the process, to enable joint decision making. Also a steering group was formed which acted more like a quorum. All specialists were placed outside the steering group and/but involved whenever needed. The project organisation operated in a similar manner. At weekly status meeting the contractor was updated on the progress of the design process. Some called for a standardized process, however the engineer contended that

'…. it is a problem because it locks things. ... Our method is to design the process in relation to the specific project....We are focused on how we organize ourselves, how we control the process, how do we ensure everyone has a good process without no one dominating so we don't have to spend time on identifying who is in charge. The size of the project is also important in regards to which the methods and tools we utilize. And that we have to deal with every time.… But an IDP is never perfect and each one is different. It is about being good at navigating in chaos.' (Engineering Consultant)

The process of designing energy was becoming a stronger synergy than normally:

‘All rooms were analyzed with regards to the internal load in relation to air change, so the architect could prioritize the locations of the room according to that. .. .In a previous project we had a very bad process, so we were a little reluctant regarding how much we wanted to dominate the process with IED. So we had some strategic considerations about how to get the best project out of it which also sells on the architecture, because it might become a hindrance to the architect. … We put a lot of efforts in preparing the details before the architects came to the part.’ (Engineering Consultant).

The architects felt that the engineers were not able to contribute in that process, as they were too slow in decision making:

‘In several occasions the engineer was sitting here. But actually it was somewhat unnecessary, because of the fact that it takes quite a long time for them to arrive at conclusions. When we had discussed an issue for 15-30 minutes, they sat down by their computers and typed in the parameters and didn’t really need us anymore and we couldn’t get more out of them, since they first had to compute. So the problem actually was in their tools, IT, and applications where it takes too long.… And sometimes I do not think that you need to compute it, but just use common sense ... In regards to explore and try new things in terms of the facade they held back a little. And it may have something to do with that if you do not possess the knowledge then it is difficult to approve it because a part of their role is indeed to be able to document the project’ (Architect).

A few tensions occurred relating to making contradictory demands meet. A ceiling design needed a compromise between thermal design and acoustics. Similarly concerning a canteen. The product was a good experience, even if it could have been more interactive (Engineering consultant). This team’s energy design was evaluated by the competition committee to be excellent, as it arrived at the active house level, being able to produce energy. However the overall evaluation meant that the proposal did not win.

The process of team 2, Mountainview

As the client demanded the project teams to use integrated energy design, this was part of the ex ante requirements and the adoption beyond debate. For the engineering consultant this was interpreted as in direct prolongation of his company’s own strategy of IDP:

‘So this way of thinking has gone all the way to the top management. In that connection a lot of workshops and internal training is held with our internal team members in order to implement this way of thinking.’ (Consulting Engineer)

Whereas the architect’s experience come from the Mountainview project only: *‘I don’t have a concrete definition of it (IDP). But it is a process where you receive input from one another which, through an effect of synergy, will be integrated into each other’s proposals and eventually… you achieve a holistic project. It is more fun to achieve the energy objectives in its whole than by pasting up solar cells’* (Architect)

The project organisation encompasses a work group and a steering group. The contractor participated in the steering group. Initially the winning parameters for the competition were discussed on a ‘mass meeting’ where everyone in the team participated. A lot of meetings followed. Four broad workshops were arranged by each of the main partners. At times, too many, in the opinion of the architect:

'I do not think that it (sitting together) can work out that way. The primary reason why that can't work out, is probably that the inertia will be too big….the main progressions (in the project) happened when you received input from the other professions. … When the engineer presented something we could discuss afterwards and design with that in mind.' (Architect)

Also the energy design was made in a strongly collective and joint manner: *'We had many meeting where architects, contractors, I and other engineers were present. There we worked on the project together and examined various opportunities. We made energy analysis of various initiatives and together we chose the best. It was not a single-handed assessment but a joint assessment about what would serve the project best. Not only energy but also in regards to architecture, price, constructability etc. We included it all.' (Consulting Engineer)*

The process emerged as two parallel tracks: *'The architect has a tendency to look at a building from the outside and in, which is a good exercise that has to happen early. At the same time you have the engineer who is working on room level from inside and out where you examine what can be done with regards to energy at the specific location!' (Engineer)*

The consulting engineers handled data on the rooms with an IT-tool enabling simulation of energy consumption with various room constellations: *'That we present for the architects and tell them the optimal solution in regards to energy, but that it also can be done in other ways. Then you have something to contribute with before the first sketches are made. And it is so important that we start on that as it is the first sketches that set the direction for the further development of the building's form. These analyses must be put on the table from day one to find out what the facts are. The overall design we still leave to the architect. … The idea is that you have a handful of rooms the architect can put together and make his design out of that.' (Consulting Engineer)*

In this manner it seems that the team was able to create synergy and synthesis even at an early stage. This team's design was evaluated as the winner by the competition committee. In term of energy design it arrived at the level 2 of the EU's "Energy Performance of Buildings Directive" (EBPD, European Commission 2003). However the overall evaluation strongly emphasizes the strong synthesis of the project, and this meant that the proposal won.

ANALYSIS

In the following we analyse the four cases, Mountainview team 1 and team 2, Zero Carbon team 1 and team 2. The interviewed actors have difficulties defining what integrated design "is" even after having participated in a process claimed to be governed by such a concept. The consulting engineers have gone further in taking up integrated design than the architects. One company (Engineering Consultant team 2 Mountainview) has implemented IDP internally. Another (Engineering Consultant team 2 Zero Carbon) have developed their version of integrated energy design, also as part of their business strategy, and claims identity between IED and IDP. The remaining two engineering companies holds competences in doing IDP, but is not strategically committed. It is clear that the actors in all four teams struggle with the meaning and content of IPD, including what new roles and behavior to adopt. For example in Mountainview team 1, the engineering consultant views EID as IDP, whereas the architect distinguished between them. In team 1, engineers appear to stick to evaluation through IT-models of the ideas of the architects. There is thus a relatively weak performance of IDP as all kind of process experiences and practices seems to get mingled in. Possibly IDP "works" more through providing a philosophy of interactive collaboration. The understanding of intensified collaboration among engineers and architects appears to be the core of the actor's appreciation of IDP. In the processes investigated, three out of four aims at collaborative and interactive decision making, whereas one openly prefers to have the architects as decision makers and the engineers as suppliers of information (ZeroCarbon team 2). The imagined participants and the timing of participation also varies as most merely refer to early interaction between engineers and architects, whereas one player, emphasizes a tripartite collaboration (Architect ZeroCarbon team 1). Another underlines that it is primarily architects and energy engineers that collaborates, whereas HVAC, and structural engineers play a more peripheral role (Architect ZeroCarbon team 2). Central enabling factors for the process is the clients demand for it, previous collaboration, a 'good feeling for each other', and an organic project organisation enabling interaction and iterations, usually flat with little emphasis on the steering group level, and more emphasis on joint workshops with many participants. Some players go further in emphasizing that overly standardized methods would be inflexible in the variety of projects they engage in (Mountainview Engineering Consultant team1). IT tools for calculating energy features of the building are contested as enablers. Some players see the tools as necessary to get the necessary valid calculations, whereas others, predominantly architects, sees the IT tools as constraining the interactive process, and ask for sound judgment instead (Architects Mountainview team1 and ZeroCarbon team 2). Petersen & Svendsen (2010) similarly notes that engineering energy design IT-tools are evaluative, rather than prescriptive, which appears to handicap the engineers in early phase design. Also scheduling is seen as an ambiguous tool: the process has to be creative and interactive but the process is short (3 months) and intensive (ZeroCarbon team1). Another contested element is how engineers manages their new role; Both the architects and the engineers points at the need of a more open minded approach towards design opportunities, rather than problemsolving. Most of the Architects asked here, evaluate the engineers as underperforming in this respect, although the interviewed engineers claimed to be focusing on these competences which emphasizes the fundamental differences between the professions and their perception of each other. The barriers for IDP currently seem to be the limited experience of most players, resource limitations, team recruitment and tools. The resource limits of the projects where the IDP was attempted carried out were significant and hindering the fostering of a process innovation (the "Tyranny" of projects, Koch 2004). For some companies IDP is still to be adopted as a business strategy to support the development of IDP (presently two out of eight companies can be said to have such a strategy). By recruiting professionals with IDP experience and/or doing internal training the companies would enable the processes also beyond cases where building requirements and clients would require it (see also Hojem & Lagesen 2011). The lack of tools and procedures to support the enforced interaction is remarkable. Neither the Petersen & Svendsen (2007, 2010), nor the Knudstrup & Hansen (2005) process models and tools are directly apparent in the process. One player refers to foreign books, but also dismisses them (ZeronCarbon team 2 engineering consultant). CIB ideas of using Building Information Models (BIM) and lean is not articulated (CIB 2009). Loosemore & Tan (2001) points at the use of stereotypes as, at a time, instrumental and detrimental for collaboration processes among building industry players. A stereotype of a player helps tackling the occurrence of new and unknown cooperation partners. If one doesn't know a person, one can act according to accumulated experience with the role and profession the player represents. Mobilizing stereotypes between architects and engineers appears to be a part of the solution to the role insecurity in the new situation occurring at IDP. This includes the architects understanding of IT tools and scheduling as being too rigid for an interactive process. And the engineers viewing the architects attempt to take control of the process through rhetorical means. Project based organisation like the present tend to prefer very flexible processes rather than mechanical ones, this becomes a barrier when trying to implement new organisation, new roles and new ways of interacting. The future development of EBPD requirements is not apparent in the process (European Commission 2003). As the two building projects studied are still under construction, it is not possible to evaluate the degree to which the climate objectives will be met, as one can expect the design to be challenged by cost cutting. At the presentation of both the designs, after the competitions, the energy features were highly flagged: At the *Mountainview* competition, team 1 actually provides the strongest proposal with a design were the house as such can be built with a negative energy consumption balance. This is characterised as excellent design by the evaluation committee. Team 2 wins the competition however, with a better balance between given design criteria; including the (other) user requirements. It was subsequently announced that the building would comply to EBPD level 1 requirements, and with active involvement of future users in changing energy consuming behaviors. There was however no mention in the competition evaluation of future higher levels of EU-regulation, but merely a reference to contemporary Danish regulation, which at the time referred to EBPD (European Commission 2003). At the *Zero Carbon* competition the winning project (team 2) designed a building actively producing energy, with energy neutral dwellings, and simultaneously healthy, with good indoor climate and quality of life (for the future occupants). The client's consultant observed that some teams had not assured consistency within the material handed in, despite the calls intention of close collaboration (client consultant Zero Carbon). The cases studied represent clients going beyond present day building regulation, and consulting enterprises with the competences needed, in contrast to Hojem & Lagesen (2011)'s result showing that most consulting engineering companies studied in Norway prefer to stick to existing building regulation (which is probably parallel to Danish consultants). Going beyond the building regulation implies that the design teams embark on less well defined ground in setting the environmental level in the design and balancing it with other criteria such as cost. As we saw in the Mountainview case, synthesized design appeared to master this balance better than design focusing on energy. However when present day building regulation is not used, then other higher, but still normative levels are referred to i.e. "active house" criteria, meaning that the house produce energy for society, and/or the high energy class of EBPD.

CONCLUSION

The analysis shows that there exist (only) several ambiguous concepts of IDP, and the architects and engineer struggle with the concepts even when directly involved. Precarious and negotiated consensus has to be created. The various players agree that an increased interdisciplinary interaction in the design team is necessary in order to tackle the increased complexity of sustainable building design. This tendency changes the traditional roles and responsibilities in the design process which leads to misalignments of expectations in the team. The cases studied represent clients willing to go beyond present day building regulation. This implies that the design teams embark on less well defined ground in setting the environmental level in the design and balancing it with other criteria such as cost.

REFERENCES

Bendixen, M. (2007). *Rådgivende ingeniørers udfordringer*. Department of Civil Engineering, Technical University of Denmark, Denmark.

Brunsgaard C. (2009). Strengths and weaknesses of different approaches of IDP. DCE Technical Report No. 74. Ålborg University. Ålborg.

Brunsgaard C., Knudstrup, M.A. and Heiselberg P. (2009). Experiences from the design processes of the first “Comfort Houses” in Denmark. *Passivhus Norden 2009*. Göteborg.

CIB (2009). *CIB White Paper on IDDS,* CIB Publication 328.

Danish Commission on Climate Change Policy (2010). *Green Energy – The road to a Danish energy system without fossil fuels.*Klimakommission. København.

European Commission (2003). *Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings*. Official Journal of the European Communities, 1, 65–70.

Hansen H.T.R. & Knudstrup M. (2005). The integrated design process (IDP): A more holistic approach to sustainable architecture. Action for Sustainability: *The 2005 World sustainable Building Conference.* Tokyo National Conference Board. Tokyo.

Haubjerg, E.L. (2010). *Team Performance in Integrated Design Processes - How to improve team performance in Integrated Design Processes in construction competitions”,* Institute of Business and Technology, Aarhus University, Denmark.

Hojem T.S. & Lagesen V.A. (2011). Doing Environmental Concerns. *Engineering Studies*.

Koch C. (2004). The Tyranny of projects- Teamworking, Organisational Knowledge and Project Management in Consulting Engineering. *Economic and Industrial Democracy,* **25** (2). 270-292.

Koch C., Hagedorn Rasmussen P. and Vogelius P. (2003). New Management and working life –the forced marriage. In H. Hvid and P. Hasle (eds). *Human Development in Working Life*. Ashgate. Aldershot. 41-65.

Keeler M., and Burke B. (2009): Fundamentals of Integrated Design for Sustainable Building. Wiley. New York.

Löhnert G, Dalkowski A, Sutter W. (2003): *Integrated Design Process. A guideline for sustainable and solar-optimised building design*. International Energy Agency (IEA). Berlin.

Marsh, R., Larsen, V. G. and Kragh, M.(2010). Housing and energy in Denmark: past, present, and future challenges, *Building Research & Information*, **38** (1). 92-106.

Moe K (2008). *Integrated Design in Contemporary Architecture*. Princeton Architectural Press. New York.

Pernick R. and Wilder C. (2008). *The Clean Tech Revolution: Discover the Top Technologies and Companies to Watch.* Collins Business. New York.

Petersen S. & Svendsen S. (2007). *Method for Integrated design*. Department of Civil Engineering. Technical University of Denmark. Lyngby.

Petersen S. & Svendsen S. (2010). Method and simulation program informed decisions in the early stages of building design. *Energy and Buildings*, **42** (7), pages: 1113-1119

SATISFACTION WITH COLLABORATION: A COMPARISON OF THREE CONSTRUCTION DELIVERY METHODS

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Collaborative relationships in construction projects are influenced by the choice of the delivery method, because it determines the requirements, expectations, and preconditions for the project organization's collaborative working. The aim of this research was to explore the differences in the levels of satisfaction with collaboration in three alternative delivery methods in Finland; traditional Design-Bid-Build (D-B-B), Construction Management (CM), and Design-Build (D&B). The data consist of over 1600 evaluation entries in a Finnish project feedback system (ProPal), which is used for bidirectional feedback between the participants of a construction project organization, i.e. the owner, construction consultant, contractors, and designers. The level of satisfaction with collaboration is found generally higher in D&B and CM projects than in D-B-B projects. Four findings are addressed: 1) the owners' satisfaction with consultants and contractors is lowest in D-B-B, 2) the consultants' are more satisfied with contractors in D&B than in D-B-B, 3) the designers' satisfaction with consultants and contractors is lowest in D-B-B, and 4) the contractors' satisfaction for consultants is highest in CM. The conclusions recommend advancing the use of ProPal as a cost-efficient data collection method and addressing the collaboration between designers and other participants as a developing topic.

KEYWORDS: collaboration, delivery method, organization, performance

INTRODUCTION

The construction project success and, thus, customer and end-user satisfaction is greatly influenced by the interdependent work performed by the parties involved in the construction project and the collaborative coordination between the parties. Regardless of the delivery method, all construction projects fundamentally comprise the same project management, design, and construction tasks. Typically for construction, the project is carried out by a temporary multi-organizations (TMO) (Cherns & Bryant, 1984), where the fragmented and multi-disciplinary array of sub-organizations often have neither common history nor defined future together. The division of the tasks among the parties depends on the delivery method, and consequently, the responsibilities and relationships of the parties vary between delivery methods. TMO's typical problems relate to its ability for collaborative working, including inter-firm risk management and learning.

The traditional Design-Bid-Build (D-B-B) delivery and the fixed price-based procurement approaches are customarily associated with an adversarial culture between the participants, whereas one of the goals of more modern delivery methods, such as Construction Management (CM) and Desing&Build (D&B) is to improve collaborative working between the owner and other parties (Latham, 1994; Egan, 1998; Morledge et al., 2006). Several studies (e.g. Hale et al., 2009; Gransberg et al., 2003) show evidence of the D&B method's superiority over D-B-B on time and cost measures but other performance comparisons have not been provided. Yet, the more dynamic delivery methods, such as CM, depend greatly on the collaboration performance between the owner and the other participants, and in all delivery methods the people's way of working together either significantly adds value or withholds it (Pryke & Smyth, 2006).

Non-financial performance information is usually limited to customers (customer satisfaction etc.), society (safety, pollution etc.), and own employees (job satisfaction etc.) (Robinson et al., 2005). Several researchers (e.g. Wilkinson, 2001; Hayden, 2004; Leung et al., 2004) have identified that collaborative working in the multi-organizational team during a project may determine a significant share of the organization's ability to reach its goals. For example, according to Leung et al. (2004) cooperation/participation, task/team conflict and goal commitment are the critical factors influencing the final outcome (satisfaction) in a complicated management process. Collaborative working should, hence, be acknowledged as a crucial performance factor.

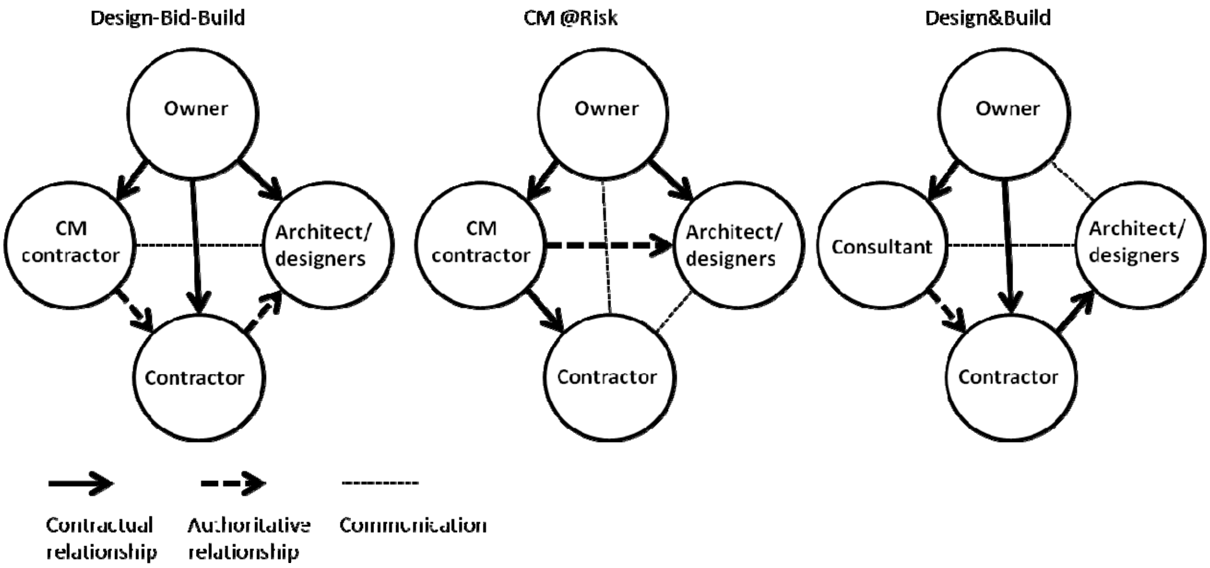
Typically, a project organization involves complex goals and the participants' expectations and requirements for collaborative relationships with each other vary. In order to attain the project goals, a systematic evaluation of the organizations' performance is required to provide feedback for guiding the participants' behavior (Liu and Walker, 1998). Thus, instead of the standard client satisfaction assessment, all parties' levels of satisfaction in collaborative working need to be acknowledged to recognize potential successes and shortcoming that will have an impact for the project organization's collaborative performance (Nzekwe-Excel et al., 2010).

This paper aims to compare the successes and shortcomings of cross-organizational satisfaction to collaborative relationships in three delivery methods, and thereby explore how the delivery methods perform as the bases for collaborative working. In practice, this is done by analysing the results of the web-based, bidirectional project feedback system (ProPal), which have been recently developed in Finland. First main characteristics of the main delivery methods are introduced, and then ProPal is shortly introduced.

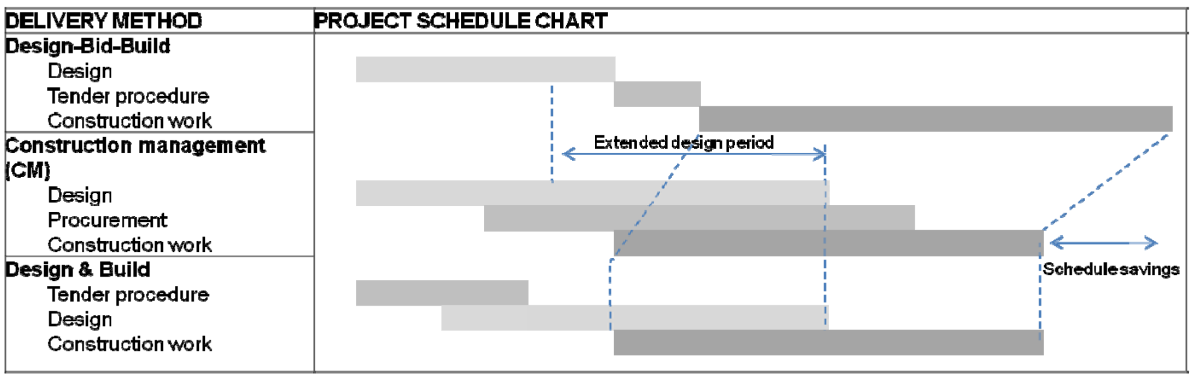
CHARACTERISTICS OF THE THREE DELIVERY METHODS

The term 'project delivery method' describes the sequential process of design, procurement and construction, main contractual relations, and responsibilities. The three major generic delivery methods are the main contracting forms, i.e. D-B-B, design-inclusive contracting, i.e. D&B, and construction management CM forms (Kiiras et al., 2002). The owner, designers and contractors are central participants in all delivery methods (Dorsey, 1997). Consultants, in the role of owner representatives or construction managers, play an additional key role in most large construction projects in Finland, and are thus included in the scope of this study. The contractual relationships and authoritative roles (i.e. the responsibility to manage and/or supervise) depend on the delivery method, as described in Figure 1. Figure 2 describes the sequencing and alignment of the main tasks in each delivery method emphasizing the concurrence, which sets its challenges for collaborative working.

Figure 1: The contractual, authoritative, and communicative relationships in three delivery methods



.Figure 2: *Comparison of the three delivery models vis-à-vis project schedule (applied from Kiiras et al 2002, D&B added)*



The D-B-B approach is the traditional and still the most widely used delivery method in Finland in terms of number of projects (Kiiras et al., 2002). In a D-B-B project the owner hires a designer to carry out complete designs including working drawings prior to commencing the tender process for the construction works. The owner procures the construction works on a fixed lump sum basis from one general contractor, who performs the works autonomously. The construction consultant's role, when employed, is to assist the owner as a construction expert in design management, tender process, and construction supervision. After the construction contract is awarded, project management including design change management is on contractor's responsibility. Thus, the sequenced delivery in the D-B-B method sets least obligations for coordination between the owner, consultant, designers, and main contractor during the construction works. The owner's role and responsibility is very limited during the construction phase and the contractors' role is omitted in design phase. The inflexible design and fixed price (lowest bid) environment does not promote contractor's efforts for quality beyond the minimum specifications, and typically results conflict over claims of extra work (Morledge et al., 2006). Thus, the common belief goes that the collaboration between the owner and the contractor is not functional.

In a D&B project the owner provides the necessary requirements for the performance of the construction, and then procures a main contractor to carry out both design and construction. The contractor is fully responsible for design management and the consultant's role is to arrange bidding and evaluate tenders and supervise the works. D&B projects highlight the functional relationship between the contractor and the designer. The consultant and the owner work closely together, as in any project delivery model, but they are not extensively involved in the construction phase. The delivery method does not support late owner decisions and requires trust on the contractor's ability to produce favorable solutions in fair price, both of which may in negative cases threaten the satisfaction to collaborative working between the contractor-designer and owner-consultant parties.

CM is a delivery method where a professional, consultant-like construction manager leads the project design, procurement and construction works collaborating closely with the owner. As a special feature, design development is made in multiple packages and procurement and construction are performed commenced concurrently package by package following design completeness. The two generic CM contract models in Finland are construction management consulting and construction management contracting. In the US these are known as Agency CM and CM @Risk, and in the UK Construction Management (CM) and Management Contracting (MC), respectively. In the former, the construction manager works as a consultant involving in the design management and procurement but the trade contracts are made in the owner's name. In the latter, the construction manager has both consultative and contractor role and directly employs the trade contractors. In Finland, the standard CM contracts imply special requirements for the collaborative relationship between the owner and the construction manager in Finland. The collaborative responsibility of the designers is substantial, too, because the designs are developed in a non-traditional, packaged manner and usually in a hectic schedule concurrently with procurement and construction. The functionality of the collaborative and innovative contribution of each main party will considerably affect CM project success.

PERFORMANCE MEASUREMENT

Project or business performance and success bear different meanings depending on the actor and purpose of measurement. Technical and financial performance measures are most common not sufficient for understanding the success or failure in project business (Chan & Chan, 2004; Robinson et al., 2005). Traditional performance measurements, "triple constraints", consider construction project environment as too simplistic (Dainty et al., 2003) and highlights production orientation in the construction (Pinto & Rouhiainen, 2001). For example, Ward et al. (1991) argued that other factors, such as the quality of relationships among participants and, can influence customer satisfaction and thus affect the success/failure of the project. The future of a company's competitive position is not only based on the financial performance of the project but on the customer relationships, societal effects, process and product performance, and staff satisfaction. Thus, non-financial factors, such as participant satisfaction (Chan & Chan, 2004), are growing in importance.

Research on project performance and the advantages and disadvantages of delivery methods is usually carried out from the owner's perspective measuring the level of project/owner goal achievement. On the operational level, goal achievement requires communicating the goals correctly, motivating the other parties' for goal commitment, and facilitating collaborative work towards goal achievement. Thus, the one-directional owner's perspective leaves uncovered the perspectives of the other key parties, whose satisfaction or dissatisfaction within the collaboratively working organization is crucial for project success. Thus, measuring participants perceptions on the collaborative performance with each other may produce valuable insights on the social side of performance management. A bidirectional evaluation method, such as the ProPal tool used in this research, is more likely to generate interesting observations and discussion of potential problems, misunderstandings, challenges and opportunities.

Yasamis et al. (2002) refer to the delivery process from resources to the constructed facility as the contracting service. The delivery method used in the projects constitutes the contractors' and other participants' elements of services in the construction project. The service dimension has been used in the literature as a functional or process quality of the process (Grönroos, 2001). The delivery method plays an important role on how the customers perceive the production process and, therefore, on how satisfied they are with the construction.

METHOD, DATA AND SAMPLE

Data for this study were gathered from a project feedback system, ProPal, which comprises ca 2300 entries, in which project owners evaluate the participants of the project delivery team and the participants evaluate one another's operations relating to their projects in Finland. The system was developed, piloted and launched as a result of a recent doctoral research (Kärnä, 2009) with the central aim of improving customer orientation and quality in the construction industry. The ProPal tool is now widely recognized and utilized within the Finnish construction industry and it is operated by Finnish Construction Quality Association (RALA), which jointly represents owners, contractors, and consultants. The system has a Web-based interface to facilitate use.

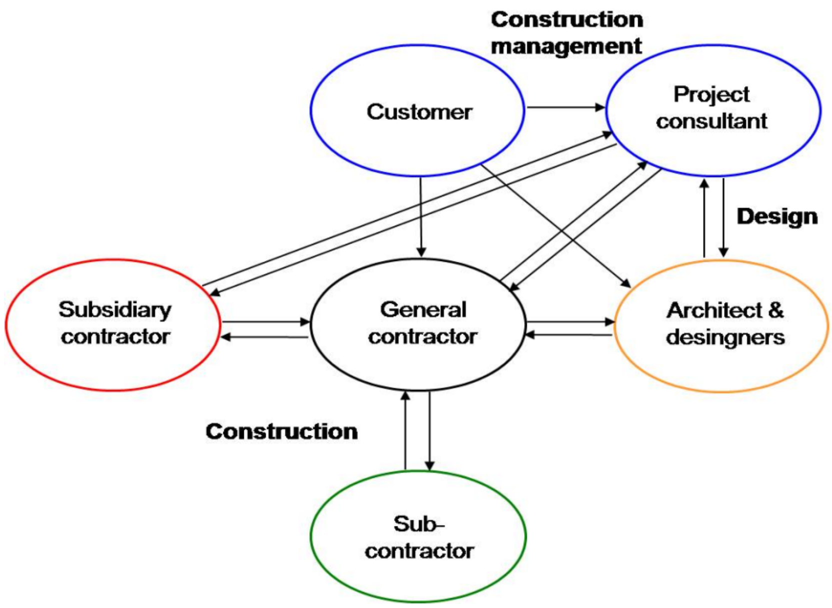
ProPal is primarily designed from construction-related companies' perspective to yield versatile information on the strengths and weaknesses within projects' collaborative relationships and work practices, which lessons the project owner's and participants may turn into operational enhancement. The feedback system offers clear, real time reports which can be targeted at the company's products and processes. Another objective of using the system is that through openness and mutual learning, cooperation between parties will develop and the customer orientation of the entire industry is improved. By comparing various background variables, the company can compare its own performance with the similar ones in the market. The system adapts to the needs of companies with different business structures and processes, so it can be utilized in, e.g., various forms of delivery methods.

Using the project feedback system, the owner will establish goals in terms of performance quality. All focal parties, for instance the owner, the consultant, the main contractor and the architect are invited to assess each others' operations by filling one of 15 standard questionnaires per each evaluated party. The owner, too, will evaluate all participants. Thus the result will present a more profound review of the projects than any one-directional feedback system could provide. By monitoring the project team's progress in reaching the set goals, team members can re-evaluate the quality of the processes necessary to reach them.

For researchers the system offers a unique and cost-efficient means for data collection. The evaluation reports from hundreds of projects are readily available and easily transferable into Excel form for analysis. The cumulated results of all projects are limitedly accessible for research and industry evaluation and may, for example, denote the areas needing improvement in the whole branch of industry and gives opportunities for setting the benchmarks of customer satisfaction. The multifaceted view on project operations and the participants "peer reviews" unfold a rewarding opportunity to study collaborative relationships.

Figure 3 illustrates the feedback flows between parties in the system. Each arrow represents the direction of the feedback and one questionnaire. All feedback flows between parties were bidirectional except for the customer as his/her operations are not assessed here. Subsidiary and sub-contractors were not included in the analysis because they are not directly connected to the owner (customer).

Figure 3*:* Feedback flows in the evaluation system



In the feedback system, the questions are formed as statements and connected to a 5-point Likert scale where answer (1) describes the operations very inaccurately and (5) very accurately. No opinion (N/A) could also be chosen as an answer. With the open comment field, the feedback giver can specify their answers. The questionnaire is answered electronically using an Internet form which displays the project and company being evaluated. The basis for the questions is derived from the various tasks in construction and the requirements of a construction project. The feedback questions concentrate on the matters each party considers important, and, on the other hand, those which each party is able to assess. The tasks and requirements of various parties in construction were grouped into fields which are similar with each other although the contents of the questions are determined by the role and task of the actor. The evaluation areas common to all parties were project management, cooperation, staff, and accomplishing goals.

This paper focuses on collaborative working, and specifically, on the evaluation results concerning the satisfaction with functionality and flexibility of collaborative working with the evaluated party. The sample includes altogether 1617 evaluation reports. The data was arranged by feedback flow (giver-receiver) and by delivery method. 407 (25%) are project owners, 478 (30%) consultants, 203 (12%) designers, and 529 (33%) contractors. 677 (42%) evaluations are completed in D-B-B projects, 528 (33%) in D&B projects, and 412 (25%) in CM projects.

Mainly, the resulted data was utilized to describe the general levels of satisfaction and outline the major differences between delivery methods (as presented in Fig. 4). To further support the descriptive analysis, a simple statistical test was conducted with the T-Test Excel tool (two-sample assuming unequal variances). To test and estimate the difference between evaluation sample population means, the results within each feedback flow are matched in pairs so that each delivery method sub-sample its tested against both of the other alternatives. For instance, the D-B-B evaluations were tested against both D&B and CM evaluations within each feedback flow. The statistical significance of the difference between each pair-wise test is determined by the resulted p-value, i.e. risk level □. When □ > 0,05 the result is not statistically significant. A risk level 0,01 > □ ≤ 0,05 refers to modest statistical significance, 0,001 > □ ≤ 0,01 to statistical significance, and □ ≤ 0,001 to outstanding statistical significance.

COLLABORATION SATISFACTION IN THREE DELIVERY METHODS

Collaboration satisfaction in D-B-B projects

The satisfaction to collaboration in D-B-B tends to get the lowest evaluations within nearly all relationships (Figure 4). The project owners' satisfaction with the consultant's collaborative working in D-B-B is considerably lower than in the other delivery methods. Their level of satisfaction with the contractors in D-B-B projects is lower than in D&B projects but the difference to CM is insignificant. Also the owners' satisfaction with collaboration with the designers in D-B-B is lower than in CM but the difference shows no statistical significance (see Table 1). The consultants rate their satisfaction with the collaboration with the contractors lower in D-B-B than in D&B but the difference to CM is not statistically significant. The consultants' level of satisfaction to designer collaboration is slightly higher in D-B-B than in CM, but not statistically significant. The designers are least satisfied to collaboration with both consultants and contractors in D-B-B projects. The contractors' satisfaction to collaboration with consultants in D-B-B projects is on a high level but lower than in CM projects. Their satisfaction to designers shows no statistically significant dependence on the delivery method.

