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REGULATIONS AND INNOVATIONS ACROSS THE UK CONSTRUCTION SECTOR: SOCIAL SHAPING IN ACTION

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ABSTRACT

It is commonly argued that regulations together with their format impact directly upon innovation in the construction sector. Opposing views are held by practitioners, with regulations positioned as either stifling innovation, or alternatively driving it forward. We argue that adopting either of these positions oversimplifies the relationship between regulation and innovation, and that an alternative perspective is required. Drawing on literature around the configuration of users by technologies, and the domestication of technologies by users, we argue that the discourses and devices of regulation, the actors who enforce them, and their 'users' create a space within which regulations are negotiated and realised in specific contexts. We utilise empirical data from interviews with practitioners to discuss four themes; practitioners' perceptions of regulations, the relationship between innovative practice and new regulation, professional tensions within regulatory practices and the social interactions which inform how regulations are enforced and adhered to. We conclude that regulations have a dynamic role to play regarding innovative activity within construction practice, as do innovations upon regulations. But we move beyond seeing regulations as either facilitating or impeding innovation, instead seeing them as agents within context-specific negotiations between regulators and practitioners.

1. INTRODUCTION

UK construction practitioners, like most of us, have to play by certain rules and the construction sector is governed by a host of planning and building regulations. Such regulations play an important role concerning the safety, suitability, and durability of innovative techniques and products used in the building process. In turn, this has implications for the performance and sustainability of the built environment more widely.

Regulations are also important when considering calls for increasing the levels of innovation within the sector. The discourse surrounding innovation takes a critical view, with the sector positioned as un-innovative or somehow backwards compared to others. The structure of the sector, and the social division of labour by which construction projects are performed are considered traditional and even a hindrance to innovation (Koskela and Vrijhoef 2001). Notwithstanding the suitability of classification schemes for comparing levels of innovation across different industries (see Winch 2003); these criticisms are often driven by government's own political concerns. Alternatively, they respond to the sector's apparent failure to implement the latest management fad. There is little, if any, consideration of the specificities of construction activity and the context in which it is undertaken.

Regulations, then, hold the promise to bring about increased innovation in the sector, by effectively forcing practitioners to adopt new practices and products. But they also threaten to stifle innovation as it happens at project level, by lagging behind practice in approving new techniques or materials. Understanding this duality requires moving beyond generic and bi-polar views of regulation to consider exactly how regulations are performed and managed in practice, and within specific contexts.

The paper is structured as follows. We begin by reviewing current paradigms within the construction management (CM) literature regarding regulation and its relationship to innovation. We then outline concepts from science and technology studies (STS) which

allow us to propose a socio-technically constructed space in which regulations are negotiated and performed. To do so we draw on the concepts of configuration and domestication. The former refers to the way material devices and artefacts can constrain some practices or ways of using them, and enable others. The latter refers to a process of appropriation, where users shape artefacts according to their local requirements and existing practices. We then discuss four themes, using empirical data from semi-structured interviews with chartered practitioners to illustrate them. The themes are practitioners' perceptions of regulations, the implications of the format regulations can take, professional tensions within regulatory practices and the social interactions which inform how regulations are enforced and adhered to. We conclude by describing regulation as a highly complex and contested arena, characterised by context-specific negotiations between regulators and practitioners. We also outline areas for further research.

2. CURRENT PARADIGMS OF INNOVATION AND REGULATION

Although often berated for its lack of innovation, there is an acknowledgement within the CM literature that there is insufficient research directed at a detailed understanding of construction contexts (Bresnen and Marshall 2001), and that more interrogation of how external directives such as regulations are actually enacted in practice is required. Early innovation research within CM can be traced back to Bowley (1966) and innovative building materials. Since then work has focussed upon the definition of innovation (Tatum 1986), linking innovations to the failure of firms (Henderson and Clark, 1990), the sources of innovation (Slaughter 1993), or the flow of innovation into industry (Arditi *et al.*, 1997; Slaughter 2000), and the methods of stimulating and recognizing innovation (Cousin, 1998).

However, over more recent years the field has seen an increase in work directed at managing innovation in context (Winch 1998), understanding the diffusion of management ideas (Bresnen and Marshall, 2001), positioning the industry as a social system (Dubois and Gadde 2002), and using more sociological concepts as frameworks for exploring innovation (Harkola, 1995; Larsen, 2005; Harty 2008). Within this work, the role of innovation remains uncertain and contested; indeed the very definition of what constitutes 'innovation' is remains up for debate.

From our perspective we would resist trying to define innovation. Instead we would argue that only through engagement with both the material and social agents interacting in specific contexts can the specificities of innovation and / or regulation in practice be understood. But literature specifically discussing regulation of the sector tends to conform to the view that it can be externally imposed and enforced, rather than accounting for contextual factors and the possibility of emergent, unforeseen outcomes. We continue to see polarisation around facilitation versus constraint, with debates often couched in terms of regulations as prescriptive (and hence over-constraining) or descriptive (and hence allowing some interpretative flexibility at the level of practice).

For example Gjerde (2003) argues that prescriptive regulations stifle creativity and innovation, which in turn leads to building failures. A causal link between regulation and (lack of) innovation is therefore implied, but arguably in an over-simplified way. Regulation equals constraint, without any consideration of contextual factors and the possibility for actors to manoeuvre within and around regulations depending on specific contexts. O'Conner and Miller (1994) further fuel the debate arguing that 'rigid, outdated codes and design standards act as a barrier to innovation'. Whilst Gann (1998) argues that regulations are seen by designers and builders as 'an additional burden', it is acknowledged that regulations can act as drivers of innovation often depending upon their type – categorised as either prescriptive or descriptive. But again, consideration of context is missing from the argument.

Whilst offering similar views to those above, Bougrain (2003) does concede that 'competition, scientific progress, change of regulations, the clients, the power of habits

and in-house R&D stimulate innovation'. This begins to appreciate broader interconnectivities and the manifold factors that can influence what actually happens in practice. Gann also argues that amendments and descriptions to regulations allow flexibility and encourage improved standards, thus stimulating innovation and integration of the loosely-coupled elements of the UK construction industry (Gann, 2000). Gjerde (2003) argues that the format of regulations impacts upon the amount of innovative activity within a construction industry, with 'performance-based' building regulations cited as facilitating innovation.

In sum, the literature is dominated by two key themes. First, it tries to polarise regulations as either impeding or facilitating innovation. From this, the focus then moves on to breakdown regulations into either prescriptive or descriptive, these categories again mapping neatly onto the enable/inhibit opposition. But simply categorizing regulations as either impeding or facilitating innovation oversimplifies the complexity of the subject, regardless of format (descriptive or prescriptive). There is little consideration of how innovations and regulations play out through mutual interaction.

3. ALTERNATIVE THEORETICAL LENSES

In order to move away from simple dichotomies, and recognise and further understand the iterative and negotiated relationship between regulation and innovation, we can turn to science and technology studies (STS) and the sociology of consumption.

3.1 Domesticating Technologies

The sociology of consumption looks at how actors adopt, adapt and embed technological artefacts into their day-to-day lives and practices. Silverstone *et al* (1992) conceptualise domestication as a process involving several stages, or transactions between technological artefacts (or innovations) and their users. First, an artefact is transferred and transformed from an abstract commodity to an artefact with significance and meaning for its owner. This phase is termed appropriation. Second comes objectification, where the artefact is displayed or aligned with other 'things', which reveal its aesthetic and cognitive meanings for its owner. Third is incorporation, where the artefact is embedded into every-day use and into the routines and activities of its owner, also now its user. These are all highly individual transformations, as the meanings and significances of the artefact are dependent on the individual and the particular contexts of practices and other artefacts in which he or she is situated. A fourth process of conversion orients the artefact within more externally understood and commensurable meanings.

The concept of domestication directs us towards appreciating the meanings, intentions and expectations of actual users and is firmly rooted in specific contexts of use. An artefact has no grounded meaning or utility for users until it is appropriated and aligned with existing practices and other artefacts. This is consistent with what has been identified as the contextual and situated nature of *innofusion* (Harty, 2006). A second and highly important point is that domestication involves the emergence of new or transformed practices, through the incorporation of the new artefact into existing contexts and routines. Users construct practices based around their own ideas and understandings of what it is and how it should be used. As Lie and Sorensen (1996) argue, when things are put to use, local routines are constructed to guide and inform application.

Moving from individual to organisational spaces, McLaughlin *et al* (1999) argue that artefacts function as the locus for multiple negotiations over their implementation. They posit a process of domestication or appropriation where overarching visions of technological advance and economic imperatives are stabilised at a local level through developing practices of use. However, these local practices can deviate from or resist the grand vision. Not only do users reshape artefacts for their own purposes (Noble and

Lupton, 1998), but also unintended and unanticipated practices can emerge (Brown and Perry, 2000). Domestication suggests a highly fluid interaction between local influences, and the potential for new and unexpected outcomes. Whether this is problematic deviation, or valuable innovation, depends on the context and perspective taken. The concept provides a useful way of conceptualising the actions of users in embedding technological artefacts or other devices and discourses into their own contexts and practices.

3.2 Scripts of Use and Configuring Users

Broadly, STS (Science and Technology Studies) provides a critique of, and alternative to, polarised explanations based upon either technological determinism (which under-determines the role of social interaction in shaping artefacts) or purely upon social interaction (which under-determines the role of material artefacts in shaping and mediating human interaction). Instead, interaction is considered socio-technical in nature; it is shaped simultaneously by both social (human) and material (non-human) entities. Without considering both as mutually constitutive, only partial descriptions of particular interactions are possible. More specifically, just as domestication can frame the ways actors appropriate and shape non-human entities in local contexts, configuration and the idea of 'scripts of use' point to the ways that these entities themselves can affect and shape the human actors that interact with them.

The design of artefacts has been described as the inscription of specific assumptions about, or particular visions of, who its users might be, and how they might use it (Akrich, 1992; Akrich and Latour, 1992). Akrich argues that a 'script' defining how, where and when an artefact should or might be used is embedded within the artefact itself. When an artefact is located within contexts of use this script informs the practices that develop around it. The artefact can inscribe actions and configure its users, or set conditions for how it can be implemented and used.

The scripts embedded into artefacts can range in their configuring abilities. Latour's (1992) example of an automatic door closer has both a 'hard' script - it always closes the door unless further action is taken to wedge it open - and a fairly straight-forward action to perform. But scripts can be both much softer and actions more complex. Woolgar's concept of 'configuring the user' refers to a process of design where:

"along with negotiations over who the user might be, comes a set of design (and other) activities which attempt to define and delimit the user's possible actions... by setting parameters for the user's actions, the evolving machine effectively attempts to configure the user" (Woolgar, 1991: 61).

Woolgar describes the usability trails of a new computer, where the ability of users to correctly 'read the script' embedded in the machine are assessed, as is the scripts' effectiveness to constrain inappropriate uses.

For the users of this machine, some actions are highly configured (such as plugging the various devices into the right holes, turning it on, loading the operating system) and some are 'softer' or more flexible (such as methods of inputting data through keyboard or mouse and the ability to load or write new programs). But users are not predictable, or able to be completely scripted, especially for complex operations like using a computer. Indeed, Woolgar discusses 'atrocious stories' that designers trade, describing the "nasty things that users have done to our machines" (Woolgar, 1991: 89). Even when hard scripting and configuring is attempted by designers, users can still often find unanticipated ways of interacting with the artefact, which may result in disaster, rather than a new and innovative practice. So to prohibit certain actions, other devices are enrolled alongside the artefact itself. For instance instruction manuals document 'proper' use, and warning stickers caution against investigation of the computer's innards.

3.3 The Duality of Domestication and Configuration

These concepts in turn describe the ways users shape artefacts, and how artefacts shape users. When put together, we can see these as two sides of the same coin. On the one hand, users appropriate artefacts in specific contexts. On the other, the artefacts configure actors to use them in certain ways and not others. Neither of these processes is certain, uncontested or predictable. But together they suggest a space which is constituted by the interplay between configuration and domestication. Within this space, actors have different amount of 'room' or capacity to reshape and appropriate within the limits of an artefacts script.

The literature described above concentrates on physical artefacts (such as televisions or computers) rather than the rules or codes which constitute regulatory frameworks within construction. However, these concepts can be equally applied to less concrete entities. In his analysis of the Deltaplan, a programme initiated in the 1950s to improve drainage systems in the Netherlands, Bijker (1995) differentiates between physical technologies and social technologies such as dyke management systems and monitoring techniques. Both the physical and social technologies were important in reaching the programme's goal of improved flood protection. We can also usefully, if briefly, draw on the work of Foucault and his conception of discourse. He defines this as sets of rules and conventions which set out the ways of thinking, speaking and acting around a specific phenomenon. Discourses therefore have significant effects on practice – what he terms the 'formidable materiality of discourse' (Foucault, 1981: 52). So we can treat regulations as a social technology which can have an effect on practice, in a similar way to a physical artefact. In any case, we should also acknowledge that regulations are not without physical manifestation, whether as written documents and forms, embedded into electronic systems, or as represented by particular actors such as building control officers who inspect and approve building work.

So, the conceptual space suggested by the interplay of configuration and domestication is highly useful when thinking about the relationship between regulation and innovation. Rather than opting for one side of a polarised view (constraining, enabling/ prescriptive, descriptive), or attempting to identify generic connections between the two, we instead offer a perspective where the outcome of regulation – whether innovative or restrictive – emerges from context specific interactions and negotiations within that particular space, and where regulations and actors are mutually shaped. The remainder of the paper illustrates this with some empirical data, taken from interviews with chartered professionals from the CIOB, RIBA and RICS. To begin, we look at the perceived role of regulations within our interview sample.

4. REGULATION AND INNOVATION: FOUR EMERGENT THEMES

4.1 Perceived Roles, Responsibilities and Relationships

Initially our analysis looked at the interviewees' perspectives on regulation within the sector, primary to gauge the connection between debates in policy and the CM literature, and what practitioners actually said. In general there was some strong resonance in terms of the facilitation versus inhibiting debate. In general our interviewees agreed on two main points; the potential of regulations within construction practice to enable innovation, and the failure of current regulations to actually perform this function. There was certainly no evidence that practitioners would like regulation removed or replaced. Respondents claimed that regulations "should and indeed could play a key driving role in innovation and diffusion" (Respondent H) and that "building control should encourage innovation" (Respondent I).

There were exceptions, of course, with, for instance, one interviewee (respondent A) commenting that regulations are only about defining a minimum standard for buildings (in terms of robustness, performance, safety etc), and suggesting that the innovative aspects would be on top, or in addition to these minimum requirements; hence regulation

neither restricts nor encourages innovation. The challenge for regulation is in fact keeping up with innovations at the level of construction practice. This perspective has practice taking the lead role, with regulation playing catch up.

There was a widespread feeling of apathy towards regulation as a driver for innovation, with practitioners arguing that regulations fall short of supporting innovation in the sector: "government policy and regulations in general, play a key driving role in innovation and diffusion, however, they are currently not doing enough" (Respondent F), and that regulations are currently allowing the industry to do only the minimum (Respondent C). The latter is an interesting point; that regulations can be considered a justification of not being innovative and resisting changes to practice. Certain practitioners noted that some contractors use the codes and regulations as a line of defence against innovation (Respondent A). Such change-averse proponents mobilize the discourse of regulation and innovation for their own conservative agendas, and especially to remove the uncertainties, extra complexity, risk and cost associated with innovation and change. This justification mechanism was also thought to be located at the construction manager or project level, rather than representing the 'company line' from directors. This perhaps connects to other respondents' ambivalence towards regulation, commenting that regulations are not an obstacle to innovation, or a mechanism for increasing it. Again a conservative view is apparent which preserves the current status quo.

From this perspective, it is not really the regulation devices themselves that inhibit innovation, but rather the way they are mobilised by construction professionals. In terms of the space between configuration and domestication, we might argue that regulatory requirements are set so low that there is too much room for appropriating them into existing practices without any requirement for finding new and innovative solutions. Effectively, practitioners are able to opt out of being innovative, instead using regulation as a justification for repeating the same activities.

4.2 The Format of Regulations: To Prescribe or Describe?

It proved difficult to separate practitioners' broad views on innovation from the format that they take. Debates in the literature were again reflected, with interviewees commenting that "regulations can... be used to encourage innovation, through either a carrot or stick approach" (Respondent H). This can be broadly aligned to prescriptive (the stick) and descriptive (the carrot) forms of regulation. But in practice, the format of regulations has more complex consequences.

For example, the area of sustainability and regulation was a key issue for the interviewees. This is an area where technical solutions and new, more sustainable practices are continually emerging, but with little consensus on the most suitable technologies or activities. This was identified as an area where regulation could lead the way. However, the regulatory framework is not apparent; "things are going to have to change because of sustainability issues but the structure isn't in place yet to make it really easy to build sustainably" (Respondent J). A specific example was given by another interviewee regarding grey water recycling. He claimed that he "has not been able to use it yet as there is no British Standard" (Respondent J) in place to approve it.

But it is not just a case of the regulations 'catching up' to incorporate new technologies and methods. Should new regulation prescribe, or describe? Prescriptive methods of regulation might include statements or diagrams demonstrating that a particular material or detail must be used. This approach leaves practitioners with little scope for improvement or change – the space within which they can appropriate regulation is tightly bounded. The alternative is the descriptive method of regulating which might stipulate a specific outcome, but with practitioners able to deliver different solutions to attain it. This therefore represents a much less constricted space in which practitioners can be innovative and domesticate or shape regulations as part of alternative new practices. Both paths have advantages and disadvantages. Constricting the space might

enable increased standardisation, but can also lead to stagnation and a lag between regulatory stipulations and options available for professionals. Description might avoid this, but could lead to a plethora of different practices to achieve the same end across the sector.

We would argue that the categorisation of regulation as prescriptive or descriptive oversimplifies a complex set of activities. It is also bound up with some assumptions about the abilities of construction professional; are they capable of finding sensible ways to attain required performance, or do they need to be forced into doing so? This reflects back on the question of whether regulation should lead the way and enforce new practices, or act as a checking mechanism for solutions developed by practitioners. This can be rephrased as a question of how on the one hand to produce regulation which can configure users to the extent that buildings satisfy standards, but on the other which can be domesticated or accommodated to foster new practices in specific contexts. But this assumes that the aim of regulation is indeed to encourage innovation. It should not be forgotten that regulation might have alternative motives, such as constraining innovation at individual project level to encourage increased homogeneity across the sector. This could, for instance, lead to a greater use of standardisation and prefabrication. Issues such as the intentions behind regulation are central in defining what the format of regulation should be.

4.3 Negotiating Spaces for Enacting Regulation

Our analysis reveals the contested nature and complex implications of different approaches to regulation. But so far we have only considered the effect of regulations as devices and discourses on the opinions and activities of practitioners. This has omitted a crucial set of actors; those who approve buildings as satisfying regulatory requirements. Their importance was recognised by respondents, who placed great value on their relationships with building officers; one practitioner described how they "have got the building control officer's mobile number, so he will ring me and I will ring him, so you start communication". Having this relationship would mean that "you know you are going to get a fair decision and that some officers "are more likely to want to make it work" (Respondent I).

There was an emphasis on using 'approved inspectors' with 'good experience'. Interestingly, what was meant by this 'experience' translated into an understanding of the need for flexibility and accommodation when approving buildings - an acknowledgement that some discretion might make the regulation process less draconian, and less burdensome for practitioners. This was contrasted to a less accommodating approach; "a bloody-minded response of 'in the 30 yrs I have been a building control officer we have never done that, so forget it'" (Respondent I).

The building control officer seems to play a key role in the performance of construction practice, and in enforcing and maintaining regulatory standards. Woolgar's example of the new computer system above reminds us of the difficulties in designing devices which can bring about the delicate balance between over-configuring and rampant, multiple domestications. There is also the issue that adhering to standards is not a clear cut process, especially where there is a lack of consensus about the interpretation of regulation. Here, the building control officer performs the important role of defining and maintaining that. In effect, she is able to interpret the script which constitutes regulation, using 'experience' to qualitatively evaluate the extent to which a building adheres to those requirements. Fundamentally, the performance of regulation is not a mechanical and measurable process, but a negotiated and fluid one.

4.4 Professional Tensions and Control

Engineers and architects were characterised as two extremes which “occur upon a sliding scale, between those who think numerically, formally and structured and those that are creative, flamboyant and innovative” (Respondent F). This of course is something of a stereotype, but does serve to highlight the diversity of interests and practices across the sector. This suggests an understanding of the concerns and operations of different actors within the construction process is required in producing regulation, and that a ‘one size fits all’ approach could serve some actors and organisations better than others. This adds further complexity, with a requirement for regulation to appreciate the tensions between a multiplicity of actors and how the tensions between them affect their views.

It is also important to remember that regulations are only one of many influences on the practice of building. Other devices such as specifications can contribute to shaping the spaces in which regulation and innovation are performed. For instance one practitioner commented that when “architects write specifications in line with guidance notes for NHS works, the contractor knows they must comply with these regulations, but always looks for the cheapest option” (Respondent A). This suggests a tension between these professions, characterising the architect as creative and interested in design, and the contractors oriented to providing cost-effective solutions.

In this case, the fact that the architect wrote the specifications, rather than the contractor imposed problems of maintaining within budget in the face of un-quantified design costs. This can also be seen as a manipulation of the specifications by the architect to make sure their own interests in a ‘designed’ end product are prioritised over the cost considerations of contractors. It is not too difficult to imagine that this could happen the other way round, with cost efficiencies cutting into the resources provided for design activities. In addition to the control of the sector as a whole through regulation, we also see examples where the manipulation of other devices such as specifications can result in different interests within the sector being satisfied at the expense of others.

5. DISCUSSION & CONCLUSIONS

There is much resonance between debates over the link between regulation and innovation within the CM literature and the responses of practitioners. However, when drilling down further it becomes apparent that the reality of regulation in practice is somewhat more complex than dichotomising regulation and innovation or prescription and description allow. In fact, the analysis reveals a number of further questions, rather than answers. What is the role of regulation? Should it be about enforcing minimum standards only, or serve to provoke the industry into innovating its practices? How can ‘top-down’ regulation and ‘bottom-up’ innovation be balanced, especially in contexts where regulations lag behind actual practice, or available technologies? How can regulations be more sensitive to the diverse interests and intentions of different actors within the overall construction process? Can mechanisms other than the discretion of building control officers be developed which can allow regulation to simultaneously encourage flexibility, whilst ensuring standards are met? All of these make interesting questions for further research.

In asking these questions, we move beyond the more polarised debates in the literature. This is where the concepts of configuration and domestication become valuable. Effective regulation can be seen as that which creates a space within which practitioners can be encouraged to innovate, but with enough configuration, enough ‘hardness’ to the script that buildings are safe, robust and, increasingly, sustainable. Given that different contexts offer different challenges to and influences upon this space, the ability to do this exclusively with regulations and codes alone is debatable. Indeed, the role of building control officers suggests that more devices have to be enrolled to manage this space in specific contexts.

Finally, it is crucial to acknowledge that regulation only constitutes one set of influences upon construction practices. For example, client requirements, contractual obligations and other policy initiatives, as well as the specifications discussed above, will also impose conditions on the space in which construction work is carried out. Future research would therefore also need to look in more detail at how these other influences constrain and encourage practice alongside regulatory devices together with the roles of the various actors involved in the process.

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PUBLIC PROCUREMENT OF INDUSTRIALLY PRODUCED HOUSING

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ABSTRACT

The paper reports on research which investigated how a model for public procurement could be designed with the aim of including industrially produced housing in the procurement process in Sweden. The study was performed in two steps: an initial literature review and then a case study. The supporting literature review created an understanding of how this is done in other contexts and what the public procurement legislation allows. The case study investigated the current procurement process using an existing project between two companies: one public client and a contractor. Conclusions from the case study are that co-operation at an early stage is desirable as is involving the contractor at an early stage. In the process, everyone involved should get the opportunity to use their knowledge in the process and form the project. The criteria for evaluation is important as well as the objectives for the project. To use industrial produced housing also demands special attention to the regulation of secrecy. An important conclusion is that it should be possible, within the existing regulatory context, to procure industrial produced housing. The adoption of competitive dialogue would, however, probably increase the possibility of it happening regularly. The paper is based on research that is complete and which has helped to identify the problems and possibilities of public clients procuring industrially produced housing. It reveals that the main obstacle is not legislation; although, at the same time, it could probably be made easier by the introduction of competitive dialogue into Swedish procurement legislation.

1. INTRODUCTION

The Swedish housing market has the last two decades been in a situation where the demand for new housing is higher than the supply. The result has been that the value of privately owned housing has increased dramatically and that there has been a shortage of rental housing apartments. Since there were better possibilities to make a profit on new housing for sale, rather than renting, the property development companies focused largely on this segment of the market, with the results that no rental apartments were built.

At the same time there were a few rather ambitious initiatives to create change happening in the Swedish building sector. Several companies were working with buildings systems, with a high degree of industrialisation, that aimed to offer a more efficient production with lower costs. To fully benefit from such industrial produced housing it requires an earlier engagement of the producer than in traditionally produced housing. Among some public clients this raised the issue of exclusion of those that do not produce industrially which potentially could be a problem in regard to the public procurement regulation. Implementing new technologies, innovations, in general are believed to be difficult by public housing clients in Sweden (Olander *et al.*, 2007). One of the main problems is that the industrial building systems may have requirements that are hard to combine with traditional bidding procedures as well as the Public procurement act. Predefined building systems have, even if they in a large extent can be configured, limits for the process and its formation (Mikkelsen, 2006).

Since the EU Public Procurement came into effect in 1994, the requirements have been sharpened for the public purchasers. The procurement processes is largely dependent of the purchasing unit and how they define the selection criterions to make them clear and consistent for the bidders (Näringsdepartementet, 2006). The research presented in this paper investigates the possibility to develop a model that creates the right pre-requisites

and documents to include industrial construction systems in the purchasing of public housing. The objectives are to study:

1. How the public procurement act affects purchasing of industrially produced multi-family housing.
2. How a model may be designed for purchasing industrially produced housing.

2. STATE-OF-THE-ART REVIEW

2.1 Public Procurement

All member states in the EC have to follow the EU regulation on public procurement. The purpose of the regulation is to enhance competitiveness, both within country borders and across within the European open market, and to eliminate non-tariff barriers to intra-community trade (Bovis, 2006), and to promote transparency and prevent corruption (Sanderson, 1998). The rationale behind the open market is that many sectors, for example the financial sector, business across the globe was already harmonising procedures and specifications – and as a sharp-edged tool, not because of bureaucratic obsession for its own sake (MacGillycuddy, 1988). Public authorities are significant market players as buyers of goods and services. Before the creation of the Internal Market, national, regional and local authorities favoured domestic suppliers. This was not only incompatible with the Treaty provisions requiring the creation of a single Internal Market but also had negative macro and microeconomic implications for the European economy (EU Commission, 2004).

The concepts of transparency and accountability are nowhere more significant in public administration than in procurement (Schapper *et al.*, 2006). Opening of public procurement national markets to the EU competition implies a series of economic and social reforms. The principal of openness, fairness and transparency are basic elements of an effective public sector, which intends to align with the mechanism of a free market (Mardas, 2005). The effects of the Public Procurement Directives have been questioned ever since first adopted in the 1970s (Gelderman *et al.*, 2006). Some argue that Empirical evidence is consistent with the ex-ante expectation that the EU Single Market Program should have increased competition and consequently reduced market power, especially for firms operating in industries where non-tariff barriers were perceived to be high (Bottasso and Sembenelli, 2001). The commission argues that an increase in cross-border contracts will be an indication of a well-functioning public procurement market (Sanderson, 1998). Several studies, for example (Cox and Furlong, 1997), of possible increases of cross-border contracts in the early 1990s did not show the expected results. The reason for this is said to be faulty application of the regulations by the member states.

The solution of this problem was to make member states to implement the regulation as correct, clear and easy as possible in the national context (European Commission, 1996). The public sector has to recognise that an effective public procurement system implies the openness of public contracts to foreign competitors (Mardas, 2005). The existence of preferential public procurement policies is a well-known fact in many countries. Favouritism in the awarding of public contracts can result from an explicit “buy local policy” when the government offers a specified preference for domestic suppliers (Mougeot and Naegelen, 2005). However, if a domestic product performs well in terms of industrial and trade structures, then it can also perform well within an open non-discriminatory public procurement market against foreign bidders (Mardas, 2005).

Regulations in the Swedish law about purchasing are based on the EU- directives. The EU directives are especially valid for purchasing of goods, services or construction and purchasing that exceed threshold values (SFS 1997:1068). Fundamental common principals in the law are the principal of non- discrimination, proportionality, transmission, mutual acknowledgement and equal treatment. A rule in the public procurement act can have direct effect in the Swedish law if the directive has not been

incorporate in time, not been entirely incorporated or wrongly incorporated (Sveriges riksdag, 2007).

The law for procurement in Sweden has got a total of six types of procedures for public procurement. Three of them are for procurements over the threshold values open, selective and negotiated procurement. To be sure about what procurement to use, the public client has to know if the project value exceeds threshold values or not. Procurement over threshold values are divided in the following steps (Konkurrensverket, 2007):

- computing of threshold value
- choice of procurement
- composing of inquiry documents
- inquiry/advertising
- submission of tender
- evaluation of tender, negotiations
- awarding of project
- agreement for project.

The first main rule for public purchasing is that all purchasing has to be advertised. The advertising has to contain information which enable the entrepreneur to decide if he wants to submit a tender or not ((SFS 1992:1528) chap.7 §1). The inquiry documents cannot either contain or refer to origin, fabrication or specific method of fabrication if that leads to benefits or disfavours for some companies ((SFS 1992:1528) chap.6 §4). The public constructor also has to decide about evaluation criterions and their relative significance for the project ((SFS 1992:1528) chap.12 §4). The evaluation process can be done in one or two steps depending on the procurement over the threshold values. A prequalification is in general carried out in the selective purchasing and negotiated purchasing ((SFS 1992:1528) chap.2 §16-22).

The European public procurement directive has given both positive and negative effects, (Ramsey, 2006, NOU, 1998). Positive effects are that public procurement across Europe has the same basic prerequisites and, thus, can generate a clearer competition among suppliers. A negative effect is cost driving and time consuming bureaucratic routines. Other issues that have been highlighted, especially by parties in the construction sector, are difficulties of adopting new forms of cooperation, innovative solutions and implementation of environmental targets in the procurement process. The new directive (Dir 2004/18/EC) is stricter, but also opens up for more collaborative forms of cooperation, such as partnering and PFIs, through, for example, the use of competitive dialogue (Finnansdepartementet, 2006, Ramsey, 2006). In particular, the 'competitive dialogue' procedure would allow early dialogue with industry and provide information on what the public sector wants to buy. This would guide and stimulate the creation of new ways of working and ideas (Manchester Business School, 2006).

The new EU directives have resulted in a preposition (2006/07:128) in Swedish law. The new changes in the law can be defined as follows (Trepte, 2007).

1. A change to make the law more clear and complementary to the words of the act.
2. Limit changes in question of fact, for example:
 - a. framework agreement
 - b. weight of criterions for evaluation
 - c. the use of another company's capacity
 - d. alternative tenders.

It has also been sent a report the 31 January 2006 (Näringsdepartementet, 2006) with 5 additionally changes. One of these changes is for example the competitive dialogue procedure. The competitive dialogue procedure is electable for every country in the EU and Sweden has chosen to make a decision about it later. It is suggested that it will be implemented in the future (Näringsdepartementet, 2006).

2.2 Industrially produced housing

In Sweden, when industrial produced housing is mentioned most connect it with the program of the sixties and seventies which was the prefabrication and volume production era in Sweden. Focus in construction at that time was on production and standardisation rather than quality and aesthetics. Both the building and the areas are today consider boring and uniform (Olander, 2000). Industrially produced housing and prefabrication became for many synonym with boring as the design and function of the components did not fulfil the needs of the users (Gann, 1996).

As a result production moved towards site built housing at the end of the seventies again. The construction of multi-family housing was at the time also heavily subsidised. This resulted in a lack of incentives to strive for more cost effective production methods. As the subsidies were abolished in the early nineties the construction industry ones more had to find ways making construction more effective (Olander, 2000).

Industrial produced housing has been defined differently at different times and in different contexts. It is used for projects where prefabricated components are used to some extent as well as for houses completely produced within the confinement of a factory. Prefabrication of components are an important part, but not enough an industrial housing concept. Industrially produced housing today is considered as a complex concept with any interlinked areas that have reached different levels of industrialisation. The design follows different routines as well as production that have, more or less completely, moved indoors. Procurement routines have changed and forms of cooperation has changed. It can be characterised as a well developed construction process where the organisation is adapted to efficient management, preparation and control to maximise customer value (Lessing, 2006).

The three main principles underpinning the development of industrialized housing construction are; standardization, prefabrication and, later, systems building (Gann, 1996). There is one important goal with the industrialisation of construction, making it more efficient. This should be achieved through an increased level of standardisation, prefabrication and feedback including all actors in the value chain (Lessing, 2006, Gann, 1996).

The traditional construction process is highly project focused, with its pros and cons. Every construction project is considered as unique and the production moves from site to site, differentiating it clearly from the traditional manufacturing process. This has in turn led to a fragmentation of and lack of continuity in the construction process (Dulaimi *et al.*, 2002). But, that a project is unique does not mean that production needs to be. The production could be considered a continuous process where similar work is carried out in project after project (Byggtjänst, 2006). Within the industrial construction the process has gained much more attention, learning from a manufacturing process. According to Gann (1996) a manufacturing process provided three main advantages over craft:

1. Economies of scale, when the cost per unit drops more quickly than production costs rise as the volume of materials being processed increases.
2. Technical possibilities to develop and deploy capital equipment.
3. Opportunity for tighter managerial control.

This in reality means that there is a need to produce a number of similar units to achieve economies of scale. This also means that the level of customisation will be limited to some extent. It also means that the more industrialised the more need for control and the more need to keep the different process in-house.

3. RESEARCH PROJECT

3.1 Project description and objectives

The aim of this project has been to investigate how and to what extent public procurement legislation affect procurement of industrially produced multi-family housing. The aim has also been to define how such a procurement process may be designed.

This research has been carried out in parallel to a research project studying the effects of different ways of implementing the European Union Public Procurement Act. Both of these projects are part of an increasing interest of how public procurement legislation affects innovation and development in the Swedish construction sector.

This in turn is spurred by the findings in a pan-European study on the competitiveness of the construction sector in various countries within the EC (Manchester Business School, 2006) which indicates that Sweden has by far the highest number, as well as the largest increase, of contested public procurements within the EC. In another Swedish study (NOU, 1998), 50% of clients answered that they cannot follow the regulations completely and according to the suppliers the agencies cannot even follow their own evaluation models, which may be one cause for the many challenged of public tender awards in Sweden. It is concluded that further studies are needed to gain knowledge of the effects of added national rules to the EU directive in relation to the transparency and effectiveness of public procurement. From a client perspective the need for further research is to map the strength and weaknesses of the public procurement in order to evaluate how the legislation will affect the public procurement process.

3.2 Research methodology

Apart from the literature study on public procurement legislation and industrial construction a case study including a public housing, called the client, company and a company supplying industrially produced multi-family housing, called the supplier, was carried out. Data has been collected through interviews and document studies, mainly through access to both companies' intra-nets.

The case study was divided into three different parts to clarify three aspects of the procurement process that will affect the possibility of allowing for industrially produced housing to take part in bidding process. The first part, the process analysis, aimed to identify where, how and when activities are carried out in the procurement process traditionally and where they need be carried out to allow for the industrially produced concepts. It also identified which actors that are involved in the different stages. In the second part, the tender and bid, the formulation of tender and bid documents were studied to identify problems that may occur because of formulations, requirements, reservations etc. Finally, the third step, bid assessment, aimed to clarify how the bids were assessed as well as the criteria the two different companies would have on each other in a real project.

Semi-structured interviews with key personnel in both companies were carried out. Three areas were targeted:

1. How is the public procurement legislation affecting the procurement industrially produced housing?
2. How would a model for inclusion of industrially produced housing in public procurement be designed?
3. How should the tenders/bids be formulated and assessments are the bids measured against.

4. RESEARCH RESULTS AND INDUSTRIAL IMPACT

4.1 Process analysis

One obvious difference in the processes was the procurement of the contractor. The assessment and awarding of a traditional project for a contractor took place when the layout design from the architect was finished. The supplier needed to come in much earlier so that the client architect could work with the architect of the supplier.

There are a lot of options and possibilities for both the client and the contractor in a traditional procurement situation. Various choices of material and architectural designs are considered when tender documents are being done. The client wants to have control over this and give approval of it in the project. The supplier wishes to have a more open discussion about the choice of material and layout. The supplier also has a strict focus on making the process more efficient so the layout design has to be finished when the production starts. This means that all decisions about layout design and materials need to be done, and finished, in the design phase.

4.2 Tender and bid

Problems for the supplier to follow the requirements of the procurement depend on how they are formulated. The supplier pointed out that the most important issue was whether the documents focused on details or if it gave degrees of freedom for layout design. Too detailed requirements, drawings and descriptions can minimize the chances for an industrial building system to submit a bid without deviating from what is asked for. As the tender cannot contain non priced reservations or pre-requisites the construction systems cannot use their specific materials or choices in the project.

As decision of awarding has to be sent out to the supplier the bid documents are open for competitors to look at. The supplier in this case has got a confidential system which means that some documents can be protected by the law of secrecy. A situation where the client can show the bids of competitors is not acceptable. Some sort of regulation needs to be worked out between the parties.

4.3 Bid assessment

It was important, the client pointed out, that tenders followed the requirements of the tender documents. No assessment could be done on other aspects than the ones defined in tender documents form or the notification of interest. The supplier who has a building system with defined presets also got rules to fulfil for the project. To use valuation criteria on general areas as purpose, feature and degree of exploitation is understandable, but remaining details as materials in the project etc. is better to leave for the supplier to define.

The supplier spends a lot of time to first formulate a bid and after the awarding of a project to adapt the specific project to the concept. It is from a competitive – and economic point of view – difficult to spend time on a project that they are not guaranteed to win. It is better for the supplier to have agreements in specific steps and have guarantees to get compensation for produced work.

4.4 Public procurement legislation and industrially produced housing

The public procurement act does not specifically influence the procurement of industrial construction. The selective, negotiated and competitive dialogue procedure is three procurement forms that work for procuring industrially produced housing. The client uses for example the selective purchasing procedure in the specific case study. It is more in the hand of the involved if public procurement is a problem or not. The tender form

cannot have too specific demands in an early stage and tenders have to comply with the tender requirements.

To work with an industrial process is all about co-operation in an early stage and that is an important aspect to remember. The industrially produced construction may get an advantage if there is a demand for an efficient building process in the project. The benefit with the selective procurement to open procurement is that some kind of prequalification is made. The benefits with that have also been pointed out in the model. When the procurer needs to use the open procurement, alternative tenders can be useable to allow the industrial systems a chance to suggest other solutions. The industrial building system can then submit alternative tenders with their 'frames' intact and still be sure that their suggestion on improvements can be valued in the evaluation. The open procurement can also be combined with turnkey contracting which gives interlinked design and production with the same company to ensure the efficiency in the industrial process.

Yet another possible path is to use the competitive dialogue when, or if, it is implemented in the Swedish public procurement legislation. The competitive dialogue includes three steps, step 1 includes preparation of project, inquiry basis and announce/invitation. Step 2 includes purchasing with dialogue and submitting of tender. Step 3 includes at last decision for terms of contract through valuation of tender and assignment.

5. CONCLUSIONS

According to the study there are no major obstacles to procure industrially produced housing under the framework if public procurement legislation. There are aspects to consider and that need to be addressed:

- The suppliers of industrially produced housing need to come in fairly early in the process or the tender documents need to define the requirements general. This to ensure that the supplier is not suffering from technological lock in.
- Patents, copyrights etc needs to be ensured. Design and "company secrets" should not be made public to competitors.
- The client cannot define materials and layouts as freely as in on site production type of projects.

Apart from that the main issue is to ensure the public clients that rightly done this should not cause any difficulties.

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DESIGN OF 21ST-CENTURY SCHOOLS: LESSONS FROM SCANDINAVIA

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ABSTRACT

The Building Schools for the Future (BSF) programme represents the biggest single UK government investment in school buildings for over 50 years. The £45 billion programme has been established to ensure that schools are designed or redesigned to allow for educational transformation. This represents a major challenge to those involved in the design of educational buildings. Inspiration is in part sought from exemplar schools around the world. The paper draws on a multiple case study of four such exemplar schools in Scandinavia that have been designed to address changes in the educational curriculum. Particular attention is given to how the design of the building was developed to support the school approach to teaching and learning. The disjuncture between commercial and educational issues inherent in designing 'good' schools is highlighted. The findings show how it is important to find a balance between good design, commercial realities and educational transformation.

1. INTRODUCTION

Increasingly, school building design is understood to play a central role in the creation of environments that enhance education. In the UK, the Building Schools for the Future (BSF) programme is a deliberate attempt to transform secondary education through the delivery of innovative school buildings. The programme represents the biggest single government investment in improving UK school buildings in over 50 years. It involves rebuilding or refurbishing every secondary school in England over the period 2005-20 (DfES 2004). The initiative comes on the back of an increasingly widely held belief that older schools, as well as those more recently built or refurbished, are inadequate in their ability to cope with anticipated changes such as shifting pedagogy, curriculum and learning expectations (Audit Commission, 2003). The overarching aim of the programme is, hence, to drive reform in the organisation of schooling, teaching and learning, and in the procurement of school buildings. In short, BSF has been established to ensure that pupils learn in 21st-century facilities (The Education and Skills Committee, 2007). Thus, the design of new BSF school buildings is expected to account for current and future developments in education and technology as well as the local and global environment. This mirrors long-established international trends of promoting design of educational facilities that address the changing curriculum (cf. Woolner *et al.*, 2005; OECD, 2006; Hertzberger, 2008). The vision put forward in the UK is to inspire new ways of learning and to provide 'excellent' facilities that benefit the whole community (CABE, 2007). Ultimately the aspiration is for schools to be designed in a fashion that inspires and engages all who learn in, work in, lead and visit them.

The purpose of this paper is to explore the relationship between the design of school buildings and the achievement of suitable learning environments. The past decade has seen a host of schools in Denmark and Sweden built or refurbished on the basis of a design that is believed to address their particular educational curriculum. In part, those involved in the BSF have been advised to seek inspiration from 'exemplar' schools abroad (CABE, 2007). The paper draws on a multiple case study of four such exemplar schools conducted as part of a longer study to inform the BSF. The cases have in common that the design of the building was developed to support the school approach to teaching and learning. Specific attention is therefore given to the relationship between the articulation of the educational approach and the accomplishment of successful learning environments. The discussion portrays how attempts have been made to integrate a wide range of

pedagogical ideas with the design of the physical environment in order to achieve the sought after learning environment. Before presenting the case study the discussion turns first to the growing literature on learning environments and the role of spatial design in affecting the behaviour of individuals. Attention is given to previous attempts to instrument changes in the curriculum and associated teaching methods through building design in the UK. Particular interest is given to how users can participate in the development of the design.

2. LEARNING ENVIRONMENTS

The idea that flexible school buildings could provide for changes in teaching approaches are by no means new. The UK has seen several more or less failed attempts to centrally impose a change in the national curriculum (Brogden, 2007); some of which have been directly linked to innovative designs. One such attempt was the open-plan movement in the 1970's (*ibid.*), which was described by contemporary commentators as representing innovation without change (e.g. Adelman and Walker, 1974). The teachers' were at the time portrayed as reluctant, and partially incapable, to move away from traditional teaching methods (Brogden, 2007). Nonetheless, recent public sector studies, such as those commissioned by the UK Department for Education and Skills (PwC, 2001; 2003), state that capital investment in school buildings have a measurable positive influence on staff morale, pupil motivation and effective learning time. These findings are, however, not without their critics. Studies on the impact of individual elements of the physical environment and the implications for the design of schools have reported that beyond the necessity of meeting basic standards there is not enough evidence to give clear advice to policy makers on how to set priorities for funding (e.g. Woolner *et al.*, 2007). Nor is there enough substantive evidence to allow for an evaluation of the relative value for money of different design initiatives (*ibid.*).

2.1 School buildings and education

The link between aspects of design and school effectiveness and educational outcome is increasingly being recognised (Dudek, 2000; Clark, 2002). Yet, the degree of the impact that design has on these issues is far from fully understood (Woolner, 2007). A number of studies have sought to establish a relationship between the nature and quality of the physical environment in which students learn and the learning outcomes associated with these environments (e.g. Fisher, 2000; Tanner, 2000; Clark, 2001; Higgins *et al.*, 2005; Williams, 2006; Bako-Biro *et al.*, 2007). The majority of these studies have focused on the tangible physical aspects of design and its functionality. In this respect, findings are presented exclaiming correlations between the physical school environment and improved levels of teaching and learning. For example, increased use of natural ventilation and lighting has been found to support concentration (Dudek, 2000) and overall pupil performance (Hathaway, 1995). Similarly the provision of 'green' schools is also claimed to enhance educational performance (Edwards, 2006). Indeed, in their literature review of the impact of school environments on students' behaviour, motivation, learning and achievement Higgins *et al.* (2005) conclude that there is consistent evidence for basic physical variables (natural ventilation, colour, temperature etc.) having an effect on learning. But they emphasise that once minimal standards are achieved the effect is less significant.

The relationship between people and their environment is, indeed, multifaceted in nature (Proshansky, 1970; Gifford, 2002). The school environment is an active part of the person-environment system, where the physical environment plays an important role in shaping behaviour (Durán-Narucki 2008). However, the physical environment is only one of the interacting factors within the school setting. Whilst individual physical characteristics might well affect student perceptions, different schools, children, cultures and context at different times will create a variety of conditions for potential learning.

It is beyond doubt that the demands and resources provided by the external world impact upon a person's emotional life. Yet, the diverse patterns of social interaction makes establishing the influence of physical settings on human behaviour a very complex task indeed (Backhouse and Drew, 1992). Individual's behaviour is both influenced and constrained by the physical and social settings (Barker, 1968). Thus, spatial design both facilitates and inhibits behaviours and relationships between different actors (Penn *et al.*, 1999; Heerwagen *et al.* 2004; Rashid *et al.* 2006). Thus, while it is clear that basic physical characteristics affect student perceptions, any study of the impact of physical environments on educational transformation needs to take into consideration the complexity of the school environment. It also needs to take into consideration the less tangible and, perhaps, less obvious aspects of the design.

For the argument put forward in this paper a useful distinction is that between 'space' and 'place'. Space can only become a 'place' if people make use of it by carrying out activities, and providing it with its own character (cf. Lawson, 2001). School buildings provide for a variety of social groups within its premises. Spaces manage and support interactions between these individuals and groups. In this context, it has proved to be problematic to deal with the dichotomy between forces of privacy and community (Lawson, 2001). Nonetheless, it can be concluded that the social interaction within the school is critical to the success of the learning environments (Tanner, 2002; Woolner *et al.*, 2007). And an overall positive impression of the school environment has an impact on the users of the building.

2.2 User-participation in design

User participation in decision-making activities in school design has received plenty of attention (e.g. Burke and Grosvenor, 2003; Clark *et al.*, 2003). It is commonly suggested that environments designed through user involvement generate a greater sense of end-user satisfaction (Higgins *et al.*, 2005). It is further believed that user participation provides with a sense of empowerment over the nature of the school environment (Horne-Martin, 2002). Several studies, thus, recommend the involvement of users, staff and students in the school design process (e.g. Dudek, 2000; Clark, 2002). The participation of children in the design process has for example been claimed to have a positive impact on innovative design and overcoming adult conservatism (Rivlin and Wolfe, 1985). The consultation process is portrayed as educational and creative for the pupils (Chiles, 2003) and their inclusion in the design and planning process is becoming increasingly common (Francis and Lorenzo, 2002).

Some portray user participation in the design process as fundamental for the achievement of a well designed school facility (Higgins *et al.*, 2005). Others are more cautious in representing such involvement as the ultimate solution (Sundstrom, 1987; Clark, 2002). The argument being that post-occupancy evaluation processes and user feedback are equally important, as they ensure an effective use of the new space (cf. Chiles, 2003).

3. RESEARCH DESIGN

A multiple case study approach was used to investigate the design of the learning environments in four exemplar schools in Sweden and Denmark. The school samples were chosen as cases for their international recognition of excellence in design. The two schools in Denmark were chosen as they have been identified as exemplar schools by the British Council for School Environments (BCSE)¹. The Swedish schools have both won

¹ The BCSE is an organisation formed by schools, local authorities, construction companies, architects, and all those involved in designing learning environments.

design awards and are put forward by local councils as modern exemplar schools. Data was collected through guided tours of the school buildings with observations of classes and other activities undertaken. Formal presentations were given by head teachers; designers and various consultants enabling an in-depth understanding of the school philosophy, organisation and design. Unstructured interviews were undertaken with head teachers, teachers and other staff. Informal discussions were also held with a wider range of end-users. For each school background information was sought in the form of written documentation including formal policy statements and official documents such as annual reports, as well as unofficial internal progress reports, briefing documents and educational visions. There appropriate photographs were taken by the researcher, as a means of added information, enabling the particularities of each case to be addressed.

4. CASE STUDY

The following section presents brief descriptions of each school. Space restrictions limit the breadth and depth of the descriptions. Each description is divided into three parts portraying in turn the physical environment; the teaching activities and how the building is used; and the design process.

4.1 Hellerup Skole

The Hellerup Skole is located in a wealthy residential area in the outskirts of Copenhagen. The school was built in 2002 accommodating 550 pupils between the ages of 6 and 16.

The physical environment

The school is a three storey building. It is characterised by the interplay between the outwardly rational relatively severe cubical form and an open, organic interior design. The building is largely open plan with an auditorium stairway in the centre. Plain and clear routes lead in all directions from the central stairway area to nine flexible home bases complete with kitchen areas and 'chill-out' spaces. Six of these areas house 75 pupils and the other three bigger rooms accommodate 100 pupils. Flexibility is achieved through the use of mobile units – cupboards, shelving and screen walls – that allow the home areas to be divided into smaller spaces. Further flexibility is achieved through the active use of the stairway, which is designed to be able to double the seating and performance spaces. A variety of activities take place in this space: traffic to and from different areas of the school, teaching, group work and larger assemblies and it is also where many pupils eat their lunch. The floor areas are a modelled landscape with staircases, plateaux, balconies and bridges. The spaces provided for the pupils are large compared to traditional school environments.

How the facilities are used

The school embraces new educational and pedagogical initiatives based on project and team-oriented teaching. The emphasis is on the multiple intelligences concept (cf. Gardner, 1993) where pupils develop their own particular strengths in order to access the project based curriculum. The teachers work in teams of six to thirteen people, put together on the basis of combining a wide spectre of skills. Each team has the responsibility for 3 or 4 classes and are totally independent from each other. All teachers have been given training on how to use the building to support the new approach to education. Central functions take place in the atrium/staircase, while teaching takes place in the home areas. The home area is the children's base in their daily routine. These areas also have tutor-rooms that are the workplace of the teachers. There is plenty of room for pupils to work in the fashion they choose. Thus, the spaces become 'places' as children feel in control of their own activities, which contributes to the perception of secure environments for the pupils.

The design process

Concerns and ideas of how to organise the day-to-day learning process were pivotal to the design of the school. The local municipality requested that inspiration should be taken from the wider world and that the design should reflect the challenges of the modern 'global' society. The end-users and members of the wider community, for example the police, helped to define the vision for the school. Through workshops and group discussions parents, staff and pupils developed the vision into educational frameworks that governed the architect's work. Thus, the building was designed through direct communication between the architect and the future end-users. No architectural drawings were used during the one year consultation period. This was generally considered to have enabled a more fluent dialogue between the users and the architects, as the same language was shared. Money was put aside in the budget to allow for 100 hours of training per staff member on the new pedagogy and how to use the building to support it.

4.2 Heimdalsgades Overbygningsskole

The HGO School is a converted bread and paper factory located in an immigrant dominated area of Copenhagen. It was built in 2001 and caters for 230 pupils between the ages of 14 and 17. The school hosts one of Copenhagen's 10th grade classes, an alternative grade for students that opt to stay in school for an additional year.

The physical environment

The old factory has been converted into an aesthetically pleasing building with a flexible interior. There are no classrooms in the building. Instead there are five curriculum areas. These competence environments are flexible in their physical design and arrangement. All furniture is immediately movable with desks on wheels, and mobile workplaces. There are plenty of facilities and niches available for those pupils who work best in peaceful, quiet surroundings, and room for those who are not geared to sitting still for any longer period of time. The five curriculum areas are: *The Studio* – a physical/arts theme area; *The Workshop* – a practical and aesthetic area; *The Station* - international and cultural area; *The Laboratory* - scientific and experimenting area; and the *10th grade environment*. Each of these individual competence environments has particular furniture and fittings in accordance to their themes. The *Studio* has a stage and is fitted with the necessary lighting and sound equipment, a fitness room, a music practice room with a sound studio, group rooms and an outdoor climbing wall. The *Workshop* consists of a workshop and pictorial environment. The *Station* has all types of virtual equipment. The *Laboratory* has a physics laboratory and a green house with a solar cell system for conducting natural science experiments. The *10th grade environment* has a traditionally equipped area but also uses the 4 theme areas.

How the facilities are used

The school philosophy follows an 'extended learning' concept, i.e. the entire time the pupils spend in the school is considered to be learning time. Each student has a logbook to keep track of their activities. The organisation of the teaching is project-oriented and significant emphasis is given to teaching pupils to work on projects. But each semester also contains more conventional subject modules. Over two years, each student spends six months in each of the curriculum areas. The teaching is divided into themes for the subjects that fall naturally under each of the competence areas. The pupils can, however, choose to work in other places in the school, for example, the pedagogical centre, which is designed as a quiet work zone. The school has 28 teachers. Their workplaces are situated in the different curriculum areas in an attempt to make them a natural part of the learning environment.

The design process

The design process was shaped by budgetary constraints and the structural characteristics of the old factory building. Converting an existing building rather than a

new build provided several limitations for the design, but was also considered an opportunity to try something different. Much pedagogical thought and care was put into the design of the school. The project-based teaching pursued by the school required great flexibility at all levels of the building. The main challenge was, thus, converting awkwardly shaped rooms into flexible learning environments. The solution adopted was to have autonomous teams of teachers, varying work schedules and plans, flexible physical settings and extensive use of IT. The involvement of the local community was crucial for the acceptance of the school in the area and the design process included extensive consultation with these stakeholders.

4.3 Bällstabergsskolan

Bällstabergsskolan is located in a middle-class northern suburb of Stockholm. The school opened in September 2002 and provides for 150 children between 1 and 5 years old and approximately 550 pupils aged 6 to 16.

The physical environment

The school is a two-storey building divided into five units or 'home' areas. The pre-school unit with children 1 to 5 years old is independent from the rest of the school, with its own entrance and a fenced outdoor area. The four other school units are divided into two areas with students from 6 to 11 years old and two areas with children aged 12 to 16. Each of the home areas is self-sufficient in terms of classrooms, recreation spaces and eating areas and has direct access to outdoor areas. There are also a number of shared facilities: art and craft rooms, workshops, laboratories, music studios, a library, a gym and a football field. The building has a proportionately large number of external windows and all the classrooms have interior windows that visually link the spaces in the home areas.

How the facilities are used

The general philosophy of the school is to create a student-centred environment that encourages pupils to discover their own learning path along with the ability to function as a team member. The teaching is centred on the multiple-intelligence concept, with the aim of developing the pupils' sense of creativity, social, verbal, musical and aesthetical intelligences. Each home area has a dedicated team of teachers. Each teacher is a leader for a smaller group of approximately 15 pupils of the same school year. The pupils and the teachers remain in their home area all day. Thus, the teachers work closely with a small number of pupils on a daily basis and support them both as a team and individually. The transparent nature of the building serves a dual purpose of providing the pupils with a sense of security and the teachers with more control over what is taking place outside their classrooms. The library is considered to be the 'heart of the school'. The walls are predominantly of glass connecting the space with the rest of the building and the outside.

The design process

The design of the school was guided by two clear visions. The first vision concerned inclusivity, i.e. how the school was to blend into the external environment. The envisaged culture was one of freedom of movement on and of the school grounds (with the exception of the pre-school unit). Furthermore, the building should be inclusive in the sense of providing a clear connection 'outdoor-indoor'. The second vision concerned the indoor environment. The wish was to create a learning environment for the students that encouraged them to develop individually. This vision was inspired by the idea that teaching and learning in small groups encourages better interaction between the students. There was therefore a deliberate push for many small but visually connected rooms in which teaching could take place. The school was designed to accommodate smaller classrooms, with no more than 24 pupils per class.

4.4 Östra Gymnasiet

This newly built school in a southern suburb of Stockholm opened in the autumn of 2005. It hosts 650 students from 16 to 19 years old from a catchment area characterised by cultural diversity and clear differences in family incomes. The school has won national prizes for its exterior as well as for its interior design and lighting solutions.

The physical environment

The school is a two storey building divided into three distinct kinds of student areas: 'class' areas, such as classrooms and auditoriums; 'study' areas, for individual studies and group work; and 'break' areas, including lunch facilities, cafeterias and access to computers, photo copiers and telephones. The class rooms vary in size fitting between 8 and 30 students. The school also has conference facilities, a large sports hall and a gym. A defining feature of the building is the very large front entrance followed by an 'open area' school reception similar to those found in industry. All the doors and doorframes in the building are higher than normal. Another defining feature is the quality of the acoustics with subdued noise levels throughout the building. A speaker system provides background music. The school has won several prizes for its use of lighting features and use of bright colours that creates a relaxed and inviting atmosphere.

How the facilities are used

The school has adopted a mixed approach to teaching and there are no set guidelines on how the teaching should be undertaken. This allows the teachers the freedom to choose the style that best suits them. Thus, there are teachers that follow the traditional way of teaching. The school uses a 'resource based teaching' approach. In this respect, the school is looked upon as a compilation of resources for teaching, where the classrooms are viewed as one such resource. Therefore, the flexibility of the spaces is crucially important. The building design is characterised by open and transparent spaces. The students have a 'place of residence' or home in their program division. These home areas are not separated by age group. The school hosts art exhibitions, conferences and provides offices for a host of local sport clubs that also use the sports facilities.