Collaboration satisfaction in D&B projects

The satisfaction with collaboration in D&B projects is on a high level (mean value over 4) in all other relationships than in the contractors' evaluation over the designers (3.81). The contractors rate their satisfaction with the collaboration with both consultants and designers on the same level in D&B than in D-B-B project, i.e. lower than in CM. In all other relationships (except in the owners' and consultants' evaluations over the designers, where the samples are of inadequate size) the satisfaction to collaboration is statistically significantly higher in D&B projects than in D-B-B projects where as the difference to CM projects is insignificant.

Figure 4: The levels of satisfaction in the bidirectional evaluation in three different delivery methods. The arrows point from the feedback giver towards the receiver. The figures refer to the mean value of the evaluations given in each category.

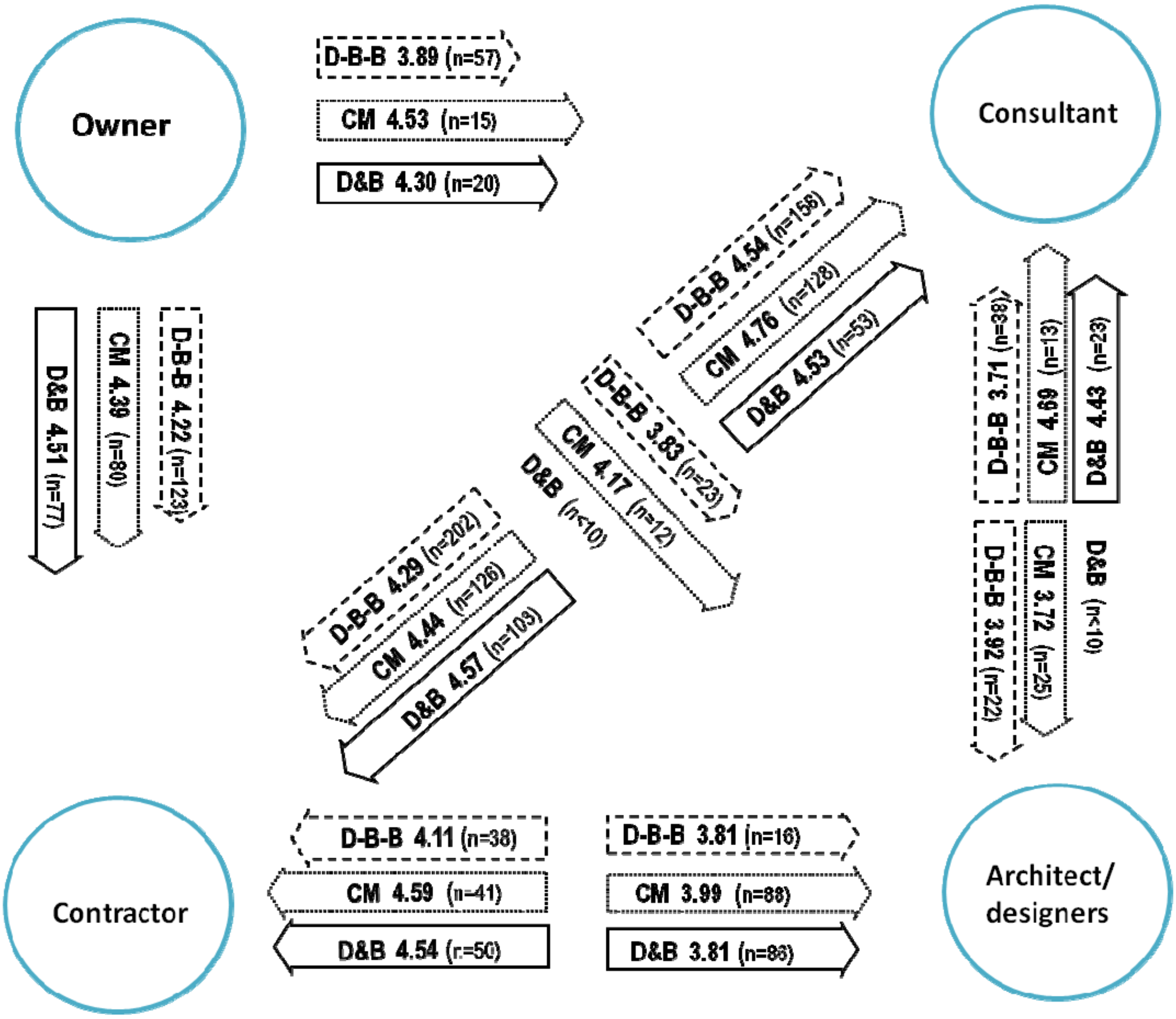


Table 1 *The statistical significance of the difference between mean values of feedback streams.*

Owner-Consultant			Owner-Designer			Owner-Contractor			Consultant-Designer			Consultant-Contractor		
	D-B-B	D&B		D-B-B	D&B		D-B-B	D&B		D-B-B	D&B		D-B-B	D&B
CM	***	-	CM	-	N/A	CM	-	-	CM	-	N/A	CM	-	-
D&B	*		D&B	N/A		D&B	*		D&B	N/A		D&B	***	
Designer-Consultant			**Designer-Contractor**			**Contractor-Consultant**			**Contractor-Designer**			-	No statistical significance	
	D-B-B	D&B		D-B-B	D&B		D-B-B	D&B		D-B-B	D&B	*	Statistically almost significant	
CM	***	-	CM	*	-	CM	***	*	CM	-	-	**	Statistically significant	
D&B	*		D&B	*		D&B	-		D&B	-		***	Statistically very significant	

Collaboration satisfaction in CM projects

The satisfaction with collaboration in CM projects is on a high overall level (mean value over 4), but the designers have received lower ratings from the consultants and the contractors (3.72 and 3.99). The three top mean evaluations are also given in CM projects and consist of the contractors' evaluation of collaboration with the consultants (4.76), the designers' evaluation of collaboration with the consultants (4.69), and the designers' evaluation of collaboration with the contractors (4.59). All three other participants score their satisfaction to collaboration with the consultants higher in CM than in D-B-B projects. The difference between CM and D-B-B is insignificant, except in contractors' evaluations over the consultants where CM project stand out as the highest scoring delivery method. Similarly the designers are more satisfied with the collaboration with the contractors in CM projects than in D-B-B projects.

DISCUSSION

The satisfaction to collaboration in each delivery method and within each focal relationship can (partly) be traced back to the roles of the participants and working practices within each relationship by delivery method. Most industry reports and development programs (e.g. Latham, 1994; Egan, 1998) are founded on the perception that collaborative relationships with contractors in traditional delivery methods and procurement models are adversarial. In this study, the owners are, as expected, found to be least satisfied with consultants and contractors in D-B-B projects but the overall level of satisfaction with contractors, even in D-B-B projects, is unexpectedly high. In Finland the owners and contractors alike are firmly accustomed to the traditional D-B-B delivery, whereas the other delivery forms are often seen risky and ambiguous. Thus, despite the lower levels of collaboration satisfaction in D-B-B, the construction industry seems to be slow in developing optimal relationships by adopting alternatives. In practice, owners, consultants, contractors, and designers have been claimed to misinterpret the roles, responsibilities and relationships in modern delivery methods. Often, the misunderstandings lead to the project implementation inclining towards the traditional delivery. The recent increase in the standardization of contract forms and practices for alternative delivery methods is likely to develop the situation.

Consultants and contractors seem to have rather clear "zones of excellence", i.e. delivery methods where they consistently get better scores for collaboration than in the others. The consultants are constantly evaluated best in CM projects, in which they have an active role in developing client requirements into workable designs, and further steering the packaged procurement and construction in close collaboration with the owner, contractor(s), and designer(s). In D-B-B the consultants' role is more limited, and may from the clients' perspective provide little added value or concentrate on claim management. Collaboration with the contractors is perceived better in D&B projects than in D-B-B project by all other participants. D&B is the delivery method where the contractor has the main role for innovation, design management, and arranging the works according to their best practices. Apparently, both the consultants and contractors seem most collaborative in the delivery methods where they have the most responsibility for the project success.

The designers, in contrast, show no real difference between the delivery methods in any of the three incoming feedback streams. Notably, the collaboration with the designers is consistently evaluated on a lower level than collaboration with the other participants. The reasons may include the inflexible design culture in D-B-B and unfamiliar working practices in modern delivery methods. Furthermore, the design contracts in Finland follow the general rules and task directories, and include little variation or promotion of flexibility and collaboration. From the designers' perspective, the CM and D&B projects' working methods mean withstanding and thriving with the cyclical work and typically re-work. Akintoye and Fitzgerald (1995) report that in D&B projects the architects may experience contractors as barriers in communication between the owner and the designers whereas in D-B-B project they have direct interaction with each other. This study reveals that direct interaction does not improve the owner's or any other party's evaluation of the collaborative relationship with the designers but it does improve the designers' evaluation of both contractors (in D&B) and consultants (in CM).

Often designers are not adequately aware of the project goals, project-specific management practices, and other parties' requirements for collaborative working, which is a design management problem. The participants' individual expectations and requirements for collaborative relationships with each other is demonstrated in, for example, CM projects where the designers evaluate their collaboration with consultants and contractors on a high level (4.69 and 4.59, respectively) but the consultants and contractors evaluate their collaboration with the designers on a mediocre level (3.72 and 3.99, respectively). From CM project owners the designers receive a fairly high mean score (4.17) for collaboration, i.e. in CM projects designers seem to be able to meet well the owners' expectations for collaboration but not as well the consultants' and contractors'. CM projects enable late and changing requirements for designs, which the owners perceive as flexible service but the consultants and contractors may experience conflicts with the designers.

From research perspective, the feedback system opens numerous avenues for further studies. For example, some the findings presented in this paper may be explained by the different nature of the projects that are typically, or in these samples specifically, carried out in each delivery method. The nature of the project, such as infrastructure/building, private/public, or small/large was not handled as an explanatory factor in this study. Doing so may further help understanding the collaborative working in construction project organizations. Expectedly, some of the most valuable research paths will be found to utilize the satisfaction information retrieved from the bi-directional, multi-relational evaluation system as a basis for deeper inquiries with interviews. Whereas the evaluation system and quantitative results will answer the questions 'what' is happening within the relationships, qualitative supplementary research is needed to answer 'why' these expressions of satisfaction or dissatisfaction take place as they do and 'how' should we respond to the positive and negative feedback.

CONCLUSIONS

This paper compares the levels of satisfaction with the collaborative relationships in construction project organizations in three alternative delivery methods. The data includes over 1600 bidirectional evaluations from the Finnish project feedback tool ProPal. The overall satisfaction to the collaboration between the participants is good to excellent (between 3.71 and 4.76 on a 1-5 scale). The satisfaction to collaboration was expectedly identified lowest in D-B-B in many relationships. The owners' and the designers' satisfaction with consultants and contractors is lowest in D-B-B. The consultants are less satisfied with contractors D-B-B than in D&B. In general, the worst satisfaction levels were found in the relationships with the designers. Contractors, on the contrary to a common believe, performed well. Consultants share opinions from mostly very good evaluations to some of the lowest in the data from the owners and designers in D-B-B projects. Both consultants and contractors get best scores in the delivery method where they have the major role for project success, i.e. in CM and D&B, respectively.

The ProPal tool will provide data for further analyses on the collaborative relationships and help finding the pros and cons of delivery methods. The benchmarking and analysis that the

ProPal tool offers will help construction-related companies to enhance their competitive advantage in service-oriented project business. Recently, several collaboration-oriented delivery methods and management frameworks have been developed and implemented. The pioneering project alliances in Finland are in progress. In a few years' time ProPal may provide information on their specific successes and challenges. Normally the methods are built to include owner-consultant-contractor relationships but the designer's critical role for the success of modern delivery methods is in most cases forgotten.

The results provided in this paper suggest that in Finland the contractors' collaborative relationships work better than expected but the designer's role in the collaborative project organization should be more prominently acknowledged and developed. As the lowest scoring relationships in the project organization, the designers' collaborative relationships have the highest potential for overall project performance improvement. The owners' collaboration with consultants in D-B-B projects is another potential development area.

REFERENCES

Akintoye, A. & Fitzgerald, E. (1995) Design and build: a survey of architects' views. *Engineering, Construction and Architectural Management*, 2(1), pp.27-44.

Chan, A.P. & Chan, A.P. (2004) Key performance indicators for measuring construction success. *Benchmarking: An International Journal*, 11(2), pp.203-221.

Cherns, A.B. & Bryant, D.T. (1984) Studying the client's role in construction management. *Construction Management & Economics*, 2(2), pp.177-184.

Construction Management Association of America (CMAA) (2003) *Construction Management Standards of Practice*, 2003 edition. USA, Virginia, Construction Management Association of America.

Dorsey, R.W. (1997) *Project delivery systems for building construction*, Associated General Contractors of America.

Egan, S.J. (1998) *Rethinking construction: the report of the construction task force*, H.M.S.O.

Gransberg, D.D., Badillo-Kwiatkowski, G.M. & Molenaar, K.R. (2003) Project Delivery Comparison Using Performance Metrics. *AACE International Transactions*.

Grönroos, C. (2000) *Service Management and Marketing –a customer relationship management approach*, 2nd ed. John Wiley & Sons, LTD.

Hale, D.R. et al. (2009) Empirical Comparison of Design/Build and Design/Bid/Build Project Delivery Methods. *Journal of Construction Engineering & Management*, 135(7), pp.579-587.

Hayden, J.W.M. (2004) Human Systems Engineering: A Trilogy, Part I: Elephant in the Living Room. *Leadersh. Manage. Eng.*, 4, p.61.

Kiiras, J., Stenroos, V. & Oyegoke, A. (2002) *Construction management contracts - forms in Finland*, Helsinki University of Technology.

Kärnä, S. (2009) Concepts and Attributes of Customer Satisfaction in the Construction. Doctoral dissertation, TKK-R-DISS-2. Helsinki University of Technology.

Latham, S.M. (1994) Constructing the team: joint review of procurement and contractural arrangements in the United Kingdom construction industry ; final report, H.M.S.O.

Leung, M., Ng, S.T., and Cheung, S. (2004) Measuring construction project participant satisfaction. *Construction Management and Economics*. 22, pp. 319–331.

Liu, A.M.M. and Walker, A. (1998) Evaluation of project outcomes. *Construction Management and Economics.* Vol. 16, pp. 209-216.

Morledge, R., Smith, A. & Kashiwagi, D.T. (2006) *Building procurement*, Wiley-Blackwell.

Nzekwe-Excel, C. et al. (2010) Integrated framework for satisfaction assessment in construction sector. *Journal of Engineering, Design and Technology*, 8(2), pp.168-188.

Pinto, J.K. and Rouhiainen, P. (2001) Building Customer-Based Project Organisation. Wiley. London

Pryke, S. & Smyth, H. (2006) Scoping a relationship approach to the management of complex projects in theory and practice. In S. Pryke & H. Smyth, eds. *The management of complex projects: a relationship approach*. Oxford: Wiley-Blackwell.

Robinson, H.S. et al. (2005) Business performance measurement practices in construction engineering organisations. *Measuring Business Excellence*, 9(1), pp.13-22.

Ward, C. S., Curtis, B., and Chapman, C. B. (1991) "Objectives and performance in construction projects." *Construction Management and Economics*. 9, pp. 343–354.

Wilkinson, S. (2001) An analysis of the problems faced by project management companies managing construction projects. *Engineering, Construction and Architectural Management*, 8(3), pp.160-170.

Yasamis, F., Arditi, D. and Mohammadi, J. (2002) Assessing contractor quality performance. *Construction Management and Economics.* 20, pp. 211-223.

INDUSTRIALIZED HOUSE BUILDING IN SWEDEN: A STRESS TEST APPROACH FOR UNDERSTANDING SUCCESS AND FAILURE

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During the last 50 years industrialized house building in Sweden has had two faces. The first is a series of failed large scale projects that tried to introduce a more industrialized approach to the building of multi-family houses. The second face consists of a number of manufacturers of single family houses that for more than 50 years continuously has produced what in Sweden is called "catalogue houses". Based on information about one firm in each category the aim of the paper is to explain these successes and failures using a "stress test" approach focusing on how the different systems can handle stress in the form of changes in the business cycle, changes in tastes, technological problems and problems with suppliers. The main conclusion is that that the failed systems for industrialized multi-family housing were not designed in such a way that it could handle different types of stress.

KEYWORDS: Industrialization, house building, Sweden, failure, success

BACKGROUND AND PURPOSE

Industrialized building of residential houses - which here means off-site production of large elements - has been a controversial area at least since the Second World War. This production method can be defined in a number of ways. A distinction can e.g. be made between closed systems where the whole structure is produced in one factory, and open systems where different components made by independent suppliers can be assembled into a ready house. Gibb (1999) makes a distinction between non-volumetric, volumetric and modular building. This will be returned to in section 3 below

The history of industrialized production of residential housing is full of ups and downs. Bullock (2009) describes the development in France: the large investments and hope for industrialized production in the early 1950s and then a quick decline caused by a number of problems that reduced the economic viability. Lind (2007) shows that whenever there has been problems with high prices for new houses or quality problems in Sweden, one proposed solution has always been a more industrialized construction process. This happened in the 1960s, in the 1980s and once again since the year 2000. But every time it seems to fail. A questionnaire to people in the construction industry in the UK (reported in Nadim & Goulding (2010)) shows a typical split picture where most agree "in theory" that increased off-site production is good and will increase, but there is at the same time a skepticism when in comes to whether these will in fact happen (see also Pan et al 2007).. It was, however, high on the governments agenda. Blismas & Wakefield (2009) describe a similar situation in Australia.

High hopes for the future, but not much is happening. Davidson (2009,p 42) sums up: "The recent (and not so recent) history of manufactured construction is rich in examples of failures"

Industrialized house building seems to have been more successful in Hong-Kong, Korea and Japan. Gann (1996) described how Toyota transferred their production skills in car manufacturing to producing residential housing. Jaillon & Poon (2009) describes how prefabricated residential building systems have been very important in public-housing projects in Hong Kong since the mid 1980s and that it has improved safety and quality in some respects , but that it has not reduced costs (p 247). Shin et al (2008) described how the Korean house building industry develops from mass production to mass customization.

During the last 50 years industrialized house building in Sweden has had two faces. The first is a series of failed large scale projects that tried to introduce a more industrialized approach to the building of multi-family houses. The last two of these failures were NCC-Komplett and Open House that will be described briefly in section 4. The second face consists of a number of manufacturers of single family houses that for more than 50 years continuously has produced what in Sweden is called “catalogue houses”. One of these companies will be described below. Most of these produce for the Nordic market even though there is one successful company that produce for the Japanese market only (TomokuHus). The purpose of this article is to discuss how these failures and successess can be explained.

The structure of the articles is as follows. In the next section some more comments are made about the concept of industrialized house building. The theoretical framework is described in section 3. Section 4 and 5 described the failed projects related to multifamily housing and the successful producers of single-family houses. The information about the failed projects is taken from secondary sources further described in section 4, while the study on the producer of single family houses primarily is based on a series of interviews. Section 6 related the results to the theoretical framework and in section 7 contains concluding comments.

WHAT IS INDUSTRIALIZED HOUSE BUILDING?

In this article a rather basic interpretation of industrialized house building will be used, focusing on two characteristics:

- The customer has a limited number of “given” (basic) products to choose between. The development during the last decade has been that the customer has been given more options to choose between and the term mass customization has been introduced. But still there is a number of given basic “models” to start from and a number of adjustments that are possible for the customer. Among the Swedish manufacturers of "catalogue houses" some (high-end) firms give more room for customer choice, some give less room - and this is of course reflected in the price.

- The house is manufactured in “blocks” ("flat" or "volumetric") in an ordinary plant and then assembled at the site where a foundation has been laid. The assembly usually takes only a few days. There are some differences between the firms in how large the “blocks” are and how much is done at the site, but there should be a significant difference between the cases that here is called industrialized and standard house production where the work at the site takes several months, even if a lot of prefabricated parts also are used in those cases. Davidsson (2009) is of course right in saying that " manufactured construction should be viewed instead as a continuum" (p 47), but in this article the focus in to compare one extreme where very little other than assembly of large parts is done on site to a more standard case where a lot of more direct production is done on the site.

THEORETICAL FRAMEWORK

The theoretical framework used in the article is based on the combination of standard economic theory and transaction cost theory, especially in the tradition of Oliver Williamson. The best example of this fusion of standard economics theory and transaction cost theory can be found in the book "Economics, organization and management "by Paul Milgrom and John Roberts (1992). The book starts with a detailed analysis of the fur trade in 1800-century Canada, comparing a British state controlled company with a local challenger. The central point in their analysis is that the second company came out as winner because it had created stronger incentives for the participants and was more flexible in the sense that it had a structure that could react quicker to new information about local circumstances. In the same way as they tried to understand why one type of organisation was more successful and another less successful in this paper the challenge is to understand why one type of approach regularly seems to fail while another survive.

The approach here is also similar to the one used in Warsame (2009) who discuss supply structure in the construction sector partly from the perspective of how they can handle uncertainty and keep a high level of competence on a changing market.

It will be argued below that similar differences in incentives and flexibility can explain why some attempts to industrialize house building fail and some success. Another way to put this, in line with the recent discussion about evaluating banks after the financial crises, is in terms of "stress tests" of a firm. The basic hypothesis in this article is then that if we want to understand why some firms, or types of production, fail rather quickly, while other survive over a large number of years, we should look at how they handle various types of "stress". In the analysis below the focus will be on whether the firms can handle the following types of situations.

1. Housing construction is a cyclical activity and changes in the business cycle tend to affect housing production comparatively more than other sectors. This is rather logical given that there is a large stock of the product, and if demand falls then the current stock might be enough. For products that are quickly consumed the reduction in sales might be of the same order of magnitude as the change in GDP while industries that produce goods with a long life – like housing and auto production – typically fall many times the fall in GDP. As an example it can be mentioned that housing production in Sweden in 2009 fell with 40% while GDP fell with 5%.

2. Housing is a heterogeneous commodity and changes in tastes or in relative prices can suddenly lead to a fall in demand for the firms´ products, even though housing demand in general has not fallen.

3. A third type of stress concerns quality problems in the product. For a number of different reasons there might be technical problems related to specific parts and components, or to the quality of the assembly.

4. Related to the third kind of stress are problems with subcontractors or suppliers of different types of materials. The problem can concern the quality of the product but also that deliveries are not coming on time.

A successful firm must be able to handle all these types of risk, and this can take a number of different forms. The risks might e.g. be spread among a large number of the actors involved, or the risk might be reduced by a system that identifies them quickly and handles them before they get to large.

INDUSTRIALIZED HOUSE BUILDING IN SWEDEN: TWO RECENT FAILURES

Several reports published during the last ten years (e.g. SOU 2002:11) argued that a more industrialized house building would be an important measure to reduce cost and increase quality in housing production. Several big projects were also started; the two largest and most publicized were *NCC Komplett* and *Open House*. In 2008, however, both of these were closed down. In this section a short description will be given of these two project (see e.g. Apleberger et al 2007 for a more detailed description). Explanations for the failures will be discussed in section 6.

NCC Komplett

NCC is one of the "big four" companies on the Swedish construction market. In 2002 they started to develop a new housing concept where multi-family housing in steel and concrete would be produced in large elements in a factory in Hallstahammar, located strategically to be within transportation distance from a number of urban areas. In the factory, walls, floors and roofs were build and also kitchen units. Bathroom units were bought from independent suppliers according to the design determined by NCC. The factory in Hallstahammar used a typical industrial process with conveyor belts, and there was also a number of automated steps. The design could be adapted in a number of ways according to the demand of the customer and the idea was that nobody should be able to see on the final product that the house was built in a factory. An advanced integrated ICT-system was used during the design, production and assembly stage.

The components were transported by truck directly to the site using a "just in time" system. At the site the foundation was built in the usual way and then a large tent was erected so the assembly could take place protected from rain and snow.

Around 300 million SEK (30 million €) was invested in the project and the investment was calculated to be profitable with a production level of 1000 housing units (apartments) per year. This can be compared to the total volume of housing production in Sweden which is around 30 000 units, of which roughly 50% are multifamily housing. When the factory was closed down in 2008 around 300 units had been produced.

Open House

The Open House concept was based on a patent from the early 1990s based on a steel structure. A contract was written around the year 2000 with the municipality of Malmö to build 1200 housing units in a southern suburb of Malmö, close to the new bridge to Denmark. A Norwegian housing company, with more resources to invest, bought the concept at the same time and was financing the project. A factory was rebuilt to produce the volume elements that were the core of the concept, but the investment was rather modest compared to the investment in NCC Komplett. A considerable amount of work was however done on site, e.g. the facades, in order to make the houses more varied. Initially the plan was to produce at least 50% of the value in the factory, but step by step this level was reduced and in the units produced just before the factory was closed down, 65% of the work was actually done on site.

When the Malmö project was completed in spring 2008 the factory was closed down and beside the 1200 units in Malmö only 180 units were produced and transported to Norway to a project there carried out by the Norwegian owner.

INDUSTRIALIZED HOUSE BUILDING IN SWEDEN: A SUCCESSFUL PRODUCER OF "CATALOGUE HOUSES"

Introduction

The firm, that we call A, was initially working with different types of carpentry but entered the market for "ready" houses in the 1990s. Many of the people has however a longer history in the area of producing "catalogue houses" as the firm partly took over machinery and staff from companies that went bankrupt in the early 1990s when there was a serious economic crisis in Sweden and housing production almost fell to zero. The firm has had several different of owners in recent years, the effect of which will be returned to below. Today it is owned by a large owner of forests, sawmills and pulp plants.

The information below is primarily based on a number of interviews with leading staff in the company. The research assistant in the project had also worked in the company for several years so we also had access to some "inside information".

The houses are constructed in wood and they are built in a factory in the countryside in southern Sweden. The houses are built in a number of sections and transported by truck and assembled on site. A number of Swedish firms are active on this market and Firm A is on the "high" end of the market, which means that the customer has a considerable influence over the design of the house and therefore the price is relatively high. (A new low-price version will however be put on the market.

The production level is around 400 houses per year. As the firm uses a lot of subcontractors the number of houses gives a better picture of the size of the company than the number of employed.

To understand how the firm works three processes will be described below, the customer related process, the production process and the product development process.

The customer process

The customer can find the company through the company website and through around 30 sales offices in major cities in Sweden. With the help of an IT-tool on the website and the sales staff the customer can design their own house within the framework given by the firm´s platforms. Usually the customer has already found a lot to put the house on, but Firm A also offer a number of lots in different parts of the country – typically in cooperation with a landowner or developer.

The company´s salesperson is actually the central person during the whole process until the house is ready. It is the salesperson that is contacted by the customer if anything is unclear when the specific design should be implemented, and the salesperson is the link between the customer and the head office where technical specifications are developed and where material and components are ordered and put together.

Formally the customer has one contract with Firm A concerning the delivery of the house to the lot, and another contract with an independent subcontractor that assembles the house and is responsible for some remaining works. Each sales office has contacts with a number of "approved" subcontractors that has been given training by Firm A.

This is a rather unusual structure in the industry where most companies use their own staff when assembling the house and offer a "turn-key" solution to the buyer. Possible explanations for the structure chosen by company A will be discussed below.

The salespersons are primarily paid by commissions on houses sold and there is almost no fixed pay. Typically the commission is pooled in each sales office and also partly funded during good years to be used in the bad years.

The production process

The final design of the house is made after a series of interactions between the customer and an architect working at firm A, with the salesperson as a middleman. All three parties typically meet early in the process. The role of the architect is to find a solution that satisfies the demands of the customer within the firm's production platform. This platform is very flexible except that the frame should have certain measures, the basic material should be wood and also that certain components – e.g. windows – should be possible to deliver by the subcontractors that the firm A works with. (If the customer has found another supplier and those components fit within the platform of the firm then there is no problem to choose that alternative instead.)

More detailed drawings are made at a rather early stage in order to get a building permit by the municipality, and this process is handled by Firm A on behalf of the customer. At the same time production is prepared by specifying components and materials needed, both in the factory and during assembly and for remaining works on site.

For a number of components – windows, doors, bathroom equipment, kitchen equipment – company A works closely with a small number of basic suppliers. Firm A has framework agreements with a number of these suppliers, e.g. guaranteeing quick delivery of products even if demand of the products has gone up. Firm A also works together with these suppliers to develop the suppliers products in order to better meet the demand that firm A has identified on the market through e.g. their sales staff. Representatives of Firm A visit the most important supplier maybe several times per year to discuss product development and other issues.

In the factory of firm A, the different parts of the house are assembled according to the specifications. As the architect and the technical designer are working in the same building complex, any unclear points that arise during the actual production process can easily be solved. As the head architect and designers have many years of experience they also know very well what can be smoothly produced given the limitations of the factory, and this is already taken into account in the basic design. As each house is adjusted to the preferences of the customer there are always some unique features that might create problems.

The factory is what could be called a “low-tech” factory – and works much as a traditional carpentry factory without any more advanced automated production lines and robots. The firm describes themselves as a “handicraft” company – meaning that most of the work is made by people using rather basic traditional tools.

The communication system used during design and construction is also very traditional. Paper drawings, telephones and face-to-face interaction is very important for transmitting information – even if emails become more and more important! The website of the firm is, as mentioned above, very advanced and there are a lot of examples of possible designs presented in order to inspire the potential customer. In this aspect it is similar to the Korean firm described in Shin et al (2008) even if the ICT-system during production is not so advanced in Firm A.

The product development process

Customer preferences and demand can change quickly and it is deemed very important to continuously develop new products within the established framework. Recently the company has e.g. launched a special "green" version with very low energy consumption.

The inspiration and ideas for the new products come from two main sources. The first is that the company´s chief architect visits national and international fairs, and follows designers' magazines to see what is presented as fashionable and what might be the coming trends. The second channel for information about needs for product development is the sales-persons contacts with prospective customers and their discussion about the company´s products. As the sales person works on a commission basis they have a strong incentive to pass this information on to the head office of company A.

HOW CAN FAILURE AND SUCCESS BE EXPLAINED?

The main idea in this section is the success and failure of the companies/projects described can be understood in the same way as the companies compared in Milgrom & Roberts (1992). A firm that creates strong incentives and is flexible enough to adjust to local information and structural changes will survive. Before this is developed more in detail below some other important differences should be noted.

The market that they sell on

Company A sells their houses to single households over a large part of Sweden. The have – compared to the size of the company - a large sales staff with direct contact with potential customers. As each household can be expected to have somewhat different preferences and also be affected by the business cycle and various kinds of trends in different ways, this reduces the risk of sudden large falls in sales. We can think in terms of the law of large numbers where some changes on the individual level cancel out and reduces fluctuations. As mentioned above – the sales staff in company A has a strong incentive to quickly identify changes in preferences and/or in willingness to pay and put pressure on the company to develop new products more in line with demand.

Both NCC Komplett and Open House were producing multi-family housing and this means a smaller number of projects with a rather large number of apartments per project. Therefore these is a rather small number of potential buyers and this makes it very difficult to predict demand and very difficult to reduce fluctuations in demand. If they get a specific project or not can have large effect on the volume of production that year. Neither NCC nor Open House had a large sales staff that worked with potential buyers, trying to secure a demand for their product. A complicating factor is that a considerable number of possible customers were municipal housing companies that according to the procurement act must use competitive tendering. They are not allowed to choose a specific company just because they like their products.

NCC had the possibility to reduce some of this uncertainty as they also act as developer of condominiums, but still the city planning department in the municipalities in Sweden has a strong influence on the design of new buildings. They can say no to a specific proposals if they are sceptical to the design. In some municipality the City Architect has very strong views on the design of new buildings and he or she may be sceptical to "factory made" buildings. A study by Unger (2006) also indicates that companies like NCC might not want to put much pressure on their local project managers or regional organizations to use a certain type of houses. If the regional office and project managers are the ones who have the best contact with the municipalities and with the local market, and can be very risky to put high pressure on them to use a certain type of house.

To sum up, it can be said that neither NCC-Komplett nor Open House could establish the same direct contact with the final buyer and they were dependend on a much smaller number of decision makers which made demand much more uncertain. It would e.g. be easy for company A to introduce discounts if demand suddenly was falling, but this would not have an effect if the planning department in the municipality did not like the design.

The technology leap

Toyota has often mentioned as the paradigm of efficient production, but what is often forgotten is that it took more than 20 years to develop this position through a number of steps. Comparing especially NCC Komplett with Company A, it is clear that Company A is much more similar to Toyota in this respect.

Even though company A is less then 20 years old, most of the management staff and the production structure have a much longer history in the business. When they develop new models and open up for more choices for the customers they always make sure that they can produce them with the existing technology and the existing human capital. There are no great leaps in technology but only small steps to improve the product and the production methods. The risk from a production perspective is very low.

NCC Komplett (and partly Open House) developed completely new complex products and – at least in the case of NCC-Komplett - a new production method compare to usual way of building multi-family houses. New here of course measn new for the construction sector. While Company A was a “reformist” – taking small steps at a time – NCC Komplett and Open House aimed a “revolutionizing” the Swedish house building sector in the sense of introducing a very different division between on-site work and what was delivered ready to the site. Both NCC Komplett and Open House underestimated the problems with implementing such a big change in the production methods. NCC Komplett had serious quality problems and in both cases more adjustments and more work had to be done on site than expected. Another way to put this is the firms launched very risky projects – and then one should not be surprised that they failed.

In the debate about industrialized house building in Sweden a common argument is that the Swedish market is too small to be able to make the necessary large investments profitable.

The capital requirements are simply too big for the small market. It seems, for example, to be a rather optimistic calculation when NCC calculated that their factory would produced between 5-10% of all multifamily houses in Sweden, and roughly 10-20% of all houses within possible transportation distance from the factory.

If we assume that the firms are rational in their decision to close down the factories, they should however *see the investments already made as a sunk cost.* This means that it is rational to continue production as long as the revenue from sales covers the variable costs, primarily the cost of labour, materials and transportation. The fact that the projects were given up *after* the investment was made, indicates that there were serious problems of the type sketched above that made the owners predict *that the revenue would not cover the operating costs*. In the concluding analysis we will return to this point.

The stress test

The information presented above makes it possible to carry out a stress test of the type sketched above.