The design process

The head teacher was involved in the design process from the very beginning. Over a period of 15 months he led a team of 4 educationalists whose task it was to put together a vision for how the school was going to function. As part of this work interviews were conducted with representatives from all the different categories of staff that would work in the school, as well as with student representatives from a range of schools. National and international study trips were also undertaken. The vision was then developed into a report outlining key themes and demands on the school design. The report formed the basis for the architects who were forced to justify to the school board how their design addressed the themes and demands raised. As a consequence almost everything in the school was purpose designed; for example the furnishing and decoration and the use of colour and the lighting. The vision for the interior was to accentuate comfort and well being, colour and youthfulness. The impression of light and space is achieved through glass and high ceilings. The monumental entrance to the school was originally intended to represent the positive force of the school in the local community. Similarly the reception area was designed with the aim to accentuate the welcoming culture of the school.

5. DISCUSSION

The case descriptions above detail the role of design in creating learning environments in 'exemplar' schools in Sweden and Denmark. The guiding visions of these schools are founded on the rather abstract concepts of: dialogue; ownership; innovation; flexibility; equality; democracy; individuality; and freedom. These abstract concepts have been translated into more concrete objectives for the school education and have had an impact on the physical design of the learning environments. Indeed, these schools have integrated a wide range of complementary ideas to achieve suitable learning environments that respond to the philosophy of the school. The case studies, thus, show that it is possible for schools to develop a holistic approach to design with a significant degree of user participation. Unsurprisingly, therefore, links can be drawn between capital investment in school buildings (as in the BSF) and staff morale, pupil motivation and effective learning (cf. PwC, 2001; PwC, 2003; Green and Turrell, 2004). However, the complexity of the school environment cannot be overlooked. Even these schools with clear visions and buildings designed to accommodate teaching philosophies have encountered a variety of unforeseen problems and have had to adapt and compromise. There are contradictions between the common perception of high quality design and the commercial realities of running a school. Finding a balance between the two is by no means trivial; examples of which are outlined below.

Structural restrictions in existing buildings impose limitations to the amount and degree of changes that can be accomplished through refurbishment. This was evident in the construction and subsequent use of Heimdalsgades Overbygningsskole. The structure of the building restricted the degree of flexibility that could be achieved in the design. The educational vision therefore had to be modified and adapted to the existing building layout. However, newly built buildings can also impose restrictions on how a school is run. This is something that has become increasingly apparent in Bällstabergsskolan. The school prides itself in being one of the most modern schools in Sweden. Pupil and parent satisfaction is very high and the school is consistently ranked in the top band in the region on this measure. However, the school has since its opening consistently operated at a deficit. At the time of the study (spring 2008) the school was operating at 2% under budget. In practice, the school needs to increase the pupil-teacher ratio. The school, thus, needs more children per classroom. However, this is not possible due to the size of the classrooms. Hence, the building is not flexible enough to accommodate an increase in pupil numbers. The problem could be alleviated by changing the approach to teaching and to make more effective the use of the building, yet to date no training has been provided to the teachers in how to use the building.

Hellerup Skole has become somewhat of an iconic school, but it is also at times accused of getting too much attention and setting a precedent that it is impossible for schools in other areas/regions to emulate. Unfortunately, it is difficult to overlook the characteristics of the school's catchment area. The teaching philosophy and the extreme flexibility within the building require that the pupils receive significant support at home. It is also fundamentally dependant on individual behaviour of the pupils, which in part could be deduced to their upbringing. As such the school is not for everyone and it is not meant to be for everyone.

The lessons for the BSF seem evidently clear: there needs to be a balance between the design of the building, how teaching is undertaken and the economy of the school. This not only necessitates a degree of flexibility in the design but also in the underlying vision. Indeed, however clear the visions and strong the reasons for certain design solutions the resulting use is a consequence of individual interpretations. It is, therefore, inevitable that there will be differences between intended and actual use of the school buildings. The school is not finished when the building is. The school setting is a complex environment that needs to mature. Östra Gymnasiet is a good example of this point. The original idea of the design of the school building was to have home bases with students

working individually or in groups in open areas. In practice this was never implemented. The spaces that were originally designed as study areas are used as communal areas with student lockers and plenty of other distractions to those who wish to study. As a consequence the school is short of classrooms, but are struggling for solutions of how to provide more. In practice the reception area is not needed and is never used, but it retains significant symbolic value.

6. CONCLUSIONS

This paper has explored how four 'exemplar' schools in Scandinavia have used design to help them achieve suitable learning environments. The findings show how these schools have developed buildings that relate to a defined school philosophy and how they have effectively used design to support the learning process. In essence, all four cases have in common that they have used innovative and flexible design to address changes in how to deliver education. Three of the four cases have succeeded in expanding the learning environment to the entire building.

The findings facilitate an increased understanding of the links between the underlying learning intentions and values of the schools and the development of the design. Design solutions that do not fit underlying values will hardly have a significant impact on the delivery of the teaching. Similarly, schools that already achieve high quality teaching through traditional modes clearly have few incentives to look into new 'innovative' designs that accommodate alternative modes of teaching and learning. Hence, the importance of discussions regarding the consequences of different design solutions for specific learning situations cannot be stressed enough. Such discussions need to be held with key stakeholders as well as with the wider community. Innovations in building design should not be allowed to outpace developments in teaching methodologies and *vice versa*. Flexibility in the design is of fundamental importance, but only if it matches the aspirations and expectations of the end-users. Finally, we would like to conclude by yet again highlighting the difficulty in balancing expectations and perceptions of high quality design and the commercial realities inherent in the running of a school.

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VALUE CREATION IN THE HOUSE OF CULTURE – VALUES FOR CLIENTS, CONSTRUCTION PROFESSIONALS AND USERS

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ABSTRACT

A municipality has an obligation to its citizens to manage and carry out political decisions. The challenge is often not only to conduct a successful project in terms of productivity and efficiency and thus not exceed a budget appropriation, but also to follow the policy and improve stakeholder values in the built environment. The purpose of this paper is to study how client's intentions have been achieved and what kind of stakeholder values have been created in a public cultural construction project. A literature review has been accomplished discussing the briefing process and how stakeholder values can be identified and analysed. Two perspectives have been discussed, economic value in terms of efficiency and effectiveness and social value in terms of building performance. From a case study of a construction project, the House of Culture, the clients' development and formulation of requirements, needs and desires in the briefing process have been analyzed. Data have been collected by interviews with stakeholders and by using secondary data (primarily the written brief). The results from the study show that the client's intention of creating a meeting place and a cultural house with different cultural activities such as a library, concert halls and an art hall for all kinds of people living in the community have been achieved based on the client's ability to develop a solution of how to combined different cultural activities; manage political rules; develop real and viable project goals and develop a written strategic brief with an overall vision and goals for the building and the building's performance. Shared goals regarding costs and time have led to a successful project and trust has been built between the client, designer and contractor in the project. End-users' values have been created when estimating building performance, such as social change, job opportunities, development of organisational and business activities, multitude of cultural activities in one building and social values related to form (easily accessible, beautiful, comfortable, safe) and place (for everybody). However, there are still questions to be answered about the client's intentions for the building. End-users' estimation of functionality and technical solutions and how these activities have been developed, the evaluation of cultural and building assets, and if the building and its performance can be valued as a symbol for the city and cultural hub for the region, are issues for further research.

1. INTRODUCTION

Everything that is built, during the building process and after, creates value in one sense or another *by* and *for* humans, organizations, companies and society. In this paper value creation is seen as a development process when resources, tangible as well as intangible, are used in value adding activities. In the early phase of the construction process, and specific in the briefing process, the client's intentions for the project and the building are defined (Barrett and Stanley, 1999; Ryd, 2003). The questions investigated in this paper are how the client's intentions have been achieved and what kind of stakeholder values they are creating.

Based on a case study the clients' development and formulation of requirements, needs and desires in the briefing process are investigated. The requirements formulated in the written brief, stakeholder values developed in the construction process and stakeholders evaluation of the building performance are analyzed.

In the next section, the briefing process and the development of client and end-user requirements in cultural construction projects are discussed. In the following two sections

two perspectives are discussed when identifying and analysing stakeholder values. The first one is by discussing economic value and economic performance measures in terms of efficiency and effectiveness measuring the performance of the process and the product on a company and organisational level (Porter, 1994; Flanagan, 2007). Measures for efficiency are usually based on the use of human, financial and material resources in the construction project. Measures for effectiveness are in common based on analyses of companies' competitiveness and the market value of the building (product) and its performance. The second perspective is by discussing social value and building performance (Preiser and Vischer, 2005). The third section will present the case study of the House of Culture. Finally, the results from the study are summarised and discussed.

2. STATE-OF-THE-ART REVIEW

In this section the briefing process, where clients and end-users requirements are developed, will first be discussed followed by a discussion of stakeholder values of a cultural construction project.

2.1 The briefing process and its value creation

Briefing enables the communication of the end-users needs and desires to the construction professionals. The briefing process could be seen as a process in which balanced and ongoing synergies can be created between the construction sectors' production demands and the clients' and end-users' operational demands (Spencer and Winch, 2002). The briefing process can thus be defined as "a dialogue between the client and the construction professionals, normally carried out by the architect, where the client's aspirations, desires and needs are captured and presented in a written form called the 'brief' (Boyd and Chinyio, 2006:11).

The briefing process can also be seen as an integrated process of the building process starting in the early phase of the building process (Boyd and Chinyio, 2006). An integrated briefing process should according to Blyth and Worthington (2001), Barrett and Stanley (1999) and Ryd (2003) address the requirements of the client by capturing, interpreting, confirming, and communicating relevant data and issues to the design and construction team during the building process.

Managing the citizens' needs and desires, the public client has to take decisions about the citizens' opinions of how the municipality should invest the tax money and what kind of activities that are going to be performed in a new public building. Building a house of culture has been a popular investment for Swedish municipalities during the last years (SKL, 2008). A new trend in the construction of these buildings is that the design and production phases include the development of different spaces and functionalities for different cultural activities, i.e. for example a concert hall is combined with a library and an art gallery in the same building complex. The construction of a house of culture combined with the client's vision and goals and end-users needs and desires creates a complex building project. A cultural construction project is an unique construction project for the public client. Famous theatre buildings, opera houses, concert halls have in general long life cycles. Today many cities have or are planning to build new opera houses and theatres. The technology development in light, sound and new art performances are putting pressure on new halls. Even traditional art performances such as classical music performed by symphonic orchestras can today be experienced in halls created with specific acoustic solutions. The challenge for the public client, when deciding to start a cultural construction project, is nearly superior. However, many municipalities discuss how the investments of these buildings are creating other values than economic to the client, construction professional and end-users.

Public buildings for art performance and sports events and other public buildings are when they are described as icon or monumental buildings in their cities, adding both an economic and a social value to the city and its citizens. Icon buildings are symbolizing

urban revival as well as they are creating a brand mark to the city or country (Jencks, 2005). According to Bröchner (2009:21) monumental buildings, landmarks or icon buildings signal innate qualities of cities, devised to attract temporary visitors or more permanent settling of firms and individuals. Buildings for sports venues are for example creating a social value to their users that is to the football team and the audience. When the sport arena also is useably for other events than sports, for example a conference, the building is used for multiple activities with possibilities to give back both an economic and a social value to its stakeholders. The example that everybody mention is the case of the Sidney Opera. The Sidney Opera has created both a symbolic value to the city and its citizens and an economic value to its occupying organisations. Another example is the "Bilbao effect" (Anon, 2007) which describes how architects have created brand marks and how urban revival has been driven in the community. Saxon (2005) argues that the design of the building should include technical and functional solutions supporting the activities performed in the building when creating stakeholder values. Thus, the clients' requirements are both related to stakeholders' economic and social values.

Short *et al.* (2007) argue that the design and construction of arts buildings have been considered to be both very different to other building types and uniquely complex due to exacting technical demands and the accommodation of the various and sometimes conflicting needs of the many stakeholders. Clients in the performing arts sector tend to be highly focused on the delivery of their original vision. Designing and delivering buildings for arts clients appears also to require additional commitment from construction professionals. Giving form to a coherent "artistic vision" and translating the "vision" into a building design is thus a cumbersome matter. Dynamic tools and technologies are required to achieve the journey from an emerging and dynamic vision to a built artefact, which is sufficiently uncompromised to deliver that vision (Short *et al.*, 2007).

Is there a need for the client in the briefing process to have a strategic perspective on stakeholders' different aims and goals, when identifying stakeholder values in a cultural construction project? The briefing process can be divided into two stages (Green and Simister (1999). The first is referred to as strategic briefing and is concerned with understanding the client's business processes. The second stage comprises the conceptualization of built solutions and issues of performance specification. According to Ryd and Fristedt (2007) all the players in the strategic part of the briefing process are responsible for adopting the operation's overall goals, developing them and realising them in the best possible way in the individual project. This process also involves the identification of the different stakeholders' aims and goals (Lindahl and Ryd, 2007).

How are stakeholders' aims and goals related to the formulation of client's requirements and to their values related to the business concept? Saxon (2005) defines value as it is what you give in relation to what you get and it is personal and not an objective fact. Stakeholder values of the project and their evaluation of the building performance are different due to their specific organizational belonging, their position in society and their personnel interests. To understand, define and evaluate stakeholder values in the briefing process, one way is to identify stakeholders and their views on the project, expressed in the form of their values (Ryd, 2008). The value the project is to achieve is with this perspective defined according to the project goals with the help of project specific criteria. The projects value contribution can be evaluated in relation to the benefits from the quality of the product (Figure 1).

Stakeholder values can thus be described in relation to the construction project and in terms of the stakeholders' evaluation of the building performance. In the following section stakeholders economic and social values will be discussed.

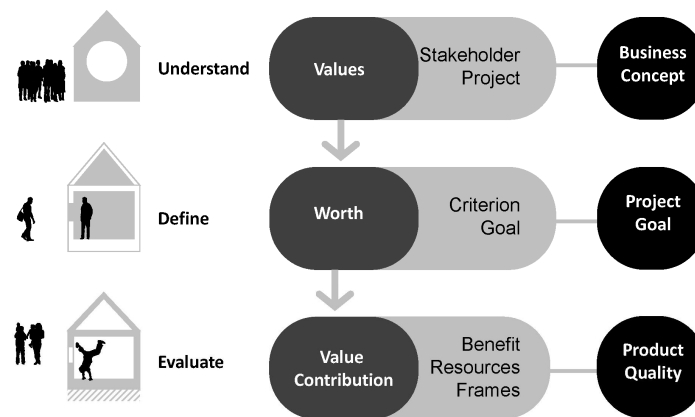


Figure 1. To understand, define and evaluate requirements in the brief (Ryd, 2008 after Saxon, 2005).

2.2 Stakeholders economic values

The building project is creating economic value directly to the actors putting resources in the building project. This perspective is based on the input-throughput-output perspective of economic growth theories meaning that an input of different resources are used and developed in a context that affects the use of resources, leading to an output in terms of economic profit (Coase, 1937/1998). Within the field of construction economics Bon (2001) explains the building process as an economic process with an input-output perspective.

The performance within the construction industry is according to Flanagan *et al.* (2007) generally discussed in terms of productivity. Various productivity measurements, i.e. labour productivity, capital productivity or total factor productivity, have captured the cornerstone of research on achieving excellence in the construction industry. Productivity is generally seen as a measure of effectiveness. Flanagan *et al.* (2007) discusses how construction researchers have recommended a shift from looking just at productivity to the wider concept of competitiveness. Competitiveness can be seen as a measure of companies' efficiency. That is how well the companies are doing the right thing by meeting customers' needs. Hill (1993) has developed the concept of qualifiers and order winning activities. In the construction industry one could argue that design and the development of specific functional solutions could be seen as qualifying and order winning criteria when they correspond to customers' demands.

On the construction project level the competitiveness refers to a contractor's capacity to compete for a project (Flanagan *et al.* 2007). It enables a contractor first to win the contract and secondly to undertake the project successfully. Clearly, competitiveness for a project stems from the competitive advantage possessed by a firm. Competitiveness for a project varies according to project attributes such as type, size, and so on. Competitiveness for a project also depends on the competitive strategy a contractor adopted to compete for that given project according to Flanagan *et al.* (2007).

2.3 Stakeholders social values

The public client, when investing in a public cultural construction, may have an interest in developing the municipality and the region by creating economic values in terms of increased population and new taxpayers but also in terms of creating social values to citizens.

Another perspective on identifying stakeholder values in the briefing process is when having a focus on the characteristics of the resources and the development of knowledge and immaterial resources. The resource-based view or the core competence approach (e.g. Penrose, 1959; Hamel and Prahalad, 1994) and the uniqueness of the resources (Grant, 1991) have lead to a discussion about the dynamics of organizational capabilities determine the success of a company (Dosi *et al.*, 2008).

In the briefing process one could argue that organizational capabilities are a combination of resources and activities developing ideas, planning for space, shaping design, architectural forms and innovative functional solutions. The quality of a building for cultural activities in terms of design, architectural forms and functional solutions should thus create social values to clients and end-users.

Building performance measures and indicators can be categorized in hard and soft measures (Preiser, 1983) and used when identifying stakeholders' social values. The method Building Performance Evaluation (BPE) is based on systematic feedback and evaluation during every phase of building delivery, ranging from strategic planning to occupancy, throughout the building's life cycle (Preiser and Vischer, 2005). Client needs and goals that arise out of end-users' interaction with a range of settings in the built environment are redefined as performance levels. As a consequence, BPE systematically compares the actual performance of buildings, places, and systems to explicitly evaluate expected performances as it relates to pre-determined criteria. Criteria for briefing, designing, and building new environments should be based on the evaluation of existing ones; however, these assessments are seldom done according to Preiser and Vischer (2005).

3. RESEARCH METHODOLOGY AND THE CASE – THE HOUSE OF CULTURE

The research methodology is based on the arguments of Yin (1994) that a case study with one or more cases and with different methods for data collection can be theorized and generalised. The case House of Culture is selected by its special functional design and conditions of combining different cultural activities involving art professionals with different goals. Previous studies (for example Short *et al.*, 2007) have discussed how arts clients require additional commitment from construction professionals. Building a house of culture is in this sense an interesting cultural construction project to study. The experience made by the public client, the construction professionals and the end-users may give new insights to the briefing process and how to identify stakeholder values in the construction projects earlier phases.

3.1 Research design and data collection

Data has been collected from a construction project, the House of Culture, based on semi structured interviews, project reports, the written brief, functional and technical documents and a survey to visitors of the building (Appendix A). The research design is based on an analytical research perspective where data first is described and then analysed by categorising the data and exploring the actors and their relations and the activities performed in the early part of the building process (Miles and Huberman, 1994). In this study the interviewed respondents evaluation of their contribution in the first part of the briefing process (actors that have participated in the project) and to the building performance have been analysed. A survey has been accomplished by visitors of the building. 449 surveys have been collected during seven different occasions and places in the building. In this paper one question has been analysed: the open question regarding visitor's opinion about the building.

3.2 Building a House of Culture

The House of Culture was built in a small town in northern Sweden by the municipal and opened in January 2007. The public client, the municipal, was the investor and developer of the project and is today also the owner and the facility manager of the building. The facts about the project are presented in Table 1. The House of Culture has two concert halls, a public library and an art hall. These three cultural activities are also managed by the municipality.

Table 1. Facts about the case – the House of Culture

Case description	House of Culture
Building period	2004-2006
Opening date	13 January 2007
Architects	Tirsén & Aili Arkitekter
Total area	14 000 m ²
Construction cost	370 MSEK (33 Million Euro)
Public Library	3 400 m ²
Concert Hall A	950 m ² , 1000 places for audience
Concert Hall B	300 m ² , 300 places for audience (450 standing)
Art Hall	500 m ² exhibition area
Conference rooms	7 rooms with places for 2-80 people
Other facilities	Tourist information office, Restaurant, Café, Reception, Local music ensemble, Administration, Parking area

The construction project was initiated by the public client starting in October 2003. In Appendix B the activities in the construction project are presented in chronological order including activities related to the briefing process.

3.3 The strategic brief

The briefing process started earlier involving several actors lead by the public client, i.e. by a project group consisting of people from the municipality with different roles related to the client's responsibilities.

Activities performed in the early briefing process, resulting in the development of the client's requirements in the written strategic brief, are firstly the rejection of the first feasibility study and the development of a new solution in the second feasibility study of the cultural construction project; the one including different cultural activities in one building presented in the second feasibility study. The key to carry out the political decision was the idea of combining different cultural activities in one building. This is an activity leading to the overall formulation of goals and aims with the building performance in accordance with the arguments of Ryd and Fristedt (2007).

After that, the politicians' management of political rules and the development of the project directive regarding costs and time have been important for creating common

project goals for the actors in the construction project. The time schedule was also crucial to the client due to the political decision and an experience that a political decision easily can be withdrawn if the project has not been started or if the project is delayed. These activities are related to the projects performance in terms of effectiveness and according to Flanagan *et al.* (2007) measuring the performance of the project and delivering economic value to the stakeholders of the project.

The formulations of the stakeholders different requirements in the written brief were based on the second feasibility study and the requirements formulated in the project directive. This is an important part of the strategic brief when communicating the operations overall goals according to Ryd and Fristedt (2007). In accordance with Lindahl and Ryd (2007) the written strategic brief is also involving the identification of the different stakeholders' aims and goals.

In the programme the client has specified the criteria's for participating in the architectural competition and winning the competition by formulating end-users needs and desires. These are the requirements the designer has to develop and visualize. These activities can be described as qualifiers and order winning activities in accordance with Hill (1993).

Finally, the clients procurements decisions including the rules for how the development of the technical and operational documents should be performed and by whom. The choice of the procurement decision need to be deeper investigated when analysing the integrated briefing process (Blyth and Worthington, 2001; Barrett and Stanley, 1999; Ryd, 2003) and stakeholder values developed during the building process. In Table 2 the above discussed activities are summarized.

Table 2. Activities in the briefing process related to the strategic brief.

The feasibility study 2002 and 2003

- a. the rejection of the first proposal consisting of private and public investor of the construction project
- b. the development of the second proposal of combining different cultural activities in one building

The political decisions 2003

- a. the political agreement of building a new house for the existing public library, the public art gallery and a new concert hall
- b. the political initiatives of starting the construction project

The development of the project directives with requirement regarding

- a. cost
- b. time
- c. responsibilities

The development of the strategic brief

- a. overall vision and goals with the building and building performance
- b. end-users functional requirements, needs and desires
- c. qualifying criteria for participating in the architectural competition
- d. order-winning criteria's for the architect

The client's procurement decision

- a. Design-bid-build based on a architectural competition
 - b. The architects creating a design team with the client planning the building processes
 - c. The contractors building the house
-

Table 3. Stakeholder values of building a House of Culture.

Stakeholders of the House of Culture	Client requirements, needs and desires related to different stakeholders	Stakeholder values (first analyses) Construction project	Stakeholder values (first analyses) Building performance
Client-Municipality Investor Initiator/Developer Building owner Construction client Facility manager	<ul style="list-style-type: none"> *Symbol for city *Future believes *Combination of different activities *Meeting place *Functionality *Flexibility for new activities 	<ul style="list-style-type: none"> *Project costs according to budget *Building delivered on time *Trust with contractor and architect (Cmc, Chp, Cpl, Ccm) 	
End-users Citizens Visitors Municipal and cultural organisations Commercial organisations Public opinion	<p>The House of Culture should be</p> <ul style="list-style-type: none"> *a house for everybody *an asset for the citizens * a cultural hub for the region <p>* The concert hall should offer comprehensive and range of varying high quality music</p> <p>*The library should focus the visitor, create a meeting place, feel open, light and "give the hole picture", etc... and be assessable to everybody.</p> <p>*The art hall should have a generous entrance etc...</p> <p>*Specific functional requirements to the concert hall, library, art hall, parking area and area for development and expansion in future</p> <p>*Parking area important to the development of commercial business in city</p> <p>*Concert hall</p>	<ul style="list-style-type: none"> *Vacant job, job opportunities in construction (BI) *Development of organisational activities (Ccm, Elm, Echm, Eam) 	<ul style="list-style-type: none"> *Social change regarding attitudes to culture (Cmc) *Increased number of visitors to all activities (library, art hall and concert performances) (Ecm) * easily accessible, meeting area for everybody, multitude in cultural activities, beautiful, comfort, safety (Evi) *Responsibility for activities in the House of Culture (Ccm) *Increased and new cultural events (Echm) *One expansion area developed (Chp) *Development of business activities (Ebm) *Increased trade and tourism in municipality (Ebm, Etm) *New desires (Epo) (Opera) (Evi)
Contractor	<ul style="list-style-type: none"> *Production costs *Time 	<ul style="list-style-type: none"> *Economic profit – winner of the bid to build (COM) 	<ul style="list-style-type: none"> *New contractor for another cultural construction project (Cop) *Building trust with designer and client (Com)
Designer	<ul style="list-style-type: none"> *Architectural and building qualities *Functional and technical solutions between space/room and activities creating synergies by flexibility, communication and corporations between activities *Viable, construction costs and operating costs *Possibilities for expansion 	<ul style="list-style-type: none"> *Economic profit – winner of the architectural competition (DA) 	<ul style="list-style-type: none"> *New projects build on trust with client (DA)
Supplier		<ul style="list-style-type: none"> *The start of the cultural construction project affected other private clients to start new construction projects (BI) 	

3.4 Stakeholder requirements, needs, desires and values

The activities performed in the briefing process have resulted in the development of the client's requirements. In Table 3 the stakeholders and their requirements, needs and desires are categorised from the strategic brief. The results from analysing the interviews (preliminary), also presented in Table 3, have generated a summary of stakeholder values in the construction project and stakeholder values estimated from the building performance.

4. RESEARCH RESULTS AND INDUSTRIAL IMPACT

In this section the research results and their impact for the construction industry are presented regarding the research questions:

- How have the client's intentions been achieved when building a House of Culture?
- What kind of stakeholder values have been created?

Table 4. Requirements and stakeholder values.

Requirements in strategic brief	Stakeholder values
<ul style="list-style-type: none"> • The construction project <ul style="list-style-type: none"> ○ Production costs ○ Time ○ Quality regarding architectural and building qualities, functionality and technical solutions in space and room, expansion 	<ul style="list-style-type: none"> • Clients <ul style="list-style-type: none"> ○ Costs according to budget, delivered on time ○ Trusts build to designer and contractor • Contractor, Designer and Supplier <ul style="list-style-type: none"> ○ Economic profit and new projects ○ Trust between client and designer; client and contractor; contractor and designer ○ New projects
<ul style="list-style-type: none"> • The building <ul style="list-style-type: none"> ○ A symbol for the city creating future believes ○ A meeting place for people ○ A functional place for performing cultural activities • The building performance <ul style="list-style-type: none"> ○ A house for everybody ○ An asset for the citizens ○ A cultural hub for the region 	<ul style="list-style-type: none"> • End-users <ul style="list-style-type: none"> ○ Social change regarding attitudes ○ Job opportunities ○ Development of organisational and business activities ○ Multitude of cultural activities in one building ○ Social values related to form (easily accessible, beautiful, comfort, safety) and place (meeting place for everybody) (see Table 3)

4.1 Quantification of results

The client's intention of creating an easily accessible meeting place and a cultural house for all kinds of people living in the community has been achieved by the ability to:

- Find a new solution of combining different cultural activities in one building
- Manage political rules
- Develop real and viable project goals regarding cost, time and quality
- Develop the brief with a strategic perspective with an overall vision and goal for the building and the building performance

- Decide how the technical and operational documents should be developed by a design-bid-build procurement.

Different stakeholder values have been created during the construction project and by the building and building performance in accordance with requirements in the strategic brief (see Table 4).

4.2 Implementation and exploitation

The results have been implemented to stakeholders of the project during a workshop. The results from the workshop have been documented and will be presented in a forthcoming study. The aim is that the result from the studies in the research project is giving increased insights into the types of evaluations needed to ensure that cultural construction projects are planned, designed, and produced to fit the particular needs they are meant to support. The results will be adaptable to most municipalities and construction companies.

5. CONCLUSIONS

Economic and social stakeholder values have been created during the construction project, by the building and its performance in accordance with requirements in the strategic brief. The development and formulation of client's requirements have been crucial for the result of the project. Shared goals regarding costs and time have lead to a successful project and trust has been build between the client, designer and contractor (builder) in the project. The client's intention of creating a meeting place and a cultural house for all kinds of people have been achieved by the client's capability by combining different cultural activities; manage political rules; develop real and viable project goals and developing a written strategic brief with an overall vision and goal for the building and the building performance. End-users values have been created when estimating the building performance, such as social change, job opportunities, development of organisational and business activities, multitude of cultural activities in one building and social values related to form (easily accessible, beautiful, comfort, safety) and place (for everybody) However, there are still questions for further research a) how the end-user estimates the value of the buildings functionality and technical solutions and how these activities have been developed; b) how the building has become an asset for the client and c) how it can be valued as symbol and a cultural hub for the city and region.

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Appendix 1. Data collection

Semi structured interviews Minimum 1 hour with each actor during 2007-08, *actors participated in workshop when implementing results	Secondary data
<p>C=Client Investor/Initiator/Developer= Cmc=Municipal commissioner * Building owner= Cme=Municipal employee* Construction client= Chp=Head of project* Cpl=Project leader* Facility manager= Ccm=Cultural manager *</p> <p>E=End-user Eci = Citizens (2 representatives participated in workshop)* Evi = Visitors (survey 449 respondents, one question analysed, but not statistical) Municipal and cultural organisations= Ecm = Cultural manager* Elm = Library manager Echm = Concert Hall manager* Eam= Art Hall manager* Etm = Tourist manager* Commercial organisations Ebm= Business manager Public opinion Epo= Orchestra member*</p>	<p>CO=Contractor COm= Manager construction company* COp= Project leader in constr. comp. *</p> <p>DA=Designer DA= Architect*</p> <p>BI= The Swedish Construction Federation BI= CEO Region North*</p> <p>Project reports Feasibility study A 2002-08-15 Feasibility study B May 2003 Planning document 2003-12-22</p> <p>Project directive 2003-10-20</p> <p>Written brief (Strategic brief) Programme 2003-12-22</p>

Appendix 2. The construction project – the House of Culture (chronology)

2003-09-29	The municipal council decided to build a House of Culture
2003-09-30	Planning - Development of the project directive
2003-10-20	Start of construction project
2003-12-22	Programme of 'The House of Culture', i.e. the strategic brief, is distributed consisting an invitation to the architectural competition.
2004-02-28	The contributions from the architectural competition are received from the selected 9 competitors.
2004-03-28	The jury process starts based on the developed qualifying criteria's.
2004-03-29	The jury proposal is handled over to the municipal council.
2004-03-29	The municipal council decide according to the jury proposal
	Design – Development of the technical and operational documents, Specifications
	The general planners, the architects which have design the winning proposal; put together their 'dream-team'.
2004-12-21	Decision of increased building to include the local music ensemble
2005-02-03	Specification phase 1 and 2 (ground and frame)
2005-03-10	The final brief is settled
2005-04-04	Start of Construction
	Phase 1 and 2
2005-07-30	Specification phase 3 (building)
2005-08/09	Start of Construction phase 3, during this phase the users requirements regarding functional solutions are modified in accordance with the users
2006-01	Specification phase 4 (interior)
2006-07	Start of Construction phase 4, during this phase the users requirements regarding interior equipment are modified in accordance with the users
2007-01-13	Opening of the House of Culture

MANAGING END USER REQUIREMENTS IN CONSTRUCTION PROJECTS

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ABSTRACT

The research presented is the initial part of a project with the aim of increasing the use of end user requirements throughout the construction process. This initial part maps how Swedish real estate companies manage end user requirements. The focus of the study was on methods for capturing and managing end user requirements. The study was conducted as a desktop study and through interviews with key personnel from 12 companies – from housing, office and school real estate management to healthcare facilities management. The literature review showed that there are a number of different methods that could be used for parts, but very few cover the whole process. The Swedish real estate companies did, in most cases, measure end user satisfaction; not in relation to construction projects, but on a general level. Feeding back the knowledge, gained from the evaluations, into construction projects was found to be difficult and thereby not done. The companies were all interested in new ways of working and thought that it would improve their business. The research identifies the problems of adopting an end user approach throughout the whole building life cycle – from briefing to evaluating the building in use. The paper reports on a collection of different methods and indicators as well as the state-of-the-art in work methods in practice in Sweden.

1. INTRODUCTION

Managing the involvement and/or understanding of the end users requirements is not easy. End users are the people, who are using/occupying the building, but are not experts of managing it, but have knowledge and opinions about its performance for their own objectives (Lai and Yik, 2007, Preiser, 2002, Kaya, 2004, Miller *et al.*, 1994, Mclean, 1979, Costabile *et al.*, 2007). The end users and the project group come from different kinds of organisations. This leads to that conceptual, institutional and social barriers have to be crossed to receive effective interactions (Lawrence, 1996). An effective interaction is often not found. The end users tend to either become a hostage where his/her opinion does not really matter, because the things that are discussed are not in his or her area of knowledge. Another common interaction problem is that the user is so much affected of the designers' opinions that they forget the persons they should represent and the designers tend not to want opinions on their design from end users (Mumford and Sackman, 1975, Dewulf and Van Meel, 2002).

The benefits of managing the end users requirements are for example that the understanding of the end user business process helps the designers and facilities manager to find solutions for them that fit and better can meet a changing business process which leads to more satisfied and less critical end users (Kaya, 2004, Rebano-Edwards, 2007, Rubin, 1995). To meet the changes in organisations and on the market measurements and evaluations are of critical importance. They provide room for working proactively (Bottom *et al.*, 1997, Campbell and Finch, 2004), increases learning and development of managing the end user requirement. Therefore evaluations are important for both the product, the organisation and the project (Sandberg and Faugert, 2007, Rubin, 1995). A number of methods and tools for understanding and/or involving end users during the whole construction process have been created during the years but not many of them are in use in the market.

The interest and complexity of managing end user requirement during construction project became clear during workshops and interviews with 12 different real estate companies; hospital, office and school and housing. The workshops and interviews were hold in Sweden during the spring of 2008. The companies involved the end users in meetings in early phases and measured satisfied customer Index (SCI) in occupation phase. The conclusion from the workshops and interviews is that there is a need for methods that ease the work of understanding what the end user really need and requires in order bringing added value for them.

This paper discusses how well the existing methods fit the wants from real estate companies in their work when trying to manage the end user requirements during the construction process.

2. STATE-OF-THE-ART REVIEW

2.1 Methods and tools for managing end users requirements in construction

This state of the art presents methods for managing end user requirement in construction projects. The methods are presented in five main phases in construction projects; strategic briefing, functional briefing, designing, construction and occupancy/facilities management (FM).

Briefing

In the beginning of a project there is a need to analyse the impact of different aspects such as functionality, safety, costs, aesthetic, schedule, quality etc. these analysis and statement of different aspects is called briefing. It is during these first meetings that the tone and communication is set among the project participators and it is crucial that the project definition is set for project success (Lee Hansen and Vanegas, 2003). A brief is the document that comes out from the briefing process. There are basically two main types of brief documents:

1. Initial brief (Kamara *et al.*, 2001) / outline brief / strategic brief (Kamara *et al.*, 2001, Preiser and Vischer, 2005a, Green and Simister, 1999) / statements of goals / statement of needs / statement of requirements / schematic brief (Preiser and Vischer, 2005a) / performance brief (Smith *et al.*, 2005)

These are the name of the same brief document which are outcomes from the first strategic planning phase and it sets the broad scope, budget and the purpose of the project (Kamara *et al.*, 2001, Preiser and Vischer, 2005a). The other type is named:

2. Project brief / functional brief (Preiser and Vischer, 2005a, Kamara *et al.*, 2001) / brief / detailed brief / output brief / output specification / specialist brief / operational brief (Preiser and Vischer, 2005a) / programme / problem statement (Lee Hansen and Vanegas, 2003) /performance brief (Green and Simister, 1999)

This brief document is used during the briefing / programming and translate the strategic brief into construction terms and can consist of several sub-briefs, it sets the clients functional and operational requirements for the completed project in construction terms (Kamara *et al.*, 2001, Preiser and Vischer, 2005a).

Strategic briefing

The strategic briefing phase is often considered to be the most problematic part of the early phases in construction projects. Different methods are proposing different ways to ease the work in this phase. Common for the methods found are that they try to understand the business process by involving the end users. This requires that the organisations are willing to let their people to participate in different activities. The information gathering can be done in interviews, workshops (sometimes called 'needer'

groups or working parties), observations, and brain storming. The workshops should preferably involve project managers, architects market researchers and represents from the end user organisation (Smith *et al.*, 2008, Gray and Hughes, 2001, Patnaik and Becker, 1999). The goal with the meetings is to really understand true goals and needs and requirements (Smith *et al.*, 2008). Needfinding propose 'needer' groups in combination with observations and interviews and ranking lists (Patnaik and Becker, 1999). MDPD are using interviews in a combination with SWOT analysis (strengths, weaknesses, opportunities and threats) (Mello, 2002). Problem seeking uses workshops and interviews (Malmqvist and Ryd, 2006). While others are using software programs like Expert choice (used in expert choice) (Smith *et al.*, 1998) and Situation structuring process or strategizer (used in SNA) (Smith *et al.*, 2005) to ease the analysis.

Functional briefing

Functional briefing can either be considered as static or dynamic. The static brief does not consider changes when set (Gray and Hughes, 2001) while the dynamic one is more open for new ideas as the project moves on (London *et al.*, 2005). Those who consider the functional brief to be static argue that it is too hard to manage the rest of the construction project process if changes are constantly to be considered. The more static functional brief believers thinks that a mature project group can manage the functional brief without the end users and if they need help quality function deployment (QFD) and value management could be used (Gray and Hughes, 2001). QFD does not bring a radical method to translate customer wants and needs into functions (Nilsson, 1990), but brings a systematic way of working to achieve quality by design and to increase communication and participation (Bergman and Klefsjö, 2003) in an iterative process (Han *et al.*, 2001). QFD uses a number of tools in the analysis for example capturing the voice of the customer analysis/table (VOCA/VOCT), robust design methodology (Gustafsson, 1995) and the seven management tools (Andersson, 1991). The benefits of QFD is a structured way of working, increased communication and knowledge building and the limits is the complexity of the process that requires a lot of training (Gustafsson, 1995). QFD has mostly been used in manufacturing industry but some attempts are made in flat and housing planning (Delgado-Hernandez *et al.*, 2007, Gustafsson, 1995) and hospital planning (Delgado-Hernandez *et al.*, 2007).

Concurrent engineering in the briefing phase propose as well the use of QFD in the briefing process among other tools. The concurrent engineering uses a mix of strategies with the purpose to reduce lead times, product costs, improve business efficiency and satisfy customers/clients (Kamara *et al.*, 2001).

There are a number of methods that attempt to manage the process with software. Their ambition is to make the client more aware of how the costs, functionality and life cycle costs are affected by different solutions to be able to make more aware decision. These software tools are BriefBuilder (Van Ree *et al.*, 2006), BriefMaker (Hansen and Vanegas, 2003), EcoProP (Huovila and Porkka, 2008), Integral client brief (ICB) and Teknisk Standard (Technical Standard) (Malmqvist and Ryd, 2006).

The ones that consider the process to be dynamic argue that the static models have a lack of flexibility that is unfortunate though the end user has a maturity process in the project and their new insight should be considered (London *et al.*, 2005). The dynamic brief development should focus on client satisfaction but there is a need to identify specific points through the project where brief activities can be evaluated and get performance feedback (Othman *et al.*, 2005). Design management (see design section) is a useful tool in this phase.

Participatory design is a consultative briefing method that uses interviews, steering group meetings to bring a voice to the end-user to create accessible design (Luck *et al.*, 2001) the method can be used in both the functional briefing and in design phase and is further discussed in the design section.

Design

In the design stage the brief documents are processed by different disciplines and brings out specifications of the building and building manuals (Preiser and Vischer, 2005a). There exist different concepts for managing the design phase in order to full fill end user requirements. The methods advocate a better understanding the end users and the purpose of the building by increase the communications in forms like workshops. Design management (DM) attempts to improve product process and the collaboration between actors (Ahire and Dreyfus, 2000). DM uses a set of traditional project management tools and advocates the use of collaborative design (Sebastian, 2005). Collaborative design uses workshops to stimulate the creativity among designers (Sebastian, 2007). Another workshop based method is participatory design that advocates the use of a facilitator as a link between end users and architect to increase the understanding between parts (Luck, 2003). To start the discussion among stakeholders (client, designer, end user and producer) is DQI using feedback from a questionnaire, among stakeholders about the design quality (Gann *et al.*, 2003). DQI tries to measure to get an understanding between value and design within different contexts from the users' perspective. The goal is to learn about design quality and to continuously improve it to achieve satisfied users (Cole-Colander, 2003, Gann *et al.*, 2003). Early supplier involvement and early contractor involvement are two key performance indicators that aim to involve the contractor and the suppliers at an early stage to create a more effective process that will gain the end user in the end (Ugwu and Haupt, 2007). To evaluate the intentions, aspirations and practices of the design, the IPA (intention, aspiration and practices) method can be used. It evaluates the process, the product and the performance in three time perspectives pre-project, project and post-project. The benefits of IPA is that it can give a picture of why and how end-users where regarded or disregarded during the design phase (Lawson *et al.*, 2003).

Design Performance Measurement (DPM) is a concept that is used in US and UK and has mainly been focusing on financial and time efficiency. An increased interest for improving the design and the communication with different actors in the construction projects have raised and there are initiatives for developing a balance scorecard for these issues (Torbett *et al.*, 2001).

Construction

During the construction process can different project management methods and standards and commissioning controls be helpful to deliver the right product within time and budget. But there exist not many tools that directly measure or focus on end-users; two different key performance indicators (KPIs) were found. Contractor Quality Performance (CQP) measures what is delivered to the clients (owners and end-users) and the corporate culture within the company with CQP indicators. The goal is to achieve total client satisfaction with the quality of the product and the service. No practical use of the tool is found (Yasamis *et al.*, 2002). The other is a KPI programme called Construction Products Industry that is a part of the Construction Industry KPIs, it focus on customer satisfaction, people and environment. People are the employees and customers are divided into four categories; builders' merchants, main contractors, specialist contractors and clients, designers and end-users (Construction Products Association, 2005). The customer satisfaction is measured by product quality, delivery reliability, sales advice, after sales advice and value for money. The data gathering procedure of customer satisfaction is made with telephone surveys with statements that should be rated on a one to ten scale (Construction Products Association, 2005).

Occupancy and FM

To keep the building attractive for its occupants or get a picture of how a new building was received different kind of evaluations can be made. Common tools for architectural evaluations with an environmental approach are (De Laval, 1997):

- Mental maps where the users in a study circle draw their experiences of the built environment and then discuss the drawings together.
- Semantic environmental descriptions the user rate opposite words that describe the environment like privacy – public on a seventh graded scale.
- Analysis of the indoor planning the user draws how they have furnished their dwellings and discusses the advantages and disadvantages with the planning.
- Walk through is inspired by Post-occupancy evaluation and can be made in study circles or separately. A map with marked places is visited and judged by the respondents. This gives an interesting view of how different people experiences the environment and can be made by architects, client, crafts men, engineers, facilities managers and users.
- Meetings with all people involved in a project, give them the same information.
- Study circles as a way of working gives the opportunity to test new methods and theories in a smaller group and brings direct responses.

There are different opinions of the use of questionnaire as an evaluation tool for a building. When evaluating not measurable aspects of a building Nylander (1999) states that the use of questionnaires is not preferable. When using questionnaires unexpected and intangible aspects are not captured (Nylander, 1999). While satisfied customer index (SCI) is using questionnaire for measuring customer satisfaction with a building and its service (Cassel and Strand, 1999, The American Satisfied Customer Index, 2008, Bergman and Klefsjö, 2003). SCI have been criticized for only measure what is delivered not wanted and that does not ensure loyal customer. For this matter customer perceived value (CPV) is an alternative tool (Swaddling and Miller, 2002).

Other concepts attempt to combine different approaches when evaluating. A generic approach to building evaluation tries to capture the users' knowledge through dialogue between end users and providers. The approach uses both walk through evaluations and meetings (Kernohan *et al.*, 1992).

Post occupancy evaluation (POE) and post-occupancy review of buildings and their engineering (Probe) attempts to change the construction industry from being supply-fed to being demand-fed by; feedback, feed forward and control (Preiser, 2001) and helps the FM to be proactive to meet the future requirements on the building performance (Eley, 2001, Rasila and Gersberg, 2007). POE evaluates the building performance (technical, functional and behavioural) from the perspective of the occupants' requirements and needs. POE can for example help designers to get a better picture of end users needs (Preiser, 2002). The POE studies can be done on different levels depending on the purpose of the evaluation but every level goes through three stages; planning, conducting and applying (Preiser *et al.*, 1988). Probe tries to improve openness and feedback to designers and clients. Probe uses among other tools BUS (building use studies) questionnaire that reflect on the occupants satisfaction and comfort (Cohen *et al.*, 2001).

To get a broader picture of the diagnosing of the building other KPIs like Quality of professional life (QPL) (Gene-Badia *et al.*, 2007), Housing quality indicators (HQI) (Hall and Meng, 2006), Building research establishment environmental assessment method (BREEAM) (Holmes and Hudson, 2002) and building performance indicator (BPI) (Shohet, 2003) can bring useful information.

Covering the whole process

Building performance evaluation (BPE) is a concept that is developed from POE that attempts to cover the whole process from strategic briefing to building in use. The

concept can be explained as; the set up of performance criteria and exercise performance measures and then compare the criteria with the outcome of the measuring. The goal of BPE is to improve the quality of every decision taken during the life-cycle of a building (Preiser and Vischer, 2005b). This is achieved by an increased and improved communication between different participants and uses methods like interviews, focusing groups and workshops (Preiser and Schramm, 2005).

3. RESEARCH PROJECT

3.1 Project description and objectives

The research presented is the initial part of a project with the aim of increasing the use of end-user requirement throughout the construction process. This initial part maps how Swedish real estate companies manage end-user requirements and evaluate the outcome.

The aim is to study what methods exist and what methods are in use for capturing and managing end user requirements in construction projects. The specific objectives are three-fold:

1. What methods are in use in order to capture and measuring end user requirement and satisfaction vs. what methods exist to manage these issues?
2. What issues is considered the hardest to manage?
3. What is the usability of these methods?

3.2 Research method

The research method takes a qualitative approach consisting of interviews, workshops and a literature survey of existing tools and methods. The choice of interviews and workshops in these initial phases of the project was to receive a picture of the problem area in this field. Without a picture of the problem area it is hard to ask relevant questions.

The project started with individual interviews with 12 real estate companies in Sweden during January and February 2008. The real estate companies are active in three areas; housing, hospital and office and school. The aim with the interviews was to obtain information of how evaluation and measurement of end user value and satisfaction is managed. The interviews followed a prewritten questionnaire with open questions. This was chosen to achieve as much information as possible from the respondents. The interviews took between 30 to 45 minutes.

After the interview phase three different workshops were held with the interviewed companies during March and April 2008. The workshops took around three hours and were coordinated by the research team. The workshops were held very open to allow the participant to really air their problems and discuss with each other to find commonalities and differences.

4. RESEARCH RESULTS

4.1 Results from interviews and workshops

This section presents the results from interviews and workshops with 12 real estate companies in Sweden during the spring of 2008.

Measurement today

The interviews with the real estate companies showed that every company had or was measuring different kinds of SCI. Two of the companies had stopped doing it of different

reasons for example organisational changes or irrelevant questionnaires. Every company hired a consultant company that performed the measurements and supplied the questionnaires. The measurements were diversely performed from every year to every third year. The questionnaires were handled out to either a randomly chosen group of tenants to every single person that moved in to their houses. A few of the companies used different kind of motivators to encourage the respondent to answer the questionnaire, for example a chance of winning rent for one month or a bike. The feedback of the result was done both external and internal. External it was made either by letters, on meetings or publishes in newspaper for their tenants. Internal it was made in meetings with staff to both make them more customer-centred in their work and better understand what should be in focus. The purpose with the measurements was to achieve feedback to be able to improve their work, be aware of "quick fixes", control hired consultants work, develop their concepts and products and get a picture of customer satisfaction.

Most of the companies were content with their SCI but most wanted to improve them. Thoughts of how to improve was a need of showing how customer values the importance of the statements, to be able to rank them in future work. It also came up thoughts of improving the feedback procedures both internal and external. In most cases received knowledge from evaluations were not further fed into new construction project.

Difficulties in managing end user requirements in construction projects

During the workshops with the real estate owners it became clear that many of their problems when managing requirements and creating value for their end users were the same. The hardest to manage was the earliest phases and to evaluate the outcome in order to get relevant information to improve the work. The estate companies considered themselves to be good at project management. The communication between the project manager, architect, designers and contractor was quite easy to manage though they spoke almost the same language. To communicate with the end users were considered much harder especially in the initial strategic phases of a construction project. This phase is generally considered as a problematic phase to manage (Green and Simister, 1999). During the occupying phase it is considered quite hard to collect relevant information from the end users but the really hard issue to manage is to transform this information to something valuable that improve their work in order to bring value for their end users organisation and be a company in the front line of the market. This can be summed up in three main problem areas:

1. Manage the end user and his/her requirements
2. Knowing what brings value in a changing world
3. Formulate relevant goals and evaluate if they are fulfilled.

Manage the end user and his/her requirements

Manage the end user and his /her requirement was found difficult from housing, hospital and office and school perspective. The difficulty laid mainly in the communication with the end users. Many of the end users have not experience of working in projects especially not in construction projects. They are not aware of their role, their rights or understanding the language used by professionals. The professionals have problems in understanding the problems that the end users can have when participate and a lack of understanding of the end user and his/her organisation. To overcome these social and cultural barriers one of the companies used so called "functional planner". A functional planner is a person with a great knowledge of the end user organisation, have often worked in that kind of organisation and is thereby more able to ask relevant questions to the end users. The functional planner becomes a link between the end users and the real estate firm. The other real estate firms did not have a functional planner but was in need of one. They wanted the function planner to be well aware of social science and

pedagogic because they lay so much time trying to explain to the end user why a solution would be appropriate for them without success. The end users were often considered to be conservative when it came to spaces. Another problem when managing the end user was to give the end users relevant amount of choices. The end users became paralysed with too many options. Therefore the real estate firms had a need to level at different type of segment of groups. But at the same time they were well aware of that every end user are unique and needed unique solutions.

Knowing what brings value in a changing world

Knowing what brings value for the end users in a changing world is a complex matter; both internal and external. The internal part is about the organisational changing that requires flexible space solutions. The external part is about the changes of the market demand and deliver. Overtime, issues such as environment demand, technique solutions changes in buildings and the value of the external context changes and raises questions like: What is the value of a view over sea/closeness to restaurant and shops? What is the value of an oak floor instead of a plastic carpet? What is the value of wireless internet? This requires a measurement tool that can give signals to the real estate owners what is the demand of the market, to be able to keep their building and services attractive. When looking at value, it is problematic to find solutions that is both profitable for the end users and the real estate firm though their time perspective is often divers. The real estate firm has a long time perspective while the end user has a shorter time perspective. In some cases other stakeholders like the tax payers and politicians have their values and their time perspective that as well influence the value picture.

Formulate relevant goals and evaluate if they are fulfilled

One of the difficulties when formulate relevant goals are the divers interests from different stakeholders. Besides the end users goals of the project, the real estate firm has their own tactical goals and in public companies have to consider political goals and tax payers goals. This brings a very complex situation to manage. In this complex situation it was found extremely important that the goals were professional set, not influenced by personal emotions. There is a need for a tool that manages different stakeholder interest on a professional level.

After the goal setting the evaluation of the goal fulfilment is often lacking. The real estate companies measure different aspects but none of them have a tool that compares the collected information to the original goals. Many of the companies have an amount of collected information but a lack of knowledge of how to manage this information in order to bring added value to their end users. There was also an interest of comparing efficiency per square meters of different aspects and to benchmark them with outer real estate firms within their area.

5. DISCUSSION

The real estate owners did not know that many of existing tools existed when they were presented to them during the workshops. POE is one of the most commonly used tool on the international market besides SCI. POE, Probe and BPI is built on the same fundamental thought of changing the construction industry from being supply-fed (providers) to become demand-fed (end users). But with opinions like:

"...they lay so much time trying to explain to the end user why a solution would be appropriate for them without success... The end users became paralysed with too many options..."

Indicates both that the ineffective interaction presented in the introduction exists and that the end users not are considered being able of taking decisions or knowing what

they want. This raises questions like; are the real estate owners willing to become demand-fed?

Kernohan *et al.* (1992) found that the demander side avoids expressing discontent and the suppliers avoid acknowledging it. Is this why the companies are pleased with the SCI? That only express what is delivered not wanted. Problems when letting end users participate in evaluation is that they always wants improvement of the quality. This is often not a problem but the difficulty of this is that in general they do not see the whole picture of what they can expect of the performance or service quality within a certain economical and practical presumptions (Sandberg and Faugert, 2007). Which raises a question if the professionals have right in their opinions about the end user or if they do not have the right knowledge of managing the situation? What came out of the workshops are that the use of a functional planner made their contact with the end users much smoother than for those without one. Some of the found methods advocate the use of a facilitator, for example SSM, participatory design and a generic approach to building evaluations, which strengths the idea of using a facilitator.

Another problem was to understand what the requirements were on the market. How is a view over sea valued? Is oak floor valued higher than plastic carpet and if so how much extra are they willing to pay? Needfinding is based on the concept that marketing people and designers need to work together to find end users needs (Patnaik and Becker, 1999). Maybe this approach of involving cross discipline professionals is a way of better understanding the needs and values of the market. It appeared during the workshops that the companies seem to be very well aware of that understanding end user requirement is important. But in the same time *"...When looking at value, it is problematic to find solutions that is both profitable for the end users and the real estate firm though their time perspective is often divers..."*

Many methods are built on very complex systems of different kinds of data gathering and analysis systems. The creators of these tools seem to be well aware of the complexity of understanding the end users and create value for them and to reconcilable them with other goals. The question is if the market is willing to change their ways of working in a radical way. The impressions from the workshops and interviews are that they are not totally unwilling of testing new concepts but they should be easy to manage.

6. CONCLUSIONS

The literature review showed that there are a number of different methods for managing end users that could be used for parts, but that there are very few that attempts to cover the whole process. Most methods exist in the early and in the late phases.

During workshops and interviews with real estate companies the early and the late phases were considered the most difficult to manage. The Swedish real estate companies did, in most cases, measure end-user satisfaction; not in relation to construction projects, but on a general level. Feeding back the knowledge, gained from the evaluations, into construction projects were found difficult and thereby not done.

The conclusions from the workshops can be summarised in three main areas of problem:

- Manage the end user and his/her requirements
- Knowing what brings value in a changing world
- Formulate relevant goals and evaluate if they are fulfilled.

One commonality for these main areas is the communication. The companies want to become better in communicating and thereby understanding what the end users needs and requires.

There are several commonalities among the findings from the literature study, the interviews and the workshops. The early and the late phases of the construction project were found hardest to manage. The many methods found in these two phases tend to be a response to the market. The found methods offer structured ways of working to

improve the interaction with the end user. The companies were all interested in new ways of working and thought that it would improve their business. The concepts needed though to be easy to manage but many of the found methods require a lot of practice to manage.

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FRAMEWORK AND PROCESS FOR GATHERING FEEDBACK IN OFFICE FACILITIES – TOWARDS IMPROVED USABILITY

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ABSTRACT

Usability is an experience about space. Usability depends on the interaction between spaces. The space, providing the interface for the experience is an outcome of a variety of processes from design of the space to use of it. It is essential to identify the processes and different actors in connection with the processes. One challenge is to capture the feedback flows between the different stakeholders who are involved in creating the interfaces for usability experiences. Next to the feedback flows, it is essential to identify the relevant feedback targets. The systematic approach to feedback flows can have a role in improving the spaces as part of the usability experience. The purpose of this paper is to introduce a theoretical framework for capturing feedback flows of different stakeholders in connection with office facilities. The framework will be used for creation of a user-oriented feedback system serving widely the real estate and construction industry. The feedback system includes the feedback processes and roles of different stakeholders in them. The intention is to compile an application which provides feedback from different stakeholders to right respondents at the right time. The development is based on the experiences of a Finnish feedback system, *ProPal*, which was created for measuring mutual feedback in the construction supply chain.

1. INTRODUCTION

End-users' satisfaction and customer orientation have received a lot of interest in recent years. At the same time, attention has been paid to creating performance evaluation methods and tools for measuring usability of buildings (e.g. Leaman and Bordass, 2001). The best-known of the methods is post-occupancy evaluation which has been used to identify and evaluate critical aspects of building performance systematically (Preiser, 1995).

A widely accepted performance criteria for a building's operational and functional properties is the building's serviceability tool (Davis *et al.* 1993). Serviceability refers to the level in which the space or building generally functions according to the demands set to it whereas the building performance evaluation (BPE) approach aims to systematize the feedback and evaluation at every phase of building delivery (Preiser *et al.* 1988).

However, the Post Occupancy Evaluation (POE) method as well as serviceability tools are focusing on building as an object, without taking into account the interaction between space and user experience. The interaction perspective between the user and the space as a source of the usability demands more about the processes and user experiences about the work environment. From the user perspective, usability means that artefacts are easy and fast to learn, efficient to use, easy to remember, allow rapid recovery from errors and offer a high degree of user satisfaction. It also means bringing the user perspective into focus (Alexander, 2007).

There is a variety of qualitative methods which have developed to serve this purpose: e.g. usability walkthrough (Blakstad *et al.* 2008) and customer journey approach. Customer journey mapping is the process of tracking and describing all the experiences that customers have as they encounter a service or set of services, taking into account not only what happens to them, but also their responses to their experiences. Used well, it can reveal opportunities for improvement and innovation in that experience, acting as a

strategic tool to ensure every interaction with the customer is as positive as it can be. (Nenonen *et al.* 2008) The quantitative and qualitative approaches together provide a possibility to gather rich data from the usability of workplaces.