1. *The business cycle*: One important difference described above is that the demand for company A´s products can be expected to fluctuate less than for the two failed companies. It is also the case that when demand and production falls in company A, the loss in revenue will directly be spread over a large number of actors: The salespersons will get lower commissions, the independent contractors working with transport and assembling the houses will get less work and all of the suppliers will of course get less orders. Both NCC Komplett and Open House had a relatively larger share of staff employed themselves with a fixed monthly pay. As the value added in their factory was higher, it also meant that relative cost reductions from less orders to suppliers were smaller. The reasons why company A choose a model with independent local contractors instead of having their own staff for assembly were probably a combination of reducing the fixed costs and the idea that the salesperson should be in focus: The salespersons had a strong incentive to make sure that the recommended local contractor made a good job, as that would affect the reputation of the company on the local market. A former owner of company A had, a few years ago, tried to force company A to use contractor´s also owned by this person, but this had led to a number of problems as these contractor´s were not as loyal to the salesperson and e.g. did not carry out all work in time.

2. *Shifts in tastes*: The close contact with the market, and the possibility to make rather large adaptations in the product when a potential customer wanted this, reduced the "preference risk" for company A. The strong incentives, especially for the sales staff, are important in this context. Even if NCC-Komplett and Open House also had a flexible product, still the structure was more fixed and the possibility to make quick adjustments was smaller due to the production technology.

3. *Technical quality problems*: Company A started with an established type of product and was very careful in their innovations to make sure that it could be produced with the existing technology. Both NCC Komplett and Open House used much more innovative techniques, and they were therefore also more risky. In both cases there were also a number of problems described above. All these problems lead to increasing costs. Some people have in the current debate argued that NCC gave up to early and if they had only continued for some more years they would have been able to increase quality and productivity in the factory and make production more profitable. Our guess is that the owners on NCC saw it as too risky to continue because of a combination of demand and supply factors.

4. *Problems with suppliers and subcontractors*. Company A used several suppliers for all products and rather short contracts that made it possible to change suppliers quickly if company A was not satisfied with the products, or if other suppliers had developed better products. As mentioned above they had problems a few years ago when the owner at that time wanted company A to use "his" construction firm for the assembly process. Company A. As both NCC Komplett and Open House used more in-house production they did not, as far as we know, have any serious problems with suppliers or subcontractors.

CONCLUDING COMMENTS

Davidson (2009, p 42) writes
"The recent (and not so recent) history of manufactured construction is rich in examples of failures; In almost all cases, problems stem from a poor three-way fit between the techniques proposed, the power and the position of the innovator in the local building industry , and the organizational design supporting the would-be innovative proposals."

Another way to put this is, as argued above, that the new systems for industrialized housing were not designed in such a way that it could handle different types of stress. It is interesting to compare with the successful company A in several respects:
- Company A spread risk among a larger number of involved actors and thereby also created stronger incentives.
- Company A had more direct contact with the market and could both learn from and influence demand to a higher degree.
- Company A used established techniques and also more products bought from supplier and subcontractors with which company A had long term relations.

Some Swedish experts have argued that NCC closed down too early – they should have continued because after a few years the mistakes would have been fixed and costs would have fallen. The question is however if this would have happened so quickly as to make the net present value of continuing positive. Our belief is that the management made the right decision because the combination of high fixed costs, an unpredictable market and a risky technology probably would lead to losses also in the future.

Perhaps the conclusion should also in this area be that revolutions are very difficult. The likelihood of failure is high when a company introduce a radically new way of producing. More interesting developments in the direction of industrialized house building are then to experiment with smaller steps, where e.g. somewhat larger components are bought from subcontractors. Beim et al (2009) describes how firms start to specialize in producing specific elements, e.g. balconies and bathrooms. A more industrialized production process on site is then also more interesting than dreaming of large quick changes in what is produced off-site and what is produced on-site.

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REFERENCES

Apleberger, L., Jonsson, R & Åman, P. (2007), Byggandets industrialisering: Nulägesbeskrivning. FOU-Väst, Göteborg.

Beim, A., Nielsen, J. & Sanchez Vibaeck. K. (2009), *Three ways of assembling a house.* CINARK, Köpenhamn.

Blismas, N. & Wakefield, R. (2009 Drivers, constraints and the future of offsite manufacture in Australia. *Construction Innovation*, Vol. 9 No. 1, 2009pp. 72-83

Bullock, N. (2009), 4000 dwellings from a Paris factory: *Le procédé Camus* and state sponsorship of industrialised housing in the 1950s. *history arq* . vol 13 . no 1.

Davidsson, C. (2009 The challenge of organizational design for manufactured construction. *Construction Innovation*, Vol. 9 No. 1, pp. 42-57

Gann, D. M. (1996) Construction as a manufacturing process? Similarities and differences between industrialized housing and car production in Japan. *Construction Management & Economics*, 1996, vol. 14, issue 5, pages 437-450

Gibb, A.G.F., *Offsite fabrication – pre-assembly, prefabrication & modularisation*, Whittles Publishing Services, 1999,

Jaillon, L. & Poon, C. S. (2009) The evolution of prefabricated residential building systems in Hong Kong: A review of the public and the private sector. *Automation in Construction* 18 239–248

Lind, H. (2007) Bygg och boendekostnader i ett historiskt perspektiv, In *Familjebostäder 60 år*, Stockholmia förlag.

Milgrom, P. and Roberts, J.(1992*)* *Economics, organization and management*. Prentice Hall, New Jersey.

Nadim, W. & Goulding, J. (2010) Offsite production in the UK: the way forward? A UK construction industry perspective. Construction Innovation, Vol. 10 No. 2, pp. 181-202

Pan, W., Gibb, A. & Dainty, A. (2007). Perspectives of UK housebuilders on the use of offsite modern methods of construction, Construction Management and Economics 25(2), pp. 183-194.

Shin, Y. et al (2008) Application of information technology for mass customization in the housing construction industry in Korea. *Automation in Construction* 17 pp 831–838.

SOU 2002:11, *Skärpning gubbar! Om konkurrensen, kvaliteten, kostnaderna och kompetensen i byggsektorn*. Stockholm.

Unger, C. (2006) *Industrialised house building: fundamental change or business as usual?* Doctoral Disseration, KTH, Stockholm

Warsame, A. (2009) Organizational modes in the residential building sector in Sweden. *Construction Management and Economics*, Volume 27, Issue 2, 2009, Pages 153 – 163

PERFORMANCE MEASUREMENT SYSTEM FOR BENCHMARKING IN CONSTRUCTION COMPANIES

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The Brazilian real estate sector experiences a period of strong growth, greatly encouraged by the abundance of financing, capitalization of construction companies on stock exchanges, extension in the stated periods for payment, flexible credit and investment in public housing. In this context, performance measurement through indicators is one of the main contributions that can be implemented to support the necessary modernization of the construction industry, also helping to detect opportunities for improvement through comparing performance (benchmarking). The purpose of this paper is to discuss the development of a performance measurement system for benchmarking in construction companies, whose standard methodology of data collecting and processing allowed the comparison of performance and the generation of benchmarks for the sector. The research methodology included accomplishing the following stages: making a diagnosis in order to identify the performance measurement systems adopted by construction companies, setting a standard system of indicators, deployment of the standard indicators in 13 (thirteen) selected construction companies in the city of Recife/PE and collecting results. The obtained results helped establish a standard for undertaking benchmarking, define reference values, and also identify a set of differences in some of the adopted indicators and a collaborative environment among the companies involved.

KEYWORDS: performance measurement, indicators, benchmarking, construction.

INTRODUCTION

Brazilian civil construction is undergoing a time of strong growth. After a period of uncertainties caused by the 2008 international economic crash, the sector seems to resume growth, boosted by prospects of new public investments in housing and increased property credit by the banking institutions. The production chain of civil construction today is one of the most robust sectors of the country’s economy. After transactions of R$ 224 billion, or 8.3% of the Brazilian GDP in 2009 – including in this figure not only the billing of the construction companies and contractors, but also the building materials, services, machinery and equipment segments, for example – it is expected to have a growth of over 10% in 2010 (Valor Setorial, 2010).

Growth in Northeast Brazil, including the state of Pernambuco, has been above the national average and is remarkable because historically the region still has a major shortage of housing and infrastructure. Federal government data show the Northeast as the main target for R$ 34 billion from the My Home, My Life programme because of the housing deficit of 2.4 million homes, corresponding to 34% of the country. The region received 71% of the property credit volume in 2009 (Construção Mercado, 2010).

This is the scenario where construction companies today are finding increasingly tough competition, in conjunction with the vital obligation to meet the stakeholders' requirements. Consequently, there has been growing interest by the different agents in the project accompanying the performance of construction companies and also by other stakeholders. As a result, many construction companies have given more importance to developing and implementing performance measuring systems, since they provide key information for planning and control of the managerial processes and for monitoring the strategic objectives and goals (Costa et. al., 2005).

Performance measuring is a process in which the decision is what to measure and from there collect, process and assess data. According to Neely (1998), there are many reasons why organisations measure performance: to establish position; because the organisation or others want to be able to benchmark performance; because measures can be used to communicate priorities; because measures provide a means of motivating people to look for ways of improving performance; among others. These reasons can fall into of four distinct categories: check position, communicate position, confirm priorities and compel progress.

Performance measurement is only a part of the improvement process. It is important that actions be taken based on the results, otherwise the measures are meaningless, costing money to obtain and not adding value to the business (Bourne et al., 2000). As stated in Lantelme et al. (2001), measurements must be grouped to form a cohesive and balanced system, with financial, operating and product and process indicators that assess the efficiency and effectiveness of the product, thereby helping to control key processes and detect possible improvement by comparing results (benchmarking).

Comparing performances between companies with a view to establish benchmarking has been much more frequent in the civil construction sector. A series of benchmarking projects have been developed in different countries in the world, namely Brazil, Chile, Denmark, Holland, Portugal, UK and USA. In a report published in 2005 the Dutch PSIBouw programme (Bakens al., 2005) reviewed a series of performance measuring projects and benchmarking in the construction sector, coordinated by government agencies or research institutes with a variety of objectives, ranging from improving performance to certification of the companies. Some of these projects, such as the Key Performance Indicators – KPI (Constructing Excellence, 2010) and the National Benchmarking System of Chile (Corporación de Desarrolo Tecnológico, 2005), undertook collaborative benchmarking processes that involve companies operating in similar business segments and that look to compare results and exchange management and technological practices.

Costa et al. (2005) claims that the existence of an increasingly high number of benchmarking programmes in civil construction around the world indicates the sector's strong interest in developing and taking part in projects focusing on this topic. The main reason for this interest is the fact that these projects are regarded as a form of upgrading the sector against the problems such as resistance to change, fragmentation of the supplies chain, little use of technologies, and the absence of standardising processes and products.

BENCHMARKING IN BRAZILIAN CIVIL CONSTRUCTION

Some specific studies for civil construction have been carried out to collect data and generate information on measuring performance in the sector. Two are worth mentioning because of their coverage and level of detail.

The first was a national survey coordinated by the University of São Paulo (USP) and carried out in various institutions in the country (16 universities, 52 construction companies and 128 researchers), which were looking for alternatives to reduce material waste on jobsites. This survey involved around 80 jobsites and from the various results obtained, it is worth mentioning that a set of indicators (global and partial) was established to help understand the main portions of material losses. The survey consisted of a benchmark to undertake other surveys, principally for the opportunity to collect loss indicators in a standardised manner and then create reference values.

The second Brazilian experience worth mentioning concerning benchmarking in civil construction was carried out by the *Núcleo Orientado para a Inovação da Edificação* (NORIE) of the Federal University of Rio Grande do Sul (UFRGS), with a view to disseminating performance measuring principles and practices associated with the new management concepts for construction companies. The project began in 2003 for developing a Quality and Productivity Indicator System for Civil Construction using information technology (SISIND-NET), and on which two mechanisms were developed to facilitate the inclusion of performance measuring in construction companies, and to encourage sharing and comparing information relating to the indicators and management practices (Costa, Berr & Formoso, 2007).

The first mechanism was to create a benchmarking club with 18 construction companies in the city of Porto Alegre, in order to discuss management principles and best practices by incentivising performance measuring and sharing information between companies from the quantitative (indicators) and qualitative (best management practices) viewpoints. The second mechanism consisted of developing a database called Online Indicator System that enabled the companies participating in the project to enter data directly and access the results of these indicators to compare performances. The member companies were given a Use Handbook structured to give details of the information collection procedure and the collected data forwarding process through the online system.

OBJECTIVE

The objective of this article is to present the development of a performance indicator system for civil construction companies, whose standard data collection and processing methodology enabled the benchmarking practice and generation of reference values for the sector.

METHODOLOGY

This study was developed by adopting a methodology with four different stages.

Stage 1: diagnosis – undertaking an exploratory study to identify the performance indicators included in the quality management systems of construction companies in the city of Recife, Pernambuco stage. Stage 2: structuring the standard performance indicator system – selecting the indicators comprising the system and defining the standard data collection methodology. Stage 3: implementing the system – developing an online platform to enter and process the data and implement the system in the companies. Stage 4: analysing implementation and results – analysing the system's implementation in the construction companies and results for the first months of collection.

Stage 1 diagnosis was carried out by the investigation through data collection from a total of 20 construction companies with certification in standards ISO 9001 and the Assessment System for Conformity of Civil Construction Services and Works (SiAC) in the Brazilian Productivity and Quality Program in Habitat - PBQP-H (level A) in Pernambuco.

The investigation was based on interviews with the company directors and board representatives. A questionnaire was created for collecting data and divided into six parts: company data, and that of the person responsible for providing the information; identifying the macro-flow of processes; identifying the worksheet of objectives, targets and indicators; investigation of the indicator results; and interest in adopting standard indicators.

After conclusion of the diagnosis stage, when it was possible to identify the current stage of development of the indicator systems adopted by the construction companies and examine the indicators divided into processes, the structuring of the system then began – stage 2, in four sub-stages in sequence: selecting the companies, pre-selecting the indicators, selecting the indicators, and defining the standard collection methodology.

To define the group of companies participating in the project, members of the Pernambuco State Syndicate of the Civil Construction Industry (Sinduscon/PE) were mobilised. The main criterion adopted for selecting the companies participating in structuring the system was the possession of ISO 9001 and/or SiAC (Level A) certification of the quality management system. The outcome was that 13 companies joined the project.

From the indicators collected during the diagnosis stage, a critical analysis was done to identify main objectives established for the indicators. A set of indicators, therefore, was pre-selected to comprise the system. Next was the start of the stage to define the system. The indicators were selected at periodical working meetings between the researchers involved and participating companies; two different processes were worked at each meeting. At these meetings the collection methodology of each indicator was also established.

The stage of developing the online platform was then begun – stage 3, consisting of the tool for processing the results of the selected indicators, not discussed in this article. After completing the data collection platform, the team of researchers in the project accompanied the implementation of the system in the companies, in order to guide those involved in collecting, processing and analysing the indicators with regard to the use of the online platform and clarify any doubts about the indicator system. Finally, the stage 4 consisted of analysing the implementation of the system in the construction companies and it was possible to have a general assessment of the data entered in the first months of collection.

PRESENTATION AND ANALYSIS OF THE DEVELOPMENT OF THE INDICATOR SYSTEM

Diagnosis

At this stage, aspects relating to data collection and processing, analysis and dissemination of the indicator results were identified, some listed below:

- All indicators of more than half the companies have periodical follow-ups by the directors. This follow-up is generally done quarterly, half-yearly or yearly;
- The companies are concerned with disseminating the indicator results, making them more accessible to the collaborators in general;
- Monitoring the results using indicators caused company directors to take relevant actions, such as, adopting new processes and reformulating the marketing strategy.

Analysing the provided macro-flows of processes made it possible to identify ten main processes that are part of the Quality Management System (QMS), as follows: commercial, human resources, planning, design, supplies, administrative, financial, works, technical assistance and training.

The results relating to the objectives, indicators and targets were organised by processes in order to summarise the information collected. Overall, 173 indicators were identified, with special mention to the 62 indicators in the job process and 38 indicators in the commercial process - the processes with most indicators.

Table 1 illustrates some objectives, targets and indicators of the works process, in order and set out to facilitate analysis of the indicators. It should be mentioned that the collected information was structured closely in line with the data supplied by the construction companies participating in the study.

Table 1: Objectives, targets and indicators of the works process

No.	Objective	Indicator	Target
1	To reduce future problems with technical assistance	Final inspection of job	7 flawed items per unit in inspection report
2	To reduce waste on the job and increase productivity	Checking subfloor thickness	To achieve average thickness of 3 cm
3	To minimise mortar consumption and check use of bricks per m²	Checking masonry services	Mortar (12 kg/m²) and brick consumed (to 25/m²)
4	To add new technology	No. of new technologies	≥ 1 a year
5	To monitor service productivity	UPR – Unit Production Ratio	-
6	To reduce waste in structural concrete	Total volume used in floor/ total volume calculated on plan	50% less waste of structural concrete on job

Similarly, all 173 indicators distributed in the ten processes identified by the survey were organised and analysed by Barkokebas et al. (2009). The analysis of the results find some problems in the performance measuring systems: difficulties in aligning the indicators with the objectives and fitting them properly in the processes, inadequate characterisation of the actual indicator, no periodicity defined for collection and no clear targets.

Structuring the standard performance indicator system

Thirteen construction companies in Recife that operate in the Commercial and Residential Construction and Incorporation market participated in the project, and formed a group of companies with similar characteristics, except with regard to size, since the group had small, midsize and large companies.

Eight processes and the prime objectives relating to them were selected next. Based on these objectives, a set of indicators to make up the system was pre-selected. It should be stressed that, after finding gaps in the analysed performance measuring systems, pre-selection was complemented with indicators found in the literature.

The set of indicators was selected at six fortnightly working meetings, coordinated by the authors of this article and attended by representatives of the companies. At each meeting, the pre-selected indicators of each process were presented, the proposal of each indicator discussed and negotiated together with all participants, bearing in mind the companies' requirements, their mutual interest, and the relevance of the indicator for comparison. At the end of each meeting, a consensus was reached about what should be measured and the collection methodology of each indicator was defined. In the end, 20 performance indicators were defined, as shown in Table 2.

Table 2: Selected indicators

Process	Indicators	No.
1. Commercial	1.1 Client satisfaction (user)	1
	1.2 Sales rate	2
2. Financial	2.1 Default	3
3. Planning	3.1 Cost variance	4
	3.2 Deadline variance	5
	3.3 Rate variance	6
4. Technical assistance	4.1 Average attendance time	7
	4.2 Cost of technical assistance services	8
5. Human resources	5.1 Internal client satisfaction (Organisational climate – Job)	9
	5.2 Absenteeism	10
6. Job	6.1 Consumption of industrialised mortar	11
	6.2 Ceramic tile waste generation	12
	6.3 Brick/block waste generation	13
	6.4 Best practices in occupational health and safety	14
	6.5 Training manpower	15
7. Supplies	7.1 Supplier assessment	16
8. Designs	8.1 Designer assessment	17
	8.2 Steel rate	18
	8.3 Concrete rate	19
	8.4 Slenderness of building	20

Cards with all information necessary for collection, processing and analysis of the selected indicators were created for their suitable characterisation. The cards contain information, for example, about the process in which the indicator is entered, the indicator's purpose, the collection periodicity and the calculation guide. As an example of the model, Figure 1 shows the characterisation card of the Sales Rate indicator, belonging to the commercial process.

Figure 1: Characterisation card of the sales rate indicator

SALES RATE

Process: Commercial

Purpose: Measuring the Sales rate of autonomous units of a new property in the first four months after launch, thus evaluating the degree of product acceptance.

Guidelines for collection: The sales rate is obtained from the ratio between the number of units sold and the total number of units of a property. To collect the indicator, it must be considered the units sold in 4 (four) months after launching the property. The sale date is set for signing the commitment of buying and selling the unit. It will be counted only the residential properties, being the indicator collected separately for units with 1 (one), 2 (two), 3 (three) and 4 (four) bedrooms.

Collection periodicity: The sales monitoring are conducted periodically by obtaining partial results each month. After 4 (four) months of launching the property, the sales rate result is obtained.

Collection responsible: Commercial sector or any other responsible for tracking sales at the company.

Calculation guide: The Sales Rate is calculated through the formula which relates the number of sold units by the total number of units:

Sales Rate

$$SR = \frac{(\text{Number of sold units})}{(\text{Total number of units})} \times 100\%$$

Guidelines for analysing the indicator results:

The analysis of results must be done by the company's commercial director, or other sectors involved.

For the analysis of the Sales Rate indicator, it is necessary to consider separately the results of the properties with 1 (one), 2 (two), 3 (three) and 4 (four) bedrooms. Moreover, it is important consider that the indicator result can be influenced by several factors, such as investments in marketing, type of property, location, market demand, pricing, among others.

It should be emphasised that information is provided in the guidelines for analysing the indicator results, and must be considered for the benchmarking practice. Figure 2 shows one of the meetings with companies.

Figure 2: Meeting with companies

Implementing the system

A dynamic site (online platform) was designed to collect and process the indicator results, which can be accessed from any internet browser without needing to install software. From the platform it is possible to enter the indicator results, creating at the end of each period, individual reports for the companies' inquiries and also general reports to help compare performance. The site can be accessed through www.indicon.net. It should be mentioned that only the companies in the project can access their results through an area restricted by login and individual password. Figure 3 shows the site's home page.

After concluding the platform, the follow-up stage began for implementation in the companies. Visits were made to introduce the system, detail the collection methodology of each indicator and pass on information about data entry.

In short, the system's information flow operates as follows: at the start of each month, the companies begin by collecting the indicators; from the first day of the following month, the online system is open for entering the collected data with the previous month as reference; the results can be entered until the 12th day of the month when the system is closed to begin the data validation stage.

The data validation stage is undertaken by the team of project researchers and consists of the numerical analysis of the values entered into the system compared to the reference values already existing and based on the companies' own past data. The validation objective is to prevent outlier values that can harm the quality of the sample stored in the database.

Figure 3: Site's home page (online platform)

Individual and general reports are issued after validating all data. The individual report consists of details of all values entered by the firm during that month, while the general report contains mean and average information, and maximum and minimum values, past benchmarking and number of entries (sample) so that the companies can compare their performance with the others.

Analysis of implementation and results

During the process of implementing the system in the companies, it was found that in general the companies tried to enter the proposed system in that which already existed in the QMS. However, due to overlapping of some indicators developed and the companies' own indicators with a difference between the collection methodologies, some companies preferred to keep their own measuring method.

In relation to the information transferred during the implementation stage, some companies successfully absorbed and disseminated it, while others failed, encountering a problem during the collection period. Consequently, failures in collection were found, leading to results not in keeping with the proposed methodology; these results had to be excluded during the validation process. Some reasons could be found for this problem, namely difficulties in disseminating the information between those involved in collection, and a shortage of people in the firm that would help implement the system, including senior executives.

Indicator collection began in August 2010, with three collection cycles, creating a volume of around 600 results. At this time, none of the participating companies managed to collect the 20 proposed indicators, stressing that some of them depend on work stages not yet reached. Moreover, there are indicators with six-monthly and yearly collection periodicity.

Figure 4 shows an extract from the general report for October 2010, while Figure 5 shows part of a firm's individual report for that same month.

Figure 4: Example of an extract from the general report

General Report	Reference Month October/2010					
Indicator	**Average (General)**	**Median**	**Minimum Value**	**Maximum Value**	**Number of Entries**	**Benchmarking**
Client satisfaction - user (Grade)	7,06	7,06	7,06	7,06	1	7,06
Sales rate (%)						
One bedroom (%)	-	-	-	-	-	-
Two bedrooms (%)	-	-	-	-	-	79,00
Three bedrooms (%)	-	-	-	-	-	88,99
Four bedrooms (%)	-	-	-	-	-	78,57
Default (%)	3,38	1,05	0,00	34,51	32	0,00
Cost variance (%)	-	-	-	-	-	-
Deadline variance (%)	-	-	-	-	-	-
Average attendance time (Days)	1,90	1,50	1,00	4,00	6	0,83
Internal client satisfaction (Organisational climate – Job)	3,99	3,98	3,50	4,60	12	4,60
Absenteeism (%)	3,22	2,30	0,00	12,63	27	0,00
Best practices in occupational health and safety (%)	84,34	94,35	7,13	100,00	30	100,00
Consumption of industrialised mortar (Kg/m²)	18,13	20,89	12,31	21,19	3	8,85
Ceramic tile waste generation (%)	1,80	1,39	1,00	3,00	3	1,00
Brick/block waste generation	4,46	3,50	1,29	9,09	5	1,29

Figure 5: Example of part of a firm's individual report

11. Best practices in occupational health and safety (%)	
Jobsite	**Value (%)**
49	66,67
58	84,09
54	85,45
50	90,00
52	91,49
46	92,00
51	94,12
Average	86,26

13. Brick/block waste generation (%)			
Jobsite	**Ceramic Brick 09x19x19 (%)**	**Ceramic Block 09x19x39 (%)**	**Concrete Block 09x19x39 (%)**
54	-	1,29	-
Average	-	1,29	-

Throughout the indicator collection period, the team of researchers gave support to the companies in the project, guiding them in the collection methodology, providing worksheets for support in compiling data and accompanying the use of the online platform.

At the end of the third cycle of data collection, a survey was conducted with the companies aiming at a general assessment of the indicator system developed and first results. It was possible identifying aspects of all different stages of the project.

Regarding to the stage of structuring the system, the companies evaluated the systematic used for defining the indicators and the set of 20 indicators selected. Moreover, it was evaluated the satisfaction of the companies with the elements developed to support the system, such as characterization cards, worksheets collection of indicators and online platform. In general, all the companies evaluated satisfactorily these items.

Of the set of 20 indicators selected, each company has collected an average of 10 indicators, and the maximum number of 15 in a company and minimum of 5 in another one. This variation is associated with the size of the two companies (big and small, respectively) and no person involved in system deployment and the collection, a fact which is attested throughout the implementation stage of the system.

The companies listed some of the main benefits gained from the implementation of the system, being the main of them the comparison of results of the company with the others (benchmarking practice). Turning to the main difficulties found, it is possible mentioning the difficulty in spreading the measurement practical between the involved and responsible for the processes. It is noteworthy that among the companies surveyed, only one said the results of the indicators are not accompanied by top management.

It is noteworthy that the present research was conducted in a Brazilian particular context. It is possible to enumerate some of its main features: Real estate market booming, medium and high standard properties, multi-floor buildings, traditional Brazilian construction process (Reticular reinforced concrete structure and masonry sealing), etc. Therefore, in order to properly analyze the results of the research, it is necessary that the aforementioned characteristics are taken into consideration.

CONCLUSIONS

The developed indicator system benchmarking, based on adopting a standard data collection and processing methodology, was designed for benchmarking and generating reference values for the sector. By structuring the system, the companies were able to adapt their indicator systems or even consolidate their measuring process.

The results show that the system meets the measuring requirements of construction companies, which were able from the project to find a favourable environment for data analysis and systematisation so that they were able to compare their performance with the other companies.

The project described herein is very important for the Brazilian civil construction sector, since there is a huge shortage of indicators and tools using online information technology that give access to comparative data and information that help in corporate decision making.

Some obstacles were found when developing the indicator system, mainly in relation to the characteristics of the construction companies that found it difficult to systematically enter the indicators in their organisational routine.

Lastly, it is worth mentioning that all the construction companies are interested in continuing with the standard data collection system through the online platform to encourage them even further to develop their practices by benchmarking.

REFERENCES

Bakens, W.; Viries, O.; Courtney, P. (2005). *International review of benchmarking in construction*. Amsterdam, Holanda: PSIBOUW. (Research report).

Barkokebas Jr., B.; LordsleemJr., A.C.; Silva, B.M.V.; Duarte, C.M.M. (2009) *Sistemas de gestão em segurança e saúde do trabalho e de gestão da qualidade na construção civil*. Recife: EDUPE, 2009. v. 1. 126 p.

Bourne, M., Mills, J., Wilcox, M., Neely, A. and Platts, K. (2000). Designing, implementing and updating performance measurement systems. *International Journal of Operations & Production Management.* Vol. 20 No. 7, pp. 754-71.

Construction Excellence. *Institutional site*. Webpage accessed 20-03-2010 at: http://www.constructingexcellence.org.uk

Corporacion de Dearrollo Tecnológico. (2005). *Sistema Nacional de Benchmarking na Indústria da Construção*. 1 ed., Santiago, Chile. (Research Report).

Costa, D.B. et al. (2005). *Sistema de indicadores para benchmarking na construção civil: manual de utilização*. Porto Alegre: UFRGS/PPGEC/NORIE.

Costa, D. B., Beer, L. R. Formoso, C.T. (2007). *Desenvolvimento de sistema de indicadores para benchmarking na construção: uso para compartilhamento de conhecimento visando à melhoria de desempenho*. Gestão & Tecnologia de Projetos, Vol 2 (Nº 2).

Lantelme, E.M.V; Tzortzopoulos, P.; Formoso, C.T. (2001). *Indicadores de Qualidade e Produtividade para a Construção Civil*. Porto Alegre: NORIE/UFRGS. (Research Report).

Netto, A. (2010). Mercado consumidor nordestino desperta. Construção Mercado, 105.

Neely, A. (1998). Three models of measurement: theory and practice. *International Journal of Business Performance Management.* Vol. 1 No. 1, pp. 47-64

Valor Setorial. *Construção Civil (Versão online)*. Webpage accessed 18-11-2010 at: http://www.revistavalor.com.br/home.aspx?pub=57&edicao=1

SCOPE ANALYSIS OF THE DESIGN AND SERVICE PROCESSES FOR PRODUCING VERTICAL NON-LOADBEARING MASONRY

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The design for producing non-loadbearing masonry offers high potential for improving the design process in building construction. However, one of the problems worth mentioning is the lack of accurate definition of the range of its scope, causing doubts about what, when and how it should be prepared, developed and delivered by the designers. The main purpose of this paper is to investigate and analyse the application of the scopes of the designs and services of vertical non-loadbearing masonry in building construction using case studies in the cities of Recife in Pernambuco State and the city of Sao Paulo in Brazil. The results obtained have shown that achieving the reference scope adopted – the Brazilian Association of Design Managers and Coordinators (AGESC) handbook – averaged 61% (builders) and 57% (designers), while the concordance with the scope averaged 45% (builders) and 56% (designers). Lastly, it gives guidelines on scope of how to use the AGESC handbook on design and services of vertical non-loadbearing masonry, describing potential uses and stressing the contributions to greater integration between expectations and resulting products, to more rationally facilitate the design and execution of non-loadbearing masonry in building construction.

KEYWORDS: design; non-loadbearing masonry; scope; building construction.

INTRODUCTION

Design for producing vertical non-loadbearing masonry

The use of the design to produce vertical non-loadbearing masonry (DPVM) has been recommended as a mechanism of high potential for improving the design process in Brazilian building construction, contributing to overcoming design incompatibilities due to lack of integration among designers and executive difficulties. Although design undeniably contributes to the approach between product and production in order to further improve the production process of non-loadbearing masonry, many problems still exist with regard to its development and use (Corrêa & Andery, 2006; Maneschi & Melhado, 2010).

Aquino and Melhado (2005) list a set of problems relating to the process of design development and use to produce vertical non-loadbearing masonry in building construction, which ranges from the work team's resistance, lack of design coordination to the absence of considerations on the performance of non-loadbearing masonry. It was evident that many of the problems mentioned by Aquino and Melhado (2005) are the result of lack of precise definition of the range of scope of services involved in preparing the design for production.

According to the Brazilian Association of Design Managers and Coordinators (AGESC) (2006), many designs (large or small) begin with maladjusted agreements between their idealisers and those responsible for preparing the designs, raising doubts on what, when and how it should be prepared, developed and delivered by the designers.

Some international publications (NASA, 2000; Cho & Gibson, 2001; Fuentes, 2004; AIA, 2010; Cherry & Petronis, 2010) show concern about defining scope in building construction, mainly with regard both to the scope of the project and of the design itself. Scopes of not very accurate projects are acknowledged to be one of the main causes of failure of projects, causing adverse effects on cost, deadline and quality, resulting in losses and deficient definition of the design scope (NASA, 2000; Cho & Gibson, 2001; Fuentes, 2004). The aforementioned authors, when discussing a specific indicator for assessing the project scope in building construction called Project Definition Rating Index (PDRI), stress the importance of design scope, listing in category F the parameters required for the different technical design specialities.

The work done by the American Institute of Architects (AIA) (2010) is also worth mentioning, relating to development of contractual documents that define the relationship and work scopes relating to design and construction. According to AIA (2010), for more than 120 years these contractual documents are being systematically enhanced and recognised as standards for the North American construction industry.

When discussing scopes in greater depth, Cherry and Petronis (2010) emphasise non-definition of scope before starting to develop the design as one of the main sources of problems, unnecessary efforts and frustrated expectations between clients and designers. In a situation of this kind there is a tendency to distortions in the contract, which encourage price competition without a clear relation with the actual provision of services associated to them, in addition to causing disputes between contracting parties and designers, thereby configuring losses in the quality of the process and project.

In this situation, the Brazilian associations representing the design sector – Brazilian Association of Structural Consulting and Engineering Services (ABECE), Brazilian Association of Building System Engineering (ABRASIP), Brazilian Association of Architecture Offices (AsBEA), with the participation of sectoral bodies representing the design contracting parties in the real estate and construction sector, Secovi-SP, Sindinstalação and SindusCon-SP - joined forces to prepare standards as a benchmark for design contracts.

The result of this collective work was a number of handbooks on scope of design and services, one of which concerns non-loadbearing masonry – the AGESC handbook on scope of design and services of non-loadbearing masonry (2008).

AGESC handbook on design scope for production

The AGESC handbook on scope1 (2008) provides for various activities relating to DPVM, comprising 61 services (types: essential, specific and optional) that form six stages in the design process. This group defines the general structure of scope of DPVM. Table 1 demonstrates the content of Stage d “Design for detailing specialities” in the AGESC handbook on design scope for producing non-loadbearing masonry (2008).

[1] Further information by consulting the site: http://www.secovi.com.br/minisites/manual/Main.php?do= Inicial&refresh=true.