Next to the user experience between the space another important issue has been investigated in usability of workplaces research, namely the usability as an outcome of the process of different stakeholders from design to use. Additionally the collaboration between different stakeholders in design phase of the building and workplaces the system of collecting feedback regarding the building is important for meeting the demands of users and for developing user orientation in the whole construction and real-estate cluster.

The field of construction and real estate has often been accused of not utilizing the experiences of former construction projects and repeating the same mistakes and irregularities in recurring projects (Latham, 1994). The same accusation is repeated in connection with the selection of design solutions in workplaces. This affects the usability and functionality of premises and buildings from the end users' perspective.

The focus of customer-orientated construction and real estate branch should lay on recognizing and fulfilling the users' needs. This demands more systematic approach for collecting and using feedback of the user for development of the design and construction processes, for provision of services and for supporting the user's business. This transfers the feedback more towards feed-forward. The usability of the built environment focuses on user perceptions of the ease and efficiency with which they can use the facility – the workplace. It is a continuing process and not a (construction/workplace) project. There was agreement that usability is concerned with the effect rather than intentions or product – it is not Post Occupancy Evaluation (POE) and is a time, place, context and situation bound concept (Alexander, 2007).

To achieve the fluent feedback-feed forward process, it is important to identify the different stakeholders as well as the processes, which are connected to the creation of built interfaces for usability experiences. The most challenging task is to identify the relevant issues to be presented in order to collect feedback which is connected to usability. The use of usability attributes, which are precise and measurable components of the abstract concept of usability has been investigated in order to capture the relevant contents for feedback. Usability attributes include e.g. that systems are easy and fast to learn, efficient to use, easy to remember, allow rapid recovery from errors and offer a high degree of user satisfaction (Nielsen, 1993). Next to this the information flow between different stakeholders is crucial to make tangible.

This study presents the framework and process of collecting feedback in office facilities. The results of this study will be used in developing a web-based user-feedback system to serve construction and real estate enterprises in Finland as an extension to a formerly compiled Propal project feedback system. First, the study introduces various perspectives which are closely related to feedback data collection from the buildings. It is also essential to understand what is meant by feedback and what is the connection between usability and feedback. Then, the framework is illustrated and the contents of the user feedback system under development are examined more closely. Finally, the study contains a discussion of the benefits of the feedback system for different stakeholders who can use it for improving the usability.

2. STATE-OF-THE-ART REVIEW

2.1 Usability and feedback

Perhaps the most common definition to usability is in ISO 9241-11(1998) according to which usability is 'the extent to which a system can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use'. Three factors defining usability are:

1. Results – realizing the user's goals
2. Efficiency – attaining the user's goals with reasonable resources (time, money, etc.)
3. Satisfaction – creating a pleasant user experience.

According to PMBOK® (1996), customer satisfaction in construction is based on two factors: how the space meets the user's needs and the outcome of the construction project: building and space. "Customer satisfaction – understanding, managing and influencing needs so that customer expectations are met or exceeded requires a combination of *conformance to specifications* (the project must produce what it said it would produce) and *fitness for use* (the product or service produced must satisfy real needs)." Thus, it can be stated that a good usability is a sign of satisfied users of the building. Additionally, as it is commonly known, usability is an experience between the space and the user.

However, the terminology of usability and its formation (expressed, for example, as a theoretical framework in the construction and real estate field of research) is still unorganized when compared to several other building-related factors and needs clarification (Alexander, 2006). For instance, Fenker (2007) emphasizes the significance of social practices and user experience on the relevance of built products. He also argues that usability is achieved through the interplay of user experiences, design and management processes, and buildings. Usability means bringing the user perspective into focus. The term usability describes whether or not a product is fit for a specific purpose. Usability, or functionality in use, is concerning the buildings ability of supporting the user organizations economical and professional objectives (Jensø *et al.* 2004).

As stated earlier, the field of construction and real estate has often been accused of not utilizing the experiences of former construction projects, and repeating the same mistakes and irregularities in recurring projects. The question is if the usability experience and the feedback of it ever meet the right stakeholders in order to improve the processes and outcomes. The stakeholders in the field of construction and real estate need versatile and systematic feedback data about the usability experiences and the buildings as the platforms and interfaces for the usability experiences in order to develop their operations and provide environments and services that enables users to achieve usability experiences.

In general, feedback is closely related to the concept of interactivity which emphasizes the fact that both parties are receiving parties. For feedback, it is essential that the party requesting feedback has some goals with which received feedback can be compared. Nevertheless, feedback should concentrate on concrete improvement of operations, quality, and user satisfaction, not just measuring them (Chudy and Sant, 1993).

Motives for acquiring feedback include various factors with various levels. The starting point is the questions related to relationship with user, as well as the role and status of the user. Assessment of changes in workplace, services and service functionality can be regarded as the second dimension, and the reputation and image of the workplaces and services and development of feedback acquiring can be seen as third. Users and cooperation partners frequently giving feedback help the stakeholders in developing operations and quality assurance. On the other hand, the changing needs of the users and stakeholder partners force the company to develop its operations and processes. Frequent feedback helps in following trends and utilizing changes occurring over time (Goodman, 2001). Feedback can function in a steering as well as motivating role (Ilgen *et al.* 1979). It can steer both right and wrong operations. In its steering role, feedback clarifies the tasks and roles in the processes by making clear the manner of anticipated operations.

Feedback data can assist in assessing the level of success of the organization's operations and the direction in which its performance is developing. Feedback should focus on developing only one thing: own operations. There are three points of measuring 1) what is improved, 2) how much is improved, and 3) how much more is improved in

comparison to competitors (Hanan and Karp, 1991). When the feedback data as a whole becomes more profound and a part of the assessment of own operations the potential of effects on a business level increases.

While the usability consist on the experience between the user and the space the question is gathering feedback from different stakeholders is complicated. Feedback of user experience demands qualitative approach and has a range of challenges to be captured, not only because it is depending on the context but also because it is depending on situation and in wider scope also on culture (Lindahl and Granath, 2006).

The focus in this study is not to concentrate on the usability experience as such but to understand how the place as a platform for different experienced is formed by different stakeholders. The intention is to understand how the space as a platform or interface for user experience can be improved by collecting feedback data of and for different stakeholders who are connected to that platform.

Based on the former approaches the relationships between user and different stakeholders are important to identify. The following section describes the different stakeholders which are involved in producing the platforms and interfaces for usability experiences.

2.2 Different stakeholders developing the usability interfaces

Construction clients, representing a large group of users, have a key role as initiators of projects. According to Spencer and Winch (2002), the clients should have a more active role in construction, which implies that the client should understand the factors that make a construction project successful. In several points of the recent debate on the construction industry, clients are seen as the major actors for directing the construction processes and results (Bertelsen, *et al.* 2002; SOU, 2002; Kamara *et al.* 2002; The Danish Government, 2003).

The client's goal of raising quality and implementing end user focus and, at the same time, outsourcing the management process of finalizing facilities, signifies a fundamental gap between two different logics, one of the client and the other of the construction project professional. In a study by Granath and Hinnerson (2002), it is noted that although there is an agreement on the values and objectives of a project there is a risk that these are changed due to the project processes of today. This is illustrated by the fact that there is a discussion on the need for facilitators in interpreting the requirements of the client, rather than a discussion on the role of the construction managers and their roles. One field of professional activities is being developed whereas another is not. This questions the role of construction managers and their relationship to and integration of client's objectives. It also asks how construction managers can combine construction management and project management in such a way that roles and goals are professionally managed. Another question concerns the roles and functions that are appropriate when managing the client's needs. In a situation in which there is an increased need for professional clients and the aim of the construction project professionals is to engage in a wider range of tasks, there is a need for an innovative approach, method that develops roles and relationships that satisfy the client's objectives and contributes to collaboration between stakeholders in the construction process.

According to research results, among construction clients there is an increasing interest towards a more value-based and operational-oriented management process (Ryd, 2003). It is reasonable to believe that this has led to a need for experts who understand the differences between a strategic/external or operative/internal management processes without focusing too much on building-related solutions. Such an expert can act as the client's link between the business development and facility planning and manage the fact that not all facts can be stated and finalized at each shift between the traditional stages of the construction process. This suggests a possibility for project management professionals in construction to develop and provide expanded services to clients.

Alternatively, new actors among other professionals in the construction sector may appear. It also implies a need to focus on the construction project with a process perspective rather than the construction project as such.

In addition to the facilitative functions used during briefing and initial stages, there is the discipline of project management to consider. This field is generic in terms of application areas and often used to describe a temporary way of organizing. Construction management focuses on the design phase and/or production phase, thus, in a way reinforcing the boundaries between the phases and actors (Winch *et al.* 1998). The field of construction project management addresses construction project management related to the construction of facilities more explicitly, most importantly, it assumes and advocates the integration of all phases from conception to completion and argues that this integration is essential on the client's behalf. The ambiguous use of the notion of project management in construction has been addressed by the network and forum developed on the basis of the World of Construction Project management conference. There is a need for an integrated approach to projects in the construction sector where different stakeholders collaborate in order to develop an optimal solution for client and end user (Poh *et al.* 2004).

A construction project is a process in which the features of the end result take shape starting from the expectations and needs of the commissioner and continuing all the way to the holistic entity of the completed building. A building is formed through the results of the operations of the various parties in the construction project as well as through the goals set. Commissioning, design, materials, and productions determine if the building fulfils the set requirements and objectives.

Quality of construction can be divided into the quality of the product, i.e., the building, and the quality of the operations, and the construction process. Usually, the quality of building and real estate is defined by how it fulfils the demands set to usability and associated experiences. The usability features can be further divided into technical and operational qualities of the building. Experiences can be divided into orientating and inspiring qualities, and the relationships between the real estate and the environment.

Along with growing competition and more demanding end-users, the significance of paying attention to the needs of the end-users has grown. Producing premises and buildings to the market is not enough but they should support the companies' business) and, on the other hand, the various actors in the field (contractors-developers-owners-managers-companies providing maintenance services) require detailed and up-to-date information about the buildings' user and their experiences). The demands on user-orientation have grown, and the actors in the field need systematic data in order to develop their operations and support their decisions (Preiser *et al.* 1988; Preiser and Schramm 2002). Fragmentation of the market, development of technology, and the arrival of new actors on the market have emphasized the needs of information regarding real estate's functionality and usability.

The significance of indicators of user satisfaction and soft quality indicators has increased in the entire field of construction. The actors in the field of construction and real estate need versatile and systematic feedback data in order to develop their operations (Kernohan *et al.* 1992). In order to collect the feedback one can concentrate on the qualitative feedback about user experience. This study concentrates on feedback data from different stakeholders enabling the platform for usability experience.

3. RESEARCH PROJECT

3.1 Research content and methodology

Framework of the study was developed in three workshops in which participants represent the various aspects of real estate and construction sector in the Finland. The focus was in office buildings as platforms for usability experiences of user. Results of

workshops were tested in the user-panel. Workshops were preceded by informal theme interviews of company partners creating a basis for the definition work of the user feedback system. The objectives and purposes of each workshop were also put together as research questions as follows:

I. Identification of stakeholders connected to the user experience in office facilities and identification of feedback flows between them

- a. To whom feedback should be given?
- b. What is the role of the stakeholder in connection with the user?

II. Determining systematic of collecting feedback

- a. Which are the main processes affecting to the development of office facilities?
- b. How is the flow of collecting feedback functioning?

III. Explore content of feedback surveys

- a. What is the content of each feedback survey?
- b. Which factors affect to the usability of the facility?

Identification of stakeholders and feedback flows

By identifying the participants it is possible to determine the feedback flows amongst participants in the feedback system. Essential for the relevant feedback is to ensure that the right stakeholders receive the feedback information directed to them. The feedback providers can be divided into various levels: company/organization, facility management, and staff. All of them have different roles in assessing and evaluating facilities and services in the main phases of the building lifecycle. The organization and facilities management produce input to the usage stage of the space influencing the usability of the space later on. The user organisations utilize the feedback by developing facilities as an active resource and in order to support organisations' core activities. In the supply side, the organisations focus on developing their products and services through reviewing the performance of past asset planning and project delivery activities (Figure 1).

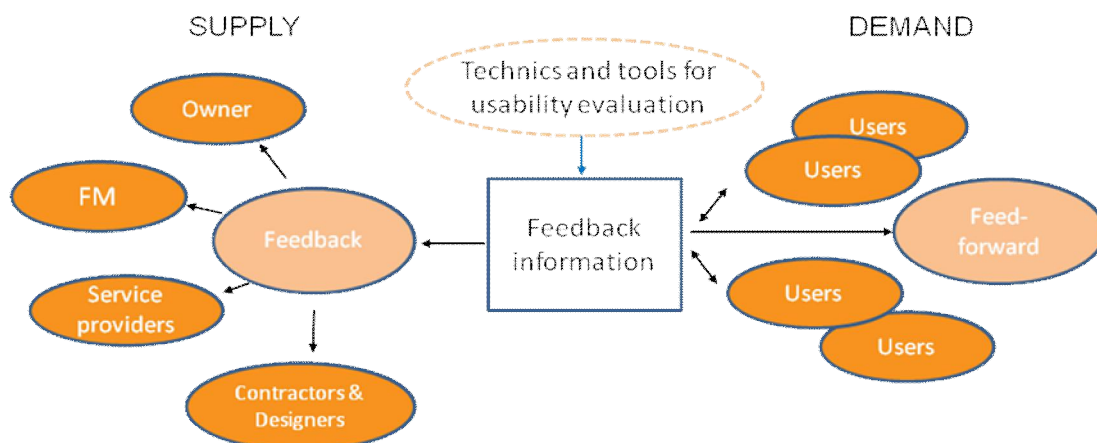


Figure 1. Framework for identifying participants.

Determining systematic of gathering feedback

Main outputs for determining the systematic of gathering feedback are user process description, system process description, and operational model for utilization.

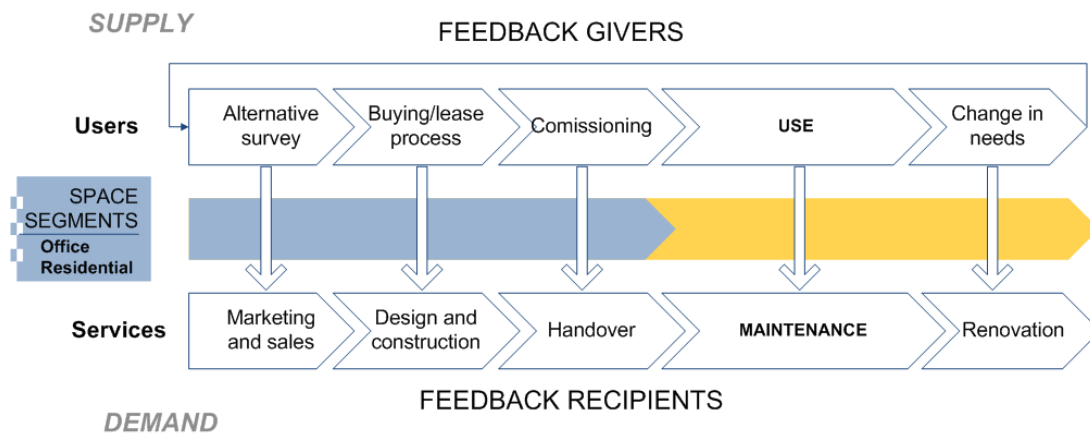


Figure 2. Processes of space users in different stages and the questionnaires derived from them.

Table 1. Main contents of the surveys.

Phase	Main content of the survey	Feedback providers
Marketing and Sales/lease	<i>Interaction</i> <ul style="list-style-type: none"> • Responsiveness • Competence • Access • Communication • Understanding/Knowing the customer • Reliability • Quality of information • Change management • Marketing channels • Quality of the material 	Company/Organisation FM
Design and construction	<i>Participation</i> <ul style="list-style-type: none"> • Customer possibilities to influence on design solutions • Reliability of information • Responsiveness • Competence • Access • Communication <i>Functionality</i> <ul style="list-style-type: none"> • Schedule • Quality • Change work 	Company/Organisation FM
Handover	<i>Information</i> <ul style="list-style-type: none"> • Functionality of handover material and maintenance manual • Quality of assignment material and maintenance manual • Degree of completion at handover inspection • Repair of defects and deficiencies noticed during handover inspection • Quality of overall service level 	Company/Organisation FM Staff
Use	<i>Comfort</i> <i>Accessibility</i> <i>Navigation</i> <i>Functionality</i> <i>Applicability</i> <i>Serviceability</i>	Company/Organisation FM Staff

Figure 2 describes the feedback in the main stages of user processes. The supply side depicts the most important user processes: alternative survey, buying/lease process,

commissioning, space-in-use and change in needs. On the demand side, the actors in the field of real estate and construction offer various services to meet the demand. These have been divided into five phases. Each phase is basis for formulating one specific questionnaire to the feedback system. The phases are marketing and sales, design and construction, handover, maintenance and renovation. It is important to note that the phases preceding the space-in-use produce *input* for the usability of the space.

Content of the surveys

After mapping the main processes and identifying the entities involved in feedback, the content of each survey was outlined. The usability attributes were defined and the important topics under them were modified. Lists of various usability attributes already identified in the previous studies are useful in the selection process (Hansen, 2004; Nielsen, 1993). Once the set of relevant usability attributes have been determined, measurable parameters for each of these attributes will be defined. As the attributes are usually very complex, each of the attributes consists of multiple parameters.

An output of content determination includes creation the content of each questionnaire. Table 1 shows an example of the main content of the surveys for the phases of marketing and sales, design and construction as well as handover and use.

3.2. Reporting and utilization of the feedback

Static feedback reports

The system produces reports for user-organisations about the current state of the usability of the space in the viewpoint of organisations' staff (respondents) in different reference levels. Organisations can utilize the feedback information in their efforts towards developing their premises as an active resource and to support organisations' core activities. The static feedback report comprises (Figure 3):

- a summary matrix which uses a graphic curve in assisting quick observations of the levels of feedback given for different usability attributes
- a summary of the fields of usability attributes in relation to corresponding comparison material
- averages of each question and distributions in relation to the comparison material.

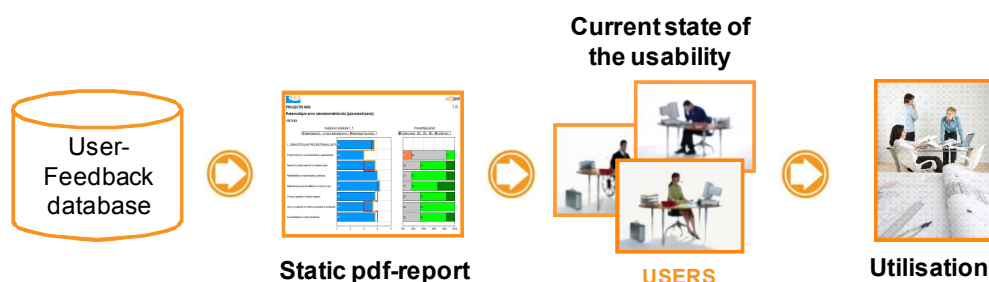


Figure 3. The static report produced by the system for the user organisations of the space.

Dynamic reporting tool

The real estate owners and constructors utilizing the system and creating surveys can use the dynamic reporting interface of the system (Figure 4). By using dynamic reports, organisations can perform various comparisons with the feedback given and received. The user organisations of the system can compare their performance with each other and

in relation to the entire material by using the classifications desired. The classifications are based on the background variables of the material. The reporting interface will be automatically refreshed when information are entered in the database.

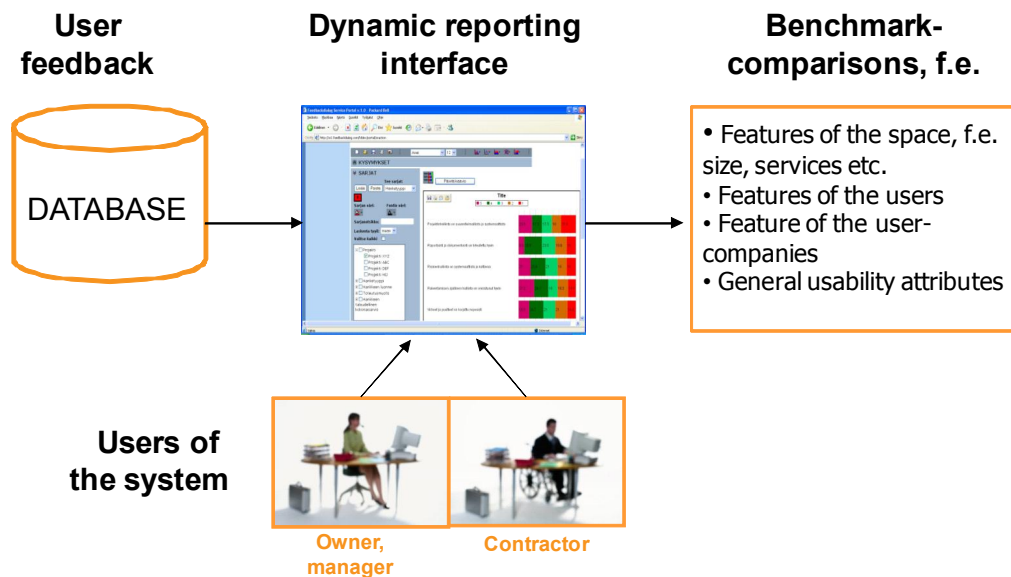


Figure 4. Reporting in the feedback system.

4. RESEARCH RESULTS AND CONCLUSIONS

This study has presented a model and a framework with which the main actors in the field of real estate and construction obtain extensive information about the buildings and spaces as interfaces and platforms for usability experiences as well as users' evaluations regarding the various stages of space acquisition. Furthermore, the paper introduces a user feedback system that meets the needs of developing user orientation in the field of construction field.

Generally in the real estate business, user feedback information enables preventive real estate maintenance meeting the user needs, and serves as a tool for improving the attractiveness and productivity of the spaces in the market. For the construction process stakeholders, the study results enable learning from their own work as well as that of others thus providing them with a tool for developing professional skills. It can also help in improving the product qualities to better meet the objectives and user expectations. In addition, it can produce information for programming the project, guiding the designing, for the design itself and as a selection criterion of design solutions in order to provide user interfaces and platforms for user experience.

The participation and influence of the user organization and users improves the satisfaction regarding the space and enhances the understanding of design effects. Moreover, it improves the quality of working environments and helps in acquiring the appropriate spaces that can also ensure the best productivity.

The feedback system also yields information about the demands and needs of different user segments per target type. Feedback information helps the real estate maintenance and management and provides tools for improving the attractiveness and productivity of the spaces in the market. Here are some of its further benefits for various actors:

- *Real estate owner*
 - User satisfaction and requirements for usable space in the various space segments

- *Building developers/constructors*
 - Developing the products and services with a user-oriented focus
- *Designers*
 - Functionality of design solutions
- *Users*
 - Usability of the spaces and suitability for business
- *FM/service providers*
 - Developing services

The developed feedback system will be piloted and tested in 2009. The use of a common feedback system brings benefits for the entire field. In order to be successful, it has to better understand the weaknesses of building orientated feedback methods. The benefits of the presented system are indeed systematic data collection and versatile reporting possibilities. When the system is bringing benefits to the direct development operations of an organisation, simultaneously it builds potential for development for other stakeholders as well. In this way, the quality of the entire field is improved, customer satisfaction increases and a beneficial win-win situation achieved.

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MAPPING BUSINESS DEVELOPMENT RELATIONSHIP TIES ACROSS SUPPLY CLUSTERS

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ABSTRACT

This paper considers the linkage between three important areas in construction supply cluster management: (i) the exploration of relationship strength in social networks of supply clusters, (ii) the application of social network analysis as a research method to this area, and (iii) operationalising the research to produce practical and theoretical outputs for evaluating (implicit and explicit) relationship practices within the relationship marketing/management paradigm. The exploration builds upon an initial conceptual consideration of these issues concerning projects, commencing from dyadic client-contractor relationships moving into the more complex social network for projects involving subgroups and isolates. This paper takes these themes and considers the issues in the specific context of supply clusters. The primary aim is to identify whether and at what stage relationship strength and ties or lack of them arise within clusters. An additional aim is to scope the conceptual opportunities and constraints for development prior to considering fieldwork exploration.

1. INTRODUCTION

Supply chain management has been and continues to be a prominent topic in management (e.g. Chopra and Meindl, 2008; Cousins *et al*, 2007) and for projects in construction (e.g. Egan, 1998; Green, 2006; London, 2007; Pryke, 2009). The typical starting point has assumed the link or relationship is already established, so the focus becomes how to conduct the management of the relationship. This is a procurement and production focus. In reality relationships first have to be formed, and even where existing they need to be transformed as a precursor to supply chain management. This is a marketing question with a service focus. It is this that provides the starting point for this paper.

The marketing mix paradigm is largely dyadic, whereas relationship marketing takes place in a network, where actors develop relationships to lever value and satisfy customers in order to secure profitable work and repeat business opportunities (e.g. Gummesson, 2002). This network is an important source of value and is added to the service or product in what economists call tacit interactions. This value is created and delivered within both internal and external networks to any single organisation. The start of the process is frequently relationship marketing for products and services delivered under contract, which contrasts with many products and services that are produced ahead of sale.

The *aim* of this paper is to examine relationships present in the business development process for establishing and managing supply chains and clusters. Social network analysis (with social taken literally in this case) is to be used as a tool for analysis to create a map of relationships in marketing and at the interface with managing the chains and clusters.

The *objectives* of the paper are (i) to examine the strength of relationships and (ii) to overlay an analysis of the types of relationships, (iii) the combination helping an assessment of the opportunities of, and constraints for, managing relationships, and (iv) possibly point towards management approaches which align with different configurations on the network maps.

This paper provides an overview of marketing, supplier markets and their networks as a prelude to exploring three areas in the management of supply chains in construction, including the links between these areas:

1. Relationship strength and ties in customer social networks
2. Research methods for mobilising relationship marketing and social network analysis
3. Research outputs for conceptual reflection and evaluation.

The paper provides an overview of relationship marketing in general and in particular pertaining to supply markets and within complex networks. Relationships strength and ties are then conceptually articulated in customer social networks, explicitly linking relationship marketing concepts with social network analysis, which is further developed for undertaking fieldwork. The paper speculates upon likely outcomes and how these may help both theoretical development and practical application, concluding with comments on possible outputs such as a prescriptive network design tool.

2. OVERVIEW OF MARKETING, SUPPLIER MARKETS AND NETWORKS

The relevance of networks was identified at an early stage in relationship marketing. Gummesson (2002:3) stated, "*Relationship marketing is marketing based on interaction within networks of relationships*". Achrol (1996) had noted that inter-organisational relations in marketing are changing, inter-firm cooperation between specialised actors was important in four dimensions: a) internal market networks, b) vertical market networks, c) intermarket networks, and d) opportunity networks. This applies in supplier markets as one market in the six relationship markets model (Christopher *et al*, 2001). Supplier markets offer customers opportunities for creating long-term business relationships based upon repeat purchases and co-creation of value in profitable ways.

Although tacit interactions are recognised, transactions cost analysis typically overlooks the asset specific nature of networks in service provision and the added value levered and delivered from network actors through suppliers. Relationship marketing has recognised this role, applying aspects of an actor's role, relationship strength and identity in industrial networks (e.g. Johanson and Mattsson, 1985), yet has overlooked social network analysis as an approach.

The importance of networks has been acknowledged in business development for construction (Cova *et al*, 2002), but the network is not just marketing and procurement, but a broader system of relationships, knowledge and reputation that potentially enhances and levers value for the supplier in delivery. While the milieu helps business development (Cova and Salle, 2006), it is a source of value for delivering value and hence secure business in the longer term through supplier, referral and influencer markets (Christopher *et al*, 2001). It is therefore a key management role to manage these networks to reduce risk and maximising opportunities (Artto *et al*, 2007), which commences with business development and can carry through the project life cycle for value creation and delivery.

3. RELATIONSHIP STRENGTH AND TIES IN CUSTOMER SOCIAL NETWORKS

Relationship Marketing

The two primary marketing paradigms are the *marketing mix* (Borden, 1964) and *relationship marketing* (Berry, 1983). The marketing mix arose for marketing mass produced consumer goods, starting with the 4Ps of product, place, promotion and price (McCarthy, 1964) and developing subsequently. It is therefore producer-orientated where aggregated consumers form segments for products using the 4Ps, producers viewing consumers as passive.

Relationship marketing was developed for intangible business-to-business (B2B) services (see Grönroos, 2000; Gummesson, 2002; Ford *et al*, 2003), where service value is delivered through relationships to enhance client satisfaction and loyalty. As a result, increases in repeat business and higher margins are secured by suppliers. Customers are active and configured in "segments of one" (Gummesson, 2002).

Other key elements of relationship marketing include understanding of customer strategies, business problems and the service solutions required; development of relationship strength; trust and confidence; consistency and continuity of service delivery. For the supplier this requires detailed. It also requires revenue and profit to be measured against relationships rather than transactions, hence relationship costs rather than transaction costs *per se* assume are important, which are evaluated against short and long term relationship value of the customer to the supplier. According to Storbacka *et al* (1994), delivering perceived (added) value leads is carried out by customers and suppliers developing strong relationships, which requires investment in service quality and customer commitment, and which also incurs costs in delivery. Relationship strength gives rise to relationship longevity and relationship profitability.