Table 1 – Contents of Stage d "Design for detailing specialities" of the AGESC handbook on DPVM (2008)

Services	
Essential	• Consolidated checking of designs of other specialities • Preparing the location map of the 1st row of masonry • Preparing the location map of points in building systems in contracted floor slabs • Preparing elevations of the walls for the contracted floors • Quantifying the non-loadbearing components for the contracted floors • Construction details for the contracted floor • Location map by coordinate axes • Consolidated checking of designs of other specialities • Preparing the location map of prefabricated components for contracted floors
Specific	• Preparing the structure fastening plan • Survey of the area of vertical non-loadbearing masonry • Executive procedure of complementary components of vertical non-loadbearing masonry • Executive procedure of vertical non-loadbearing with no details from the contracting party
Optional	• Executive procedure of components produced on site • Design for producing vertical non-loadbearing masonry for customising units • Preparing the location map of the 2nd row for contracted floors • Floor compatibility • Executive procedure of complementary components of vertical non-loadbearing masonry

The result of the widespread discussion and participation of the sectoral agencies helped draw up a comprehensive set of services for the scope of non-loadbearing masonry design, which acts as a reference for application and adaptation to a certain project. It is worth considering, however, that there is no evidence that the scopes of the existing services involved in preparing the design for production is are being fulfilled or fully in line with the interests of the builders and designers.

OBJECTIVE

The main purpose of this article is to present the results of a case study survey relating to the investigation and analysis of the application of the scopes of design and services of vertical non-loadbearing masonry.

METHODOLOGY OF THE CASE STUDY SURVEY

The methodology for undertaking this survey consisted of the following steps. Step 01 – review of literature addressing the insertion of design for production in the design and scope process of non-loadbearing masonry designs and services. Step 02 – preparation of the questionnaire for data collection. The references adopted for the questionnaire were based on the bibliographic review, technical standards and the AGESC handbook on scope of design and services (2008). Two questionnaires were drawn up, each applying to the construction companies and vertical non-loadbearing masonry designers responsible for the projects used for the survey, respectively. The two questionnaires were formatted as described: 1st) characterisation of the construction companies, the design coordination, the project, the design process, the premises of DPVM and DPVM scope ; 2nd) characterisation of the designer companies, designer, design process, DPVM process, premises of DPVM and DPVM scope. Step 03 – undertaking a field investigation for applying the questionnaire in real estate construction firms to check the existence of the questionnaire's elements in four projects in the cities of São Paulo and Recife. Step 04 – analysis of the results and drawing up guidelines for applying the DPVM scope. The survey began in March 2010 and ended in August 2010, over a total six-month period.

PRESENTATION AND ANALYSIS OF RESULTS

The four construction companies in the case study survey and their projects are identified by letters A, B, C and D, while the designer companies of vertical non-loadbearing masonry are identified by letters E, F, G and H. It should be mentioned that this information was provided spontaneously and separately by the design coordinators of the construction companies and the companies that design vertical non-loadbearing masonry of each of the projects at the time of the interviews.

Characterisation of the companies

The results obtained from characterising the companies in the case studies are given in Tables 2 and 3.

Table 2 – Characterisation of construction companies

Characterisation	Construction companies			
	A- Recife	**B - Recife**	**C - São Paulo**	**D - São Paulo**
Operating area	Construction and incorporation			
Lifespan	60 years	43 years	20 years	29 years
Certification	ISO 9001 & PBQP-H		ISO 9001, PBQP-H & ISO 14001	-
Projects underway/ in design process	10/10	3/2	4/2	13/4

Table 3 – Characterisation of companies that design vertical non-loadbearing masonry

Characterisation	Designer companies			
	E - Recife	**F - Recife**	**G - São Paulo**	**H - São Paulo**
Operating area	Construction management & technology, DPVM	Construction management & technology, DPVM	Design coordination, IT management & DPVM	Design coordination & DPVM
Lifespan	4 years	4 years	10 years	8 years
Projects in design process	4	4	3	15

Companies A, B, C and D operate in similar areas and are traditional in their markets with a lifespan of over 20 years. Except for company D, which is undergoing a certification process, all the others already have the ISO 9001 certificate and SiAC of PBQP-H, with special mention of company C that is also ISO 14001 certified. Companies A and D have the largest quantity of works and designs in progress.

Companies E, F, G and H that design vertical non-loadbearing masonry have a diversified operating area, mainly as a result of the skills of their specialists in charge. The lifespan of companies E and F differs when compared to companies G and H. Company H is outstanding with regard to the number of designs in progress.

Characterisation of the projects

The results from characterisation of the projects belonging to the case studies are presented in Table 4. Projects A, B, C and D belong to the companies A, B, C and D, respectively.

Table 4 – Characterisation of the projects

Characterisation	Projects A	B	C	D
Building process	Traditional	Traditional	Traditional	Traditional
Type-floors	7	30	24	15
Masonry components	Concrete blocks & industrialised mortar	Ceramic blocks & industrialised mortar		Concrete blocks (different widths) & industrialised mortar

The building process of the projects of companies A, B, C and D is characterised as traditional, with streamlined non-loadbearing masonry. The buildings vary in height, with the largest belonging to company B with 30 typical floors. It is clearly noticeable that the non-loadbearing masonry of the projects is streamlined by means of industrialised mortar and components with holes on the vertical, in addition to a family of sub-modules that can provide improved executive quality. Unlike the others, the company D project still has different block widths.

Design process

Design coordination

The results relating to design coordination from the viewpoint of the construction company's design coordinator and DPVM designer are given in Tables 5 and 6, respectively.

Table 5 – Design coordination from the viewpoint of the construction company's design coordinator

Design process	Company's design coordinator A	B	C	D
1) Coordinator's educational background	Civil Eng., specialization	Civil Eng., specialization	Civil Eng., specialization	Architect
2) Immediate hierarchy	Technical director	Works director	Technical director	Project management
3) Coordination	Internal	Internal	Internal	Internal
4) Process indicators	No	No	No	No
5) Potential improvements of process	Yes, professionalization	Yes, process indicators	Yes, new procedures & shorter deadlines	Yes, interface w/incorporation, feedback works

When analysing Table 5, from the viewpoint of the construction company's design coordinator, the following characteristics of design coordination are worth mentioning:

- design coordinators of the construction companies are civil engineering university graduates with specialization course, except in company D;

- hierarchical subordination of design coordination in company D shows a wider distribution of tasks among the team responsible for the activity;

- all coordinators consider that the design process needs to be improved, quoting some development opportunities.

Table 6 – Characteristics of design coordination from the viewpoint of the DPVM designer

Design process	**DPVM designer**			
	E	**F**	**G**	**H**
1) DPVM designer's educational background	Civil Eng., PhD	Civil Eng., PhD.	Architect, Master's	Architect
2) Immediate hierarchy in coordination	Design coordination	Design coordination	Design coordination	Design coordination
3) DPVM designer's records	Minutes	Minutes	Minutes and plan notes	Minutes
4) Knowledge of construction company indicators	No	No	No	No
5) Potential coordination improvements	Yes, developing design guidelines		Yes, integration between designers	Yes, definitions by correct deadline

When analysing Table 6, from the DPVM designer's viewpoint, the following characteristics of the design coordination process are worth mentioning:

- DPVM designers are civil or architecture university graduates, mostly post-graduates;

- all are under the hierarchical subordination of the design coordinator;

- all coordinators consider that the design process needs to be improved, quoting some development opportunities;

- DPVM designers are seen to have an advanced university education; but both professionals see potential improvements in the design coordination process.

Elements of coordination

The main elements deemed pertinent to design coordination were listed, whose results showed that:

- the existence of design coordination elements from the viewpoint of the construction companies was 54%, higher than the 48% of the DPVM designers. Probably the design coordinator of the construction companies undertook activities concerning the elements mentioned that were not necessarily perceived by the DPVM designers;

- designers' proposals used as a contract instrument between the parties in all cases. The construction companies do not provide specific drafts;

- the only element not existing in coordination, in the opinion of the companies, was the lack of communication of post-occupation assessment results for DPVM designers; ratified by their perception on the non-use of post-occupation assessments in new designs and no feedback from customer satisfaction surveys;

- the key contradictory element corresponded to the first stages of providing the services, in which the DPVM designers do not know the design plan and/or its stages, and lack of specific guidelines.

Design process for producing vertical non-loadbearing masonry (DPVM)

Figures 1 and 2 demonstrate the results relating to the existence of premises in DPVM development in the opinions of the construction company design coordinators and vertical non-loadbearing masonry designers.

The premises are a set of basic principles that must exist or be encouraged in the company and, consequently, the people who constitute it, to make possible the development of the DPVM. The establishment of the assumptions listed considered the literature review (AGESC, 2008; Corrêa & Andery, 2006; Maneschi & Melhado, 2010) and the authors experience over more than ten years working in the area of the matter under study.

Figure 1 – Premises in DPVM development from the viewpoint of construction companies

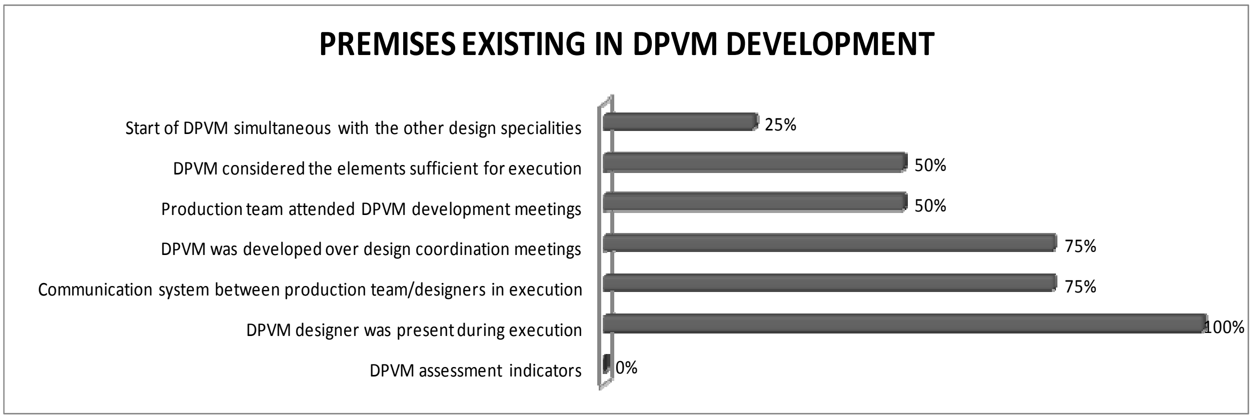
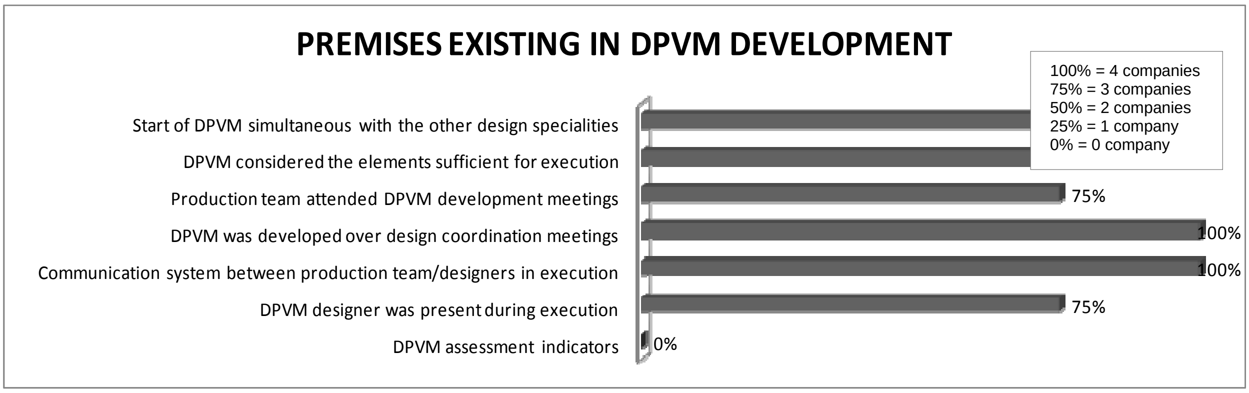


Figure 2 – Premises in DPVM development from the DPVM designers' viewpoint



When analysing the results in Figures 1 and 2 in percentage of the number of companies that confirmed the existence of premises, it may be considered that:

- 54% of premises existing in DPVM development from the construction company viewpoint, under the 71% of DPVM designers. The design coordinators of the construction companies were more critical of the premises under their responsibility, when compared with the DPVM designers;

- there is no specific indicator for DPVM assessment, a fact that could hinder the factual comparative assessment between the various designers that may be or will be working on development of DPVM of the construction companies;

- the main difference from the construction companies and DPVM designers relates to the simultaneous start of developing DPVM with the other design specialities.

Attention to the Brazilian Association of Design Coordinators and Managers handbook (AGESC) on DPVM scope

Tables 7 and 8 show the results relating to attention to the AGESC handbook on DPVM scope in function of the project and stages in the design process. The criteria adopted for calculating Total 1, Total 2 and Total 3 were the following:

- Total 1: corresponds to the mean of the averages of positive attention to the services at each stage in the design process;

- Total 2: corresponds to the sum of weighting the averages of positive attention at each stage in the design process. The weights used when weighting were attributed to the quantity of essential services at each stage in the design process in relation to total essential services at all these stages, namely: a – 4 services (11%), b – 3 services (8%), c – 14 services (37%), d – 14 services (37%), e – 2 services (5%) and f – 1 service (3%);

- Total 3: corresponds to the mean of the averages of positive attention to the services at each stage in the design process, considering all projects.

Table 7 – Attention to the AGESC handbook on DPVM scope per project

Projects	Construction companies		DPVM designers	
	Total 1	Total 2	Total 1	Total 2
A	62%	69%	62%	67%
B	64%	77%	62%	67%
C	50%	58%	24%	43%
D	27%	41%	40%	49%
Average	51%	61%	47%	57%

The following is found when analysing the results obtained in Table 7:

- irrespective of Total (1 or 2), attention to the handbook on scope from the construction company's viewpoint is greater than for the DPVM designers, although with just a slight difference. Probably the designers are more critical when adopting the handbook because of their greater knowledge of the established activities relating to each service;

- considering only Total 2, it is found that attention to scope varied between 41% and 77% (construction companies) and between 43% and 67% (designers).

Table 8 – Compliance in function of the stages in the design process

Stages in the design process	Construction companies	DPVM designers
	Total 3	Total 3
Stage a – Concept of product	13%	0%
Stage b – Definition of product	33%	39%
Stage c – Identifying and solving design interfaces	71%	67%
Stage d – Design details	71%	66%
Stage e – Design post-delivery	68%	60%
Stage f – Job post-delivery	50%	50%

When analysing the results in Table 8, it is found that whoever the respondent is stages c and d are indicated with the highest compliance percentage; while stage a has least compliance with the scope handbook. Probably little is still known of the benefits of the pertinent activities established in the concept phase of the product.

Extending the view of the results, the lowest percentage of compliance is associated with the first and final stages of the design process. It is possible to imagine that the DPVM designers do not feel part of these stages, bearing in mind that when they occur they are not so present, a view shared by the construction companies.

Concordance regarding the AGESC handbook on DPVM scope

Tables 9 and 10 show the results relating to concordance in relation to the AGESC handbook on DPVM scope in accordance with the project and stages of the design process.

Table 9 – Concordance per project

Projects	Construction companies		DPVM designers	
	Total 1	Total 2	Total 1	Total 2
A	54%	46%	61%	60%
B	29%	38%	61%	60%
C	48%	37%	63%	54%
D	44%	59%	39%	49%
Average	44%	45%	56%	56%

The following is found when analysing the results in Table 9:

- irrespective of Total (1 or 2), the concordance regarding the scope handbook in the opinion of the DPVM designers is greater than that of the construction companies, with a slightly higher difference of 10%. Probably the fact that the DPVM designers have more knowledge of the handbook contributes to the result, even more so considering that the majority participated in the concept of the handbook in question;

- considering only Total 2, it is noticeable that the concordance of scope varied from 37% to 59% (construction companies) and from 49% to 60% (designers);

- considering only Total 2, the highest percentage of concordance is attributed to project D (construction companies) and projects A and B (designers), while the lowest concordance is attributed to projects C (construction companies) and D (designers). Note here the different opinion between the construction company and the designer of project D.

Table 10 – Concordance in function of the stages in the design process

Stages in the design process	Construction companies	DPVM designers
	Total 1	**Total 1**
Stage a – Concept of product	19%	63%
Stage b – Definition of product	53%	14%
Stage c – Identifying and solving design interfaces	49%	61%
Stage d – Design details	44%	53%
Stage e – Design post-delivery	48%	68%
Stage f – Job post-delivery	50%	75%

When analysing the results in Table 10, major differences can be found in the opinion of the construction companies and DPVM designers. While the construction companies have more concordance with Stage b, the DPVM designers have more concordance with Stage f. In relation to less concordance, the differences are also present since the construction companies have less concordance with Stage a and the DPVM designers have less concordance with Stage b, the latter being the main difference.

Guideline for application of scopes of the designs and services of vertical non-loadbearing masonry

The AGESC handbook on scope of vertical non-loadbearing masonry designs and services (2008) is unequivocally the top and most comprehensive national reference on this subject. It is however necessary for the main users of the technical content, namely designers and contracting parties, to progress in the application of the AGESC scope handbook (2008). The following comments are intended as a guide on how to use/apply the AGESC handbook on scope of vertical non-loadbearing masonry designs and services.

a) It can be used more than once in the design process.
   When forming the design team, still at the stage of hiring the designers, it can be used as a reference to define DPVM activities and services, establishing the operating coverage, objectives and responsibilities of the stakeholders.

   During the design process it can be used to monitor the activities/services undertaken at each stage, setting a benchmark standard to assess the DPVM status in the period of interest.
   Depending on the time of contracting the DPVM in the design process, the AGESC scope handbook (2008) lists the activities/services that can still be undertaken. Similarly, it can be used to point to defects regarding the DPVM content when analysing designers' proposals.

b) Help in developing the design plan.
It can help the design coordinator and other designers (design team) to determine and hierarchise the activities/services considered crucial for developing the design plan. It also helps to standardise the terminology used, helps design team communication and to establish control points in the design timetable, defining the conclusion of a group of activities/services or stage, for approval and formalisation by the client (entrepreneur or construction company).

c) Definition of the DPVM scope.
The AGESC scope handbook (2008) provides the various activities relating to DPVM, consisting of 61 services (essential, specific and optional) that form six stages in the design process. This group defines the general structure of scope of DPVM. When defining the DPVM scope, all selected activities, irrespective of the initial classification of the service established in the AGESC scope handbook (2008), now belong to an essential service. In this sense, it also helps align and converge objectives between the entrepreneurs, designers and executors. Another important tool that may be provided concerns the activities that are mentioned throughout the AGESC handbook, since each can be a target of a specific checklist consisting of all the necessary elements for checking the scope of the DPVM, measuring progress, assessing the risks of non-compliance, and redirecting efforts to integrate this set of absent activities. Moreover, the activities listed in the AGESC scope handbook (2008) are the starting point for those companies interested in standardising their services in the development of DPVM.

d) Checking DPVM scope.
Checking attention to the AGESC scope handbook (2008) is a way to assure the contracting party that the DPVM considers the set of elements required for the vertical non-loadbearing masonry. Therefore, developing an indicator to check the integrity of the DPVM scope is a valuable tool, as discussed in item 5.5 of this paper in relation to Total 2, which permits monitoring the compliance with the pre-established scope, in this case, the AGESC scope handbook proper (2008). In order to appropriate the aforementioned indicator (Total 2), here called Indicator of the Non-loadbearing Masonry Design Scope (INMDS), the following formula can be adopted:

$$\text{INMDS} = \sum_{F}^{A} Pi \times \overline{Si}$$

where:

i: stage in the design process (a, b, c, d, e and f);

Pi : ratio between the quantity of essential services at each stage in the design process and the total quantity of essential services;

$\overline{Si}$: average of positive compliance of existing services (essential, specific and optional) at each stage in the design process.

Some further comments are pertinent to the INMDS:

- it can be used as a benchmark to compare earlier DPVMs and new DPVMs;
- it can be used both by the contracting party and designer jointly or separately to check the status of the DPVM scope defined initially;
- it can be used as a decision-making parameter, releasing the documents/plans of activities/services for undertaking a job.

e) Control of the changes in the DPVM scope.

When there is some change in scope from that existing in the AGESC scope handbook (2008), it is easier to identify the activities/services that were not initially defined and the effort required to develop them. It is essential to define the scopes of any new activities/services, as learning for future DPVM.

CONCLUSIONS

Solving problems arising from the absence of precise definition of the design scope coverage has appeared as one of the main requirements to improve the design process. Lack of definition of the scope of vertical non-loadbearing masonry designs and services is not an exception, since there are still doubts, stress and misunderstandings between the agents involved on what must be part of the designs and the level of details required.

In the international context there has been ongoing development of the topic over the years, showing standards of contracts with well-defined scopes, now common to civil construction, in addition to the development of application methodology and monitoring of the progress of scopes by means of indicators. In the national context, the Brazilian benchmark on the subject – AGESC handbook on scope of vertical non-loadbearing masonry designs and services (2008) – was developed more recently, and it is believed that the stakeholders are still in the earlier stages of its knowledge and application. It was evident that there is a lack of data to corroborate the level of use of the handbook in question and details that the services are being effectively provided at each stage of the design's development.

The case study survey focused on checking compliance in projects and harmonisation of the aforementioned handbook with the opinions of the construction companies and DPVM designers. With regard to compliance and concordance with the benchmark adopted – the AGESC handbook on DPVM scope (2008) – the results obtained demonstrated that the compliance of the scope averaged 61% (construction companies) and 57% (designers), while concordance was 45% (construction companies) and 56% (designers). A wider difference was found between compliance and concordance among the construction companies compared to the DPVM designers.

Lastly, it is believed that the guidelines proposed for application of the handbook on scope of vertical non-loadbearing masonry designs and services will contribute to further integration with the products desired by the stakeholders, facilitating a more streamlined development of the actual design and providing the service and, consequently, the quality of the execution of vertical non-loadbearing masonry in buildings.

REFERENCES

AIA Contract Documents. (2010). Produced *by The American Institute of Architects.* Available at: <http://www.aia.org/contractdocs/index.htm>. Access on: 14 Jan. 2010.

Aquino, J. P. R. & Melhado, S. B. (2005). Diagnóstico das dificuldades no uso de projetos para produção de vedações verticais. São Paulo, 2005. 19p. *Boletim Técnico da Escola Politécnica da USP*, BT/PCC/394.

Associação Brasileira de Gestores e Coordenadores de Projetos. (2008). *Manual de escopo de projetos e services de vedações.* Webpage accessed 30-12-2008 at: http://www.manuaisdeescopo.com.br/Main. php?do=ListaManual &refresh =true

Cherry, E. & Petronis, J. (2010). *Architectural programming.* Webpage accessed 14-01-2010 at: http://www.wbdg.org/design/dd_archprogramming.php

Cho, C.S. & Gibson Jr., E.G. (2001). Building project scope definition using project definition rating index. *Journal of Architectural Engineering ASCE*, EUA, V. 1, n. 1, p. 115-125, Dec. 2001.

Corrêa, C. V. & Andery, P. R. P. (2006). Dificuldades para a implementação de projetos para a produção de alvenaria: um estudo de caso. *Gestão & Tecnologia de Projetos,* São Paulo, v. 1, n. 1, p. 104-125, Nov. 2006.

Fuentes, P. A. U. (2004). *Validation of the Project Definition Rating Index (PDRI) for MIT building projects.* 2004. 95 f. Dissertation (Master's) – Massachusetts Institute of Technology. Massachusetts, 2004.

Maneschi, K. & Melhado, S. B. (2010). Scope of design for production of partition walls and facade coverings. Architectural Engineering and Design Management, 6, 3-17.

National Aeronautics and Space Administration. (2000). *PDRI Project Definition Rating Index* - Use *on NASA Facilities*. Houston, 2000.

STRATEGY WORK IN A LARGE CONSTRUCTION COMPANY: PERSONIFIED STRATEGIES AS DRIVERS FOR CHANGE

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Strategizing can be seen as a balancing act between aggregating knowledge and experiences from an organization's past business cycles and forecasting future possibilities over a longer period of time. Yet knowledge about strategizing over business cycles and in rapidly changing market conditions in the construction sector is scarce. This paper takes a micro perspective on strategizing and examines individual narratives of change processes to identify driving factors. The empirical data is part of an ongoing longitudinal case study in a large construction company on strategizing over business cycles from 1990 until today. The study comprises in-depth interviews with 14 key actors and a wide range of documentation covering the period. The Strategy-as-Practice perspective serves well as a retrospective description of strategizing over time; understanding the dynamics that underlie the various strategic changes is a matter of understanding what the strategists have done. The paper shows that strategy processes mainly are related to a few individuals (mostly the CEO's), rather than to the activities or rationale behind them. This paper contributes a novel perspective on the strategy literature in construction by emphasizing personified strategies as drivers for change. We argue that personified strategies are an intra-organizational phenomenon related to power distribution, governance, and the tensions between individual agency and the institutionalized context.

KEYWORDS: diachronic perspective, strategy as practice, personified strategies

INTRODUCTION

Corporate strategies are context-dependent and forward-looking conceptions, formulated by a given configuration of actors, at a specific time, under particular socio-economic conditions. As such strategizing can be seen as a balancing act between aggregating knowledge and experiences from an organization's past business cycles and forecasting future possibilities over a longer period of time. A company's strategizing impacts its efficiency, innovativeness, competence development, customer focus, environmental sustainability and its work processes. Yet knowledge about strategizing over business cycles and in rapidly changing market conditions in the construction sector seems to be scarce. Research within the strategy field has predominantly focused on a single strategizing cycle (Kaplan et al., 2008), steady-state conditions (Eisenstatt et al., 2008), dramatic change (Christensen et al., 2003), or the importance of employee involvement for implementation (Björnström, 2007). However, studying strategy from a diachronic perspective would help us understand how organizations use strategy to manage their history – their past, present and future.

The construction industry is an important player in the Swedish economy and on the labour market. However, it has been criticized for low productivity, lack of innovation, negative environmental impact and its large percentage of errors and waste (Lutz & Gabrielsson, 2002). These problems may in part come from the industry's difficulty to leverage knowledge and to develop and foster its unique competencies, which in turn may be explained by a lack of integration of human-resource and knowledge management at the strategic level (Björnström, 2007). There seems to be a lack of awareness among strategists of the interdependencies between strategizing and its operational implications over business cycles. This is probably related to a strong tendency to focus on functional strategies, resulting in efforts being concentrated to a single, short-term objective such as project costs. However, the world in which we live is changing rapidly, driven by globalization, internationalization and technological advances. To maintain an edge in a changing market, construction companies must continuously cultivate and develop their competences and intellectual capital. The need for improvements has induced new subjects on the agendas: including for example the pursuit of a more efficient building process, increased safety for the workers, ethical code of conducts, and sustainable development. Such initiatives force management in construction to administer their organization based on more standardized ways of work and this is often accompanied by a more centralized organizational structure (e.g., Zábojník, 2002).

All these issues pose challenges for practitioners as well as researchers. To propose viable models and solutions, researchers "need to get close to the sense-making of key organizational actors and appreciate the world from their point of view" (Johnson et al., 2008). Over the last decade Strategy-as-Practice has grown as a distinctive field of strategy-management study (e.g. Whittington 2006; Jarzabkowski et al 2007). Strategy-as-Practice focuses on strategizing as situated, social practice constructed through interactions of multiple actors embedded in institutional contexts. The foundation of Strategy-as-Practice is to highlight the micro-actions by which human actors, the strategists, create strategic outcomes; strategy is not something that an organization has, it is something that the "strategists" do. (Whittington, 2004; Jarzabkowski et al., 2007; Jarzabkowski et al., 2008; Gerry Johnson et al., 2007; Whittington, 2007).

This paper takes a micro perspective on strategizing by examining individual narratives of change processes, and draws on a Strategy-as-Practice perspective to support the argument that strategy processes are often associated with individuals (mostly the CEO´s), rather than with the activities or rationale behind them. This paper contributes a novel perspective on the strategy literature in construction: it shows how many of the major changes implemented in the studied construction company can be viewed as *personified strategies.*

DATA COLLECTION AND ANALYSIS

The empirical data is part of an ongoing longitudinal case study at Alpha, on strategizing over business cycles from 1990 to date. In-depth interviews with 14 upper-level managers were carried out during 2010; 11 out of the 14 interviewed managers had been working at Alpha for 15 years or more. This part of the study has applied an explorative and interpretative approach.

During the interviews, lasting between 1-2 hours, the respondents were asked to give their retrospective accounts of major changes over time, from 1990 to the present, through an undirected story-telling. Interviews were conducted until no (or little) new information was provided from yet another interview. The managers' unified view that emerged account for the concern: the managers' stories appeared to be overall consistent, albeit from different perspectives. Complementary to interviews, a wide range of documentation (company specific as well as media and judicial documentation) covering the period have been analyzed in order to identify phenomena that have had a bearing on strategic action over time and that documented most of the changes that the managers highlighted. All the interviews were transcribed. In a first phase these transcriptions were reviewed, without any pre-determined propositions and with no particular codification technique; at this stage we wanted the data to "speak to us". From these readings a pattern gradually emerged. A content analysis was carried out, resulting in a list of key words sorted into categories. The salient feature of these interviews was their repeated references to persons rather than events or objects. In the following we have aggregated the narratives to render an account of Alpha´s trajectory as perceived by the interviews

The first part depicts the overall change over the studied period: how Alpha transformed into a more centralized organization. The second part presents two perspectives of the way in which managers related changes to persons.

THE STORY OF ALPHA

Alpha is one of the largest domestic contractors within building and civil construction as well as services related to road construction and civil engineering. This story takes its point of departure in the early 1990s. The Swedish recession at this time seriously impacted the construction sector, e.g. by forcing them to review their operations to adapt to a more competitive market with lower profit margins and shorter construction times.

From a decentralized towards a centralized organization

Throughout the 90s Alpha was divided into a number of geographical units, with the company slogan: "*we build everything, everywhere*". The different units were operated by their respective managers and controlled by very few common strategic overall guidelines; as long as each manager managed to deliver profit for the unit, few questions were asked from Alpha´s board of directors. The company could be described as a conglomerate of autonomous companies, as expressed by two of the interviewees (underlining indicates speaker emphasis):

> *The different divisions worked <u>very, very</u> independently. Each division manager had <u>his own</u> management team and staff, and focused <u>very much on its own business</u>. When the managers met, they cared for their own interests, their own divisions [E. E.].*

> *There were autonomous units. We had some kind of board of course, but with limited impact. […] There was a fear to introduce common ways of working [H. H.].*

During the 90s, top management realized that the potential of this company setting had reached its upper boundaries; in order to be competitive the different geographical units needed to collaborate. Based on these rationalities, top management formulated a number of new goals: to generate predictable profitability; to decrease marginal costs; to implement codes of conduct; and, to increase overall efficiency. One concrete example initiated in the early 90s was the “X-program” that aimed to shorten production times at a lower cost with fewer defects in the final inspections.

> *[The X-program] was a vital project. It initiated something important, that is, to work with plans which we had never done before. So it was a fundamental driving force to start a process of developing a structured way of working. It contributed to an awareness that we needed to improve [H. H.].*

These goals were to be achieved by capitalizing on the potentials of scale; the building process should be more standardized, purchasing done by a centralized unit and the indigenous knowledge should be collected and fed back.

> *In the early 90s there was not much business planning or strategizing, The X-program was a pure efficiency program. […] ‘A way of working’ was introduced in the mid 90s, which was a milestone for the company. This initiative came from one geographical unit, and then the whole company adapted the ideas. All best practice examples in the company were collected and documented – that became ‘Alpha´s Way of Working’ [E. E.].*

Moreover, during the 90s, pressure from the market grew regarding ethical conduct and environmental concerns. Accordingly, “soft issues” gained the attention of the CEO. As exemplified by the following quotes, the opinions diverge whether or not this was a change of direction for the company or not:

> *It was something special when [CEO] P. introduced soft parameters. Our [Code of conduct] was unique for our branch, and all of a sudden we started to speak about how to be open-minded, honest and to listen. [The CEO] P. was tough and dared to drive these issues, because many in the organization were very skeptical. But today, it is a natural part of work. […] The [Code of conduct] was a milestone” [E. E.].*

> *Our Code of conduct is just a policy document: this is how we view our external environment, and how we want the external environment to see us [H. H.].*

> *In my world the Code of conduct was a ‘quick fix’, and I cannot understand why it has got so much attention. […] It could be described as a list of goals for us as an organization [I. L.].*

In 2003, a major re-reorganization of the company took place which coincided with a change of CEO. When CEO W. entered the scene, he did away with a whole hierarchal level, in order for the central units to come closer to the building projects. This was experienced by several of the interviewees as a breakpoint. At the same time, new corporate strategies were formulated, and in 2004 the official launch of a performance measurement tool took place. The CEO himself presented the tool at an annual management meeting where all upper and lower managers were gathered.

> *The fact that a whole hierarchal level was removed, that was a big deal [I. L.].*

> *When we formulated our business plan 2003 we got a lot of criticism for having too many initiatives at the same time. The [Alpha´s measurement tool] was*

launched and we started to measure and follow up our business. This was a great water spread [H. H.].

[CEO] W. introduced transparency, to measure and follow up competitions. Everybody was measured, and nobody wanted to be the loser. It was an extreme competition between all units, and that was something new [E. E.].

Moreover, during the last decade there was also an increased focus on industrial construction as well as purchasing issues. Due to increased costs the company was forced to act;

It was quite obvious at the time; purchasing and industrialization. And it was [CEO] W. who put them on the agenda [I. L.].

In the latter half of the 00s, and when CEO C. took over from CEO W., the market and the customers were brought into the limelight. As expressed by one of the managers, the company moved from being introvert, i.e. focusing on internal efficiency, to a more extrovert company, i.e. focusing on external factors;

[CEO] W. never talked about customers and market issues, he only talked about internal efficiency. But now we have started to talk about 'extrovert' issues. Well, I don't think it is such a big change in what we actually do, but at least we talk about it" [I. L.].

But despite these changes the business managers at Alpha did not experience a satisfactory implementation of the formulated plans, and 2009 Alpha underwent another major organizational makeover; support functions including HR, economy, and business support were moved from the geographic units to form one overall support unit.

The interviewed managers all seem to agree that the major changes that Alpha has undergone during the last two decades have been in the best interest of the company, at least in theory. In order to support these changes Alpha needed not only a different organizational structure, but new organizational roles. The managers' opinions regarding the changes that were initiated during the 90s often concerned the challenge of changing the attitudes of the managers, who had run the geographical units with a free hand during the 90s, to accept the new constraints and delimited leadership role in a centralized Alpha. One manager described the situation in the beginning of the 00s when Alpha already had taken a number of steps towards centralizing the organization:

…during [CEO] E's time the management team was like a committee with different interests. There existed some sort of underlying understanding that the less they decided collectively, the more influence they would have over their own operations [X. X.].

Individual agency: turning 'handymen' into 'specialists'

Traditionally, in most cases managers at different organizational levels at Alpha have been recruited internally and the vast majority of the interviewed managers have therefore experienced all the mentioned changes. The interviewees kept repeating that there was a challenge to make the managers align with the centralized organization and use the standardized ways of working when operating in their units of responsibility. Opinions expressed in relation to this were that the responsibility distribution has now become somewhat unclear in the centralized organization:

> *The [2009] re-organization has led to a somewhat vague responsibility distribution, meaning that 'if I don't act, at least I haven't done anything wrong'. This leads to a kind of 'no action' […] We are moving from a simple world to a more complex one, and consequently more intelligent control system is needed. However, I do not think that Alpha has chosen the easiest solution [I. L.].*

Such views might be rather natural consequences in an organization going from less control to more control. Vibes of 'the happy times back then' were worded:

> *Yes, we play to win, but [nowadays] we play a pretty boring game [laughter] [M. Y.].*

Or:

> *We lost a few to Beta*[1] *a couple of years ago, and I guess it was those that felt it wasn't as free at Alpha anymore, and that was only right. We shouldn't keep those who want to be 'handymen' if we want to attain our new strategy [K. K., regarding the overall change from the 90s up to now].*

The managers also described their constant effort to increase the 'team spirit' at Alpha: during the 90s individuals had been very much in focus:

> *These unit managers [of the 90s] were really Alpha's strongmen [X. C.].*

However, Alpha's 'strongmen' seem to be re-emerging, albeit in different roles, as was alluded to in most interviews. Below, the importance of the individual agency symbolized by the metaphor 'strongmen' will be exemplified from two different perspectives: *epochs* and *strategy processes as one manager's decision.*

Relating change to persons: two different perspectives.

Epochs

A common feature in all the interviews was the strong focus on Alpha´s leaders, or 'strongmen' and the epochs that were ascribed to them. The latter were alluded to as leader-epochs. As described above, Alpha has undergone a number of structural and strategic changes during the last two decades which were often described in similar terms,

> *That would have to be when Mr. E was CEO if I remember correctly [Y. F. regarding a certain strategy that Alpha had during a certain time].*

> *That disappeared when…what was his name…Mr. P. became CEO [W. W. regarding the fact that the basis for the product divisions changed at some point].*

[1] Beta is the name of one of Alpha´s main domestic competitors

These examples show how several of the interviewees related a certain strategic plan or an organizational structure to a particular CEO. The following example elucidates the same pattern, even when asking them closed questions.

> *Interviewer: "Was the organization structured on the basis of products or geography then?"*
>
> *Products. It was on the basis of products back in 97. Alpha was basically divided into two parts back then; one part was Alpha Building and the other was Alpha Civil and then different divisions within these. That particular structure was between 97 and 98 and it was with Mr. G. as the manager… Mr. G. took the Civil-part in Sweden and Mr. P. took the Building-part….or…did he really take the building-part? Maybe it was Mr. C. that took the Building-part as well? I think it was Mr. C. And then in 98, Mr. P. became the CEO for the whole Alpha Sweden [X. C.].*

Here is another example;

> *Interviewer: "How often do you have your regional manager meetings?"*
>
> *It has been more frequent. [CEO] W. introduced, he was the one that started to focus on the regions and it was then…Well, he started to have these regional manager meetings [Y. F.].*

The managers expressed themselves in this manner during the interviews, and it was not only in the descriptions of certain time epochs or specific events that the managers seemed to relate to the company leaders; even their personal experiences seemed to be related to Alpha´s leaders. The next example is from a conversation regarding one of the Alpha´s company archive. A manager was asked what kind of documents this archive contains, and the manager in question delivered a rather informed answer.

> *I have been there actually. I was there with the management team, when Mr. W. was CEO and we stayed there a whole afternoon and had the opportunity to go through a lot of old magazines and articles. It was very interesting [E. E.].*

Strategy processes as a leader's decision

One part of this study focused on Alpha's procedures for developing a new strategy and the main driving forces behind strategy changes. It was rather surprising that none of the interviewees talked of strategy work as a process; rather, strategy was seen as "belonging" to the CEO. He (all of the CEOs have been men) is seen as "owning" the strategic decision, i.e. as personified action.

The first example below is from a section when one of the managers described a major strategy reform and organizational makeover that Alpha carried out in the beginning of the 00s.

> *When Mr. W. was appointed CEO he wanted to remove this whole hierarchal level. <u>He thought</u> there was just too much management staff [E. E].*

Some more examples where the managers refer to strategic decisions as owned by a leader:

It was the idea of [CEO] E. who believed that we should come closer to our customers by having geographical divisions [I. L.].

[CEO] E. split up the product divisions and made geographical divisions instead [E. E.].

Our [Code of conduct] was [CEO] P.'s idea. He was an 'ethical man'. He took that initiative; otherwise it would never have happened [H. H.].

One of the managers captured the role of the leaders with the following clauses; *"…and then we changed CEO, and he wanted it in another way"*. Several of the managers referred to individual agency in combination with 'a sense of urgency' as the main driving forces behind strategic changes at Alpha.

The individuals are strong forces [for changes], but it is also a matter of trends [H. H.].

It is more about the individuals who drive the changes. The format is not <u>that</u> important. […] I think it is a combination of these two; a sense of urgency and the right man at the right place [I. L.].

However, this notion of leaders as central figures in relation to company epochs, strategy work, and personal experiences is contradicted by one of the interviewed managers. This manager did not mention any of Alpha's leaders throughout his long narrative, but instead consistently describes epochs, strategy work, and overall changes as devoid of personal agency. He had however worked for Alpha a considerably shorter time (approx. ten years) than the most of the other managers interviewed and had therefore not experienced the 90s when the 'handymen/strongmen' operated the different geographical units. When we asked him about the roles played by the leaders, he confirmed their centrality. The next example is extracted from a section in which he then is talking about W.;

This work with ´developing a more efficient building process´ and ´increasing the overall performance at Alpha´ was [Mr. W.'s] baby. That was when I worked with the [Alpha´s measurement tool]…because he was the father of that project [R. S.].

As mentioned above, the vast majority of the interviewees had worked for Alpha for more than 15 years and they had been recruited internally; a tradition that is common for the construction industry. Two of the managers were exceptions and had other backgrounds; they were not fostered in Alpha´s building projects, but were recruited straight into an upper-level manager position. The few contradictions to relating change to persons (mostly the CEOs) came from these three managers; the one that didn't work for Alpha during the 90´s, and the two that were recruited externally. All three of them did however support this indication, when we asked them specific questions about it. One of them said:

So, I was very into the idea of 'the insignificance of single individuals', but I really had to revise this perception when I started to work for Alpha. … These individuals actually mean a lot for Alpha, for good and for bad. I have realized that a CEO actually has a lot more influence over a company than what I thought when I first started to work here [A. B.].

DISCUSSION AND CONCLUDING REMARKS

During the period covered by this article, there has been both direct and indirect pressure on construction companies to develop a more efficient building process as well as obliging to growing ethical and environmental concerns. This has called for, and resulted in, a gradual transformation into a more standardized and centralized organization. This transformation is not unique for Alpha; but common for the whole construction industry, which has been looking to the manufacturing industry for models to emulate. The first part of Alpha's story shows that even though the managers appreciated the needs for a more centralized organization, there seemed to be some criticism regarding the consequences. This criticism manifested itself mainly as a discontent of having to give up decision-making mandates, as a sacrifice to organizational standards. The transformation that Alpha underwent can be described as unification in the name of economies of scale: merging activities into centralized functions and standardizing ways of work. As a consequence of these changes, Alpha is now, to a larger extent, run by a pre-determined plan with less room for subjective decision-making within the operational routines. It could be argued that top-management still decides what kinds of standardization that should be applied, but incremental standardization accumulates into indigenous 'givens' and will therefore delimit managers´ choices (e.g. Melander et al. 2008).

We identified an interesting phenomenon when examining the managers´ narratives. Epochs, personal experiences, strategy processes, and decisions were all dimensions in which a salient individual focus emerged. All these dimensions were *personified* to a large extent, the interviewees seldom referred to the rationale behind the time epochs, the personal experiences, the strategy processes, and the decisions, but rather to the specific CEO that they associated the events with; that person embodied the events to the point of representing the event itself.

The Strategy-as-Practice perspective advocates an emphasis on what people do, but it would probably have appeared as reasonable for many researchers and practitioners, to understand Alpha's transformation throughout the years as the strategies that Alpha (as a company) had and the strategies that Alpha (as a company) changed – in relation to e.g. their market, their competitors, their internal resources. Such units of analysis, however, risk ignoring the inter-subjectivity dimensions of what the strategists do; and overestimate the degree of causality between e.g. market, competitors, internal resources and specific company actions. The story told in this article supports this point as well as the most fundamental standpoint of the Strategy-as-Practice perspective – "strategy isn't something an organization has, it is something that the strategists do", and from the perspective of a number of upper-level managers in our study, it is something that some few individuals did (mainly the CEOs).

It is clear that Alpha throughout time has reacted to circumstances, e.g. by changing their strategies – but via the subjectivities of these persons (the strategists). Some of the strategic actions presented in the case are however examples of when the strategists' subjectivities probably align closely with the institutionalized context, e.g., "*the stock owners and the customers don't tolerate morally questionable behavior; we <u>must</u> do something about it*". But even these more "obvious" strategic changes were *personified* in the narratives; processes and decisions are formalized, but they are also *personified*. The upper-mangers included in this study related changes throughout time to the different CEO´s; and it seems like every CEO is associated with major changes. Noel (1989) concludes that it was the CEO´s unique personalities that decided the strategic direction for a number of companies that were studied in a field research setting, and the stories told in this article indicate something similar –

strategic change is perceived as something that the CEO´s have done, rather than as a process or as a rationale. Using another quote:

“ … it was common for a CEO to do something and you shouldn’t do the same something as the CEO before you; that was more important than doing something good and right” [D.E. (upper-level manager), regarding the different CEO´s that Alpha have had throughout the years].

The largest change described by the managers is the transformation from a decentralized organization to a more centralized organization, via a period in the 1990´s where Alpha´s different geographical units worked independently from one another, relying on their “strongmen” to make decisions.[2] It is possible that the circumstances during 1990´s created a company culture in which the subjectivity of a few leaders became a strong driver for strategic change; today, a number of upper- level managers relate strategic change to the “strongmen”, mostly the CEO´s.

It is however important to point out that little is known about the cause behind the identified phenomenon of personified strategies; the stories told are reconstructions of events and relating events to persons might be a mnemonic strategy rather than a mechanism of strategic change in real-time. It could also just be a version that seemed appropriate to share with researchers. We believe however that the degree of conformity among all the individual perspectives provides reason enough to pay attention to *personified strategies* and the implications.

Burgelman et al. (2005) note that internal corporate development cycles usually span over a longer period of time than a CEO usually stays at the same company; important long-term development strategies might therefore be disrupted if every CEO wants to (or feel they have to) change the strategy. Regardless of the effects from development cycles; *personified strategies* could likely diminish the holistic effects of strategizing; as the sum of a company’s competencies all together – which is the rationale behind the more standardized organization that Alpha has transformed into in order to meet the challenges on the changing markets.

The notion of "strategist" remains unproblematized in the Strategy-as-Practice field. This article is a first attempt to bridge this gap. Concentrating on upper-level managers, we have seen that there seems to be a tendency to associate strategic change with one specific strategist (the CEO). Such a perception could result in norms that put all responsibilities and risks onto one person. Furthermore, such pressure may be one reason why new CEOs may feel obliged to institute change (of any kind). However, associating strategies and changes with one person may also exaggerate the role of one strategists, understating the roles of others who may be equally involved in strategising; if upper-level managers associate change mainly with one top-level strategist, what responsibilities do they ascribe to themselves? If strategic change is actually driven by one strategist’s subjectivity; then we could ask ourselves whether we can refer to strategy as a concept at all.

On the basis of the above, we conclude by suggesting that *personified strategies* could be important drivers for strategic change in construction, albeit not necessarily to drive strategising as such. Rather to drive the legitimacy of a new CEO. Research needs to be carried out in order to further explore the complexities of *personified strategies.*

[2] Documentation confirms some parts of this: there existed no common business plan for Alpha until the beginning of the 2000´s.

REFERENCES

Björnström, J. *(2007)* Communicating strategy for better implementation, *Licentiate thesis, Chalmers.*

Burgelman, R. Välikangas, L. (2005) Managing Internal Corporate Venturing Cycles, *MIT Sloan Management Review*. **46**(4), 26-34

Christensen, C. and Raynor, M. (2003) The Innovator's Solution: Creating and Sustaining Successful Growth, *Harvard Business School Press.*

Eisenstatt, R.E., Beer, M., Foote, N., Fredberg, T. and Norrgren, F. (2008*) The Uncompromising Leader, Harvard Business Review.* **1**(86), 51-57

Johnson, G. Langley, A. Melin, L. Whittington, R. (2007) *Strategy as Practice.* Cambridge University Press Research Directions and Resources

Jarzabkowski, P. *(2008)* Hard to Disagree, Mostly, *Strategic Organization.* **6**(1), 101-106

Jarzabkowski, P. Balogun, J. Siedl, *D. (2007)* Strategizing: The challenges of a practice perspective, *Human Relations.* **60**(1), 5-27

Johnson, G. Scholes, K. Whittington, *R. (2008) Exploring Corporate Strategies – text and Cases,* Pearson Education Limited; 8th Edition.

Kaplan, S. (2008) Framing Contests: Strategy Making Under Uncertainty, *Organization Science,* **19**(5). 729-752

Lutz, J. Gabrielsson, E. (2002), Byggsektorns struktur och utvecklingsbehov. Byggkommissionen.

Melander, A. Nordqvist, M (red.) (2008) Att förstå Strategi. *Författarna och Studentlitteratur* 2008

Noel, A. (1989) Strategic Cores and Magnificent Obsessions: Discovering Strategy Formation Through Daily Activities of CEOs. *Strategic Management Journal.* **10,** 33-49

Whittington, R. (2006) Completing the Practice Turn in Strategy Research. *Organization Studies,* **27**(5). 613-634

Whittington, R. (2007) Strategy Practice and Strategy Process: Family Differences and the Sociological Eye. *Organization Studies.* **28**(10), 1575-1586

Whittington, R (2004) Strategy After Modernism; Recovering Practice, *European Management Revi9ew.* **1**(1), 62-68

Zábojník, J (2002) Centralized and Decentralized Decision Making in Organizations, *Journal of Labor Economics.* **20**(1), 1-22

THE USE OF SUPPLY CHAIN MANAGEMENT TO REDUCE DELAYS: MALAYSIAN PUBLIC SECTOR CONSTRUCTION PROJECTS

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Construction delays are a critical problem for Malaysian public sector projects. These delays have been blamed mainly on inefficient traditional construction practices that continue to dominate the current industry. This paper reports the progress to date of a Ph.D. research project aimed at developing a framework to utilize Supply Chain Management (SCM) tools to improve the time performance of Malaysian Government projects. The potential of SCM has been identified for public sector governance and its use in Malaysia is now being considered within the strategy of the Malaysian Construction Industry Master Plan (2006-2015). Encouraged by success in the UK, there is a cautious optimism concerning the successful application of SCM in Malaysia. This paper considers delay as a problem in Malaysian public sector projects, establishes the need to embrace SCM and then elucidates the need and strategies for the development of a delay reduction framework. A literature review, survey mechanism and structured interview schedule will be undertaken to achieve the research objectives. The final research outcome will be a framework that addresses root delay contributors ("pathogens") and applies SCM tools for their mitigation.

KEYWORDS: 'Supply Chain Management', 'construction projects', 'construction delay', 'public sector', 'Malaysia'

INTRODUCTION

The inability to complete projects on time is a problem in the global construction industry and more particularly in developing countries (e.g. Ahmed et al., 2002). This problem is manifested in the underachieving Malaysian construction industry (CIDB, 2009), with recent public project delay rates of 80% (Joshi, 2009). Abdullah et al. (2010) have also reported a 90% delay rate for projects handled by Majlis Amanah Rakyat (MARA), a government agency that plays an important role in implementing the Malaysian Government's construction policies.

This situation has, for a long time, been blamed on ineffective management (Munns & Bjeirmi, 1996) and the dominance of traditional construction practices. Love and Sohal (2002) claim that these practices create unnecessary waste, errors and misapprehension amongst the project supply chain. Current construction practice in Malaysia has also resulted in duplication of work, lengthy approval and work time, lack of transparency and surging costs (CIMP, 2007). Calls for improvement have been made through the Malaysian Construction Industry Master Plan 2006-2015 (CIMP, 2007) with similar efforts being previously made in other nations such as Australia, Sweden, Finland, Hong Kong, Norway, Singapore and the United Kingdom (Love et al., 2004). This suggests the need for a transformation in the way projects are managed.

Many researchers and practitioners have recognised the potential of Supply Chain Management (SCM) as a way forward for the construction industry (Egan, 1998; Strategic Forum, 2002; Love et al., 2004). Existing research also supports the fact that SCM benefits client organisations (London & Kenley, 1999) and has later appeared as an important concept for the public sector (London & Chen, 2006). Therefore, SCM appears to have the potential for helping the Malaysian public sector achieve better project time performance. Thus, the research described in this paper aims to develop a framework utilizing SCM tools and present a clear guide for the adoption of SCM techniques to reduce Malaysian Government project delay. As part of producing a holistic and workable delay mitigation framework, the delay causes will be tackled from their “latent” condition - described by Busby and Hughes (2004) as “pathogens”. With suitable modification, it is anticipated that the framework will be useful for public sector projects in other parts of the world.

Malaysian Construction Industry Outlook

Following independence in 1957, the Malaysian’s construction industry developed initially through the inaugural economic plan (1956-1960). Since then, Malaysia’s construction industry has played a significant role in improving the community’s lifestyle, generated wealth for the country and contributed to the economic development of the nation. In addition to realising the Government’s socio-economic policies, the sector also creates a multiplier effect on other industries such as manufacturing, services and professional services. Considering its importance to the nation, however, the growth of the sector has been slow, recording an average growth of only 0.7% from year 2000 to 2007, and, with the share of GDP shrinking from 3.3% to 2.5% over the same period, the lowest percent in the region (CIMP, 2007). With the aim of achieving a world-class industry by 2015, major improvement is needed within the Malaysian construction industry.

Construction Delay

It is generally accepted that time is one of the main efficiency measures of projects (NEDO, 1998), thus projects that experience delays are severely criticised. However, delivering projects on time is often very difficult due to the dynamic, complex, multidisciplinary and uncertain nature of the industry (Wright, 1997). Delays can have a major effect on construction organizations, resulting in increased costs, lost opportunity costs, reputation damage, arbitration, litigation and, in the worst cases, the total abandonment of projects. Construction delays also directly relate to the performance of a project and customer satisfaction level. Research in Finland by Kärnä et al. (2004) found that the customer satisfaction level declines when a project negatively deviates from the planned schedule. Therefore, customers appear to be dissatisfied when construction performance is less than what is regarded as standard (Kärnä et al., 2004).

The severity, and seeming intractability, of delays has triggered much research to identify their leading factors. There are studies from Saudi Arabia (Al-kharashi & Skitmore, 2009), Hong Kong (Chan & Kumaraswamy, 1997), Jordan (Al-Moumani, 2000), Ghana (Frimpong et al., 2003), Malaysia (Sambasivan & Soon, 2007). Previous studies have also described the “blame-game” that is played out every time a project exceeds its planned time (Al-Kharashi & Skitmore, 2009), picturing an adversarial scenario. In reality, the construction processes are inter-related (Love et al., 1998), which is a major issue in current management philosophies (i.e. SCM). SCM adopts a system perspective that suggests that the whole system is responsible for the project performance. Therefore, a different method for categorising delay causes is needed to detect the execution and system problems rather than individual errors.

Busby and Hughes (2004) have introduced the term “pathogens”, whose greatest conceptual value is that they remain dormant in the system until an actual failure occurs. This means that participants may be carrying out defective practices that have not yet resulted in a failure and so are continuously exposed to the same risk of error. Therefore, the identification of delay pathogens could avoid the risk of implementing similar mistakes over and over again. In construction, pathogen identification is also considered to be the first step towards attaining process stability (Love et al., 2008). For that reason, the identification of latent factors of delay allows mitigation to be carried out from the root cause and appears to be a positive move towards the development of a holistic delay reduction framework.

Delay in Malaysian Public Sector Construction

Delays in completion are a very significant problem for the Malaysian construction industry, with the latest statistics indicating that these occur on 80% of all public sector projects (Joshi, 2009). This is not a new problem and has created a negative image for the industry, with the delays being the subject of previous research by Abdul Rahman et al. (2006) and Pratt (2000). According to CIDB (2009), limited trust, adversarial relationship and problems in communication and coordination are major causes of the time overruns in Malaysian construction projects. The convoluted and inefficient nature of traditional Malaysian practices (Rowlinson, 1999) is thought to responsible for the fragmented and unpleasant attitudes of construction industry participants (CIDB, 2009). Research by Abd Shukor et al. (2011) also revealed that traditional and Design and Build procurement arrangements are preferred by most Industrialized Building System (IBS) contractors in Malaysia.

Few other initiatives have been made despite the introduction of numerous forms of private initiative modalities. For example, the Private Finance Initiative (PFI) was officially implemented by the Malaysian government in 2006 via the Ninth Malaysia Plan (2006-2010) under the National Privatization Plan (Netto, 2006) and still remains at the initial stage. Since then, several private-public collaboration initiatives have been undertaken. However, these have often been combined with traditional practices, leading to limited outcomes from the schemes on which they have been used. In fact, the PFI initiatives also deviate from the international PFI framework in terms of risk transfer to the private sector (Jayaseelan & Tan, 2006).

In addition, partnership practices in the Malaysian public sector mainly involve the contractor and client organisations, with little or no consideration given to involvement of other supply chains (e.g. supplier, sub-contractor) in its processes, deviating further from the main idea of collaborative approaches. Shortcomings also appear in terms of risk allocations, benefit sharing and encouragement of innovative ideas.

It could therefore be suggested that the current partnership approach in Malaysian public sector practice is merely an improved version of Design and Build practice, which has not yet managed to integrate the whole supply chain throughout the construction process. The failure to do this has missed the point of forming collaborative relationships thus fails to eliminate the adversarial nature and opportunistic behaviour that occurs in traditional practice. As a result, project performance has yet to achieve a convincing state, and time overruns remain a severe problem for the industry. This suggests a further shift is needed in the way projects are currently managed.

In the past, some significant delay cases have been experienced in public sector projects. For example, the MATRADE project experienced nine years of delay and a 70% cost overrun, said to be due to inferior construction and the abandonment of the project by the first contractor, resulting in the appointment of another contractor. Similarly, Pandan hospital took approximately six years to build rather than the planned two years due to many extensions of time. Other projects include the Middle Ring Road (2) that underwent post-occupational ratification due to the appearance of cracks in 31 of its flyover piers. Meanwhile, the second Penang Bridge, which is currently under construction, has been delayed for more than 12 months due to additional technical aspects that were not considered in the early stages, thus affecting the project execution date. A recent case is the Shah Alam hospital that scheduled completion for August 2010 but required an extension to June 2011, again due to contractor incompetence. Most of these cases were due to the incompetence of the whole project team, specifically the contractor. Incorrect selection and lack of integration among those involved in the supply chain has lead to problems, such as mistakes in project planning, buildability issues, wrong project team selection, miscommunication of information, etc.. This non-productive condition has caused the Malaysian construction industry to be inefficient and of low quality and productivity, leading to a comprehensively negative image and economic volatility (CIDB, 2004).

Need for Change

The construction industry worldwide has been heavily criticized for decades for its adversarial relationships, fragmented nature, poor customer/end-user focus, limited investment in improvement and innovation, poor time and cost performance, and low quality, productivity and satisfaction levels (Chan et al., 2003; Egan, 1998; Latham, 1994). There is now an urgent need for revolutionizing construction practice, technology, mentality, work practice and processes and to maintain continuous improvement through effective benchmarking and performance measurements. Such a change would ensure an advantage over conventional practice (Ibrahim et al., 2010), as the survival of the industry depends on its improved capability and aptitude (Abdul Rahman et al., 2005). Calls for greater project success have been made in recent times (Kärnä & Jonnonen, 2005). However, the Malaysian Government's investment in the industry has declined considerably (Abdul Rahman et al., 2005), forcing work to be undertaken with limited resources and with concomitant sacrificing of productivity and satisfaction levels (Ibrahim et al., 2010). Thus, in order to adapt in the new era, considerable improvement needs to take place to improve the country's construction performance.

Realizing the need for change, Malaysia's initiative came through the Malaysian Construction Industry Master Plan (CIMP) 2006-2015. This has resulted in a greater demand for improvement issues such as quality, human resources, innovation, communication, technology and environmental sustainability, with utmost priority being placed on integrating the industry's value chain (CIMP, 2007). Other programs include the "zero delay" target via the 10th Malaysia Plan which covers the 2011 to 2015 period (Abu Mansor, 2010). These initiatives clearly indicate the urgency faced by the Malaysian construction industry in terms of improving its overall industry performance, especially concerning the value chain attributes. Construction delay has been affecting the industry for many years and thus the elimination of delays has been prioritized in the most recent Malaysia Plan.

Examining the improvement needed for Malaysian construction practice, the industry could possibly benefit from the best practices from other industries such as manufacturing and production. The UK's Egan (1998) also stresses the need for industry to modernize itself to become more competitive and efficient. The increasing complexity and dynamic nature of today's construction industry (Gidado, 1996) suggests that conventional practice should be 'a story of the past' (Naoum, 2003). A move towards a longer-term relationship that nurtures better integration, knowledge sharing, investment in relations and greater flexibility is vital (Rahman & Kumaraswamy, 2002). Improvement in the management of supply chains is therefore necessary for increased construction productivity (Vrijheof & Koskela, 2000). In the case of Malaysia, effective construction supply chain integration practice needs to be related to the current trend in order to enhance its competitiveness and innovativeness (Abd Shukor, 2011).

SCM in Construction

Project success has long been sought after by construction practitioners (Mitchell & Trebes, 2005) and growing competition means that construction organisations need to find better ways to improve project success (Kärnä & Jonnonen, 2005). This has resulted in an increased call for more collaborative approaches. Recently, initiatives have supported SCM as a new mechanism for effective construction management (Egan, 1998; Love et al., 2004; Strategic Forum, 2002). In his report Egan (1998) urged the construction industry to engage higher integration, improve performance, nurture harmonious inter-organizational relationships and offer better value in projects.

SCM is a concept that originated and flourished within the automotive manufacturing industry and has recently gained the attention of the construction industry. It emerged in the late 1990's (Jones & O'Brien, 2003) and has been the focus of construction industry ever since. SCM has been defined by Christopher (1992, p. 18) as, "The management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole". Unlike traditional practice, SCM promotes competition between supply chains, not merely single entities (Gier et al., 2006), which motivates all parties to be competitive and productive (Jones & Saad, 2003).

SCM lacks theoretical support to explain its existence and boundaries; however a few theories are able to explain its nature, structure and survival. These include Transaction Cost Theory, which contends that asset specificity creates inter-dependence between partners to avoid the cost of creating new collaborations (Noteboom, 2000). Another theory in use is Resource-Based Theory (RBT) which believes that having control over and access to resources provides an extra edge to an organization's competitiveness (Rungtusanatham et al., 2003). On the other hand, Knowledge-Based Theory (KBT) compensates the RBT by recognising the value of sharing knowledge-based resources. Other applicable theories include the Contingency Theory, which suggests that the external environment could facilitate the establishment of an organisation's tactical strategies (Ranganathan & Lertpittayapoom, 2002) and Social Exchange Theory, which is based on the assumption that people tend to return favours (Gouldner, 1960). Finally, Industrial Organisation Economic Theory illustrates behavioural aspects of how market structures affect organisations and inter-organisational performance (O'Brien et al., 2002).

SCM is based on the notions that inter-firm and intra-firm relationships are important for organisations to be more agile in the global market. It claims that individual organisations cannot be self-contained and need to collaborate in a 'win-win' manner in order to supplement each other in terms of resources and experience, while at the same time nurturing long-term business relationships, increasing trust, configuration and control, and continuously improving the performance of the whole supply chain. SCM is said to be better than traditional practice in various aspects, such as reduced inventories, sustained improvement, cost efficiency, speedier operation, improved information flow, higher coordination and shared risks and rewards (see Cooper & Ellram, 1993).

It is necessary for the entire scope of the supply chain to be understood for successful implementation of SCM (Vrihjhoef & Koskela, 1999). Past SCM initiatives in construction, however, have had limited coverage, with studies restricted to split issues such as the contractor/supplier interface (Vrijhoef & Koskela, 2000), rework (Love et al., 1999), environmental performance (Ofori, 2000), design management (Khalfan et al., 2001), service quality (Hoxley, 2001) and purchasing behaviour (Dubios & Gadde, 2000). Research in construction SCM has yet to take a holistic approach (e.g. Barker et al., 2000). Furthermore, despite many researchers concluding clients mostly benefit from SCM (London & Kenly, 1999), most research initiatives focus on the contractor's supply chain, not particularly on SCM (Vrihjhoef & Koskela, 1999).

In Malaysia, SCM is a new concept with little or no application in industry. The relational approach as a whole is still in its infancy within the industry (Rashid, 2002), as are 'lean' practices (Abdullah et al., 2009). This review invites the conclusion that SCM has a great potential within the local construction industry, especially for public sector projects which experience the most delays. Due to the limited coverage of previous SCM studies, the research needed to be conducted in a holistic manner covering a subset of issues that lead to delays in Malaysian public sector projects. In light of the success of its application within the UK's Ministry of Defence (Pearson, 1999), there is some optimism that SCM could similarly benefit the Malaysian construction industry.

The Research Route

The first step in the research is to obtain existing relevant information on the causes of construction delays, pathogens of delay and the construction of SCM tools relevant for improving time performance. This involves a literature review and preliminary structured interviews conducted with Malaysian construction industry experts and aimed at identifying Malaysia's current issues, and take into account the locality factors that may apply. These have now been completed and are proving to be essential for the preparation of comprehensive questionnaire and survey forms for data collection in the later stage of the research.

The next stage of the research will adopt both qualitative and quantitative methods for data collection in order to achieve a broad array of data available for analysis. The survey forms will be prepared, tested and sent to industry practitioners in order to identify the main causes of delay in Malaysian public sector projects, which will then be grouped into distinctive pathogens. To increase the validity of the survey outcomes, the research will ensure that questionnaires are purposively scattered throughout the industry's supply chain, with the proposed sample size of 300 responses and at least a 35% response rate. After analysing the data from the first survey session and establishing a list of pathogens of the main causes of delay, this research will carry out another survey session with the aim of matching each delay pathogen with suitable SCM tools for the purpose of framework development. To ensure reliability of information, the same strategy will be applied as for the first survey session.

The data obtained from both surveys will then be translated into a framework which will illustrate how each unique SCM tools could be utilized in order to improve each pathogen of delay. Finally, the framework will be validated through two sessions of structured interviews with the experts and decision makers of the Malaysian construction industry to ensure that it is workable and suitable for Malaysian public sector application.

CONCLUSIONS

The Malaysian construction industry has been plagued by project delays for decades. This has led to the conduction of much research to address the problem; however, the industry is showing few signs of improvement. In the case of Malaysian public sector projects, time performance is at critical level, suggesting there are major issues with the industry's current practices.

The "*leitmotiv"* of published works is the call on industry to improve its sense of integration, communication, collaboration and coordination through embracing SCM. For example, the effectiveness of SCM in improving construction efficiency and productivity has now made it the preferred choice of partnering in the UK construction industry. Several client and contractor organisations have also benefited, suggesting that it could have significant potential within the Malaysian public sector.

Having realized the limited research coverage of SCM domains, the research will examine SCM tools needed to reduce the delay in Malaysian public sector projects in a holistic manner, covering all the sub-set issues grouped into 'pathogens'. Identifying the delay pathogens first enables a framework to be developed to address delay problems from their fundamental causes, thus avoiding future problems with unidentified causes.

The outcomes of the research aim to fill the gap in empirical studies in relation to SCM and will be of particular use to the Malaysian public sector and the construction industry as a whole. The proposed framework is also expected to be a useful guide for similar initiatives in other countries.

REFERENCES

Abd Shukor, A.S., Mohammad, M.F., Mahbub, R. & Ismail, F. (2011). Supply Chain Integration in Industrialized Building System in the Malaysian Construction Industry. *The Built & Human Environment Review*, **4**(1), 108-121.

Abdul Rahman, H., Berawi, M. A., Berwai, A. R., Mohamed, O., Othman, M. & Yahya, I. A. (2006). Delay mitigation in the Malaysian construction industry. *Journal of Construction Engineering and Management*, **132**(2), 125-33.

Abdul Rahman, H., Mohd Rahim, F. A., Hamid, M. & Zakaria, N. (2005). Beyond basic: the potential role and involvement the QS in public projects – an observation. *Sustaining the Profession – Towards Diversification.* Kuala Lumpur, Malaysia: QS National Convention.

Abdullah, M. R., Abdul Rahman, I. & Abdul Aziz, A. S. (2010). Causes of Delay in MARA Management Procurement Construction Projects. *Journal of Surveying, Construction & Property*, **1**(1).

Abdullah, S., Abdul Razak, A., Abu Bakar, A. H. & Mohammad, I.S. (2009). Towards Producing Best Practice in the Malaysian Construction Industry: The Barriers in Implementing the Lean Construction Approach. *Paper presented at International Conference on Construction Industry*, Padang, Indonesia.

Abu Mansor, S. (2010). The Construction Sector at the Onset of the 10th Malaysia Plan. *Presented at the 7th Malaysia construction sector review and outlook seminar*, Putra World Trade Centre, Kuala Lumpur.