The value delivered for each relationship can then be measured and the relationship revenue and profitability measured against that (Smyth and Fitch, 2007). The cost focus is upon the time and effort required to "go the extra mile", direct and indirect costs of failing to deliver on any aspect, including withdrawal from relationship marketing. The way in which unexpected critical events, especially the configuration of events, are managed is central to maintaining relationship strength. These add up to the relationship costs and are offset against relationship revenue and profit. In a project context there are added factors (Pryke and Smyth, 2006), in particular the investments made across projects to support developments to service delivery for each project – investment in programme management (Smyth and Pryke, 2008). Application of relationship marketing to construction has been developing over recent years (see for example Centre for Construction Marketing, 1996; Thompson *et al*, 2003; Smyth, 2000; 2005; Preece *et al*, 2003; Smyth and Fitch, 2007; Smyth and Edkins, 2007).

Relationship Strength and Ties

Therefore relationship strength is important in value and profit realisation, strength being seen in two ways from the supply side: regularity of contact and quality of contact in social and financial terms. Ford *et al* (2003) consider evidence of relationship strength through actor bonds, which they couple with activity links and resource ties. This can be considered dyadic, strength of ties being managed through branding, products and service identification, firm reputation, referral and influencer markets, yet are also network based (Katz and Shapiro, 1985; Shapiro and Varian, 1999), for example the strength of the relationship ties personally created by employees (Leone and Bendapudi, 2001) between suppliers in managed chains (Artto *et al*, 2007), between customers (Ambler *et al*, 2002:18), and other external and internal parties that consciously or unconsciously induce value creation opportunities for suppliers, which suppliers can manage through a service orientation as part of systems integration to deliver project value (Söderlund and Tell, forthcoming).

Management and marketing refer to vertical and horizontal ties, although in networks this is controversial. It is frequently difficult to clearly categorise organisations as one or another in a network and individuals representing the same organisation can have different roles in this regard. Putnam *et al* (1993) found that dense horizontal networks reinforce trust and norms, yet Knack and Keefer (1997) reported conflicting results, which may suggest that network relationships are contextual and moderated by specific external and internal factors. Vertical ties appear more significant, as vertical network value is critical to supply and value chain management. Identifying relationship points or nodes of trust is important for effectively leveraging value from the broader network into

specific chains and provides focus for relationship nurture (cf. Gilligan, 1982; Smyth, 2008).

Conversely, people who work in networks of weak ties have less management control over reputation and outputs (cf. Meyerson *et al*, 1996), and thus lose value and associated repeat business and profit. Relationship strength can be set in the wider conceptual context of social network analysis (e.g. Wasserman and Faust, 1994; Wasserman and Galaskiewicz, 1994; Brandes and Wagner, 2003) where relationships are typically referred to in terms of the strength of *ties* between nodes (Granovetter, 1972; see Badi and Pryke, 2006 for projects).

Social network analysis involves the representation of organisational relationships as a system of nodes or actors linked by precisely classified connections, along with the mathematics that defines the structural characteristics of the relationship between the nodes. As Wasserman and Faust (1994:20) put it, a social network is:

"A finite set or sets of actors and the relation or relations (between them)."

It is making this analysis of the relationships in business development across supply chains, using a structured approach that will lend richness of analysis to qualitative data that otherwise would be presented in purely qualitative categories that may not be so easy to grasp or accept as having more general pertinence for most or all supply chains and clusters on projects. It is the method of categorising and structuring such data which is the focus for the next section.

4. RESEARCH METHODS FOR MOBILISING RELATIONSHIP MARKETING AND SOCIAL NETWORK ANALYSIS

There is no single method for characterising a relationship or measuring tie strength in relationship marketing and social network analysis. We intend to characterise relationships in supply chains according to the thirty relationships, grouped into four categories (Table 1), because they provide a richness of characterisation and because they have been tried and tested in construction (Smyth and Edkins, 2007).

Supply chain relationships are not only *classic market relationships* where contracts of exchange take place but particularly fall into the *special market relationship* category. When located within their wider network *mega relationships* are also relevant. Measuring tie strength and path length will be important for each relationship type. This is an important yet neglected area because of the congruence of ideas. Social network analysis is a quantitative method that permits qualitative evaluation of data that arises from combining elements of mathematics, anthropology and sociology. It is a form of *structural analysis*, allowing mathematical and graphical analysis of essentially qualitative data (Pryke, 2008), in this case on supply chain relationships. As Loosemore (1998) has argued, social network analysis is a quantitative tool capable of being applied within an interpretative context in construction research, arguing that jointly they have a part to play in understanding social roles, positions and behaviour for construction projects.

Table 1. Relationship Types and Categorisation Source
(adapted from Gummeson (2002)).

1. Classic Market Relationships – incorporating the customer-supplier dyad, competitors and the distribution network.

R1. The Classic Dyad

R2. The Classic Triad

R3. The Classic Network

2. Special Market Relationships – incorporating interaction in the service encounter, alliances and loyalty programmes.

R4. Relationships via Full-Time Marketers (FTMs) and Part-Time Marketers (PTMs)

R5. The Service Encounter

R6. The Many-Headed Customer and the Many-Headed Supplier

R7. The Relationship to the Customer's Customer

R8. The Close versus the Distant Relationship

R9. The Relationship to the Dissatisfied Customer

R10. The Monopoly Relationship

R11. Customer as 'Member'

R12. The e-Relationship

R13. Parasocial Relationships

R14. The Non-Commercial Relationship

R15. The Green Relationship

R16. The Law Based Relationship

R17. The Criminal Network

3. Mega Relationships – incorporating non-market external relationships, embracing lobbying, PR, NGOs, social networks and bonds.

R18. Personal and Social Networks

R19. Mega Marketing

R20. Alliances Change the Market Mechanisms

R21. The Knowledge Relationship

R22. Mega Alliances Change the Basic Conditions for Marketing

R23. The Mass Media Relationship

4. Nano Relationships – incorporating internal organisational relationships, including internal customers, internal systems and logistics.

R24. Market Mechanisms are brought inside the Company

R25. The Internal Customer Relationship

R26. Quality and the Customer Orientation

R27. Internal Marketing: Relationships with the 'employee market'

R28. The Two-Dimensional Matrix Relationship

R29. The Relationship to External Providers of Marketing Services

R30. The Owner and Financier Relationship

A number of social network terms are in common use: *webs of relationships*, *networking*, *cliques*, individuals who become *isolates*, or conversely the *prominence* of individuals, of individuals' *centrality* and *links* between firms and individuals; telecoms firms refer to issues of *connectivity* for network users (Pryke, 2008). Social network theory gives precise meanings to each term (Pryke, 2008). Social networks consist of a finite set or sets of actors and the relation or relations defined on them, the word 'finite' presenting a challenge where networks are extensive and boundaries are difficult to identify. Network actors are discrete individuals, corporate or collective social units, the position an actor occupies in the network being described as a node, in this case positions in supply chains or clusters. Relations are a collection of ties of a specific kind among members of a cluster. Dyads and triads are relationships within clusters. Network density refers to the number of links between each node across a cluster, expressed in relation to the maximum number of links possible for that cluster and/or wider network. Actor centrality concerns prominent actors that are extensively involved in relationships with others, which is an expression of prominence and possibly power, depending on the nature of the relationships being measured (Wasserman and Faust, 1994).

Relationship strength is measured through an analysis of how two supply cluster actors are related to each other, that is, the structural position regarding centrality in social network terms and type of relationship in relationship marketing terms. The structural position is affected by the location or role that individuals engaged in business development occupy on the one hand and those involved with other roles, such as procurement on the other hand. These roles affect individual power and influence and this in turn moderates the power and influence occupied by the firms in the supply market (cf. Nohria and Eccles, 1992). The purpose is to map of relationships according to social network conventions and overlay this analysis with the type or character of the relationships.

A case study approach will be applied, using compare and contrast techniques between the cases (Eisenhardt, 1989; Yin, 1989). The case study unit will be a network based around a group of linked suppliers in a chain or cluster, including a 'client' as the node for supply. The basis of comparison will be the maps of the case clusters, with the relationship types and categories overlaying social network maps of nodes, ties and density calculations.

5. RESEARCH OUTPUTS FOR CONCEPTUAL REFLECTION AND EVALUATION

The research seeks to produce practical and theoretical outputs for evaluating relationship practices that are both implicit and explicit. This can be achieved by triangulating data on roles and functions with social network analysis and with relationship categories and types derived from relationship marketing. The outputs will have two foci:

1. Articulating the business development relationships across supply clusters;
2. Articulating how the business development processes connect and inform the project management and delivery processes of suppliers through adding value derived from the network.

First, the research output links two conceptual areas, sharing a network focus that have yet to be concertedly linked theoretically and through empirical investigation. Second, the output will feed into wider debates on (i) the nature of the management of projects (e.g. Morris, 1994), linking into marketing which has been a neglected area within this broader field of the management of projects (cf. Smyth, 2000; 2005); (ii) systems integration, especially linking supply chain management with a service orientation (Söderlund and Tell, forthcoming) rather than the production one *per se* (cf. Smyth, 2005); (iii) the sources and delivery of (added) value in supply clusters.

Whilst it is not possible to pre-judge research findings and contextual factors are expected to be influential concerning uncertainty, risk and product and service complexity. Yet, it is important to consider the output parameters in terms of:

1. Relationship strength and ties in supply cluster social networks;
2. The stages at which relationship ties develop and/or weaken;
3. Relationship marketing in relation to the above;
4. Supply clusters and business development in the broader context of the management of projects.

In particular, it is expected that the research will produce a new definition of tie strength that will inform research using social network analysis and help to develop and clarify network operations in connection with relationship marketing.

6. CONCLUSIONS

This research considers the nature of the social and inter-organisational structures and their influence upon the establishment of network paths that create new business in supply clusters. The research will establish a method for measuring tie strength and will identify a number of network structural characteristics that facilitate effective supply relationship development and management. It is hoped that the research analysis of the data will enable organisations to configure their business development and delivery to achieve tangible benefits in supply clusters and for client organisations. The endeavour is to be able to produce a more concrete understanding of the nature of relationships in construction supply chains and clusters and by implication a firmer understanding of how to improve relationship marketing, and hence business development, to inform future research and guide industry practice.

Analysis of the findings will therefore help to provide a prescriptive network design tool for dyadic and broader value relations in project coalitions. In future it may become possible to regularly use path length, tie strength and actor characteristics to design supply clusters that enable more effective business development and actor relationship management.

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A CASE STUDY OF PARTNERING IN LEAN CONSTRUCTION

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ABSTRACT

Lean construction is a relatively immature literature field in need of unbiased theoretical reasoning and case studies in order to investigate how lean thinking can be applied in a construction project context. The purpose of this paper is to increase the understanding of how various measures of lean thinking can be implemented in a construction project and how these measures work. In order to enhance unbiased theoretical reasoning a frame of reference is first developed through a literature review of peer-reviewed journal papers. The empirical part of the research utilises a lean construction pilot project as a case study. Empirical data was mainly collected through a series of three questionnaire surveys, responded to by project participants who were involved in the lean implementation effort (approximately 30 responses) and three follow-up workshops in which the key individuals from all partner companies participated (15-20 individuals). The author functioned as a facilitator and action researcher, responsible for the design and analysis of the surveys and for planning and facilitating the workshops. Document studies and interviews of 12 project participants were also conducted in order to increase the richness of the case study data. The empirical results show that many of the lean related measures identified in the literature review have been utilised, either implicitly or explicitly, in the pilot project. These measures have mostly focused on increasing the cooperation among project actors, for which reason the pilot project is very similar to a partnering project. Much work remains in order to obtain a full-fledged lean construction approach. The pilot project, however, has the potential to serve as a well-built starting point for long-term continuous improvements and development of lean construction in future projects.

1. INTRODUCTION

Lean thinking, with its roots in the Toyota manufacturing system, has been adopted from manufacturing sectors to the construction industry (i.e. lean construction) as a means to improve productivity and project performance (Egan, 1998, Jorgensen and Emmitt, 2008). The adoption of innovative management practices, such as lean thinking, from a manufacturing context to construction is, however, not problem free (Bresnen and Marshall, 2001, Riley and Clare-Brown, 2001, Bresnen *et al.*, 2005, Mao and Zhang, 2008). Some lean production measures may not be equally applicable in construction, for which reason lean construction has to be developed and modified (Mao and Zhang, 2008). In order to learn more about what measures work or not in a construction context, case studies of different approaches to lean construction can add to our knowledge.

The lean construction field has been criticised for being built on somewhat weak theoretical foundation, since many publications refer to management books instead of rigorous research efforts in peer-reviewed journals (Green, 1999, Jorgensen and Emmitt, 2008). Furthermore, many proponents of lean construction have an overriding positive bias, ignoring the extensive critical literature on lean manufacturing (Green, 1999, Jorgensen and Emmitt, 2008). Recently, however, there have been fruitful attempts to look into also the negative aspects of lean construction (Green, 2002, Green and May, 2005, Fearn and Fowler, 2006, Jorgensen and Emmitt, 2008). It is important that any research effort is based on such unbiased and critical stance, in which earlier experiences are utilised but nevertheless open for questioning. This paper addresses the abovementioned weaknesses of the lean construction field by adopting a critical and

unbiased theoretical stance when reporting the findings of a case study. The purpose of this paper is to increase the understanding of how various measures of lean thinking can be implemented in a construction project and how these measures work.

2. STATE-OF-THE-ART REVIEW

A distinctive feature of lean construction literature is the lack of commonly used definitions (Jorgensen and Emmitt, 2008). The same is, however, true also for other innovative management practices, like partnering and alliances (Bresnen and Marshall, 2001, Nyström, 2005). In the latter cases some researchers argue that the definitions and understanding of those concepts are best developed by investigating their core elements (Nyström, 2005, Yeung *et al.*, 2007). Although developing a definition of lean construction is outside the scope of this paper it has a similar approach, i.e. understanding lean construction by investigating its core elements. This literature review has identified six core elements of lean construction and how they can be achieved through specific measures, see section 2.1. By utilising different specific measures lean construction can be implemented in different ways. In section 2.2 different types of lean construction implementation efforts are discussed and a frame of reference is developed.

2.1 The core elements of lean construction

Waste reduction

Perhaps the most obvious and important element of lean is waste reduction (Green, 1999, Jorgensen and Emmitt, 2008, Mao and Zhang, 2008), which can be facilitated through the implementation of several different measures. A central aspect of waste reduction is *housekeeping*, that is, keeping the construction site well organised, clean and tidy (Ballard *et al.*, 2003, Salem *et al.*, 2006, Tam *et al.*, 2006). Workers should therefore be encouraged to clean the job site once an activity has been completed (Salem *et al.*, 2006).

A related aspect is efficient transportation and stockholding of construction material, often referred to as *Just-In-Time* (JIT) delivery, which is a central part of waste reduction in lean construction (Green and May, 2005, Fearne and Fowler, 2006, Salem *et al.*, 2006, Jorgensen and Emmitt, 2008, Mao and Zhang, 2008). JIT is based on the notion that inventories are not valuable and should be regarded as waste (Akintoye, 1995, Salem *et al.*, 2006). Through JIT, contractors strive to receive smaller batches of material to the site when they need it in order to reduce stockholding and double-handling of material (Fearne and Fowler, 2006, Mao and Zhang, 2008).

Another important waste reducing measure is information technology (Ballard *et al.*, 2003, Green and May, 2005). *Joint IT-tools* in form of 3D-modelling allow detection and correction of most errors prior to production (Ballard *et al.*, 2003). Research has found that joint IT-tools, enhancing integration among project actors and their tasks, increase the chance for cost and schedule success (O'Connor and Yang, 2004, Yang, 2007).

A fourth central aspect is off-site manufacturing of components and units, i.e. *pre-fabrication* (Green and May, 2005). Pre-fabrication has many advantages similar to lean production in manufacturing industries, such as reducing material waste, shortening construction duration, improving work environment, etc.

Process focus in production planning and control

Process focus is central in lean production but a bit more complicated and problematic in the project-based environment of lean construction. This literature review has, however, identified three measures that can be adopted in construction projects in order to enhance focus on production processes and time schedule.

The *Last Planner* (LP) system is a key measure, enhancing efficient production planning and control (Wright, 2000, Ballard *et al.*, 2003, Green and May, 2005, Salem *et al.*, 2006, Winch, 2006, Jorgensen and Emmitt, 2008). Last planners prepares weekly work plans to control the work flow and if assignments are not completed on time they determine root causes and develop action plans to prevent future problem occurrences.

Another important aspect is autonomation, which is the notion that each individual takes immediate action regarding their own work (i.e. *self-control*) to prevent defects at the source so that they do not flow through the process (Ballard *et al.*, 2003, Green and May, 2005, Salem *et al.*, 2006). This quality aspect should be adopted in all activities during the whole buying process (Salem *et al.*, 2006). Traditionally, self-control of construction work is not performed satisfactory. It requires commitment on behalf of the contractors' staff since they are used to be controlled by the client side. Nor design consultants perform self-control satisfactory due to lack of time (Andi and Minato, 2003). Empowering all types of co-workers to control their own work is therefore decisive (Ballard *et al.*, 2003).

A third measure that enhances the focus on the schedule and production plans is to establish project *milestones* (Salem *et al.*, 2006). By clarifying the importance of production milestones and making them explicit for everyone the project participants feel more involved in the execution of the project (Salem *et al.*, 2006).

End customer focus

End customer focus is vital in lean construction (Wright, 2000, Winch, 2006, Jorgensen and Emmitt, 2008, Mao and Zhang, 2008). Components and processes that do not add value for the end customer can be regarded as waste which should be minimised. Customer satisfaction is dependent not only on the end product but also on the process during which it is created, i.e. service quality (Maloney, 2002, Forsythe, 2007). Customer satisfaction is therefore highly affected by most activities and choices made during the buying process (Forsythe, 2007).

Increased end customer focus requires the adoption of lean principles already in the design stage (Wright, 2000). Early involvement of contractors and integration of design and construction work in *concurrent engineering* is therefore important in lean construction (Gil *et al.*, 2004, Green and May, 2005, Winch, 2006, Mao and Zhang, 2008). Concurrent engineering increases the contractors' understanding of customers' demands and facilitates an efficient construction process through increased buildability. It also improves teamwork and joint problem-solving, resulting in significant time savings (Wright, 2000).

Relying on competitive bidding is not an efficient way to procure customized products in lean construction (Elfving *et al.*, 2005, Green and May, 2005). Hence, a *limited bid invitation* of trustworthy and competent contractors should be coupled with a bid evaluation based on *soft parameters* so that partners capable of satisfying the customer's requirements are selected (Maloney, 2002, Eriksson and Nilsson, 2008).

Continuous improvements

Lean construction involves a continuous struggle to reduce waste and increase the efficiency of the construction process over time. A long-term perspective on continuous improvements is therefore important (Green and May, 2005, Pheng and Fang, 2005, Salem *et al.*, 2006).

An important measure that enhances continuous improvements is *long-term contracts* (e.g. framework agreements), since they can reduce the traditional short-term focus on cost reduction (Green and May, 2005) and instead promote lasting improvements. By working together over a series of projects the actors can more easily transfer knowledge

and experiences from one project to another. Traditionally, such knowledge transfer is limited in construction due to short-term relationships.

Additionally, staff and workers should be given the opportunity to initiate ideas and solutions to improve and solve problems encountered on site (Ballard *et al.*, 2003, Pheng and Fang, 2005). This is often not the case. On the contrary, site workers often believe that they do not have sufficient opportunity to state their opinions (Riley and Clare-Brown, 2001). In order to address this weakness it is important that *suggestions from workers* are taken seriously in order to enhance their commitment for suggesting improvements (Ballard *et al.*, 2003).

Knowledge sharing and joint learning is crucial in order to enhance continuous improvements in lean construction (Green and May, 2005). This can be facilitated by quality circles, also referred to as "*special interest groups*" (SIGs), giving project staff opportunities to participate in the process improvement (Salem *et al.*, 2006). These teams meet periodically to exchange knowledge and experience in order to jointly propose ideas for the most visible problems in the workplace (Salem *et al.*, 2006).

The project participants' understanding of the lean concept and its pre-requisites must be improved in order to increase their will and skill to contribute to continuous improvements. Hence, relevant *training* is a precondition for effective lean implementation (Green and May, 2005).

Cooperative relationships

Cooperative relationships (e.g. partnering) is important in lean construction (Green, 1999, Green and May, 2005, Jorgensen and Emmitt, 2008) in order to integrate the different actors' competences and efforts in joint problem-solving. The higher the complexity, customisation, uncertainty and time pressure, the more cooperation is required (Eriksson, 2008).

Since traditional procurement and governance forms are often criticised for producing waste, long lead times, and adversarial relationships (Miller *et al.*, 2002, Elfving *et al.*, 2005) they need to be changed into a lean contracting approach (Toolanen, 2008). Central in this aspect is good communication among different project actors, which improves integration and coordination (Elfving *et al.*, 2005, Pheng and Fang, 2005). This is enhanced by utilising various *collaborative tools* (e.g. joint objectives, joint project office, facilitator, workshops and teambuilding) throughout the project duration (Green and May, 2005, Eriksson and Nilsson, 2008).

Since subcontracting account for much of the project value and project activities are totally interrelated, the relationships between different contractors demands much cooperation and transparency (Shammas-Toma *et al.*, 1998). Hence, a harmonization between different types of contractors is a prerequisite for lean construction (Miller *et al.*, 2002). Accordingly, it is important to involve key subcontractors in a *broad partnering team*, allowing them to contribute to the joint objectives (Eriksson *et al.*, 2007).

In terms of compensation, it is important that all parties will benefit from improved performance resulting from the implementation of lean construction (Green and May, 2005). Hence, incentive based compensation including *gain share/pain share* arrangements, which increases the actors' commitment for achieving the joint objectives, is important in cooperative relationships (Eriksson and Pesämaa, 2007).

Systems perspective

It is important to adopt a systems perspective in order to increase the overall efficiency of lean construction projects and avoid sub-optimizations (Green and May, 2005, Pheng and Fang, 2005, Winch, 2006, Jorgensen and Emmitt, 2008). A reliable workflow

(throughput) in the system as a whole is more critical than individual activity speed or cost (Miller *et al.*, 2002, Elfvig *et al.*, 2005, Winch, 2006).

An important aspect of systems perspective is to consider the whole buying process and make *coherent procurement decisions* (Eriksson and Pesämaa, 2007). It is, for example, not enough to rearrange only a specific part, such as compensation forms, when trying to achieve collaborative relationships. Instead all procurement related choices must be coherent and support or complement each other.

Furthermore, by minimising the number of steps, parts and linkages the construction process is simplified (Pheng and Fang, 2005). Lean can not be achieved by considering construction, design, and operation in isolation, for which reason a rearrangement of the contractual boundaries between the parties is required (Green and May, 2005).

Accordingly, dividing a project into many small pieces, involving many different actors during short periods of time, should be avoided. In order to enhance coordination and integration *large scope contracts* are therefore desirable.

A systems perspective is also central in terms of the end result of the process, i.e. the product (Green and May, 2005). Hence, from an end customer perspective it is important with *properly balanced objectives* (e.g. cost, schedule, and quality). In order to obtain the demanded balance each project objective should receive suitable amount of attention, relative to its importance, during the whole project duration.

2.2 Different lean model types: development of a frame of reference

Green and May (2005) identified three stages of lean construction implementation, with an increasing degree of maturity and sophistication. This section discusses how the aforementioned measures and core elements of lean construction are related to the three different lean model types.

Lean Model 1

Green and May (2005) mean that Lean Model 1 focuses on waste elimination from a technical and operational perspective (i.e. a focus on the "hardware"). However, the responsibilities and focus are tied to managers rather than individual workers (i.e. a top-down perspective). Essential parts of this model are: elimination of needless movements, cut out unnecessary costs, optimize work flow, and assure that all organizations will benefit from improved performance (Green and May, 2005). Accordingly, the measures that are closest related to Lean Model 1 are: *housekeeping, just in time deliveries, milestones, and gain share/pain share compensation* (Table 1).

Lean Model 2

Lean Model 2 has a distinct focus on eliminating adversarial relationships and enhancing cooperative relationships and team work (Green and May, 2005). In this aspect cooperation, long-term framework agreements, partnering workshops, and partnering facilitator are essential parts of this model (Green and May, 2005). Accordingly, the measures that are closest related to Lean Model 2 are: *limited bid invitation, soft parameters in bid evaluation, long-term contracts, collaborative tools, and broad partnering team*.

Lean Model 3

Model 3 is the most sophisticated, involving a structural change in which the way projects are delivered (Green and May, 2005). Its essential parts are information technology, high extent of pre-fabrication, Last planner, stronger emphasis on individuals and bottom-up activities, a complete rethink of design and construction, some degree of shelter from

competitive forces, long-term contracts, training at all staff levels, and a systems perspective of both processes and the product (Green and May, 2005). Accordingly, the measures that are closest related to Lean Model 3 are *joint IT tools, pre-fabrication, Last planner, self-control, concurrent engineering, limited bid invitation, soft parameters in bid evaluation, long-term contracts, special interest groups, training, suggestions from workers, coherent procurement decisions, large scale contracts, and properly balanced objectives*.

2.3 Presentation of the frame of reference

The frame of reference (Table 1) illustrates how the six core elements and their specific measures are related to different models of lean construction.

Table 1. Frame of reference.

Core elements	Measures	Lean model type
Waste reduction	Housekeeping	Model 1
	Just in time deliveries	Model 1
	Joint IT-tools	Model 3
	Pre-fabrication	Model 3
Process focus	Last Planner	Model 3
	Self-control	Model 3
	Milestones	Model 1
End customer focus	Concurrent engineering	Model 3
	Limited bid invitation	Model 2+3
	Soft parameters in bid evaluation	Model 2+3
Continuous improvements	Long-term contracts	Model 2+3
	Special interest groups	Model 3
	Training	Model 3
	Suggestions from workers	Model 3
Cooperative relationships	Collaborative tools	Model 2
	Broad partnering team	Model 2
	Gain share/pain share	Model 1
System perspective	Coherent procurement decisions	Model 3
	Large scope contracts	Model 3
	Properly balanced objectives	Model 3

The measures related to Model 1 are of basic and operational nature and can be adopted in any efficient and professionally managed construction project. Hence, Model 1 is perhaps the default and normal state in properly managed projects and the lean implementation efforts described in the research literature aim to go beyond this normal situation and achieve Model 2 or 3. In line with this argument Pheng and Fang (2005) mean that lean construction does not foremost involve new principles of management techniques; rather they are a combination of existing principles. Only when striving to achieve the second and foremost the third model of lean construction, more radically new and innovative measures are required.

3. RESEARCH PROJECT

3.1 Project description and objectives

The empirical part of the research involved a case study that investigated a lean construction pilot project. The client Scania is a manufacturer of heavy vehicles (i.e.

trucks and buses). Scania is a professional client, procuring construction work recurrently, often in form of industrial production facilities. However, the actual construction management role is mostly outsourced to their subsidiary company DynaMate, which normally procures and governs construction projects in a traditional manner. Since Scania has worked with lean production successfully over many years they have now together with DynaMate decided to initiate the implementation of lean principles also in the construction activities. The main idea behind this new approach is to utilise radically different and innovative ways to govern the construction process with the aim of reducing waste and decreasing costs and lead times from investment decision to finished project.

The case study project is DynaMate's first effort to implement lean in their construction management work. This particular project was chosen as a pilot project mostly due to its aggressive schedule. During the programming stage DynaMate realised that they would never be able to deliver the project on time with traditional procurement and governance forms. Additionally, the project size of approximately €7M was considered appropriate for a first effort. Third, both parties were ready and felt that the time was right to try lean construction. Hence, this particular project was judged to be suitable for a pilot effort in order to implement lean in a situation requiring change. Four contractors responsible for construction, electricity, ventilation, and plumbing were involved in the lean implementation.

Although the decision to implement lean was taken during the design stage it kept to the construction stage until it was implemented in larger scale. Right from the start Scania and DynaMate decided to focus the lean approach on increasing the cooperation among different project actors through partnering related procurement procedures. They judged that much waste can be related to adversarial relationships and that increased cooperation is a suitable start in enhancing a more efficient construction project. The author of this paper was engaged by DynaMate and Scania as a facilitator responsible for managing the partnering process. It was jointly decided that the facilitator was responsible for designing a partnering survey that would be responded by the project participants three times during the project duration. Furthermore, the facilitator analysed the survey results and based on the findings designed and managed three subsequent workshops during which lean and collaboration aspects of the project were discussed.

3.2 Research methodology

The case study data collection was based on the aforesaid series of three survey investigations and subsequent workshops. The three surveys were responded by 26, 29 and 32 project participants. The three workshops were half day events attended by 15-20 participants. Additionally, twelve project participants were interviewed in the end of the project. Each interview lasted between 1 and 3 hours, summing up to a total of approximately 20 hours of interviews. The interviewees included the owner of the building, the client's representative, the client's procurement manager, the project leader from DynaMate and two of his superiors, the architect, the project leaders from the four contractor partners, and the contract manager from one of the contractor partners. The interviews were semi-structured and based on the developed frame of reference. The respondents were asked if and how various measures were utilised in the pilot project and also if and why they were satisfied/dissatisfied with the way each measure had worked. Furthermore, approximately 20 hours of document studies were conducted, focusing on documents regarding joint objectives, contracts, bonus arrangements and compensation forms.