Ahmed, S., Azher, S., Castillo, M., & Kappagantula, P. (2002). Construction delays in Florida; an empirical study. *Final report submitted to: Mr. Michael Ashworth, planning consultant, state of Florida, Department of Community Affairs.*

Al-Kharashi, A. & Skitmore, M. (2009). Causes of delays in Saudi Arabian public sector construction projects. *Construction Management and Economics*, **27**(1), 3-23.

Al-Momani, A. (2000). Construction delay: a quantitative analysis. *International Journal of Project Management*, **20**, 51–9.

Barker, R., Hong-Minh, S. & Naim, M.M. (2000). The terrain scanning methodology: assessing and improving construction supply chains. *European Journal of Purchasing and Supply Management*, **6**(3-4), 179-93.

Busby, J. S. & Hughes, E. J. (2004). Projects, pathogens, and incubation periods. *International Journal of Project Management*, **22**, 425–434.

Chan, A., Chan, D., & Ho, K. (2003). An Empirical Study of the Benefits of Construction Partnering in Hong Kong. *Construction Management and Economics*, **21**(5), 523-33.

Chan, D. W. M. & Kumaraswamy, M.M. (1997). A comparative study of causes of time overruns in Hong Kong construction projects. *International Journal of Project Management*, **15**(1), 55–63.

Christopher, M. (1992). *Logistics and Supply Chain Management - Strategies for Reducing Costs and Improving Service*. (2nd ed.). London: Financial Times Professional Ltd.

Construction Industry Development Board Malaysia (CIBD). (2004). *Master Plan for Occupational Safety and Health in Construction Industry 2005-2010*. Kuala Lumpur, Malaysia: CIBD.

Construction Industry Development Board Malaysia (CIDB). (2009). Integration of the construction industry through partnering – the Malaysian initiative. *Part 2: Theme paper of the 15th Asia Construct Conference*, Kuala Lumpur, Malaysia.

Construction Industry Master Plan Malaysia 2006-2015. (2007). *Construction Industry Development Board Malaysia (CIBD)*. Kuala Lumpur, Malaysia: CIDB.

Cooper, M. C. & Ellram, L. M. (1993). Characteristics of Supply Chain Management and the Implications for Purchasing and Logistics Strategy. *The International Journal for Logistics Management*, **4**(2), 13-24.

Dubois, A. & Gadde, L-E. (2000). Supply Strategy and Network Effects – Purchasing Behaviour in the Construction Industry. *European Journal of Purchasing & Supply Management*, **6**(3-4), 207-15.

Egan, J. (1998). *Rethinking Construction*, London: Department of the Environment, Transport and the Regions & HMSO.

Frimpong, Y., Oluwoye, J. & Crawford, L. (2003). Causes of delay and cost overruns in construction of groundwater projects in a developing countries; Ghana as a case study. *International Journal of Project Management*, **21**, 321–326.

Geir, G., Marianne, J. & Goran, P. (2006). Supply chain management – back to the future? *International Journal of Physical Distribution and Logistics Management*, **36**(8), 643-659.

Gidado, K. I. (1996). Project Complexity: The Focal Point of Construction Planning. *Construction Management and Economics*, **14**(3), 213-25.

Gouldner, A. W. (1960). The Norm of Reciprocity: A Preliminary Statement. *American Sociological Review*, **25**(2), 161-178.

Hoxley, M. (2001). Purchasing UK public sector property and construction professional services: competition v. quality. *European Journal of Purchasing and Supply Management*, **7**(2), 133-139.

Ibrahim, A. R., Roy, M. H., Ahmed, Z. & Imtiaz, G. (2010). An investigation of the status of the Malaysian construction industry. *Benchmarking: An International Journal*. **17**(2), 294-308.

Jayaseelan, R., & Tan, M. (2006). PFI-cure for all ills. *The Egde Malaysia*, 72-74.

Jones M. & O'Brien V. (2003). *Best Practice Partnering in Social Housing Development*. London: Thomas Telford Publishing.

Jones M. & Saad M. (2003). *Managing Innovation in Construction*. London: Thomas Telford Publishing.

Joshi, M. (2009, June 1). *80 per cent of Malaysian government projects delayed, minister says*. Webpage accessed 01-10-2009 at: http://www.topnews.in/80-cent-malaysian-government-projects-delayed-minister-says-2173299.

Kärnä, S. & Jonnonen, H. (2005). Project feedback as a tool for learning. *Paper presented at International Group for Lean Construction-13*, Sydney, Australia.

Kärnä, S., Junnonen, J.M. & Kankainen, J. (2004). Customer Satisfaction in Construction. *Paper presented at International Group for Lean Construction-12*, Copenhagen, Denmark.

Khalfan, M. M. A., Anumba, C. J., Siemieniuch, C. E. & Sinclair, M. A. (2001). Readiness assessment of the construction supply chain for concurrent engineering. *European Journal of Purchasing and Supply Management*, **7**(2), 141-53.

Latham, M. (1994). *Constructing the Team.* London: HMSO.

London, K. & Chen, J. (2006). Construction supply chain economic policy implementation for sectoral change: moving beyond the rhetoric. *OBRA 2006: Proceedings of the Annual Research Conference of the Royal Institution of Chartered Surveyors*, University of Newcastle, Australia.

London, K. & Kenley, R. (1999). Client's role in construction supply chains - a theoretical discussion. *Proceedings CIB Triennial World Symposium W92*, Cape Town, South Africa.

Love P. E. D. & Sohal A. S. (2002). Influence of organisational learning practices on rework costs in projects. *Proceedings of the Eighth International Conference on ISO 9000 & TQM (Change Management)*. RMIT Storey Hall, Melbourne: Centre for Management Quality Research at RMIT University.

Love P. E. D., Li H. & Mandal P. (1999). Rework: a symptom of a dysfunctional supply chain. *European Journal of Purchasing and Supply Management*, **5**(1), 1–11.

Love, P. E. D., Davis, P., London, K. & Jasper, T. (2008). Causal Modelling of Construction Disputes. *Association of Researchers in Construction Management 2008 Conference Proceedings*, Cardiff, UK.

Love, P. E. D., Gunasekaran, A. & Li, H. (1998). Putting an engine into re-engineering: toward a process based organisation. *International Journal of Operations & Production Management*, **18**(9), 937-49.

Love, P. E. D., Irani, Z. & David, J. E. (2004). A seamless supply chain management model for construction. *Supply Chain Management: An International Journal*, **9**(1), 43-56.

Mitchell, B. & Trebes, B. (2005). *Managing reality: Book 1 – Introduction to the engineering and construction contract*. London: Thomas Telford Limited.

Munns, A. K. & Bjeirmi, B. F. (1996). The role of project management in achieving project success. *International Journal of Project Management*, **14**(2), 81-87.

Naoum, S. (2003). An Overview into the Concept of Partnering. *International Journal of Project Management*, **21**(1), 71-6.

NEDO. (1998). *Faster Building for Industry*. UK: HMSO.

Netto, A. (2006). Malaysia's newfangled privatization fudge. (*EPU. 2006).*

Nooteboom, B. (2000). *Inter-Firm Alliances: Analysis and Design* (2nd Ed.). New York: Routledge.

O'Brien, W. J., London, K. & Vrijhoef, R. (2002). Construction supply chain modelling: A research review and interdisciplinary research agenda. *Proceedings from IGLC-10*, Gramado, Brazil.

Ofori, G. (2000). Greening the construction supply chain in Singapore. *European Journal of Purchasing and Supply Management*, **6**(3-4), 195-206.

Pearson, A. (1999). Chain reaction. *Building*, pp.54-5.

Pratt, R. (2000). Project management in Malaysia, some ideas on the way ahead. *Paper presented at Asia Pacific Diligence Sdn Bhd seminar, Project management: strategies, techniques, operations and control*, Kuala Lumpur, Malaysia.

Rahman, M. & Kumaraswamy, M. (2002). Joint Risk Management through Transactionally Efficient Relational Contracting. *Construction Management and Economics*, **20**(1), 45-54.

Ranganathan, C. and Lertpittayapoom, N. (2002). Towards a conceptual framework for understanding strategic alliance in e-commerce. *Proceedings of the 35th Hawaii International Conference on System Sciences.* Hawaii: Computer Society.

Rashid, K. B. A. (2002). *Construction procurement in Malaysia: processes and systems constraints and strategies.* Kuala Lumpur: Research Centre, IIUM.

Rowlinson, S. (1999). A Definition of Procurement Systems. *In Procurement Systems: A Guide to Best Practice in Construction*, ed. S. Rowlinson and P. McDermott., 27-51. London: E & FN Spon.

Rungtusanatham, M., Salvador, F., Forza, C. & Choi, T. Y. (2003). Supply-chain linkages and operational performance: A resource-based-view perspective. *Journal of Operations and Production Management,* **23**(9), 1084-1099.

Sambasivan, M. & Soon, Y. W. (2007). Causes and effects of delays in Malaysian construction industry. *International Journal of Project Management*, **25**(5), 517-526.

Strategic Forum (2002). *Rethinking Construction: Accelerating Change.* Consultation paper. London: Strategic Forum for Construction.

Vrijhoef, R. & Koskela, L. (1999). Roles of supply chain management in construction. *Proceedings of the Seventh Annual Conference of the International Group for Lean Construction.* Berkeley, US: IGLC-7, 133-146.

Vrijhoef, R. & Koskela, L. (2000). The four roles of supply chain management in construction. *European Journal of Purchasing & Supply Management,* **6**, 169-178.

Wright, J.N. (1997). Time and budget: The twin imperatives of a project sponsor. *International Journal of Project Management.* **15**(3), 181-186.

CIVIL ENGINEERING DRIVERS AND INDICATORS

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Once a closed market, civil engineering is now genuinely opening up. In the past, forecasting the industry has consisted mainly of assessing the public sector's budget realisation, but now there is a gradual move towards a market-based model, introducing an opportunity to assess the construction market by means of market research. The opening and globalisation of the market also presents additional information needs and needs to indentify the pieces of information that best predict future development.The research question has been to define future development of the civil engineering markets. The key indicators have been chosen for several reasons, the main reason being that despite the availability of some longitudinal data statistics remain, on the whole, inadequate. The used method on analysing the change is contextualism, in other words, studying long-term process in their context. In a closed market, activities are planned according to the available resources. In an open market, demand depends on the needs of customer industries and on financial considerations. The most important indicators for forecasting civil engineering construction are public sector budget, private sector outsize projects and GDP change.

KEYWORDS: key indicators, civil engineering, market change, forecast

INTRODUCTION

Infrastructure construction has undergone a transition from a largely closed market to an open one resulted from EEA Agreement (1994). In a closed market, activities are planned according to the available resources. In an open market, demand depends on the needs of customer industries and on financial considerations; as a result, the significance of reliable business information has increased. Market information is needed both for short-term operational planning and for long-term strategic planning.

The migration of customer and production sectors to a market open both nationally and internationally has created discontinuities on many different levels. Customers no longer need to content themselves with the local or national service selection. Instead, they have the chance to look for suppliers from an international market. Suppliers in turn can specialise in this regard and seek customers from a broader geographical area.

The rate of change in the open market is accelerating. The impact of changes in the international economy, international contracts, the marginal terms of the customer industry's economics, etc., on civil engineering are stronger and more direct (Nippala & Petäjä, 2004). It has been an objective of this project to produce key indicators for the infra-construction market that can be used to evaluate the current status and future development of the market.

The remaining part of the paper is organised in the following way. Firstly, I introduce some literary foundations for the research area. Secondly, I describe the methodology of the study. Thirdly, I report my empirical case on how the forecasting of civil engineering works has had to change along with market structure changes, and how it must continue to change. The focus is on the period of time before 1990 and the two decades 1990–2010, and on suggestions for how things should be after 2010. Finally, I draw conclusions and propose further research.

LITERATURE

No theoretical foundation exists in the economic theory for the construction industry for estimating and forecasting the demand for civil engineering in a closed market. There is an unquestionable need for channels and networks, but it cannot be made to fit the supply-demand theory of business economics. One possible way to approach the demand for civil engineering is to comply with set standards or meet a recognised need. Examples of standards that must be complied with are clean water quality standards or threshold values for processing waste water. One example of meeting a recognised need is when the amount of renewable energy used increases or when congestion is reduced in population centres. In this way, the desired outcome or state can be forecast, along with the need for civil engineering it creates, but not the actual demand. Many different sectors compete for public funding. It is not possible for any one sector to increase its volume, even when the need to do so is recognized. (Hillebrandt, 2000)

A study of construction carried out in Germany showed that the development of civil engineering should be estimated by using information from micro-sectors (Ottnad & Hefele, 2006). However, this is a challenging task as statistics are often incomplete or inadequate. Political decisions affect investments significantly, so that the total may not equal the sum of its parts. One end product substituting for another may greatly affect the investment; a rail network can be used to replace a highway network, for example, or locally produced energy to avoid building an energy network. On one hand, growth of traffic volumes demands investment in the traffic infrastructure; on the other, reduction in energy consumption, the amount of waste and water consumption reduce the need for investment. However, in this case there was a need to modernise and make local-level investments for the replacements of all of these systems. Part of the infrastructure is owned by private companies. For these companies, the amount of production is clearly defined by the demand and the financial conditions for meeting it.

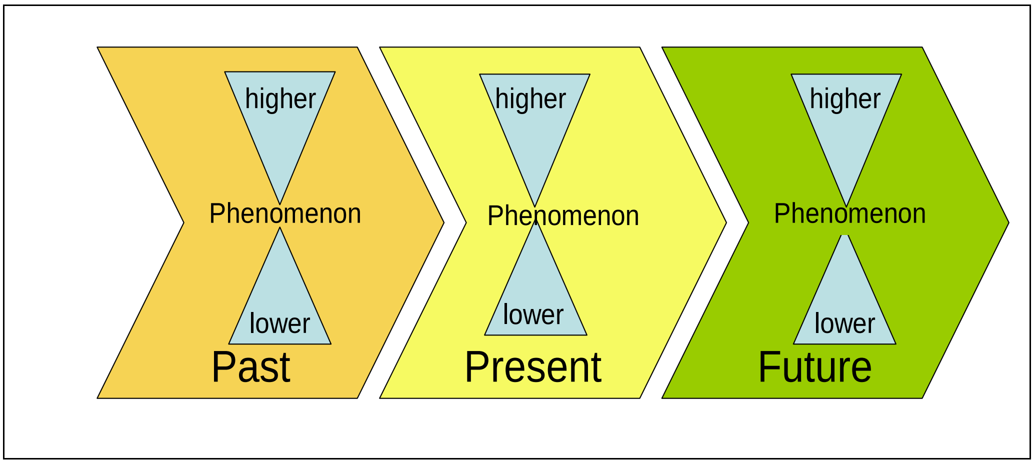
Fluctuation in the level of economic activity is quite common in developed countries. These movements are known as business cycles. A business cycle usually has four distinct phases: the upswing or recovery phase, the peak, the downswing phase and the trough. As most forecasters know, establishing one's current position in the business cycle is not that straightforward. Better results appear to be achieved, therefore, when combining quantitative and qualitative data in the economic forecasting models (Snyman, 2009).

RESEARCH METHOD

According Pettigrew (1990) contextualism as a the research method on change is proposed initially by the philosopher Stephen Pepper in his book "World hypotheses" (1942). The research on change includes context, content and process of change together with their interconnections through time. The focus is on changing, catching reality in flight; and studying long-term process in their context, a return to embeddedness as a principal of method. Context refers to the outer and inner context of the organisation. Outer context includes the economic, social, political, and sectoral environment in which the firm is located. Inner context refers to features of the structural, cultural, and political environment through which ideas for change proceed. (Pettigrew, 1990).

A contextual analysis of a process such as change draws on phenomena at vertical and horizontal levels of analysis and the interconnections between those levels through time (see figure 1). The vertical level refers to the interdependences between higher or lower levels of analysis upon phenomena to be explained at some further level; for example, the impact of a changing socioeconomic context on features of intraorganisational context and interest-group behaviour. The horizontal level refers to the sequential interconnectedness among phenomena in historical, present and future time. (Pettigrew, 1990)

Figure 1. In this paper the past is time before 1990, the present is time 1991-2010 and future is time after 2010. Higher level changing is for example political changes and lower level changes take places inside civil engineering sector.



RESEARCH QUESTION

The research question has been to define future development of the civil engineering markets. The key indicators have been chosen for several reasons, the main reason being that despite the availability of some longitudinal data statistics remain, on the whole, inadequate. The variables produced by the official statistical body are supplemented by tailored time series, collected either by the researchers themselves or by industry entities.

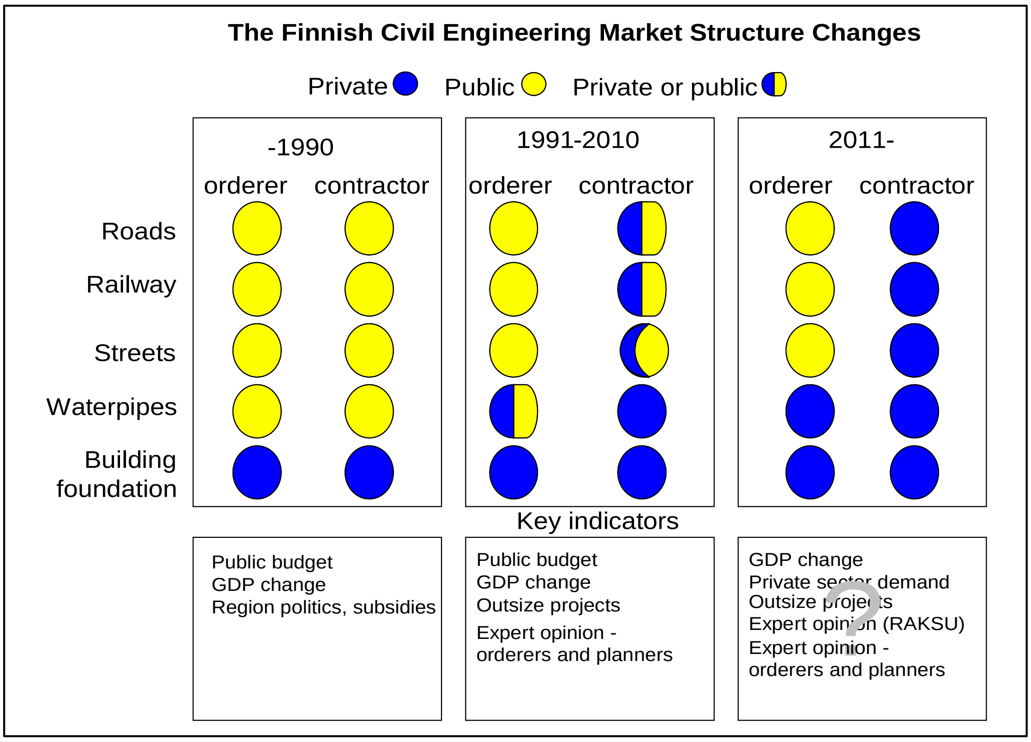
The Finnish civil engineering market has been divided into three periods: before 1990, 1991–2010 and after 2010. In the 1990 the state outsourced the first civil engineering department (Civil Aviation Administration) and in the 2010 the last one (Navigation Administration). Each time period requires its own indicators. The first period consists of the time when state organisations and municipalities had their own planning and contracting units, and private industries were alone in contracting out to private contractors. A prime example of this type was the building contractor (see figure 2). The other indicators for the first period were forecasted public sector civil engineering investment and gross domestic product (GDP). GDP growth explained the possibility for state investment in the civil engineering sector.

During the time period 1991–2010 a change occurred in civil engineering construction, with the public sector outsourcing its contracting units and motivated market research. Technical

Research Centre of Finland (VTT) began researching investors' (state, municipalities and industry) investment intentions and following up outsize projects.

Today new indicators must be found to describe further more open civil engineering market because the old indicators fail to describe the future market. The research frame have to be renewed, for example more economic indicators are needed.

Figure 2. The transformation of the Finnish civil engineering market.



PHENOMENON PAST, PRESENT AND FUTURE

Time period before 1990, market structure

Civil engineering has always been closely tied to the development of society and business life. Civil engineering is needed when suburban areas and communities are constructed. The needs of industries and societies affect the traffic, energy and communication networks (Karjalainen, 1985). In addition to specific needs, the civil engineering industry was used as a tool in labour and regional politics up until the 1980s. The labour political dimension was discarded due to technological development and unemployment benefits, while the regional political dimension remained until the 1990s.

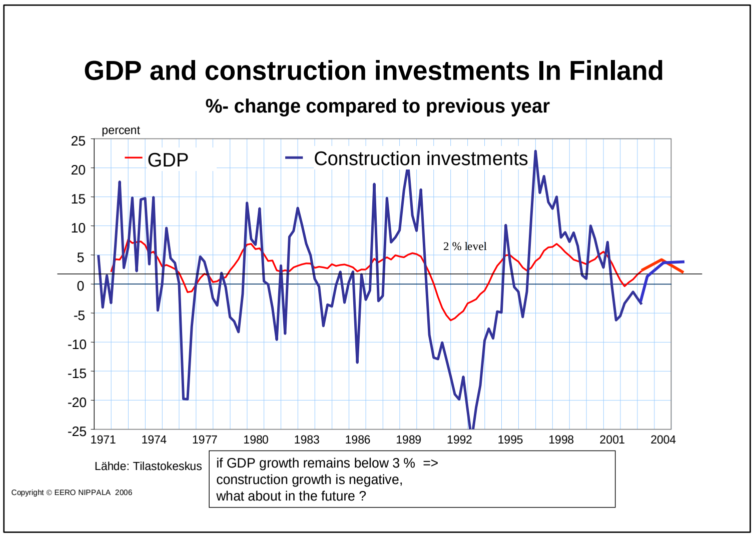
Forecasting indicators before 1990

Public sector budgets. VTT has been carrying out civil engineering market forecasts since the 1980s. The first forecasts were made mainly with state and municipal civil engineering investment plans in mind (Karjalainen, 1985). There was no advance information concerning additional state budgets even if a plan were known, which is one reason why forecasts went wrong. At that time the majority of civil engineering work was in the form of road building contracted by the state's own contracting unit. If extra money were available, more work (subcontracting) could be ordered during the year.

Railway, street, water supply, sewerage and many other civil engineering sector constructions were also carried out by state or local municipal organisations, all with budgets and investment plans for the following year (Karjalainen, 1985).

GDP forecast. Even before 1990 GDP was one important indicator for forecasting future development of the civil engineering market. The GDP growth explains other sectors' need. If during the last 50 years GDP growth has been less than +2 per cent annually, construction has grown negatively. If GDP has grown more than +2 per cent, construction has grown more than 2 per cent. If GDP has grown about +2 per cent, the growth of construction has been zero.

Figure 3. If GDP growth remains under +2 per cent, construction growth will be negative.



Time period 1991–2010, market structure

Since the recession at the beginning of the 1990s civil engineering has also been guided by economic realities. Projects are given priority according to how they boost the economy. Part of the public infrastructure has become privately owned; in this respect, decisions are made on a purely economic basis.

In recent years, construction has been an outgrowth of the change in regional structures and by migration, which concentrates the population in attractive cities and their surrounding communities. The altered and increased traffic flows demand both mass transport solutions and highway investments. Construction in an existing urban area brings with it marginal terms: tampering with an existing built environment and taking part of the construction underground (Nippala & Petäjä, 2004).

Since the mid 1990s many of the formerly closed markets of infra construction has been opened up for competition. This has brought an expansion in the selection of end products and increased significance for the private sector as constructor. However, the public sector still dominates, with 80 per cent of all infrastructures (Nippala & Petäjä, 2004; Nippala & Vainio, 2008).

Investments in construction concentrate on the buildings, highways and networks of the existing built environment. While some investments are used for renovations, others are used to upgrade constructions to meet the requirements of society. The role of companies as implementers of investment work has grown to 70 percent and in infrastructure maintenance to 65 per cent (VTT).

Currently, the end products of civil engineering can be either private or public. Often, they are classified according to their role as transfer or distribution networks, but most commonly, their classification is based on their functionality. As an example, a function can be the transfer and distribution of electricity.

Infrastructure	Public Private	Transfer Distribution	Transport Energy Water Telecommunication Sport and recreation ….

The examination framework of the national economy divides the end products (use) between the public and the private sectors. This use can be either investment or consumption. Based on this division, construction can be divided into public sector construction investments and consumption, i.e. upkeep and maintenance, and to the corresponding construction investments and consumption of the private sector.

In addition to the work of their trademark industry, companies in the civil engineering industry also carry out foundation work for residential buildings and property maintenance of outdoor areas. By this definition, civil engineering work in Finland in 2009 totalled around EUR 9.2 billion (figure 1). In recent years, the significant changes in the residential building industry have made a major impact on the civil engineering market (table 1) (VTT).

Table 1. The % change of civil engineering production volume in Finland compared to previous years

	2009 EUR Billion	2007 %	2008 %	2009 %
Total	5,5	0	+2	-2.5
Investments	3,9	0	+3	-4
Maintenance	1,6	-1	-1	+1
Foundation work for residential buildings	0,6	+14	0	-27

The statistical information is historical and can be used to analyse the market to a certain degree. Current information and forecasts for the future are nevertheless required for operational control purposes.

In the closed market, planning information gave a clear enough picture of the civil engineering situation. The same source of information is used when looking at the situation in the open market. The economic cycle of civil engineering is typically said to be synonymous with the figure describing the large single civil engineering investments in the government budget. If the paragraph outlines a major change due to an impending highway project, “civil engineering works are on the rise.” The end of the highway project means that the “civil engineering works are in decline.” This information is broadcast, being deemed reliable and easily accessible.

Companies and central government have often viewed the economic cycle of civil engineering somewhat differently. Central government sees the increase in its civil engineering funding, while companies see foundation and earth construction ending with the slump in residential construction (Raksu).

Forecasting indicators 1990-2010

Surveys. Several industry-specific economic surveys are used to evaluate the development of the economic cycle in the civil engineering market. The surveys are produced by actors such as building designers, earthworks contractors and machinery contractors. The Earth Construction Branch Advisory Committee publishes the traditional biannual economic survey that covers the outlook on the industry (VTT). The survey reports on the economic cycle of civil engineering owners (municipals, companies), designers and contractors, and provides economic forecasts, market observations, cost changes, and so on. The economic survey is also supplemented with calculated data to describe the changes in volume.

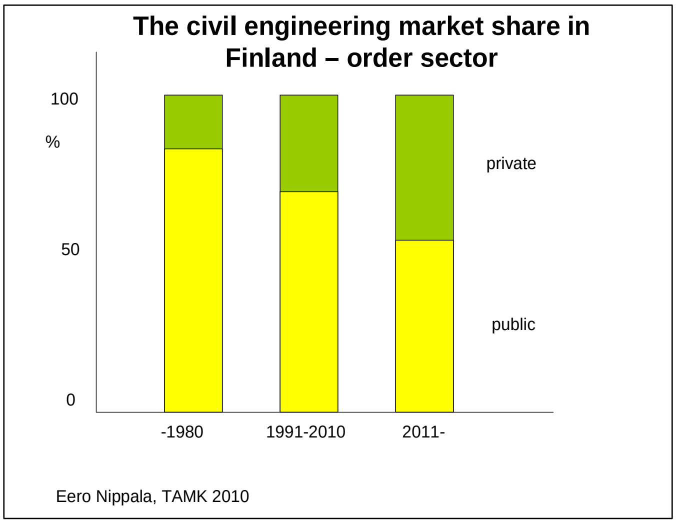
This report on the outlook of the civil engineering industry has been published since 1993. The same questions have been used from the beginning to gather survey data on the development of operations.

Outsize projects. Although the influence of outsize projects on the civil engineering market was realised as early as the 1980s, no system existed for collecting sufficient information. VTT began collecting information between 1991 and 2010 from all civil engineering construction sites where construction costs exceeded EUR 50 million. The collected information helps to forecast the construction volume for the following year. The total cost today of outsize projects (>EUR 50 million) is about EUR 500–1,000 million and of civil engineering EUR 6–7,000 million. Outsize projects have special influence on certain sectors. In the aviation sector, for example, one outsize project may double or triple the construction work for the whole year.

GDP growth. In Finland the beginning of the 1990s was marked by a recession. The forecast for civil engineering was in error and nobody could see the depth of the coming recession in advance. Civil engineering companies were still buying new excavators in 1990.

Public budget. State and municipal ownership in the civil engineering market decreased during 1991–2010. Ownership changes in the Finnish civil engineering industry began at the onset of the 1990s. The first big change came in the aviation sector, with the transformation of a state-owned organisation into a commercial enterprise. In 1995 the Finnish State Railways separated into the Finnish Rail Administration, VR Track Ltd Contractor, VR Cargo Oy and VR Henkilöliikenne Oy (handling passenger traffic). This was followed by changes in the organisation of road and sea traffic.

Figure 4. Market share by order sector. The share (total market in euros) of the private sector is slowly growing.



Period after 2010, market structure

The period after 2010 starts with an insecure financial situation. The world monetary crisis in 2008 and the subsequent rapid recovery keep the oil price high and have influence on the Finnish civil engineering sector. The European economic situation is also insecure because of the Greek and Irish economic difficulties.

The economic situation for the Finnish state is also worsening, with Finland having to pay back loans taken out for the 2008–2009 recession. For Finnish civil engineering this will mean a greater onus in future on the private sector.

The indicators are used to describe the interaction between civil engineering construction and its operating environment. The interaction is couched in specific terms, for example in the supply-demand situation and in the development of costs. The indicator system's approximations are suitable for analysing international infra construction.

Forecasting indicators after 2010

Private sector investment. Investments in energy, district heating, water supply and airports are made by the private sector. These sectors, more or less dependent on the economic situation, decrease their investments very quickly if the economic situation gets worse, weighting GDP as an even more important indicator.

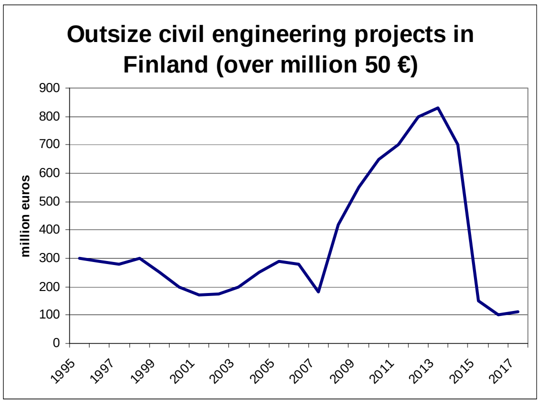
RAKSU group expert opinion. In Finland a group of experts meets four times a year to discuss market development of the civil engineering and the economic situation. The experts represent various sectors, such as contractors, scientists, ministries and associations. The group forecasts the civil engineering volume for the following year for publication on the web pages of the Ministry of Finance (Raksu).

Surveys of actors. VTT conducts biannual surveys among contractors and civil engineering investors (municipalities, state and private organisations).

Over recent years the survey of planning engineering offices has been reasonably successful in forecasting the changes in civil engineering. Contractors' surveys are another good indicator for future development, with knowledge months in advance of the forthcoming market situation based on the number of calls for bids. A further useful indicator is the number of contracts, although with forecasting only four months ahead there are some limitations to the use of this information.

Outsize projects. The state budget finances a number of large-scale projects, as do private companies. The influence of outsize projects varies year by year (See Figure 5). Examination of years 1195–2015 reveals that the influence on the total civil engineering market in 2013 will be about 400 per cent greater than in 2005. While acknowledging that these are only planned figures, decisions have in any case been taken to finance all the projects. The private sector projects in Figure 5 all started before 2009, and incorporate the risk of some delay.

Figure 5. Total for public and private projects (over EUR 50 million) in Finland.



DISCUSSION

The most important indicators for forecasting civil engineering construction are:

- public sector budget
- private sector outsize projects
- GDP change.

The public sector finance still approximately 55 per cent of civil engineering in Finland. The remaining 45 per cent share of other sectors is growing. The most important single factor is the state budget. An annual additional budget supplemented the state budget during the 1990s as civil engineering construction was inadequately forecast in the main budget. A number of these also appeared during the 2000s. The main budget, published in September, covers nearly 100 per cent of yearly civil engineering investments.

The outsize projects over EUR 50 million (both public and private) make up about 5–10 per cent of the total construction volume in Finland. In some civil engineering sectors one single outsize project may represent 50 per cent of all investments. For example, the Vuosaari harbour project in the Helsinki Metropolitan Area constituted over 50 per cent of total waterway investment at that time.

GDP is a fairly accurate forecast of building construction. The foundation of new houses forms about 15–20 per cent of the work carried out by civil engineering contractors. This is also a key sector for companies operating outside growing city areas.

Experience of which data are relevant and which are not is derived from surveys for contractors carried out by the Confederation of Finnish Industries (EK) over 30 years and those for owners and civil engineering planners performed by VTT over a period of about 17 years. While the 17 owner surveys appear incapable of providing explanation, those for planners and contractors have proved more valuable, forecasting future civil engineering construction volume approximately 0.5–1 year ahead.

PHENOMENON IN EUROPEAN AND NATIONAL (FINLAND) LEVEL

The comparison between European level and national level civil engineering drivers are illustrated in table 2. The source of the European level drivers, including Finland, is Euroconstruct conferences held during 2000–2010. The conferences are focused to construction short-term forecasts in nineteen European countries.

At the General level nearly all European level drivers has some influence also over national level. But not vice versa, a small country doesn't have influence in European level civil engineering markets.

A positive economic growth does not have direct positive influence in civil engineering investment because public sector tax income has some delay. In the long run, of course, it has positive influence in civil engineering investments. The negative economic growth has in many countries also positive influence in civil engineering investments. Stimulus packages activate civil engineering investments (table 3). At local level elections have positive influence in civil engineering investments.

Table 2. Examples of European level and national level civil engineering investment drivers mentioned during 2000 and 2010 in Euroconstruct reports.

Driver	***European level drivers***	***National level drivers, (case Finland)***
EU directive and legislation	*Directive 2000/60/EC, secure of clean water*	*National legislation (National Building Code)*
TEN Network	*Investment in infrastructure in new member countries*	*State road and railway investment budget*
Expansion of EU	*Aid to new member countries infrastructure investment*	*Encourage companies to export civil engineering work to new member countries*
Economic growth - depression	*stimulus package*	*stimulus package*
Budget deficit less than 3 percent and government debt less than 60% of GDP	*Retrictions in finance (Greece, Ireland)*	*Future restrictions in Finland*
Elections	--	*Local elections accelerates civil engineering investments*

Table 3. Examples of European level and national level indicators for short term forecasting mentioned during 2000 and 2010 in Euroconstruct reports.