4. RESEARCH RESULTS

4.1 Presentation of case study data

Waste reduction

Housekeeping was considered well executed although it was not affected much by lean thinking. The site was very well planned and organised resulting in efficient handling and stockholding of material. The cleaning of the site was somewhat improved due to the lean approach. Workers were encouraged to clean up after themselves and the collaborative climate even resulted in that workers from different companies helped each other to clean.

Just in time deliveries was not explicitly focused in the project. Some respondents argued that the project was too small for such an effort. In spite of this the material deliveries functioned well. Space was a scarce resource at the site so the material could not be ordered too far in advance. The good timing of the deliveries was therefore important although it was not affected by lean thinking. Due to the construction boom in Sweden some material had very long delivery times, but due to the early involvement of the contractors they had plenty of time to plan purchases. The respondents have different opinions regarding the suitability of JIT in construction. Some argue that it has great future potential, although it requires significant changes, while some mean that it is overrated, increasing the risk for delayed material.

The degree to which *joint IT tools* was utilised was not affected by lean thinking. The actors implemented a joint IT database for exchange of documents (e.g. drawings and protocols). This implementation was decided beforehand and not as a result of lean thinking. The IT tool was easy to use and functioned satisfactory for which reason it will be utilised also in subsequent projects. Some respondents consider 3D modelling to be a useful tool in future projects but they did not miss it in the pilot project.

Pre-fabrication was not affected by lean thinking. Some respondents argued that extensive pre-fabrication is more difficult in complex industrial facilities than in standardised projects such as apartment buildings. Nevertheless, much of the reinforcements and some parts of the concrete framework were pre-fabricated and the participants were satisfied with the degree of pre-fabrication in the project.

Process focus in production planning and control

Last Planner was not utilised. In fact, only one respondent was aware of the Last planner concept and considered that it would be interesting to try it out once to see how it worked.

Self-control was affected to some degree of lean thinking. The only explicit effort was that self-control was always brought up on the agenda at the coordination meetings, which were held every other week. This resulted in increased commitment for the execution of self-control since the contractors knew that they would have to present their actions to the group regularly. The quality of self-control varied among the different actors, due to internal differences. It functioned better among contractors than among consultants. Especially the electrical contractor performed self-control very well. An important reason to this is that the electrical workers had an explicit responsibility for always controlling their own work, a task for which they received a salary raise.

One *milestone* was established as a result of lean thinking. It had a high symbolic value since it was connected to the delivery of a very important piece of machinery which had to be installed directly upon delivery. The four contractors would receive a shared bonus of €50 000 if the construction work was finished to such a degree that the installation of the machine could start the day it was delivered. The respondents agreed that this milestone increased the commitment for the schedule and contractors who were late made a significant effort to increase their speed and finish their part of the package as

promised. In fact, many of the respondents would like to have more frequent milestones to avoid heavy time pressure in the end. Bonus connected to milestones can also be in the form of teambuilding events, in order to transfer rewards from the company level to the individuals who are actually performing the work.

End customer focus

Concurrent engineering was a central part of the lean approach, chiefly in order to save time since the deadline of the project was very important for the end customer. Both the client representative and the contractors were involved in the design stage to a larger extent than normal. This resulted in faster decisions, improved knowledge about the customer and increased buildability. The contractors contributed with suggestions of improved technical solutions, cheaper material, and improved site logistics. All respondents agreed that concurrent engineering is important and that it functioned well in the pilot project, although it can be further improved.

Limited bid invitation was taken one step further since DynaMate negotiated directly with all four contractors. Competitive tendering is traditionally used for all contractors but was abandoned altogether due to the lean approach of the project. All contractors were obviously very happy with this arrangement and argued that it decreases their focus on short-term profits and increases their focus on satisfying the customer.

Due to the direct negotiation approach DynaMate relied solely on *soft parameters* when selecting contractors. All four contractors had worked widely for the client in the past so they were all well known. Two of them are actually subsidiary companies to DynaMate and they were chosen partly from a strategic/political perspective since their participation in the pilot project was sought after. The construction and electrical contractors were chosen due to their high competence and experience of partnering projects.

Continuous improvements

Scania do not have *long-term contracts* regarding construction project work with the four contractors. However, all contractors have framework agreements regarding more continuous work involving construction and installation related maintenance and services. Hence, the contractors have deep knowledge about the customer's whole business and also a long-term commitment to deliver satisfying products. The respondents argued that these framework agreements facilitated continuous improvements in the project although they were related to other parts of the business.

Special interest groups were not utilised. Many respondents, however, considered SIGs to be a good idea for increasing commitment and enhancing knowledge transfer among different trades. However, they raised the question if such SIGs can be beneficial and cover their costs in a single project setting. The client probably has to adopt a long-term perspective, reaping the benefits of SIGs in the long run over a series of projects.

The amount of *training* was not affected much by lean thinking. During the second workshop many respondents expressed a demand for training and education related to partnering and lean construction. As a result of this demand the action researcher held a short lecture about partnering and lean construction during the final workshop. It was also agreed that in the future an introductory lecture and discussion about these concepts would be held in the initial stage of the project and that similar lectures could be held continuously as parts of the workshops.

In order to facilitate *suggestions from workers* a 'suggestions box' was established. Workers were encouraged to hand in formal and written improvement suggestions to DynaMate's project leader. Scania had earmarked an amount of €10 000 for rewarding such suggestions (€500 per suggestion). In spite of good intentions this 'suggestions box' did not work satisfactory. The handling and follow-up of the suggestions were not

performed in a structured and continuous way due to the project leader's overload of work. In order to encourage the workers to hand in such suggestions they have to be handled in a fast and efficient way so that the workers see what happens with their suggestions. During the final workshop it was suggested that in future projects the suggestion box should be a permanent part of the agenda of construction meetings so that suggested improvements are dealt with shortly after submission.

Cooperative relationships

Several *collaborative tools* were explicitly utilised in the project. Joint objectives were formulated first by Scania and DynaMate and then discussed and approved by the contractors. Two joint project offices were established: one on the site for the contractors and one client office near the site for the client representative, the project leader, and some additional staff. The author of this paper served as a facilitator responsible for the execution of three partnering surveys and three subsequent follow-up workshops. One teambuilding event was held during the second half of the project. It was attended by approximately forty participants. These collaborative tools were considered very important although there was room for improvements. The fact that the project was not initiated as a lean project resulted in that the collaborative tools were not utilised in the very beginning which is an important stage for establishing a collaborative climate. During the final workshop it was suggested that in future projects the establishment of joint objectives should be based on teamwork efforts during a kick-off workshop instead of being initiated solely by the client side.

A *broad partnering team* was established, including the client Scania, the construction management company DynaMate, and the four contractor companies. Instead of letting the construction contractor serve as main contractor with the three other companies as subcontractors DynaMate chose to establish equivalent contracts for all contractors, making them work side by side as equals. The respondents argued that this solution was very important for promoting cooperation and teamwork. They were, however, of the opinion that also important consultants (e.g. the architect and construction engineer) should be involved in the partnering team.

The compensation form was based on open books and a *gain share/pain share* arrangement in which the parties' shares were relative to their part of the total project value. Hence, the incentives were based on group performance instead of performance within the individual contracts. The respondents stated that this arrangement was a central measure, facilitating cooperation. No actor had anything to gain by improving his own performance on the expense of someone else's.

Systems perspective

Coherent procurement procedures were implemented, establishing an appropriate foundation for increased cooperation. The key contractors were procured early through direct negotiation and involved in concurrent engineering. The compensation form was based on group incentives and the broad partnering team used several collaborative tools. The respondents agreed that these procurement procedures were suitable and a central aspect of the collaborative lean concept that was sought after.

The four partner contractors had *large scope contracts*. The electricity, ventilation, and plumbing contracts even included design services, since these companies had such competences internally. The architect and construction engineer were, however, contracted by DynaMate. An exclusion of the large scope approach was that the mechanical supplier and contractor were procured and managed directly by Scania and therefore outside the scope of the project managed by DynaMate. The interface between the mechanical delivery and the construction project did not function perfectly smooth in all instances so this division of responsibilities was a drawback from a lean perspective.

The respondents stated that the project had *properly balanced objectives*. Quality and function is often most central for Scania. In this project the time schedule was also highly prioritised and the cost was ranked as third objective. The actions taken during the project duration were also in line with this ranking. The actors did never choose alternatives that saved costs on the expense of quality and time. The ranking of these objectives was not, however, explicitly discussed. In order to enhance clarity and mutual understanding the respondents thought that it would have been useful to discuss the balance of the objectives in the beginning of the project.

4.2 Identification of lean model type in pilot project

Table 2 illustrates the extent to which different measures were used: measures that were explicitly used to a large extent are marked in bold, measures that were implicitly used to a large extent are marked in bold/ italic, measures that were explicitly used to some extent are marked in bold/ brackets, measures that were implicitly used to some extent are marked in bold/italics/brackets, and measures that were not used are in normal text.

Table 2. Lean measures utilised in the pilot project.

Core elements	Measures	Lean model type
Waste reduction	Housekeeping	Model 1
	<i>(Just in time deliveries)</i>	<i>(Model 1)</i>
	<i>(Joint IT-tools)</i>	<i>(Model 3)</i>
	<i>(Pre-fabrication)</i>	<i>(Model 3)</i>
Process focus	Last Planner	Model 3
	(Self-control)	(Model 3)
	Milestones	Model 1
End customer focus	Concurrent engineering	Model 3
	Limited bid invitation	Model 2 + 3
	Soft parameters in bid evaluation	Model 2 + 3
Continuous improvements	Long-term contracts	Model 2 + 3
	Special interest groups	Model 3
	(Training)	(Model 3)
	(Suggestions from workers)	(Model 3)
Cooperative relationships	Collaborative tools	Model 2
	Broad partnering team	Model 2
	Gain share/pain share	Model 1
System perspective	Coherent procurement decisions	Model 3
	(Large scope contracts)	(Model 3)
	Properly balanced objectives	Model 3

As illustrated in Table 2, all four measures of Model 1 were utilised in the project to a satisfactory degree. Milestones and the gain share/pain share arrangement were explicit strategies, whereas housekeeping and just-in-time deliveries were used more implicitly. This finding is in line with the argument put forward in Section 2.2 that Lean Model 1 is the default that is performed in most efficient construction projects, although they do not involve explicit lean thinking. The table also shows that the measures connected to Model 2 were explicitly utilised to a very high degree. Model 2 focuses on reducing waste and increasing efficiency foremost by establishing cooperative relationships among the project actors, which was the explicit aim of the pilot project. Also the measures connected to Model 3 were used to some extent, both implicitly and explicitly, but there is, however, still a long way to go in order to obtain this full-fledged model of lean construction.

5. CONCLUSIONS

The purpose of this paper was to increase understanding of how various measures of lean thinking can be implemented and how they work in a construction project. A frame of reference, identifying the core elements of lean construction and how their specific measures are related to three different models of lean construction, was developed. It served as a basis for data collection in a case study of a lean construction pilot project, in which the author of this paper served as an action researcher. The case study findings show that the pilot project utilised a broad range of measures that resulted in a lean implementation comparable to the intermediate model, focusing on cooperation. Some measures related to the third model were also utilised, although there is a long way to go in order to reach this more sophisticated lean approach. Hence, one can argue that the pilot project had more similarities to partnering than to a full fledged lean project. Increased cooperation is, however, a prerequisite for a further development of the lean concept. The project was successfully executed; both within budget and schedule, much due to the specific measures that were implemented. The participants, both at the client and at the supply side, are satisfied with the project execution and its results. This pilot project will serve as a well-built starting point of a long-term continuous development of the lean construction concept within the business of Scania and DynaMate.

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ANALYSIS OF EXTERNAL STAKEHOLDER INFLUENCE ON CONSTRUCTION PROJECTS

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ABSTRACT

Construction projects inevitably cause varying degrees of deterioration and change at the local level. Representatives of these local interests can be referred to as the project's external stakeholders, meaning that they are affected by the project in a significant way, but not directly involved in project execution. The aim of the research is to enhance the knowledge concerning the influence of external stakeholders for construction projects. A case study was undertaken on how varying views and opinions of external stakeholders affect the implementation of a construction project. The basis for the results was five construction projects of which all have had to manage various needs and demands from external stakeholders. The study showed that the outcome of an external stakeholder management process mainly depended upon how well the project managers portrayed the benefits and the negative consequences brought on by the construction project. The initial research is complete insofar as it states the need to analyse the impact of stakeholders on construction projects. However, further studies are needed to investigate how a sufficient stakeholder management process is to be conducted. The result of an insufficient stakeholder management process is that the project manager is not prepared for the possible conflicts that might arise, and thus had no plan of how to resolve or handle them. Thus, an analysis of external stakeholder influence should be seen as a relevant area of expertise that currently is somewhat neglected in construction project management.

1. INTRODUCTION

The planning and construction of a facility can affect a variety of interests. Various positive effects it can have are those of creating better communications, better housing, and a higher standard of living. However, construction projects inevitably bring varying degrees of deterioration and change at the local level, not least at the construction site. Representatives of these interests are referred to as the project's stakeholders. A stakeholder is any group or individual who can affect, or is affected by, the achievement of an organisation's purpose (Freeman 1984). Stakeholders can be divided into internal and external ones (Gibson 2000), external stakeholders being those affected by the project in a significant way, but not directly involved in execution of the project (such as neighbours, the community, the general public, as well as trade and industry).

The aim of the research presented here is to determine the various theoretical and practical factors that need to be addressed by a construction project manager when analysing the influences of stakeholders in general, external stakeholders in particular.

2. STATE-OF-THE-ART REVIEW

2.1 Who are the stakeholders?

Freeman's (1984) definition is a development of the first stakeholder definition, which he had traced back to a memo from Stanford Research Institute in 1963. The memo states that stakeholders are those groups without whose support the organisation would cease to exist. In conclusion, Freeman (1984) states that the stakeholder approach is about groups and individuals who can affect the organisation, and is about managerial behaviour taken in response to those groups and individuals.

Phillips (2003) adds that stakeholder theory should be concerned with who has input in decision making as well as who benefits from the outcomes of such decision. Thus, for construction projects it is the responsibility of the project manager to respond to the needs and expectations addressed by the project's stakeholders and to be concerned with how the decision making process is carried out.

There has been debate on how to define stakeholders. Freeman's (1984) definition, those that affect or are affected, is viewed as being broad, because it merits all to be stakeholders. If everyone is a stakeholder of everyone else there is little value-added in the use of the stakeholder concept (Phillips 2003, Sternberg 1997, and Mitchell *et al.* 1997). The view expressed in the Stanford definition – those without whose support the organisation would cease to exist – is regarded as narrow since relevant groups would be excluded. Post *et al* (2002) state that the fundamental idea is for stakeholders to have a stake in the organisation, and they define the stakeholders as those that contribute voluntarily or involuntarily to the organisations wealth creating capacity and activities: they are, therefore, its potential beneficiaries and/or risk bearers. Donaldson and Preston (1995) identify stakeholders through the potential harms and benefits that they experience or anticipate experiencing as a result of the organisation's actions or inactions.

Broad and narrow views can also be seen in the definitions of project stakeholders. PMI (2004) has basically adopted the Freeman (1984) definition and states that project stakeholders are individuals and organisations that are actively involved in the project or whose interests may be affected as a result of project execution or project completion. Thus, PMI (2004) suffers the same criticism as Freeman (1984) that all groups or individuals in some sense can be defined as stakeholders. McElroy and Mills (2000) adopt a narrower view much in line with Post *et al* (2002). Project stakeholders are a person or group of people who have a vested interest in the success of a project and the environment within which the project operates. The term 'vested interest' can here be viewed as equal to the key term 'stake'. From Post *et al* (2002), and Donaldson and Preston (1995), stake could be defined as actual or perceived benefits or risks/harms from organisational activities.

Mitchell *et al* (1997) further address the problem of defining "stake". Even though influencers do not have legitimate claims or perhaps any claims at all, they do have power over an organisation or project. Power and legitimacy are different and sometimes overlapping dimensions, so that theory of stakeholder identification must accommodate these differences. Thus, Mitchell *et al* (1997) define power and legitimacy as core attributes in a comprehensive stakeholder identification model and add a dynamic attribute of urgency to complete that model. Classes of stakeholders can be identified by their possession of one, two or all three of the following attributes: the stakeholder's power to influence; the legitimacy of stakeholder relationships; and the urgency of the stakeholder's claim (Mitchell *et al.* 1997). Based on the discussion above a project stakeholder can be defined as:

"a person or group of people who has a vested interest in the success of a project and the environment within which the project operates. Vested interest is defined as having possession of one or more of the stakeholder attributes of power, legitimacy or urgency. There are essentially two categories of stakeholder: internal stakeholders, who are those actively involved in project execution; and external stakeholders, who are those affected by the project." (Olander, 2007)

2.3 Impact, probability and position

Johnson and Scholes (1999) state that it is not enough simply to identify stakeholders. Managers need to assess each stakeholder's interest to express its expectations on project decisions and if there is the power to follow it through. Johnson and Scholes

(1999) propose a stakeholder mapping technique, the power/interest matrix, for this evaluation. In the power/interest matrix, project stakeholders can be categorised depending on their power towards the project and their level of interest (Olander and Landin 2005, Winch and Bonke 2002, and Newcombe 2003). Olander and Landin (2005) addressed the need to grade the two parameters, power and interest. However, it is hard to assess power on a scale, rather one assesses the impact each stakeholder has on the project. The interest level is in the same sense an assessment of the probability that a stakeholder will have an impact on project decisions. Thus, the assessment can alternatively be made by using the probability-impact analysis of risk assessment, see for example Ward and Chapman (2003).

Evaluating the total impact of stakeholders in relation to the project requires more than identifying the impact level and probability of impact. Project managers need to assess the stakeholder attributes and classes (Mitchell *et al.* 1997), and their position towards the project (Cleland 1986, and Winch and Bonke 2002) – are they opponents or proponents? The concepts of impact, probability and position need to be valued together with stakeholder attributes to form a tool for comprehensive stakeholder analysis.

2.4 Stakeholder impact index

There are methods for analysing and determining the claims of stakeholders and their possible effect upon project decisions. Olander (2007) presents a conceptual model, the stakeholder impact index, which comprises three different parts.

The first part is about evaluating the type of stakeholders involved in the project. This part of the model is based on the work of Mitchell *et al.* (1997), where it is suggested that stakeholders can be divided into different groups according to the attributes they possess. The attributes are power, legitimacy and urgency. The power of stakeholders may arise from their ability to mobilise social and political forces, as well as from their ability to withdraw resources from the project organisation (Post *et al.* 2002). Legitimacy can be defined in terms of stakeholders who bear some sort of risk in relation to the organisation, be it beneficial or harmful. The dynamic character of stakeholder influence is covered by the term urgency, which is defined as the degree to which claims (or stakes) call for immediate attention. At any given time, some stakeholders will be more important than others (Jawahar and McLaughlin 2001). Concerns and priorities change over time, with new classes and configurations of stakeholders appearing in response to changing circumstances.

The second part of the stakeholder impact index as suggested by Olander (2007) is based on the work of Bourne and Walker (2005), who present the vested interest-impact index (ViII). The parameters vested interest levels (*v*) and influence impact levels (*i*) are qualitatively assessed on a scale from 1 to 5. The vested interest index is then calculated as $ViII = \sqrt{(v*i/25)}$. The index scales the level of the impact and interest of project stakeholders. This model could be compared with the power/interest matrix (Johnson and Scholes 1995), where the key questions are:

- how interested is each stakeholder group in impressing its expectations upon project decisions?
- do they mean to do so?
- do they have the power to do so?

With the power/interest matrix (Johnson and Scholes 1999) it is possible to interpret how the influence of various stakeholders has developed over the course of project implementation (Winch and Bonke 2002, Newcombe 2003 and Olander and Landin 2005). The model does, however, not scale the levels of power and interest; rather it evaluates different stakeholder groups depending upon whether the level of power or interest is high or low. The vested interest impact index as proposed by Bourne and Walker (2005) does give the opportunity to exercise this option. It can be argued that the vested interest level (*v*) corresponds to the level of interest, which is basically an evaluation of

how likely it is for the individual stakeholder to impress expectations on the project decision-making process. Bourne and Walker (2005) use the level of impact instead of power, which in terms of scaling is a more relevant concept. Power is something that a stakeholder possesses or not, which is evaluated in grades of high or low within the power/interest matrix.

The last part of the stakeholder impact index is the evaluation of each stakeholder's position towards the project: are they proponents or opponents? Here, Olander (2007) uses the work of McElroy and Mills (2000), where they propose five different levels of stakeholder position towards the project: active opposition, passive opposition, not committed, passive support and active support. The position that each stakeholder has towards the project sets the direction of the impact that each stakeholder has on the project decision-making process.

3. RESEARCH PROJECT

The influence of external stakeholders in facility development and construction projects can be studied from a variety of perspectives. There is a democratic aspect that relates to the citizens' right to influence decisions concerning their local community. There are legal issues in relation to the rules and legislations concerning facility development, which cover the question of how good the legal process is at valuing the importance of different external stakeholder concerns. There is the sustainability aspect of how the development of a new facility affects the present and the future conditions of external stakeholders in terms of economic, ecological, social and cultural considerations. However, the focus of this research is the developer and the project manager from a project management perspective. The activities within project management that cover the influence of external stakeholders can be related to an external stakeholder management process. However, to conduct this process sufficiently, the project manager needs to obtain knowledge about:

- the external stakeholders,
- the nature of their claims,
- their influence on project decisions
- and the effect of project implementation on external stakeholder influence.

The research was conducted as a case study to obtain empirical on how external stakeholder influenced the implementation of a construction project. A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident (Yin 1994).

The purpose of this case study was to examine how the influence of external stakeholders affects a construction project, and how the project managers for the projects had handled this influence. Five projects were examined. The projects were chosen for their different characteristics, i.e. they differ in size, type (civil engineering or housing) and purpose (local, regional or national). The common feature is that all projects, proactively or reactively, have had to consider and commit resources to a process of external stakeholder influence.

Case 1: The construction of a multi-family housing project consisting of about 60 apartments. This project attracted opposition for two reasons primarily. First, the location had intrinsic cultural value that needed to be considered. Secondly, the proposed development differed from its surroundings, which basically consisted of single-family housing. Alternative choices for the development were limited to development of about the same design and size, since the developer was bound to the location by the resources committed in the process acquiring the property to develop.

Case 2: The construction of a multi-family housing project consisting of some 1,200 apartments. The main concern of opponents was not that of the

development in itself, but rather its size and location. The local community would, if this project proceeded, nearly double in size within three years. This would negatively affect the social services in the community, which were already at the limit of their capacity.

Case 3: Expansion of an existing single-track railway into two tracks. The existing railway passes through densely populated areas, which would be faced with the consequence of significantly increased movement. The main argument from opposing stakeholders was that the railway could instead be rebuilt so as to pass along an alternative route, one leading through less populated areas.

Case 4: The construction of a grade-separated intersection for a highway. This is an example of a fairly normal external stakeholder management process. The opposition had no concerns about the project itself, since they agreed with the developer that the increased traffic safety that the project would bring about was necessary. The concerns of opposing stakeholders in the community had more to do with the question of where the intersection should best be placed in order to minimise the negative impact it would have on living conditions, local trade and industry, and recreation.

Case 5: A major civil engineering project involving the building of an 8km long railway tunnel under certain highly-populated areas. The size of this project might indicate that there would be problems in dealing with opposing stakeholders. However, there was little or no opposition to the project, even in the most affected areas. One explanation for this is that there was a fairly broad consensus about the need for the project, and the benefits of it within the community in which the facility was to be located. This is to be understood in terms of the developer having set in motion from the outset and having maintained a consistent and ambitious external stakeholder management process. Resources committed to communication with stakeholders and to efforts to build trust, along with open communication with stakeholders concerning all negative and positive impacts, could have had the effect of increasing the acceptance from otherwise opposing stakeholders.

The case study began with an examination of public documents and newspaper articles about the projects. The purpose of studying these documents was to obtain relevant background information about the projects in order to plan and structure forthcoming interviews with key stakeholders. A total of 37 persons were interviewed, and they covered a wide range of different functions in the project environment:

4. RESEARCH RESULTS AND INDUSTRIAL IMPACT

4.1 External stakeholder analysis process

The relative importance different external stakeholders possess, and the influence they can inflict on project decisions can be described in terms of the stakeholder attributes as defined by Mitchell *et al.* (1997). Stakeholder attributes are also an integral part of stakeholder impact analysis (Olander 2007). From a purely project perspective, it can be argued that stakeholders possessing the attribute of power are those most relevant to consider in the external stakeholder management process. However, stakeholders who possess attribute of legitimacy are in a sense more important, because they are the risk bearers in the project. Thus, it is important from a moral standpoint, to address the needs of the legitimate stakeholders fully. If not, they may try to achieve a powerbase by themselves or by forming an alliance with more powerful stakeholders. In either case, the project manager loses control over the external stakeholder management process. An external stakeholder analysis is essential for determining the obligations that the developer and project manager have towards the external stakeholders in a project.

The external stakeholder analysis presented in the present research context is of a qualitative nature, which means it can never be better than the input provided by the project manager or by other agencies involved. Before each major decision in a project, a stakeholder analysis should be conducted in to obtain feedback regarding how alternative ways of proceeding will affect the positive input and the negative impact of project stakeholders. Stakeholder impact analysis evaluates how external stakeholders influence project decisions; even so, it is equally important for the project manager to analyse how the project itself influences the needs and concerns of the external stakeholders.

Acknowledging the needs and concerns of the external stakeholder will improve the chances of a communicative stakeholder management process taking place. It is important, however, to define clearly both the goals and the framework of a project and to not promise anything that cannot be fulfilled. A broken promise can quickly tear down the trust that has been built up. Communicative approaches have the shortcoming of being too optimistic in efforts to overcome significant diversities in values and interests. Thus, a communicative external stakeholder management process needs to be conducted in such a way that project goals are respected and that possible trade-offs, in order to obtain agreements, can be realised.

Stakeholders will impact the project differently according to their potential threat or benefit to the implementation of the project. The stakeholder impact index (Olander, 2007) is a means for structuring and analysing information about external stakeholder impact on project decisions. The stakeholder impact will also depend on the needs and concerns of different stakeholders, and the extent to which these can be satisfied without compromising the overall purpose of the construction project.

Acknowledgement of stakeholder needs and concerns will also affect the nature of the external stakeholder impact. The projects that were studied also indicate that external stakeholder analysis to be a dynamic process. The set of stakeholders and the nature of their impact can change considerably over time, which means that it has to be an iterative process, where one loop links stakeholder identification, stakeholder needs and concerns and stakeholder impacts (see Figure 1).

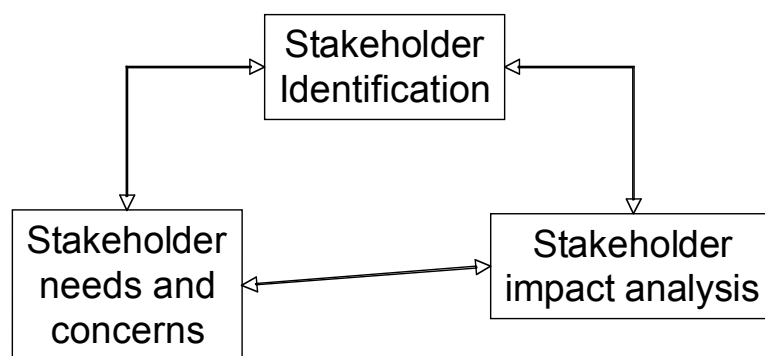


Figure 1. Relationships between stakeholder identification, stakeholder needs and concerns and stakeholder impact analysis.

In studying the various projects, a further consideration also became evident, namely that the needs and concerns of stakeholders and the choice of alternative solutions affect the level of acceptance that each stakeholder has about the project. Depending on how the needs and concerns are fulfilled, and on how the project manager has addressed and acknowledged these, each stakeholder will choose to accept or not accept project decisions. The acceptance level also determines to a large extent the position that each stakeholder (of being an opponent or a proponent) takes towards the project, and thus

the impact each stakeholder imposes upon the project. A second loop in the external stakeholder analysis process is thus relevant for consideration (see Figure 2), consisting of stakeholder needs and concerns, the evaluation of alternative solutions, the level of acceptance and stakeholder impact analysis.

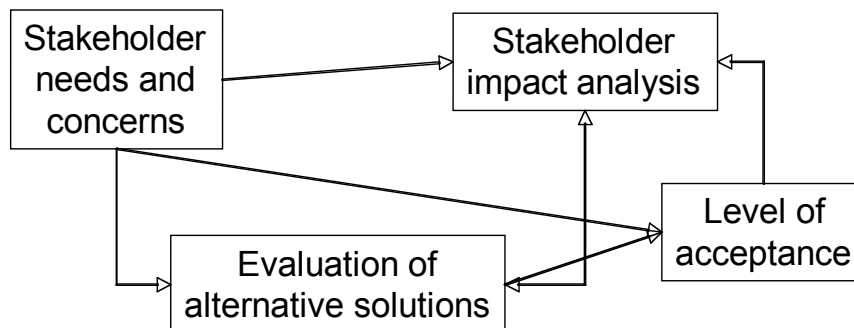


Figure 2. Relationship between stakeholders' needs and concerns, evaluation of alternative solutions, level of acceptance and stakeholder impact analysis.