Indicators	***European level indicator***	***National level indicator, (case Finland)***
Expert opinion	*Euroconstruct member group*	*Ministry of Finance Construction market Analyst group*
Economic growth	*Bank, IFO institute etc. forecast of GDP growth*	*Bank of Finland etc. forecast of GDP growth*
Outsize project	*Euroconstruct country level reports of big projects*	*Follow up of outsize projects in Finland (over million 50 euro)*
Infrastructure owner	--	*Opinion of different sector civil engineering owners*
Demand of private sector	*Industrial investment forecast, mining sector forecast, energy supply forecast*	*Industrial investment forecast, mining sector forecast, energy supply forecast*

CONCLUSION

This paper explains the indicators for Finnish civil engineering construction in three different time periods: before 1990, 1991–2010 and after 2010. Indicators have changed because of structural changes in the Finnish civil engineering sector. The most important indicators before 1990 were the public sector’s investment plan (state) and regional investments (municipalities). The time period 1991–2010 required two further indicators, namely outsize projects and owners’, planners’ and contractors’ surveys. The new indicators brought a significant improvement to forecasting.

The official statistics consist of traditional civil engineering – road, railway, streets, waterways, airports, ports, energy sector networks (e.g. gas, electric and district heating), water supply, the telecommunication network and environmental structures, parks and leisure areas. The industry (civil engineering contractors) also operates in the building construction sector and the maintenance of buildings (outdoor area). These works are not included under civil engineering in the official statistics.

Two further indicators are necessary for the period after 2010. The first is the expert opinion of the RAKSU group (called up by the Ministry of Finance); the second is civil engineering investments of the private sector. The second indicator is more problematic because of the absence of statistics; use can only be made of weak anticipatory signals.

Development work on the indicators continues in 2011–2012. A new research (Vainio & Nippala, 2010) will possess a more scientific touch, including testing of the theory described in this paper.

REFERENCES

Euroconstruct conferences

68th EUROCONSTRUCT Conference - Zurich, November 2009
66th EUROCONSTRUCT Conference - Brussels, Dezember 2008
64th EUROCONSTRUCT Conference - Vienna, November 2007
62nd EUROCONSTRUCT Conference - Munich, December 2006
60th EUROCONSTRUCT Conference - Barcelona, November 2005
58th EUROCONSTRUCT Conference - Paris, December 2004
56th EUROCONSTRUCT Conference - Funchal, November 2003
54th EUROCONSTRUCT Conference - Munich, December 2002
52nd EUROCONSTRUCT Conference - Rome, December 2001
50th EUROCONSTRUCT Conference - Paris, December, 2000

*European Economic Area : EEA and EFTA agreements. (*1994). Abridged edition / compiled by the Legal Department of the EFTA Secretariat, Stockholm.

Hillebrandt, P. (2000). *Economic theory and the construction industry*, Macmillan Press Ltd, London.

Karjalainen, J. & Pajakkala, P. (1985), *Maa- ja vesi- rakennustuotannon määrä 1980-luvulla,* VTT Tiedotteita 453, Espoo.

Nippala, E. & Petäjä, S. (2004), *Infra-alan liiketoimintaympäristön muutos - Vaikutuksia PK-yrityksille [The changing business environment - SME point of view]*, Suomen maarakentajien keskusliitto, SML, Helsinki.

Nippala, E. & Vainio, T. (2009). *Tienpidon markkinoiden toimivuus, yritysten ansaintalogiikka 2008–2009 [The road maintenance markets and business models of companies]*. VTT, Tampere.

Ottnad, A. & Hefele, P. (2006). *Die Zukunft der Bauwirtschaft in Deutschland: Umfeld, Probleme, Perspektiven.* IWG Bonn, Olzog Verlag, Bonn.

Pepper, S. (1940). *World hypothesis. University of California Press, Berkeley*.

Pettigrew, A.M. (1990). "Longitudinal Field Research on Change: Theory and Practice", *Organization Science*, vol. 1, no. 3, pp. 267-292

Raksu, *Rakentaminen [Construction] 1975–2011*. Biannaul outlook. Ministry of Finance, Helsinki. Webpage accessed 25-02-2011 at:
http://www.vm.fi/vm/fi/08_talousnakymat_ja-politiikka/01_talousnakymat/02_raksu/index.jsp

Snyman, J. (2009). "Leading indicators and business cycles" in *Economics for the modern built environment*, ed. L. Ruddock. Taylor & Francis, 2009, pp. 130–152.

Vainio, T. & Nippala, E. (2010). *Infrarakentaminen muutoksessa [Changing civil engineering]*. VTT, Tampere.
VTT, *Maa- ja vesirakentamisen näkymät [Civil engineering outlook] 1993–2010.* Biannual Business Tendency Survey. Construction Branch Advisory Committee (MANK), Helsinki.

DATA ORGANISATION IN CONSTRUCTION – AS AN AID TO THE USER

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The basic assumption in this paper is, that it will be possible to organise data in construction in a non-hierarchical way, following the lines of facet-based classification. This involves tagging data in a horizontal rather than a vertical order.

We have experienced a long and intense discussion of how to organise data. At a glance the discussion can seem to be merely technical but indeed it involves a broader perspective regarding different understandings of how to perceive, present and organise knowledge. Actors (consultants – contractors) present solutions that are appropriate in relation to their own specific needs, but at the same time they can be difficult to use for other actors.
Empirical examples from the on-going Danish debate will be included. A comprehensive and all-embracing system is promoted ("Digital Construction – a government initiative"). Theoretically the paper builds on "classical thinking" represented by the work of Linnés, and connects to contemporary theory on facet-based classification.
Facet-based classification has not affected the thinking in the construction industry. Presumably this is due both to the mental dominance of hierarchical thinking, and the (earlier) cost of powerful computer hardware. Today it seems obvious to take the facet-based approach into consideration, making it possible to specify ordering of data to the users' practice and frame of reference, rather than fixing the structure of data already when they are saved to the system.

KEYWORDS: Data organization, hierarchical classification, facet classification, user interface, Data filtering

INTRODUCTION

The use of digital data in construction has, at least in Denmark, involved a long and intense discussion of how to organise data. At a glance the discussion can seem to be merely technical but indeed it involves a broader perspective regarding different understandings of how to perceive, present and organise knowledge.

The introduction of Building Information Models (BIM) has fuelled the discussion about contemporary classification models. In Denmark this debate has been accelerated the last years (se for example Jørgensen 2010 and 2008).Those models require a firm and clarified understanding of how to classify and denote data in the models. The way to handle data can be crucial for the ability to serve different partner specific wishes for information as an output.

Problem

At least in Denmark, there seems to be a widespread understanding of BIM as a model gathering and carrying all possible information's, and with the key object representing the physical component. Hence, the classification is primary based on the physical component, and is intended to fill out all parts needs.

This approach is useful for some, but not necessary for all, and in praxis it tends to require that all parts have the same product based point of view. This common point of view will probably be (more) easy to communicate when explaining the idea of BIM but will not benefit the core business of the different partners.

On different levels clients, consultants, contractors and FM organisations present solutions that are appropriate in relation to their perspective of matters, which reflect their specific needs. This perspective can be difficult for the other actors to understand or even accept. This issue reflects the more general point that many scholars (Beghtol 2010) emphasize, namely that all sorts of knowledge handling – including classification is formed by time, cultural context and a specific agenda that the actors hand in mind when they are working in a certain field. This means, that classification systems always have to adapt to cultural and technical changes over time. Crutz and Nicolle (2007) have a similar discussion with an outset in work connected to the semantic and syntactical dimensions in XML programming.

In the field of construction each part understandingly wants a classification to cover their special need, but to develop one classification that is covering all the involved groups' needs, is a major task bound to create problems.

This paper presents a different approach to organising data in construction. The basic assumption is that it will be possible to organise data in construction in a non-hierarchical way, following the lines of facet-based classification.

Facet classification is useful in connection with managed electronic environment such as catalogues and databases. As Broughton and Slavic (2007) puts it "The logic and predictability of the structure of a faceted system, the methodology for the analysis and categorization of concepts, and the existence of reliable rules for synthesis make it an obvious choice for building tools for electronic data management." Building the "tool" involves tagging data in a horizontal rather than a vertical order, with the consequence that the specific ordering of data can be adjusted to the users' practice, needs and frame of reference, rather than be dependent of a fixed data structure.

Although examples of facet-based classification have been used for some years in applications on the Internet, it has not affected the approach of handling information in the construction industry as seen in the matrixes of the initiative of Digital Construction (Bips 2007). Presumably this is due both to the mental dominance of hierarchical thinking, a sector with a tradition for slow response and the cost of powerful computer hardware. The matter of costly hardware is not an issue any longer and today it seems obvious to take the facet-based approach into consideration.

CLASSIFICATION - THE NEED FOR ORDER

Humans try to bring order to their world to understand its relations. A method is to create a shared intellectual understanding, which allows groups of people, sharing the same need of order, to communicate on an operational level. This shared understanding is best when based on an idea that the systems users find logical and natural for their needs. The logicality and the natural use are based on simplicity and clarity.

Classification deals with the process for handling and the systematic approach to data. Classification is traditionally closely connected with the concept of taxonomy, which we will choose to denote as the principle of ordering with validity for a certain field of knowledge. According to Taylor (2006) this definition lies within the broad and quite imprecise understanding that can be found in the literature. Further Taylor states that taxonomy originates from the Greek "Taxis" (order) and another Greek word "nomos" (law). Sometimes the use of taxonomy is almost similar to "Classification". He points to (Taylor, 2006:463) the fact that more recently (with the need of organising documents at the web) taxonomy is often synonymous with "categorized list of terms and include classification schemes, subject heading lists, internet directories and gateways". The taxonomies can be property of organisations which you need a licence to use. Linné's systematics for botany (and other biology) is often mentioned as an example of a (hierarchical) taxonomy. Classification is intimately connected with the embedded understanding of how objects and separated parts are understood as a part of a greater hole. In this way it could be argued that the classification scheme originates in a certain community of knowledge, as discussed by Wenger (Wenger, 1998).

The discussion about classification is constantly actualised by the need for ways of organising information that has to be saved and re-found in different constellations.

Contemporary demands to classification systems – the need for order

Since the days of Aristotle there has been a tendency to classify hierarchically. A hierarchic system draws an understandable image of the order and relationship of the system's objects. The image is well known and looks like the roots of a plant, spreading out the further down we get.

Today we have operational alternatives to the hierarchic structure. The facet structure is such an alternative, in which the object of the system is not placed in a given order, but defined through the descriptions of the object. With this system, different orders can be created, depending of the properties demanded. The object can be placed in an order defined by a specific need.

Through the use of information technology the mass of data has grown considerable and the hierarchic systems that embrace this data are getting ever more complex, so the activities used for handling these systems are correspondingly complex. The problem is known by everyone trying to keep order with the computers pathfinder. The key to understand the application with the facet order goes through the ability to filter data. The problem with the facet order is that it is not hierarchic, and for that reason not the usual way of arranging objects.

Hierarchical classification – the "traditional way"

The hierarchical way of classification takes its beginning in the modern world with the Swedish botanist Carl von Linné’s (1707–1778) work 'Systema Naturae', published in 1735. His concept of subspecies has been discussed but nevertheless, Linnaeus is credited with establishing the idea of a hierarchical structure of classification which is based upon observable characteristics (Keita 1993).

The hierarchical point of departure has shown a considerable strength over time in spite of DNA sequencing another new invention in biology, (Kwasnik 1999:26 ff). It is certain that the hierarchical classification was well suited for search in indices, catalogues or bibliographical registers correspondence with a certain area of knowledge. The problem with the hierarchical approach first begins when you wish to assign, re-find, seek or use combinations of data in a way that was not anticipated or prioritised when the classification scheme was founded.

The situation can to some extent be compared with printed non-fiction (e.g. scholarly book). The table of content will usually represent a specifically understanding and structure of the knowledge field that the book deals with. It is easy to use the information and work with the book if we are familiar with this understanding. If on the other hand we wish to juxtapose information from quite different angels, or with the help from concepts (combinations of) other than those originally defined in the book, we would not get much help from the table of content.

A combination of knowledge which crosses the vertical and horizontal divisions of the classification would demand that the concepts represented in the book were transformed to flat structure that we could search in. With the example of the printed (analogous) book in mind, it would be difficult to solve the problem above. If we stay in the book-analogue universe, it is not possible to come up with a realistic solution – we cannot find data in a flat structure without a form of structural support from an organised list, table or similar. In this situation the facet classification offers an interesting alternative.

Facet-based classification

Although examples of facet-based classifications have been used for some years in applications on the Internet (Hearst, 2006), it has not affected the thinking in the construction industry.

Taylor describes facet classification as different from a traditional approach as "(it) does not assign fixed slots to subjects in sequence, but uses clearly defined, mutually exclusive, and collectively exhaustive aspects, properties, or characteristics of a class or specific subject. Such aspects, properties, or characteristics are called facets of a class or a subject…" (Taylor, 2006:394).

As an example on facet classifications, in relation to classifications of food, Brian Vickery writes “The various facets relating to these are different attributes by which they may be classed, and a particular object may be represented by a combination of its attributes.” (Vickery, 2008:149), in other words - the properties define the object.

Both Taylor and Vickery connect the breakthrough of facet classification with the upcoming electronic data processing. Today’s huge internet-based database systems, used for e-commerce, are based on facet classification. Special studies of interface design used in facet-oriented systems have been produced, to facilitate these systems (Hearst, 2006). Ideally it should not, (for web purpose) be necessary to know a certain subject area and its break-down in sub-discipline in order to retrieve relevant information (Broughton and Clivic 2007).

THE PARTNERS OF THE BUILDING INDUSTRY

Different professions and areas of interests have a natural focus on different objects, and it will be difficult to imagine one classifications system, containing object such as planets and plants, and at the same time being practical useful. For at specific area as the building industry, the natural objects of intersection will be the actual physical object. But do the partners have that much in common, to create a sufficient working space, and to do it in a hierarchical model. These questions require an analysis of those parties' use of data in relation to their responsibility.

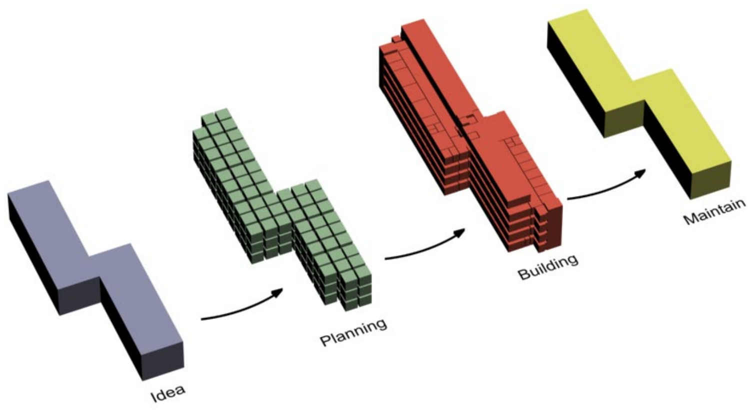
The used terms for the main partners in the construction industry are reflecting a specific task and area of responsibility. Client, Consult, Contractor and Maintenance

These partners can be subdivided e.g. into Architects and Engineers. Depending of a project, some types of consulting partners cover more than one responsibility area. Partners belonging to the chain of supply and the end users are not consisted as hard-core members of the building process.

The parties' classification is closely connected to the phases of building. Idea, Planning, Building and Maintain.

The four phases reflect more than the distribution of responsibility. They also point at the object type each phase is corresponding with, and consequently what level of knowledge and type of data each phase, and part produce and communicate.

Figure 1: The four phases of the building process.



BIM as the partners mean of communication

One of the major problems in the digitization of the building industry has been to solve the problems of data exchange between the partners and throughout the phases. The government initiative Digital Construction has strived to solve this problem, based on the consults world view, and with consideration to the other partners. However, the case concerning the DFK development is, as an evidence of this consideration, inadequate.

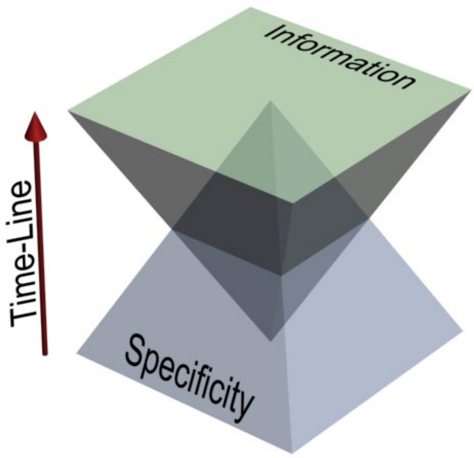
With the introduction of BIM, the consults has establish his own basic point of view, and a quick look on the home site of Digital Construction (www.detdigitalebyggeri.dk) reveal a concentration of digital news, terms and stories of 3D virtual models of physical building, and very little of BIM as a non-physical phenomenon, collections of task descriptions and very little about the actual use of BIM data in maintenance.

Areas of interest, outside the strict visual geometric, and covering other partners, are taken into account in the ten client demands, outlined in the working committee rapport (EBST, 2001). The best example of the range on these demands is to be found in the third demand, where it emerge that: 'The client must insure that the set of drawings must be produced, hence the production drawings can be printed in A3 format or less, and the client must ensure that scale is visually applied on all drawings.' (Retsinfo, 2007). This demand is to be put forward by the client, ensured by the consult, and used by the contractor. The executed demand will enable the contractor to carry around the BIM model, in an analogue version on the site. As reasonable as it may be, this demand doesn't consider other partners use of the high-tech solution. An alternative approach would be a demand, giving the contractors the responsibility to update the as-build BIM.

Project clarification

The partners need information, to make the right decisions and solve the problems arising throughout the process. In the end, all these information's are connected to the building, more or less specific, depending on the positions of the project's timeline. The amount of information, e.g. measured as GB, and level of specificity is two well-known orders in the history of building, and are important parameters for handling documents, ways of communications, contracts etc.

Figure 2: Throughout the building process, the amount of information's rises and the specificity narrows



The partners must resolve all kind of problems at any given time in the process. One partner will have focus on economics, another on materials and a third on functions. Each partner will need to fulfil they requirement through access to sorted information, and the information's must be sorted in relation to their responsibility. Hence, a common understanding of order, allowing all parties to search specific information's, must be established. Therefore, it is necessary to take a closer look on each partner's fundamental tasks and responsibilities, and the types of information needed to satisfy this.

Partner’s data

The different tasks can be put by:

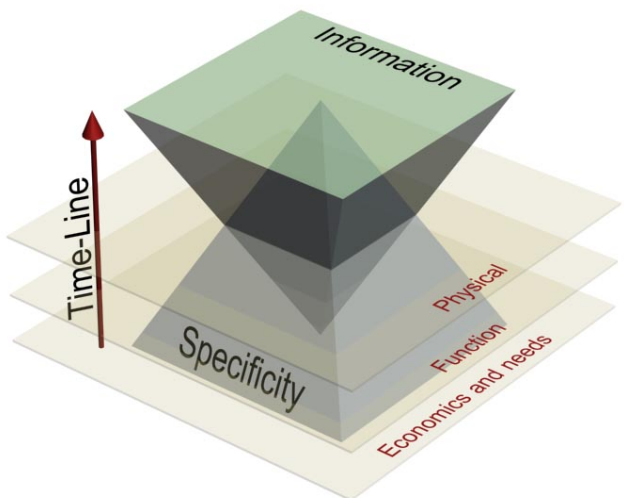
- Client's (idea phase) define a need and procure the economy
- Consult's (planning) convert the specified need to a possible solution
- Constructers convert the solution to a physical condition
- Maintenance keep the building going

The different tasks and the type of data involved, combined with subcontractor's type of data, present an image of the complexity in the idea of a joint system of order.

Basically, the problem is a question of different, but close connected views of the building process. These different views cannot be converted into one unambiguous type of data. Each view is a focused reflection on building information, on a given position on the time line, and each focus will be determined by one partner's specific need and related to his competence of decisions.

In principle, the narrowing of specificity will take a virtual form as illustrated in figure 3. In the early process the client will use a data model with economics and needs as key objects, next phase could have functions as key object, and so on through the phases. The phases inherit the result of the object use, from the previous phase, and not necessary the objects itself. Each phase interconnected with the responsible parts view, competence and business. Previous phase's data specifically used in this phases, must be removed or narrowed down. If not, the vast amount of information will strangle the transparency, and reduce the productivity.

Figure 3: Information focus and use of data types will vary through the process.



The parties’ field of focus, the use of data in decisions making and data transfer have particular interests in understanding how to create an operational form of order.

Economic include the cost to the erection of the physical building, the cost of maintenance, expected income, in short the turnover of the building. All partners have an interest in the economic, but have different reasons. First of all, in the construction process the client pays, the others earn. This entail that the clients focus is on the value, created for his money, and e.g. the constructor focus on the money, as the result of his effort. The client's model of economic is a model of insuring the connection between need, function, and solution. This model is built on experience, gained from previous projects, and the primary source of data is extracted from the maintenance companies. For the consults and contractors the model of economic is the framework for the job, and their primary source of data is previous projects. The source and use of data is very different between the parties.

A need can e.g. extend from the local societies need for a school to the clients desires to create a monument. Simultaneous needs, being complementary or contradictory, are usual. The client giving the local society an opera can be complementary, if the society wants it. To build a cheap concert hall on international standard is contradictory. Needs are satisfied through actions. These actions are exercise within a function. A society's need for e.g. education is satisfied with education facilities. On a lower level, the need of water can be satisfied with a pumping system. The client defines the needs, the consult transforms these needs to specific functions, the contractor transforms the function to a real solution, and the maintenance will run it and the user uses it.

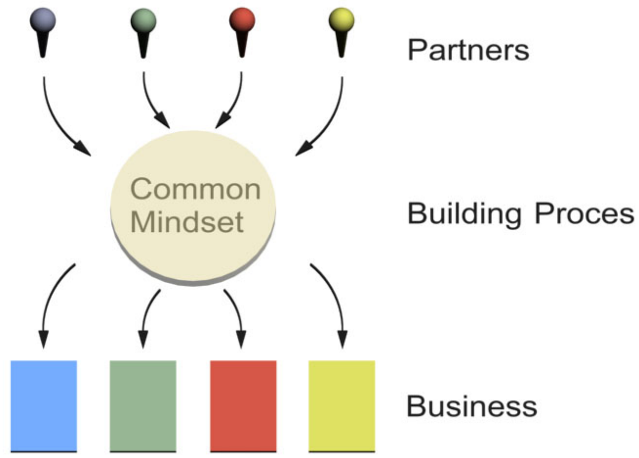
The client's source of knowledge regarding needs would be the end user, the maintenance organizations or the public voice. Different views of economics, needs versus functions, can be the cause for negotiation between the parties, because their tasks and experience vary. The different point of views will cause two different set of data, being difficult to unite in one common precise order.

The physical solution deals with fundamental physical components. In this concept it's the components, or object, we can visually percept. The physical components are the ones the client pays for, the ones the consultant draws, models and uses for calculation and the ones the contractor buys and assembles and the maintenance re-paints and washes. However, the components themselves do not tell anything about the capability of the building. The client and the end users get their needs honoured through those functions emerging from the components combinations.

Point of view

Economics, needs or functions and physical objects can be assigned to different orders, and sub-divided dependent on the situation. If the architect wants to examine a possible change in the functional model, caused by a change in the physical solution, it is necessary to arrange one data type, so it may correspond to another data type. Whatever triggers the activity of rearrangement, it is a question of comparing different types of views, to make it possible to see deviations. Hence, one point of view model must not just be an automatic extract of a primary model, because each point of view model is closely connected to one partners business.

Figure 4: The vision of BIM is to be the 'mother of all information'

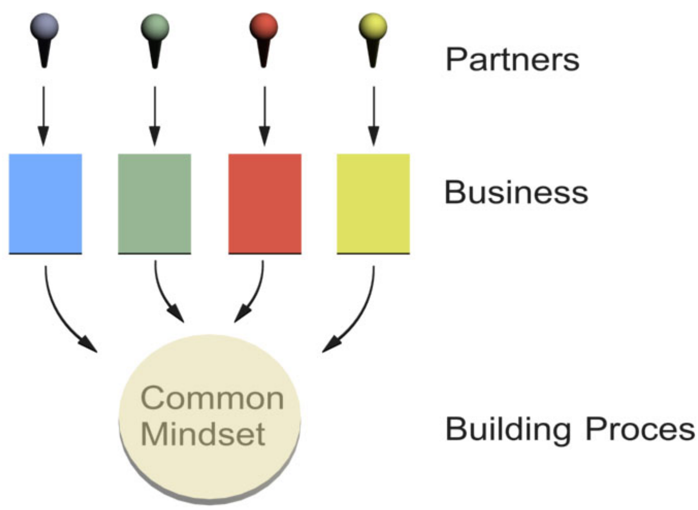


If a BIM model must be able to contain information for all partners, the size will be considerable. This is not a technical problem, which is one of the reasons that gave inspiration to the idea of an all-in-one model. The mind-set is a renaissance idea in a modern digital form.

All information in one model requires one mind-set among all the model users, a nearly impossible situation. One model, representing both needs, functions, economics and the physical, will base its objects on one type of representation, e.g. the physical, and that will create dependency of this specific representation. A building can be represented as needs to be fulfilled, a result of functions or a result of investment, the list can be continued. Each representation will have a specific purpose, and must be sorted accordantly. This kind of order can be obtained by two approaches:

1. The partners agree on a common understanding of order - the original DBK approach
2. Each partner provides own order (as it is seen with the initiative from FM managers in social housing, see Landsbyggefonden 2009)

Figure 5: An alternative BIM vision could be as a collector the necessary information between the partners.



To ensure that the order of each partner will support a flow in the building process, to the benefit of all, a change of fundamental orders is required.

To ensure that each partner support a flow in the building process, to the benefit of all, without losing overview and direct access to own business core data, requires a change in the mind-set of order.

DANISH BUILDING INDUSTRY APPROACH

In construction in general a broader understanding of classification is applied that ranges from classification of building types and real estate to the properties of building materials. Most of these classifications were established in the 1950s and 1960s. Basically we can identify at least three different types of registers, namely:

Administrative registers for registration of properties and buildings - the complex and rather comprehensive Danish building and dwelling register, is an example. *Product registers* can typically be seen as object libraries in different CAD programs organised as building parts. *Registers used as part of business systems,* for example suppliers' product and ordering systems embedded in facility management systems).

Thus the parties of the building industry use all three types of register, but they use different sections. If one part uses administrative data of a building, another part uses data regarding the same buildings physical conditions.

The Digital Construction initiative

The report "Digital Construction – Report from a working group" (Erhvervsministeriet 2001) marked a comprehensive beginning of the digitalising efforts by Danish construction. The report pointed to areas where it would be fruitful to initiate the efforts.

The first area for action was described in the report ("IT-retningslinier for offentlige bygherre' in Danish "IT guidelines for public clients", our translation) aimed at supporting the client with a line of advantages connected with the digitalisation, and in this way motivate the client to be a driver for development.

The second initiative described in the report was 'Udvikling af standarder og IT broer mellem byggeriets brancher' (in our translation "Development of standards and IT bridges between the sub-sectors of construction"). The report states that there is a massive need for a mutual digital foundation for all the parties of construction and that this foundation has to encompass a uniform, object-oriented and systematic approach. The systematic should include documents, building objects, buildings parts and be coordinated with international standards for the different areas. When the outlined initiative was launched in 2003 (Erhvervs- og byggestyrelsen 2003), it was driven by consortia with the consultants as the most important drivers. Taking this into consideration, it was not a surprise that the sketched classification reflected the consultants' views of construction.

The proposed model was not able to fully comply with the consortia's own design guidelines - the development of a particular classification system especially meant for administration and facility management (with special emphasis on social housing), demonstrated this. In the first out of nine reports the authors state (Landsbyggefonden, 2009) that it is regrettable that DBK does not take the perspective of Facility Management into consideration, and this is the motive behind the development of the classification system for FM and administration.

If other parties in the field of construction do not consider DBK to an adequate tool to satisfy their needs, they will fall back on their particular classification systems and DBK will probably fail as mutual platform. Different platforms will hinder one of the primary goals of DBK, namely to harvest the rationalisation profit of a more smooth dataflow in the whole business of construction.

The plan for DDB's deployment (EBST, 2003), was focused on partners variations in the use of ICT. This was done through six focus groups, which largely reflected the parties' business affiliations. The report also discussed the partner's common vision and concept for the industry as a 'product' model (EBST, 2003: page 10) in which product model is clearly a product register and all other data are the product characteristics, or properties. In this case the vision and development of a common classification system does not involve the fact that some parts are working with objects that are probably related to a building but not necessarily related to physical product.

NEW DEMANDS AND NEW POSSIBILITIES – A RETHINKING OF SYSTEMS WITH THE USERS IN MIND

Several examples are giving by Kwasik (1999), on how the overall structure laid down on the field of knowledge, becomes a barrier for the unfolding of the complexity embedded in this field. There can be several reasons for this. Relations and coherence, which are a part of the constitution of the very field of knowledge, can in a growing extent be unsuitable for accommodating new scientific conquest – e.g. cognitions.

Often a simple attempt at caching the "defining criteria" of the classification, neglect the complexity in the field, and in this way in fact becomes a sort of barrier for new development (technological or in other ways) can be accommodated in the classification, and the classification becomes a conservative force for incorporating developments in the professional understanding of the field of knowledge.

It is obvious that the level of complexity in construction is high. This is relevant both for what factors the different parties (client, facility manager etc.) finds relevant and in relation to where on timeline you approaches the process of construction. A classification approach has to deal with this complexity – or be more specific the changes in perspectives due to shift in actor and due to localisation on the timeline – it has to be flexible.

This description of what a kind of challenges the classification system has to deal with makes it possible for us to give short design characteristics of the classification system.

It has to have a flat - vertical oriented structure. The structure does not have to be based on a theoretical argued understanding on how different parties, actors relate to one another, inside a certain structure. Such an attempt would be deemed to fail due to the complexity in the field and a generic classification model would be impossible.

An alternative approach would be to provide the classification system with relative few objects which all are supported by a long line of properties. The objects has, as mentioned above, to correspond with the perspectives belonging to the different parties of construction. From our discussion of the general problems in construction it will be possible to deduce both the object and the properties. In a system with those principles it will be possible for the user, dependent on their special assignment in construction, to choose or rediscover exactly those data they will need at a certain time in the building process. Besides of this vital advance it would, potentially, be possible for the user to add properties, including data to the system. As a main principle, properties have to be located at the same level – in a very flat system of classification.

It is obvious that in a system as the described there will, over time, be acquired a considerable amount of properties with data and not all will be equally relevant for all users. Thus the system needs to have the ability to extract data according to search (mostly by standard-) profiles relevant to that kind of user, although there a possibility for letting the user make his/hers own search profile.

Speaking in the terms of traditional (hierarchical) classification, classification is reshaped by each lookup. Some predefined lookups can be available for use. But it is not an option for the user to create a template for an exact purpose.

A solution as the proposed, has in theory been possible for many years, but is first feasible now due to the very low price on computing power.

Technic matters or/and organization

Data in a BIM model will inherently result in a larger work in terms of data organization, regardless of the type of data organization is involved. When the BIM is intended as a successively built chunk of data, to be refined through the process, the idea is that all parties have access to data in precisely the form that supports their needs. This sounds obvious, and something that all partners have already joined. However, the answer to how data is organized as a practical item is not exclusively a technical choice but also implicate the organizations themselves, i.e. each party's self-organization, working method and location in the process.

Where the partners in the construction industry sees itself as pearls on a string, the introduction of BIM, with all this entails, make it more relevant to consider the partners as consistently present facets of a continuous process. This change in perception of positioning can be a major challenge for each party than the choice of technical solution.

A review of the partners internal organization, will involve a review of data. Where data can be structured in the interests of logic of data itself, the data can also be structured from a logic based on its use, in this case each party's needs with due regard to the other partners. These two logics are not necessarily contradictory, but require that the focus of the discussion concerning data organization, involving data use.

The building industries approach has so far been that if we have only established a collaborative mind-set, the technical solutions could be implemented properly and the industry will achieve a productivity improvement. The question is whether this common mind-set can be found through an adoption, or whether that mind-set first emerges when the technology has resulted in a productivity boost. This could very easy be a "chicken and egg 'dilemma.

Our approach is that the partners must implement data organization, and related technologies with their own business operations in mind, and this is to be done with due considerations to other parties. In the Danish context, the consultants have been engaged to development, and this has led to that this part's own business has been put in front, which is both natural and reasonable from their perspective. Problems arise when they needs is to be the solution for all parts. The idea that 'if everyone does like us', will not necessarily improve the other parties' business areas.

The core in this problem lies in understanding what a due regard to the other parties involved. And a recommendation is that the flat data structure provides better opportunity to support each part. In this structure, the object cannot be only a representation of the physical components. The object must be defined through its properties, so all parties can add properties that exactly support their own business.

CONCLUSION

To classify is not about to put everything in this world into boxes, reflecting the true world, but is to place things and matter into a meaningful structure, and making it operational.

Weather BIM is organizing the construction data in one way or and other, it will be a massive mass of data. The problem is not to generate data, but to pick out relevant data, in other words, to filter data in a proper manner and at a proper point.

To do this we need two things. A way to organize data, making it more searchable and available, than in the hierarchical system, and a filter mechanism as a universal user interface, which on the one hand can create an interface between the users perception and context, and on the other hand function as a dedicated search engine.

The partners of the building industry must revise their own procedures and see the choice of data organization in relation to own organization. This exercise will most likely require changes in the organization, because implementation of technology and the associated software systems cannot be tackled with a technical trick.

To achieve a common mind-set, without ending in the discussing about the chicken and the egg, every part must play with two balls. Where the first ball is a change or revision of own organization the second is the consideration for the other parts and their needs. This is more possible with a flat data structure, because it does not require that everyone agrees upfront. With the flat data structure no single party set the agenda and that each party can optimize their own business and that all parties contribute more specifically to the overall process.

REFERENCES

Beghtol, C (2010): Classification Theory. Encyclopedia of Library and information Sciences, Third Edition, 1: 1, 1045 – 1060

BIPS (2007): Matrix’s. Webpage accessed 01-03-2011 at: http://bips.dk/v%C3%A6rkt%C3%B8j/dbk-2006-klassifikationstabeller

Bips (2008): *Objektstrukturer - F103*

Broughton and Clivic (2007): Building a faceted classification for the humanities: principles and procedures. In Journal of Documentation, Vol. 63 No. 5, 2007, pp. 727-754

Crutz, C & Nicolle, C (2007): Ontology-Based Integration of XML Data – Schematic Marks as a Bridge between Syntax and Semantic Level. In Filipe, J Cordeiro, J and Pedrosa, V

DDB (2010): *Det Digitale Byggeri*. Webpage accessed 10-12-2010 at: http://www.detdigitalebyggeri.dk/english

Erhvers- og byggestyrelsen (EBST) (2003): *Implementering af det digitale byggeri*

Erhvervsministeriet (2001): Det Digitale Byggeri - rapport fra en arbejdsgruppe

Filipe, J. Cordeiro, J. and Pedrosa, V (Eds.) (2007): WEBIST 2005/2006, LNBIB 1, PP. 97 – 110, Springer Verlag

Hearst, Marti A. (2006): *Design Recommendations for Hierarchical Faced Search Interfaces.* UC Berkeley

Hunter, Eric J. (2009): *Classification made simple*

Jørgensen, Kaj A. 2008: Building Concepts and Classifications. Draft version. Webpage accessed 10.12.2010 at:
http://www.iprod.auc.dk/~kaj/documents/common/Classification.pdf

Jørgensen, Kaj A. (2010): Derfor er det digitale byggeri på vildspor(1): Forkert udgangspunkt

Keita, Shomarka O. Y. (1993): The Subspecies Concept in Zoology and Anthropology: A Brief Historical Review and Test of a Classification Scheme. *Journal of Black Studies*, Vol. 23, No. 3, pp. 416-445. Sage Publications

Kwasnik, Babera H. (1999): *The role of Classification in Knowledge Representation and Discovery*

Landsbyggefonden (2009): *Forvaltningsklassifikation*. Hæfte 1 - 9

Retsinfo (2007): *Bekendtgørelse om krav til anvendelse af Informations- og Kommunikationsteknologi i byggeri. Webpage accessed 12.12.2010 at:*
https://www.retsinformation.dk/Forms/R0710.aspx?id=27419

Taylor, Arlene G. (2006). *Cataloging and Classification*. London: Libraries Unlimited

Vickery, Brian (2008): *Faceted Classification for the Web*. In Axiomathes vol.18, nr.2, 2008. SpringerLink

Wenger, E. (1998): Communities of practice - learning, meaning and identity

COMPARATIVE STUDY OF DANISH PREFAB HOUSES MADE OF WOOD

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The use of wood in Danish prefab building projects is increasing, but there is not a strong architectural tradition in Denmark for constructing timber housing. This paper therefore contains a comparative study of various manners of incorporating architectural features in prefab houses made of wood. In the study four Danish prefab housing concepts based on wood construction is compared and discussed, in order to investigate and exemplify how it is possible to work with architectural quality in prefab timber housing and maximise the use of the material, the prefab production and the architectural values. It was concluded that especially two aspects are of great importance for the concrete handling of the architectural quality of prefab houses made of wood; 1) flexibility in relation to user and site, and 2) the interaction between form, logics and material. It is suggested that keeping these two aspects in mind makes it possible to design prefab timber houses of good architectural quality in a Danish context.

KEYWORDS: Prefabrication, quality, timber construction, communication

INTRODUCTION

Wood is increasingly used in Danish prefab building projects as it is considered to be cheap, strong, environmentally friendly and easy to handle in prefab processes (Kraul & Madsen, 2007). However, there is not a strong Danish architectural tradition for building with wood. For the last century, wood has mainly been used as a building material for secondary or temporary houses, such as summer cottages, allotment huts, post-war house replacements and refugee camps (Lind, 1998; Storvang, 2000). Therefore, the idea of a house made of wood is often connected with temporary buildings, whereas the idea of a permanent house is closely connected with the heaviness and robustness of brick or stone walls (Lind, 1998).

In the past decade several new manufacturers of prefab houses have emerged in Denmark. Some of them have introduced houses made of and with wood drawn by architectural offices (Juul, 2008; Åberg & Stenberg, 2005); for example ONV and HP3 started manufacturing the ONV house. The ONV housing concept has a loadbearing construction made of wood and is built of 3D modules produced at a factory. However, a building can be prefabricated in a variety of ways and most building projects today use prefabricated elements to varying extents (Anderson & Anderson, 2007; Thorsen, 2005). As illustrated in Figure 3, building systems can be based on 2D or 3D elements and can be more or less open to changes in relation to the specific customer and site. Industrialisation of architecture therefore brings up the question of to what extent a building should be specifically designed for the context and a specific customer (Anderson & Anderson, 2007; Svendler, 2005). The builders, or the architects, often design and build for a customer unknown to them and to some extent also for a context not known to them in advance –prefabricated detached houses are good examples of such buildings. Many architects have rejected the whole idea of prefab building with reference to its rigidity in relation to aesthetics (Arieff, 2002; MacKeith, 2005; Mikkelsen et al., 2005) – maybe this is why only five per cent of the single-family housing stock in Denmark is designed by architects (Ingels, 2003), and both single-family houses, as such, and the suburban areas where they are situated are often accused of lacking in architectural experiences (Knudsen et al., 2000). For some time there had been a continued and heightened focus on the quality and the values of our physical surroundings spanning from city planning to household products, and architects are therefore challenged by other trade groups to explain their values and aims (Jensen & Beim, 2006). This puts pressure on architects to actually verbalise their factual and intuitive knowledge, which had previously not been that important, as the discussion has mainly existed within a closed group of like-minded people brought up in a well-established master-apprentice tradition. This paper aims to put into words the architectural potential and pitfalls of prefab houses made of wood. This is meant to be a support for communication and discussion between architects and other trades that use wood in prefab processes in a Danish context. Three theoretical approaches were used to develop a model of analysis that covered a wide range of aspects tied to architectural quality. The approaches of the model were concretised through an analysis of three unique houses that were often described in architectural literature as having good architectural quality. The model was then used to analyse four prefab building systems. Through a discussion, the architectural features of prefab building systems were compared with the architectural features of the unique quality houses. To conclude the paper, two main areas of interest were identified that were crucial when working with the architectural quality of prefab houses made of wood.

METHOD

This paper builds on the investigations and findings of a PhD thesis (Wraber, 2009). The main aim of this paper was to identify and exemplify the most common pitfalls for architectural quality in Danish single-family prefab houses made of wood. To make the discussion of architectural quality structured, precise and applicable to prefab houses made of wood, the project was divided into three superior levels. The first level was a listing and discussion of existing theories of architectural quality with the intent of forming a model of analysis, then came the collection and discussion of concrete examples of architectural quality that formed a frame of reference for the third step, which was an analysis of contemporary prefab wooden houses that should point towards strengths and weaknesses of this typology.

Model of analysis

The first step was to outline and structure the body of theory in the subject of architectural quality in order to create an overview and solid foundation for the analysis of the architectural quality of prefab wooden houses. Main theories, debates and problems were identified and described, but as the field was quite complex and did not immediately seem to have a clear direction and consensus, the theories were further reflected upon and organised in a model of analysis. The aim was not to define an absolute or mathematical model, but rather a discursive model that could assist a discussion of the different perspectives and aspects contained in architectural quality.

Comparative analyses

In the first of the comparative analyses, the aim was to collect references of architectural quality for the later analyses of Danish prefab houses made of wood. Therefore the analysis included buildings that are often described as having good architectural quality. Quality buildings of various styles were chosen to cover as wide a range as possible. The houses were chosen with an offset in literature on architectural quality and houses of the 20th century. Houses that are often mentioned are probably generally considered to possess some kind of quality by a wide range of people, since they keep being mentioned as good and interesting examples. The houses were chosen in relation to the different theoretical clusters; a dwelling that in some way reflected the same focus as the theories, although it was not necessarily developed with an offset in the theoretical cluster – such clear bonds between theory and practice were seldom seen. The intent of the second comparative analysis was to analyse the architectural quality of various Danish prefab houses made of wood in order to exemplify potential and pitfalls of the typology. The examples were selected in order to cover as wide a range of different typologies as possible, production methods and use of wood in buildings.

ARCHITECTURAL QUALITY

There are not only various theories of what architectural quality is – the theories can also be related to completely different categories of ontology; natural scientific, social scientific and humanistic. Architecture therefore contains both the concrete technical aspects of construction, the matters of how we act and interact as human beings, and the more abstract aspects of art. The technical, and to some extent the functional, aspects can be held up against different standards and recommendations, but the aesthetic aspects are more difficult to measure.

In this project the focus was on creating a foundation for the discussion of the immeasurable parts of architectural quality. These can be viewed as (1) a part of a universal order, like the renaissance architecture relating it to the mathematical relations of musical harmonies (Le Corbusier, 1971; Scruton, 1979; Venturi, 1966/1977), (2) a result of our body and brain substances reacting to different stimuli and therefore initiating specific feelings biologically (Gibson, 1950; Hesselgren, 1977), or (3) a more poetic and subjective interaction between human beings and the phenomena of the world (Bachelard, 1994; Heidegger, 1997; Merleau-Ponty, 1945/2002; Norberg-Schulz, 1963; Pallasmaa, 1996).

Therefore the model for analysing architectural quality was described accordingly through a definition of three theoretical clusters – **classicism/structuralism**, **perception psychology**, and **phenomenology**. The two first theory clusters (structuralism/classicism and perception psychology) were focused on the visual aspects and the concrete coherency between the details and unity of a composition whereas phenomenology also included the other senses and cultural aspects for the understanding and interpreting architecture. However, structuralism/classicism implied a universal and mathematical understanding of architectural quality, whereas perception psychology focused on the more abstract balance between harmony and tension. This seems interesting to the human brain providing it with neither a too monotonous (boring) nor a too complex (confusing) experience. The combination of the three theoretical clusters covered both subjective/personal aspects (through phenomenology and parts of perception psychology) and objective/universal aspects (structuralism/classicism and parts of perception psychology). From each of the theoretical clusters three keywords of particular significance were chosen as the basis for the model of analysis, see Table 1. They were chosen to represent the general and strongest concepts of the theories included in a cluster – however, by no means did they cover the whole spectrum and aspects of the theory clusters.

Table 1: The keywords of the three theory clusters of the model of analysis.

Theory cluster	**Keywords**
Structuralism/Classicism	Proportion and order Form and material Detail and unity
Perception psychology	Unity and variation Balance and harmony Dynamics
Phenomenology	Relation to cultural/personal framework of understanding Support of a multisensory experience Relation to context

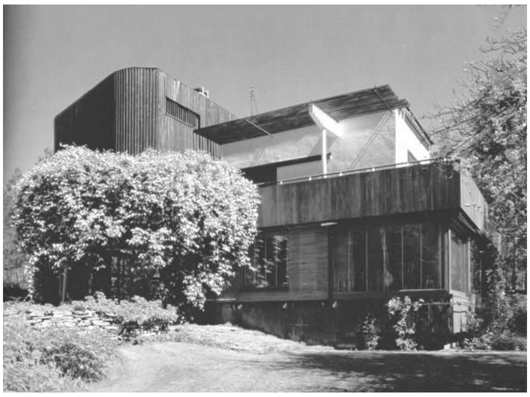
CLARIFICATION OF ARCHITECTURAL QUALITY

Three houses commonly considered to be of good architectural quality were analysed in order to see how the different perspectives and keywords of the model were manifest in concrete works of architecture and formed a frame of reference for the discussion of architectural quality in prefab houses made of wood. The houses were chosen in order to cover different perspectives, theoretically and stylistically; Utzon's house in Hellebæk (Jørn Utzon, 1952) representing the logical aesthetics and a fine balance between material and form, Vanna Venturi house (Robert Venturi, 1962-64) representing a rather strictly visual composition, and Villa Mairea (Alvar Aalto, 1938-39) representing the multisensory and context-related phenomenological view. The analysis confirmed that all of the buildings could be said to be of good architectural quality as it manifested itself in several of the keywords from the three theory clusters. Utzon's house in Hellebæk and Villa Mairea actually manifested almost all the keywords, whereas Vanna Venturi house did not manifest the full set of keywords from any of the categories. The main 'problem' of Vanna Venturi house was its lack of relation to a larger whole due to its sharp focus on the visual composition, see Figure 1.

Figure 1. Vanna Venturi house has a sharp focus on visual composition (Schwartz 1992).

In the structuralist view, this larger whole was related to 'form and material', and 'order and proportion', in perception psychology to 'balance and harmony', and to all the keywords in phenomenology. The strengths of the other two buildings were the wide range of aspects taken into consideration in the design; the concrete, near context – the site – but also the relation to materials, users, to cultural aspects, and to stylistic currents. The simplicity and clarity in their design also gave them credit in relation to several keywords – especially in perception psychology and structuralism. Phenomenology on the other hand is more abstract and therefore also leaves more space for subjective interpretation. This was for example relevant when dealing with the experience of materials as can for example be seen in Utzon's house in Hellebæk where wood was used to contrast with the heavy brick walls, which seemed tactilely interesting, as it showed the interplay between hard and soft, rough and smooth, cold and warm etc., see Figure 2. In Villa Mairea wood was for example used as cladding on the more organic elements of the house. These were also complemented by harder materials, such as stone and brick, which gave a varied multisensory environment, where form, material and function underline each other, see Figure 2. All three houses were furthermore built for a specific site and a specific user. Especially Utzon's house in Hellebæk and Villa Mairea clearly bear the marks of site and user influence, which is crucial to the architectural quality in the phenomenological view. With these three houses as a frame of reference the next step was to discuss what architectural quality was in relation to prefab houses made of wood in a Danish context.

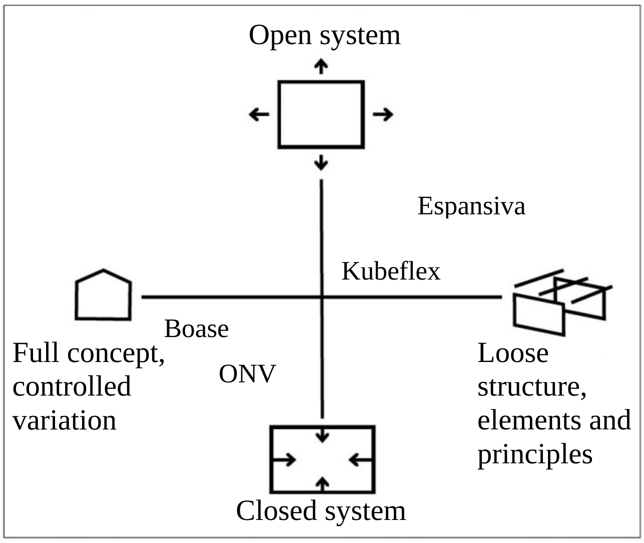
Figure 2. The use of wood to contrast with other, heavier materials in Utzon´s house in Hellebæk (left) (Keiding, Dirckinck-Holmfeld 2004) and Villa Mairea (right) (Lahti, Jetsonen 2005).



ANALYSIS OF DANISH PREFAB HOUSES MADE OF WOOD

Various types of prefab houses were studied in order to detect advantages, disadvantages, and potential in different building and design systems. Four concepts were analysed. The first two were both Danish modernist prefab prototypes and open systems; the panel building system Espansiva by Jørn Utzon and the room-sized building block system Kubeflex by Arne Jacobsen. The third example was a more closed, and quite successful, standard house; the ONV house which was built with 3D room-sized modules. A fourth example was Boase, which was an experimental building concept for semi-communal urban life on polluted sites. This project was a rather closed 2D system that used wood as a more aesthetically dominating material than most other contemporary Danish prefab projects, see Figure 3. What was interesting in this analysis was to compare the pros and cons of the four concepts in relation to the three theoretical clusters – thus being able to identify general as well as specific pitfalls and potentials.

Figure 3. Prefab building systems can be characterised according to their openness (y-axis) and the type of the elements (x-axis) (figure based on Mikkelsen et al. (2005)).



Structuralism/Classicism

A closed system was clearly better able to ensure desirable proportions and order. Espansiva provided a vast number of possible combinations; differently sized pavilions with sloped roofs of various heights and a wide range of panels that could be freely applied to the pavilions, see Figure 7. It was not possible to foresee how users might put them together and thus ensure aesthetic and spatial qualities. Kubeflex was also flexible but still more closed than Espansiva. The basic module was a characteristic box of light green timber frames, in which only seven different panels could be inserted. The boxes could be combined in many ways; however, the basic concept would be distinct no matter how they were put together. The panels were also very simple and therefore no big aesthetical harm could be done when combining them. Espansiva's timber frame construction was mainly seen from the inside of the house and through the major openings of the façades, see Figure 4. However, the boards of the façades were obviously not loadbearing but formed a light envelope indicative of the light construction underneath. In Kubeflex the light green frames could be seen both from the outside and the inside, and the screens in between them were also obviously light, see Figure 4. In both these cases the basic construction also formed the aesthetical foundation for rhythm and order.

Figure 4. The wooden frames of Espansiva (left) (Utzon, 1970) and Kubeflex (right) (Trapholt, 2009).

The framework construction was less important in the ONV house and the Boase dwelling unit. Here the idea of a light wooden box was more important, and the surfaces were used as the aesthetic scene for expressing this. Both projects had a simple basic-box shape and used large holes in the façade to express the lightness of the construction. The ONV house also had light panels, of slender wooden lamellae, which underlined the lightness and presented a multi-layered and airy surface, see Figure 5. In the Boase dwelling the long façades had large window areas with only little material between them, which made them look light and the corners had been cut away and replaced with wooden columns that also supported the house, see Figure 5. This underlined the idea of the design as being a combination of columns and beams, as loadbearing construction, and surfaces, as a thin protecting envelop.

Figure 5. The use of wood in the exterior of the ONV house (left) and the Boase dwelling unit (right) (Force4 Architects 2009).

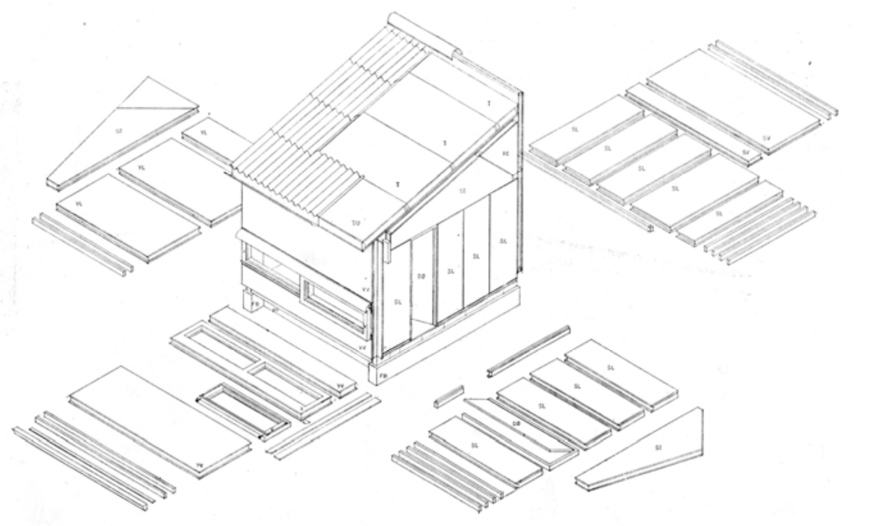
In Boase, the wooden boards were used both on the inside and the outside of the dwelling, which gave a coherent expression in relation to material and form, whereas in the ONV house, the inside of the dwelling had quite a different expression from that of the exterior; the interior was dominated by white plaster boards and therefore looked like a traditional heavy construction house, see Figure 6. All of the five dwelling concepts had a clear and refined detailing. Boase, for example, had a raw detailing that followed the main concept, whereas for example the ONV house had a more sophisticated detailing with the more refined concept.

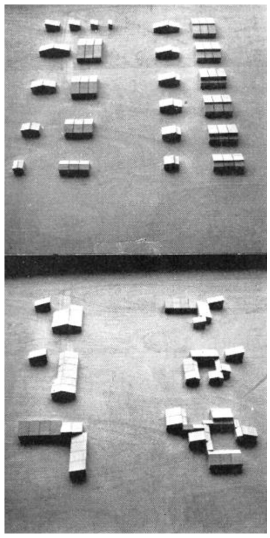
Figure 6. The interior of the Boase dwelling unit (left) (Force4 Architects 2009) and the ONV house (right) (Willa Nordic, 2011).

Perception psychology

The keywords of the perception psychological view were all quite important when speaking of prefab houses as those were the aspects that should be ensured through the design of the building system. A very flexible system made it more difficult to ensure such compositional matters. In Utzon's Espansiva, it was for example very difficult to foresee the actions of the builders due to the amount of possible combinations. The house could become extremely simple, maybe only a single box with a singly pitched roof and unvaried façades, or extremely complex with courtyards, labyrinthine corridors and intricate façade compositions, see Figure 7. Jacobsen's Kubeflex was only slightly less complex and had a more solid base – the 10 m^2 frame box – that could only be filled out by seven different panels. The light green frame box was more characteristic than the pavilions of Espansiva and the possibilities of combining boxes and panels were not so multifarious that the main expression would be as varied as in Espansiva. The worst that could happen in Kubeflex would probably be that the façade and the spatial sequence would appear a bit unvaried. In the ONV house and the Boase dwelling, the matters of perception psychology could be ensured and would be more or less precisely repeated in every dwelling of these types.

Figure 7. Espansiva provides opportunities for a wide range of different designs, both of the façade and of the spatial composition (Utzon, 1970).





Phenomenology

When speaking of both prefab houses and houses made of wood, the first keyword (related to cultural/personal framework) was very important. Houses in Denmark have traditionally been built by craftsmen in heavy materials and houses made of wood are often considered to be of a more temporary character than the traditional brick house. Additionally prefab building has the reputation of being boring and monotonous. Therefore, building prefab houses of wood could be quite a challenge in a Danish context. The Boase project played with the associations with temporariness, and, together with the fact that wood is viewed by many as an environmentally friendly material, it went well with the concept of temporary communal houses on polluted plots. Raw timber boards were used both on the inside and on the outside of the dwelling units, which gave a coherent expression. In the ONV house, wood was mainly used on the outside, where the horizontal boards were used for covering the joint between the 3D elements that the house was built of. However, there was not much play with the material and the conceptions of it. From the exterior it was possible to understand the house as being a light construction whereas seen from the inside it might as well be made of concrete or brick. Both Espansiva and Kubeflex used the wooden frames as exposed ornaments. Espansiva might be composed in a manner so that it would look rather traditional from the outside, but the building system could also result in quite untraditional houses for a Danish context. Kubeflex was not understood specifically as a timber dwelling, as the laminated wood used for the framework was painted light green, but it was indeed understood as a light construction. In relation to supporting a multi-sensory experience, the ONV house was rather interesting experienced from the outside with façades of multi-layered character and different kinds of wood and other pure materials such as metal and glass. However, on the inside, the tactilely poor material of plaster board dominated the wooden floors and fine tiles of the bathroom. In the Boase dwelling, wood, on the other hand, was everywhere, which indeed underlined the raw concept, but did not give a very varied experience, as for example seen in Villa Mairea. In Espansiva there was a contrast between the board materials and the wooden frames which gave a more complex experience, and in Kubeflex the situation could have been almost the same had the wooden frames not been smooth and painted. To the possibility of adjusting to varying contexts the degree of openness of course means a great deal. The ONV house and the Boase complex were the most fixed units, and they did not give many possibilities of customisation. The ONV house could be put onto different types of base, either directly on the ground or with a basement, and the combination of several Boase dwelling units might be adjusted, but the unit in itself could not be customised. Espansiva might be composed so as to be placed on many different kinds of plots, as also Kubeflex, but especially Kubeflex would stand out in a common area of single-family houses with its flat roof and green colours. There were not many possibilities to adjust materials or colouring according to for example neighbouring houses. However, different spatial needs of the customer could be fulfilled in both projects – most flexibly in Espansiva.

DISCUSSION

The three houses in the first analysis, Utzon’s house in Hellebæk, Vanna Venturi house, and Villa Mairea, should form a frame of reference for the analysis of Danish prefab houses made of wood and both analyses therefore followed the same method. It was seen that the most problematic areas of the prefab concepts, compared with the unique houses, were related to **flexibility** and **form, logics and material**.

Flexibility could be a problem in relation to the matter of proportion and order in the structuralist view and the complete set of keywords in the perception psychological view. A high degree of flexibility in a system would provide few possibilities of controlling the result and the final composition, as seen most clearly in the case of Espansiva, whereas a lower degree of flexibility in the construction provided good opportunities of securing the visual and compositional aesthetics of the dwelling, as seen most clearly in the ONV house and the Boase dwelling unit. On the other hand, flexibility was positive in relation to the matters relating to the cultural/personal framework, and in relation to context in a phenomenological view, as flexibility in this context provided the possibility of adapting the houses to users, sites and wider contextual factors. This was very important to the assessment of the architectural quality, as was also seen in the analysis of the unique houses; Utzon’s house in Hellebæk, Vanna Venturi house, and Villa Mairea. It was therefore neither a good idea to have a too high nor a too low degree of flexibility if aiming at creating a dwelling that should be perceived as being of high architectural quality to a large group of people and at many different sites.

The relationship between form, logics of construction, and material also covered several keywords and spread across the theoretical clusters. It was observed that this factor was very well elaborated in two of the unique buildings analysed – Utzon's house in Hellebæk and Villa Mairea. In the prefabricated houses, it was much weaker, and the care for the detailing of the materials was not at all as specific and sophisticated. In relation to the material of wood, there was not only one logic that could be communicated as easily like for example the case of a brick, which comes, more or less, in one module and can take compression but not tension; therefore it is good for building walls, vaults, and arches which are constructions primarily with compression. Wood, on the other hand, comes as small shingle cladding modules, stabilising plywood boards, traditional boards and construction timber of whole pieces of wood, large gluelam beams etc. This means that the logic of wood can be interpreted in many different ways, which was also seen in the analysis of the Danish prefab houses made of wood. In Espansiva and Kubeflex, wood was used according to its constructional logic, as a framework for holding a light envelope of panels of different kinds, whereas in the ONV house it was mainly used in accordance with its smaller modules of weather protecting cladding boards or shading lamellae. In the Boase project, it was used as a multipurpose material, i.e. light and strong, plywood boards that protect and provide floors, but also according to a constructional logic, as there were large visible columns attached to the corners of the house, where the detail made it clear how these two different logics are connected. Therefore, the Boase dwelling was the most complex and most interesting in relation to its use and exploration of wood, but when compared to Utzon's house in Hellebæk and Villa Mairea, the treatment of the material in the Boase project was quite monotonous; there was no differentiation in the materials that accorded with what functions or impacts they were exposed to. In Utzon's house in Hellebæk, the bricks were treated differently according to where in the house they were situated; glazed in the bathroom, more thoroughly burned for the flooring near the fireplace etc., and in Villa Mairea there was both raw and polished, treated and untreated wood, which gave a variation in the visual, tactile and scent experiences. However, both of these houses also used wood together with other, heavier materials, which gave them both variation and harmony between heaviness and lightness, openness and closedness, as it underlines the properties and architectural qualities of the materials in isolation, as well as in combination with each other.

CONCLUSIONS

Four Danish prefab timber building systems were analysed in order to investigate what factors were particularly important when working with this building typology. The systems were chosen to represent a wide spectrum of different methods of prefabrication – and thus there were both opened and closed systems, and constructions built from 2D and 3D elements, or combinations of these. It was concluded that **flexibility** and **experience of form, logic, and material** were the most crucial aspects for the architectural quality of prefab wooden houses. Flexibility was both a problem when there was too much of it and when there was too little of it; in Espansiva, for example, it was difficult to make sure that all possible combinations would result in a well-proportioned and harmonious building, as the flexibility of the system was very high, whereas in the ONV house there were very few possible ways of adjusting the dwelling to a specific site or user, which was problematic mainly in relation to the phenomenological perspective. Especially in two of the unique houses, there was much focus on the materials; how and where they were used in relation to functions and the constructional logic. In Utzon's house in Hellebæk, this was for example seen in the varied use of bricks, and the play between the heavy and the light loadbearing elements. In the analysed prefab houses, the detailing of the materials was less elaborate. The interior surfaces of Kubeflex, Espansiva and the ONV house did not provide the same kind of experience of variety and meaningfulness in relation to the total concept of the houses. The Boase dwelling, on the other hand, used the raw wooden surfaces; however, they were everywhere, which did not provide a variation in the perception of the materiality – but it did indeed reflect the construction of the building. Espansiva and Kubeflex also exposed the prefabricated framework construction and used it as an important part of their aesthetical expression, whereas the prefabricational logic was hidden in the ONV house where horizontal boards of wood cover the joints between the 3D elements. A focus on these two points - **flexibility** and **experience of form, logic and material** – therefore covered many of the aspects that are important when working with prefab houses made of wood. Care and elaboration in relation to these could therefore add to the architectural quality of this building typology.

REFERENCES

Åberg, L., & Stenberg, F. (2005). Prefab sprout. *Forum,* (4), 76-95.

Anderson, M., & Anderson, P. (2007). *Prefab prototypes - site-specific design for offsite construction*. New York: Princeton architectural press.

Arieff, A. (2002). *PREFAB*. Layton: Gibbs Smith, Publisher.

Bachelard, G. (1994). *The poetics of space* [La poétique de l'espace] (M. Jolas Trans.). Boston, Massachusetts: Beacon Press.

Force4 Architects. (2009). *Housing: Boase.* Webpage accessed 15-04-2009 at: http://www.force4.dk/#/144461/

Gibson, J. J. (1950). *The perception of the visual world*. Boston: Houghton Mifflin Company.

Heidegger, M. (1997). Building, dwelling, thinking. In N. Leach (Ed.), *Rethinking architecture - A reader in cultural theory*. London: Routledge.

Hesselgren, S. (1977). *Vad vacker är - varför vi vill ha vackra hus och städer*. Lund: Byggforskningsrådet.

Ingels, B. (2003). In B. D. Stang (Ed.), *Nye generationer af byggekomponenter - prisopgave for studerende ved arkitekt- og designuddannelserne*. Hørsholm: By & Byg, Statens Byggeforskningsinstitut.

Jensen, K. V., & Beim, A. (2006). *Kvalitetsmål i den arkitektoniske designproces*. Copenhagen: CINARK, Kunstakademiets Arkitektskole.

Juul, E. (2008). Erfaringer med præfab. *Arkitekten,* (9), 84-89.

Keiding, M., & Dirckinck-Holmfeld, K. (Eds.). (2004). *Utzons egne huse*. Copenhagen: Arkitektens Forlag.

Knudsen, G., Andersen, P. A., Christensen, A. S., Hammer, B., Hansen, L. O., Harrebek, M., et al. (2000). *Arkitektonisk helhedssyn - temagruppe 7*. Copenhagen: Arkitektens Forlag for By- og Boligministeriet.

Kraul, A., & Madsen, K. S. (2007). *Parcelhusets pionerer - da Jensen flyttede på Lærkevej*. Ballerup: Bolius.

Lahti, M., & Jetsonen, J. (2005). *Alvar Aalto houses* (K. Köhli, G. Griffiths Trans.). Helsinki: Rakennustieto Oy (Building Information Ltd).

Le Corbusier. (1971). Architecture and the mathematical spirit. In Le Lionnais, & F (Eds.), *Great currents of mathematical thought*. New York: Dover Publications.

Lind, O. (1998). Det miskendte træhus. *Boligen, 65*, 8-9.

MacKeith, P. (Ed.). (2005). *Encounters - architectural essays.* Rakennustieto Oy (Building Information Ltd).

Merleau-Ponty, M. (1945/2002). *Phenomenology of perception*. New York: Routledge.

Mikkelsen, H., Beim, A., Hvam, L., & Tølle, M. (2005). *Systemleverancer i byggeriet*. Kongens Lyngby: Institut for produktion og ledelse, DTU.

Norberg-Schulz, C. (1963). *Intentions in architecture*. Oslo: Universitetsforlaget.

Pallasmaa, J. (1996). *The eyes of the skin*. London: Academy Group Ltd.

Schwartz, F. (ed) (1992). *Mother's House: The evolution of Vanna Venturi's house in Chestnut Hill*. New York: Rizzoli International Publications, Inc.

Scruton, R. (1979). *The aesthetics of architecture*. London: Meuten & Co Ltd.

Storvang, P. (2000). Træhuse som boliger i Danmark. *Nordic Journal of Architectural Research,* **13**(4)

Svendler, H. P. (2005). Vi har brug for en ny-industrialisering. In L. D. Lund, L. Eriksen & J. V. Nielsen (Eds.), *CINARK sætter fokus: Indistrialiseret arkitektur/ økonomi - proces - produkt/værk*. Copenhagen: CINARK Kunstakademiets Arkitektskole.

Thorsen, P. (2005). Gentagelse er en udfordring. In L. D. Lund, l. Eriksen & J. V. Nielsen (Eds.), *CINARK sætter fokus: Indistrialiseret arkitektur/ økonomi - proces - produkt/værk*. Copenhagen: CINARK Kunstakademiets Arkitektskole.

Trapholt. (2009). *Arne Jacobsens kubeflex sommerhus.* Webpage accessed 15-04-2009 at: http://www.trapholt.dk/00327/00358/

Utzon, J. (1970). *Additiv arkitektur*. Copenhagen: Arkitektens Forlag.

Venturi, R. (1966/1977). *Complexity and contradiction in architecture* (2nd ed.). New York: The Museum of Modern Art, in association with the Graham Foundation for Advanced Studies in the Fine Arts, Chicago.

Willa Nordic. (2011). *ONV bolig.* Webpage accessed 11-01-2011 at: http://www.willanordic.se/da/Vores_hus/ONV-Bolig/

Wraber, I. (2009). Prefab Quality: Architectural quality in Danish prefab wooden dwellings. Aalborg Universitet. Webpage accessed 25-01-2011 at: http://vbn.aau.dk/da/publications/prefab-quality(4b042510-4613-11df-84c0-000ea68e967b).html

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