An external stakeholder analysis process should, thus, consist of the following five components:

1. stakeholder identification
2. stakeholder needs and concerns
3. stakeholder impact analysis
4. evaluation of alternative solutions
5. level of acceptance.

The process is dynamic and iterative, where the different components interact across the project life cycle (see Figure 3), and where every part of the analysis will have to be conducted several times over as the project progresses in order to provide sufficient information about the effects of different project decisions.

4.2 Implementation and exploitation

For sufficient performance of an external stakeholder management process, there needs to be an understanding of the complexity of the external stakeholder influences. The impact of external stakeholders changes throughout the life of the project and depends largely on the perceptions external stakeholders have of the project. The controversies that were observed in the empirical study were due mainly to miscommunication and to the mismanagement of the impacts and concerns of stakeholders.

Developers should thus acknowledge the external stakeholder management process as an important task for which adequate resources should be committed. One main objective of the external stakeholder management process should be to communicate the various aspects of a project correctly, be they good or bad. The challenge for project managers is to communicate and to implement the construction project in such a way that the perceived benefits and the negative impacts are realistically defined. Additionally, the effects of negative impacts should be minimised and, if possible, the benefits for all affected stakeholders should be maximised.

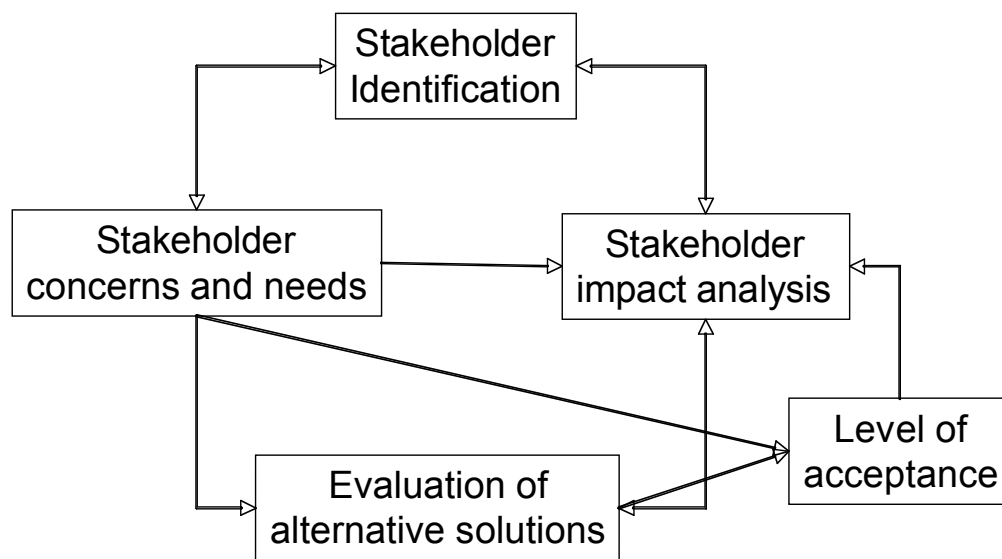


Figure 3. The external stakeholder analysis process.

External stakeholder analysis is a relevant and neglected area of expertise. Four of the five projects studied had not conducted any analysis of how the project would influence external stakeholders or how the stakeholders could have influenced project decisions. The research findings are thus important for construction project managers and facility development companies to help them understand the influence that external stakeholders might have on the implementation of projects. The theoretical contribution of the research is increased understanding about the influence of external stakeholders on construction projects, and how construction project managers can analyse and structure information about stakeholders in the form of models and tools that support analysis.

5. CONCLUSIONS

The empirical findings obtained concerning the projects that were studied show that conflicts between external stakeholders and the developer of a facility depend to a large extent on their perceptions of each other. If the developer failed to acknowledge the concerns of external stakeholders, an environment of distrust would surely be the outcome. An effective external stakeholder analysis should identify the possible trade-offs that can be made without compromising the purpose of the project. Thus, the aim of an external stakeholder analysis process should be to identify the extent to which the needs and concerns of external stakeholders can be fulfilled, and analyse the possible consequences if these are not fulfilled. From the perspective of the developer and the project manager, an external stakeholder analysis needs to be conducted with respect to the project's purpose. The aim should be to complete the project according to the requirements of the project owner. A clear challenge is to find trade-offs that satisfy as many external stakeholders needs and concerns as possible. The external stakeholder analysis should provide a basis for forthcoming project decisions. One definite source of controversy and conflict is that decisions on a course of action for the project were made without analysing the consequences the decision would have for external stakeholders. This tends to result in project manager not being prepared for the conflicts that could arise, and thus having no plan of how to resolve or to handle them.

The concept of project stakeholders has been developed by using existing research on corporate stakeholders and on empirical findings resulting in an alternative definition of project stakeholders. This narrows the project stakeholder concept by addressing the

aspects of claim and stake. Literature reviews and empirical data have also added to knowledge of why different stakeholders choose to accept or not to accept the implementation of a project.

External stakeholder analysis is a relevant and neglected area of expertise. Four of the five projects studied had not conducted any analysis of how the project would influence external stakeholders or how the stakeholders could have influenced project decisions. The research findings are thus important for construction project managers and property development companies to help them understand the influence that external stakeholders might have on the implementation of projects. The theoretical contribution of the research is increased understanding about the influence of external stakeholders on construction projects, and how construction project managers can analyse and structure information about stakeholders in the form of models and tools that support analysis.

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A QUEST FOR THE THEORY OF PROJECT MANAGEMENT

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ABSTRACT

The purpose of the paper is to investigate whether the theory of project management really exists or is the widely used and advocated methodology for project management wrongly labelled as a theory. We claim that, in fact, there is no properly established theory for project management, the methodology used stems from certain historical reasons (Cold War, high technical nature of early projects) and the methodology is not evaluated critically from both philosophical and practical points of view. The specific scope of the research is projects implemented in the public sector, including – but not limited to – large-scale infrastructure projects. The main methodological approach is the critical examination of literature related to the 'body of knowledge' in project management, especially to the explanations for the frequent failure of projects. These explanations are weighed against the critical rationalist philosophical approach developed by Karl Popper and expressed in the conceptions of "piecemeal social engineering", "spontaneous orders" (Friedrich Hayek) and "self-organisation". It will be shown that several failures stem from the uncritical application and over-estimated high expectations of the project management method without questioning its appropriateness for managing the problems to be solved. The paper poses some important questions and aspects for the further quest for the establishment of project management theory. The paper is one of the first to link together the critical rationalist approach and the methodology of project management. The practical application could be more rational approach to project management and fewer errors committed during the project design and implementation phase.

1. INTRODUCTION

During the last ten to twenty years project based approach has become an integral and common managerial technique for solving problems and achieving objectives both in public and private sector. This phenomenon can be explained by the fact that the tasks to be solved have become more complex. Project based activities occur currently in almost each area of entrepreneurship including construction and related sectors. Aaron Shenhar and Dov Dvir (2007, p 93) note: „Even stabile industries such as banking, retail or insurance that were used to stick their traditional business processes, find that they need more and more new initiatives, and that those can only be initiated through projects.”

However, the majority of projects tend to fail. By failure we mean mainly one of the following occurrences: a) the project does not meet its objectives; b) the project does meet – to some extent – the set objectives, but the activities carried out in order to achieve these objectives were not the ones initially planned or were carried out not according to the time-frame; c) the project falls completely out of its designed boundaries, in terms of financial resources, time, manpower etc is concerned. The failure is traditionally explained by the "how" issues – poor planning, hostile environment, weak management. We claim that the real reasons for failure are the "why" issues, i.e. lack of proper theoretical and philosophical background.

2. STATE-OF-THE-ART – PROJECTS

Projects are defined as “temporary endeavour to create a unique product or service” (PMI 2000:4) or as “a temporary organization and process set up to achieve a specified goal under the constraints of time, budget, and other resources” (Shenhar and Dvir, 2007:94). Turner has characterized a project as an environment where human, material and financial resources are organized in an innovative manner in order to implement unique task in limited time and with limited financial resources, for achieving determined qualitative and quantitative objectives (Turner 1993).

Although different sources give different definitions, we summarize in short, that projects are attributed in project management textbooks and other respective literature with following characteristics (Rang and Targama 2007):

- the objective(s), result(s) and tasks of the project are predetermined;
- in order to achieve objectives and results only limited resources (money, time and persons) can be used;
- each project is unique (the results and objectives do not reoccur in the same way in other projects).

In studying the projects in detail it is usually noticed that severe deviations from the initial project plan occur while implementing the project. As a result of these deviations the projects do not meet the planned results or initial objectives, overrun the budget or results are changed to a great extent (Flyvbjerg, 2006; Flyvbjerg *et al.*, 2003; Hansen 2006). Flyvbjerg states, that according to empirical surveys the budget estimates for large transportation infrastructure projects differ (increase) in an average of 44.7% for rail, 33.8% for bridges and tunnels and 20.4% for roads and “for the 70-year period of which (real) cost data is available, the accuracy in cost forecasts has not improved.” (Flyvbjerg, 2006:6) He calls it “the planning fallacy” and gives two (interrelated) explanations: (1) when the political and organisational pressure is relatively low and there is no need to justify and make preliminary studies for the budget, the optimistic bias caused by self-delusion, but (2) if the political and organisational pressure is high (e.g. for getting approval for the project or finances from state or municipal budget) then the inaccuracy more likely is conscious and deceptive (Flyvbjerg, 2006).

Usually these deviations are explained rather naively. To the question “Why do projects go wrong?” Barbara Allan (Allan 2006), for example, offers the following answers: ‘lack of steering committee; the wrong project manager, i.e. someone without the necessary skills; team members with insufficient time to carry out the project work; lack of co-ordination between the project and everyday services’. These explanations concentrate solely on the methodological side (how the project is being implemented), but never questioning the foundations of the methodology. Similar explanations have been offered throughout decades with no actual improvement taken place, although the methodologies and techniques for project management have been considerably elaborated and fine tuned.

This has lead us to step backward from studying the methodological side and turn to the search for the theoretical and philosophical principles of project management. We are, of course, not the first ones, who have studied these issues (see for example Flyvbjerg, 2003; Koskela and Howell, 2002a; Bredillet, 2002; Kumar, 2005; Shenhar, 2001; Shenhar and Dvir, 2006; 2007). The philosophical approach of these studies has been rationalist and normative – i.e. they have been investigating the methods used in project management and offered solutions for improving the model in the form of guidelines in order to achieve better results.

Louis Lousberg and Hans Wamelink have investigated this issue from a different point of view, reformulating the criteria and definition of project failure and success (Lousberg and Wamelink 2007). They claim that that failure or success can also be “an agreement” or social construction. Unlike the normative perspective, that concentrates on results (output) the emphasis of the narrative perspective is put on impact (outcome).

The building of Sydney Opera House serves as an example here to distinguish between the perspectives. From a normative/rational perspective the project of construction was a failure. From the narrative perspective the Opera House is a success. "This project took three times longer than anticipated and cost almost five times higher than planned. But it quickly became Australia's most famous landmark, and no tourist wants to leave Australia without seeing it" (Shenhar *et al.* 2001:700).

However, we hope that we can add some more aspects to the quest for finding better working theory for projects. Our research takes place in the frames of normative perspective rooted in critical rationalism, as for the organisation / company implementing a concrete project the most important task is to achieve tangible outputs. Achieving the outputs is crucial for concluding future contracts and is the basis for the entrepreneur's credibility.

We state that the ideology of typical contemporary project management does not pay attention to three very important issues:

1. the self-organizing nature of the world surrounding us,
2. the emergence of spontaneous orders as a result and consequence of the self-organizing world and
3. the impossibility of managing all necessary information/knowledge for implementing a successful project.

In this paper instead of "how?" we shall pose the "why?" question and explore the possibilities to shift theoretical and philosophical underlying principles from organization paradigm to that of conception of self-organization. In our research we concentrate on projects initiated and financed by public sector or in public interest, in order to highlight the potential risks what might occur in misspending public finances.

As Karl Popper has remarked (Popper, 2005b) "... we do not accept an abstract theory because it is convincing in itself; we rather decide to accept or reject it after we have investigated those concrete and practical consequences which can be more directly tested by experiment ... our decision depends upon the results of experiments. If these confirm the theory, we may accept it until we find a better one" (Popper, 2005b:258).

3. EARLY DEVELOPMENT OF PROJECTS – A GLIMPSE OF HISTORY

In this paper, we give an overview of the historical development of projects². In particular and as an example we look at the early activities of the National Aeronautics and Space Administration (NASA), because they are well documented as well as their impact has been notable to the Western hemisphere in last five decades.

On October 7, 1958 the first NASA project called Mercury³ began. The objective of the project was to create the necessary preconditions and secondly, to carry out the first manned space-flight (*ibid.*). Scientists (Dyson, 1965) as well as US presidents Eisenhower and J.F. Kennedy were initially against manned flights (The White House Historical Association). The same research could be carried out also with unmanned flights with lower costs⁴. There would not have been the NASA program at all if it had not been an exciting one to wider public. That was the reason for manned space flights (Glennan, 1993:xxiv). After the successful launch of the first manned space flight by

² The first acclaimed large-scale project was building the Cheops pyramid (Process Quality Associates, 2007) although it is not known which limitations typical to a project were forced upon it. We can also state, that the objective of this project was somewhat dubious.

³ Although some researchers (Shenhar, 2001:394) prefer to start contemporary project history with Polaris Submarine project, where a diagramming technique (Program Evaluation and Review Technique – PERT) was used.

⁴ Dyson (1965:143) said: "... that ten dollars spent on unmanned vehicles are scientifically more useful than a hundred spent on manned vehicles, and that often one dollar spent on ground-based observations is scientifically more useful still."

Soviet Union in April 12, 1961, in his famous speech, on May 25, 1961, J.F. Kennedy to the Congress on urgent national needs said: "I therefore ask the Congress ... to provide the funds which are needed to meet the following national goals: ... before this decade is out, of landing a man on the moon and returning him safely to the earth" (The American Presidency Project). So the goal was set and the space race got a fresh kick and continued in full speed. As a consequence, NASA budget in 1961 was raised by 1.98 times compared to 1960; in 1962 the increase was again 1.98 times (Murphy, 1971:364)⁵).

According to Levine (Levine, 1982), no systematic planning or control of projects was established at the first stage (1958-1961). The needed resources were allocated without asking any questions. As the projects turned out to be in an average 4-5 times more expensive than the initial budget, the Congress as well as Office of Management and Budget (OMB) started to question the budget overruns. Thus NASA initiated several surveys to find out the causes as well as developed series of methods we know today as classical cornerstones of project design and management methodology.

There were two main findings concerning budget overruns: (1) in the first phase of projects (what we today know as planning phase) it was practically impossible to estimate the cost and timing of the (novel) research and development (R&D) (as well as engineering) activities, and (2) as the different parts of the projects and products were delivered by tens and hundreds of different vendors, who did not know about others products (partly because of semi-military nature of the projects and partly because of using different and not matching engineering solutions), there were constantly problems of delivering them in-time⁶. If the deliveries came in planned time, it was often not possible to compose from them the usable/workable body/whole (Levine, 1982).

Although the programme evaluation and review technique – PERT⁷ was used it did not improve the gap between the estimates and real expenditures. Moreover, Levine (1982:156-7) quotes from Erasmus Kloman's Case Study of the Surveyor Program (typed manuscript, June 1971:216): "PERT did not build the Polaris, but it was extremely useful for those who did build the weapon system to have many people believe that it did ... the program's innovativeness in management methods was ... as effective technically as rain dancing ... It mattered not that management innovations contributed little directly to the technical effort; it was enough that those outside the program were willing to believe that management innovation had a vital role in the technical achievements of the Polaris."

Levine also denotes, that although in the planning phase of the projects the initiators tried to estimate how much the result could cost, but the costs for development as well as for administrative and management overheads were not taken into consideration (*ibid.*).

In 1965 NASA initiated 'four-phases project life planning' (PPP), it included: advanced studies (phase A), project definition (phase B), design (phase C) and development/operations (phase D) (Levine, 1982:159).

The most valuable outcomes of introducing PPP according to Levine are that (1) it helped NASA top-management to obtain information about the current state of play of the projects and that "*no one could bury a problem and keep it buried*"⁸. (2) Based on PPP it was possible to hold successful budgetary negotiations with Congress. However, there is no evidence that PPP improved the process of achieving project results, compared to those projects where the method was not used. It was not used for making decisions

⁵ NASA approved budget was following (in millions of dollars): 1959 – 222.8; 1960 – 485.1; 1961 – 964; 1962 – 1825.3; 1963 – 3674.1; 1964 – 5100; 1965 – 5250; the budget started to slightly decline in 1966, when it was 5175 million dollars (Murphy 1971:364).

⁶ Similar concerns are familiar for contemporary construction industry, where there can be several sub-contractors.

⁷ PERT was specially created in 1958 by Booz Allen Hamilton for joint team of US Navy Special Projects Office and NASA for the Polaris mobile submarine-launched ballistic missile project.

⁸ Here Levine refers to exit interview with Harold Finger, 16 April 1969 (p24), italics by Levine.

which projects will be financed as well. Those decisions were made elsewhere and by other officials (*ibid.* 160-77).

PPP still serves as the founding principle of all project-based activities. Later developments have been only modifications of the set of ideas, as PCM (Project Cycle Management) and Waterfall Method follow the same four-phase scheme. As explained before, there does not exist an argumentation or explanation for the adoption of the method – or they were not those that are advertised today.

In PPP/Waterfall/PCM method the emphasis has been put on planning. The way to success has been described as a norm in the planning phase:

- the objectives, results and activities should be formulated (popular tool: logical framework matrix);
- the sequence and contingency of tasks and activities should be planned with utmost accuracy (popular tools: Gantt, PERT, Critical Path Method (CPM)); and
- all results, tasks, sub-tasks and activities must be described (popular tool: work breakdown structure (WBS)).

According to surveys in the majority of cases the project plan that was designed in the planning phase (Shenhar *et al* 2001, Hansen 2006, Flyvbjerg *et al* 2003 etc) is not followed. The previous argumentation shows that reason for this discrepancy between *the planned* and *the implemented* is based on following a method that has no theoretical foundations.

To sum up, we can state the following.

1. The roots of the underlying principles of project-based thinking and project management derive from space-race between two super-powers. The actual result and goal achievement had ultimate importance and money was allocated respectively.
2. Due to that additional resources were easily allocated, methods (PPP) and tools (PERT) were rather used by managers to explain and visualise the state of play of the projects, establish a connection with existing plans as well as to allay top-management and decision-makers in order to get approval for continuation of the projects.
3. The constraints for a project, such as exact budget, novelty of the project, time and other resources cannot be determined beforehand in the planning phase, but can only be measured afterwards, being then nothing but *post-factum* knowledge. This was already known when PPP was designed. PPP was taken into use not because it worked, but because people liked to believe that it works.
4. Today PPP approach is the most popular (classical) project method. In contemporary project practice similar methods such as the Waterfall method and project cycle management (PCM) method have grown out of PPP. Although those methods are currently supported by several ICT-tools for monitoring and control, it does not help to meet its actual goal – to be able to stay in initially planned limits. This method has been widely taken into use, despite of the fact that its effectiveness and efficiency have never been proved, although being advocated by all acknowledged project management handbooks: Project Management – Body of Knowledge (PMI, 2000), Project Cycle Management Guidelines (2004) and The Handbook of Project-Based Management (Turner 1993).

4. THE QUEST FOR A PROJECT THEORY

"Theory is necessary only if *the truth is not obvious*" (Jeffrey Friedman, 2005)

There are several explanations of what a theory is. We have used in this paper Lauri Koskela's description of a theory. A theory explains a noticed (observed) behaviour which helps to understand the issue studied as well as to make predictions. Theory helps to create ways and methods for analyse, design of activities and control. If a theory is used on a wider scale it gives a unified explanation or framework for organizations, enterprises and project operate. A theory shows the way ahead and is the source for further development. If a theory is explicitly stated it serves as a mean for further learning while being tested in practice. Innovative practices may lead to a theory and thus to its implementation in practice. A theory can be seen as „thickened” knowledge: it enables also the novices or less-experienced to achieve the results once only limited to experts (Koskela, 2000).

Several researchers note that there is no explicit project theory (Koskela, Howell, 2002a; Shenhar and Dvir, 1996). Project management handbook by Robert Kimmons and James H. Loweree states that different technical and management-based skills are needed in order to implement a project, thus the roots of project-based thinking and project management lay in different management theories (Kimmons and Loweree, 1989). Lauri Koskela notes that lack of explicit project theory does not mean that theory is not important in project management or that project management develops only according to best practices. He is of the opinion that the projects are being implemented according to a theory (set of principles) that is clandestine (tacit) and not explicitly articulated. However, the general support to implement projects according to the established rules is strong, although the underlying basis is narrow (Koskela and Howell 2002b) Peter Morris (2006) states that the contemporary theory of "management-as-planning" does not function and the need for a paradigm⁹ shift is required.

Mats Engwall has described current project management knowledge as normative and practitioner driven, that has emerged from practical problems and that it concentrates on two issues: "(1) how to structure and plan project activities in order to meet the stipulated objectives and (2) how to ensure that project activities decided upon are executed according to the stipulated plan (Engwall, 2003:791).

Generally speaking, the contingent prevailing "theory" of project-based thinking and project management can be described as follows. There exist explicitly articulated principles (e.g. A Guide to the Project Management – Body of Knowledge), elaborated methods (Waterfall, PCM) and research tools (PERT, CPM, WBS etc.) for implementation as well as sufficient proponents (e.g. PCM, which is the official project method for all European Union funded projects; the Project Management Institute has more than 265 000 members in over 170 countries¹⁰).

5. CONCEPTS OF ORGANISATION AND SELF-ORGANISATION

There exist two fundamentally different categories to explain the world surrounding us: the conception of organisation and that of self-organisation. Both conceptions are similar, as the result of both of them is some kind of order, some kind of organisation. The fundamental difference lies in *how* the order/organisation is achieved. In principle, the following scheme (Figure 1) depicts the two different ways of achieving an order (organisation):

⁹ Thomas Kuhn defines paradigms as structures of scientific research, acknowledged scientific advancements that serve as a model for scientists in a certain period of time for determining and solving problems (Kuhn 1996).

¹⁰ See: <http://www.pmi.org/GetInvolved/Pages/The-Benefits-and-Types-of-Membership.aspx>



Figure 1. Two ways of achieving an organisation.

"Thus the term *organisation* expresses the relationship between three inseparable terms: *organiser* (man, society or other outer agent) – *organising* (process directed by conscious activity or regulated by outer factors) – *organisation* (result). The term *self-organisation* shows the relationship between the terms *self-organising* (process, that takes places either outside of conscious activities or outer ordering impact) – *organisation* (result)" (Näpinen 1993:379-80).

In case of self-organisation the outer (conscious) agent who organises (arranges, guides, directs) the process in order to achieve organisation does not exist. In case of organising, the situation is *vice versa* – it is the outer conscious agent who carries out the process of organisation. This is the fundamental difference between the two conceptions. This difference may seem trivial in the first place, but it has fundamental impact upon planning and the methods used therein.

The conception of organisation presupposes that everything in the world around us can be reduced to simple (although often technically quite difficult) subject / object relationship. The human being (subject) lays down in front of himself objects that he arranges (organises) according to his will. Therefore, the world around us must be simple, makeable and re-makeable (constructible) by its nature. If the constructed system does not work (or does not work with planned effectiveness and efficiency) the parts within the system must be relocated in order to achieve the desired situation (another possibility is, of course, to blame the organiser for not achieving the goals). It is presumed that by mending parts of a system it is possible to mend the functionality of the system as a whole. If an operating system has been constructed according to these premises it should be possible to predict the situation within the system at any given point of time. There would be no fundamental difference between the past and the future, as everything (including time), would be in principle reversible.

In social sciences these issues have been studied by, for example, Karl Popper, Michael Polanyi, Ernst Friedrich Schumacher, Friedrich Hayek and Leo Näpinen.

As shown by Karl R. Popper ("*only a minority of social institutions are consciously designed, while the vast majority have just 'grown', as the undesigned results of human actions*"¹¹; (Popper, 2005a:59) and Friedrich August Hayek (complex associations – like language, culture, market economy, democracy – have been formed without the conscious activities of mankind; (Hayek 1992), the inevitable outcome and result of the self-organizing world is the emergence of spontaneous orders (or self-organizing systems). These orders are characterized by their complex nature, ability to serve common good, foster the living of a large number of individuals while being not created purposefully.

In project management it means that a project is a mental construction that is arbitrary isolated from the actual world with specific restrictions imposed upon it. As a mental exercise it cannot be objected. However, if being implemented, the activities foreseen are bound to take place in an uncontrollable environment. Complex institutions do not

¹¹ Italics in original

operate according to a single plan, but act in a flux of opposing and contradictory movements. The implementation of a project is inevitably like swimming upstream. Thus – and paradoxically – a project with its predetermined results, course of action and indicators tries to act as a safe haven in the general tumult of entropy. However, a local appearance of negentropy will cause increase of entropy globally.

In contemporary society, much of the constructions, innovations and product developments are tried to implement according to the principles of project management. The reasons being transparency of activities (predetermined objectives, results and respective actions), value-for-money (the cost of each action / result should be calculable and thus predetermine as well) and public control, as well as reasons indicated above.

The conception of organisation is strictly followed while planning and implementing a project. On the other hand projects are implemented in an open environment, where numerous interactions simultaneously are taking place, where events and activities of others have impact on our project. In the words of Mats Engwall "No project is an island and can be treated as a lonely phenomenon" (Engwall 2003). The self-organising principles of the world are left aside and ignored by the used classical project management methods. This is, in our opinion the main reason for project failures.

Generally speaking: in *real* world the future is unpredictable, there does not exist "cause-effect" relationship and that complex orders emerge not as a result of the conscious plan of the organizing agent. In terms of project management this indicates, that the design and plan of a project could be as competent and precise as could ever be possible, the future that will come into being is somewhat different. The environment has changed to an unknown direction. The new circumstances tend not to have a positive sign resulting into the poorer-than-expected performance of the project. We do not think that the project manager ought to be blamed (although we do not exclude the possibility of him committing some grave errors). The split between the desired state of the future during the planning phase and the grim reality of afterwards can easily be explained by human psychology, where the best solution and outcome is always hoped for.

6. POSSIBILITIES OF PROJECT-BASED ACTIVITIES IN SELF-ORGANIZING PARADIGM

Fine-tuned normative machinery has been set up to manage and control management of project-based activities. The normative basis describes what and how is to be carried out in the framework of a particular project. It means, that practical project promoters "bend" themselves to the normative criteria for getting approval for their project idea as well as during the implementation phase they present themselves according to the prefixed rules¹².

There are several – often bureaucratic – hindrances that have been established in order to hamper the implementation of the projects by the authorities, but this criticism falls out of the scope of this paper. Some experts, arguably, know which is the course the state ought to take by setting out the road-map "deemed worthy by the planning authority" (Heath, 2007); some others can judge according to the project application the suitability of an idea, the third group is able to value the success of the project by weighing the foreseen results and the actual ones etc. This is a sad misconception of the reality, as it does take into account neither the self-organizing world nor the appearance of the spontaneous orders. In practical terms, this has been rejected also by the so-called *vox populi* phenomena (Knight, 1921; Treynor, 1987). To our best knowledge, the last strain of ideas has not insofar been developed in the context of project management. This ought to prove a fertile ground for further studies.

¹² This means, that often actual problems are not being solved, but activities have been carried out according to the rules.

As it has been previously indicated, planning forms an innate part of the conception of organization. It has also been shown, that following the mind-frame of organization does not enable to achieve project success. It is, however, mentally and psychologically quite difficult to grasp the notion that a project plan is neither perfect nor final. Even when a "perfect" project plan is composed it is not fully applicable. A much more viable solution is to realise the self-organizing nature of the world and to try to cope with it. In the context of project-based activities and project management this means to take a pragmatic and stepwise approach. In project-based activities this could be realised by following Karl Popper's idea of "piecemeal social engineering"¹³.

Popper distinguishes two types of planning: piecemeal and utopian, which are better known as "piecemeal social engineering" and "utopian social engineering" (Popper, 2005a: chap. 21)¹⁴. The main difference between the two lies in fact how planning (engineering) is carried out by the engineer. The utopian social engineering aims at grand reforms on a large "social" scale. The whole of the society has to be reformed according to an agreed blueprint, preferably at once and notwithstanding the volume of the undertaking. The piecemeal social engineer rather carries out small steps. Although the general well-being and welfare of the society as such may even occasionally haunt his mind, he is aware that it can be achieved only through small advancements, through trial and error. Thus the piecemeal social engineer sets out to solve a concrete problem. Problem-solving process will take place through trial and error or through the principles of falsification. There will be setbacks and his obvious tinkering is an easy object to criticism. The utopian social engineer does not satisfy himself with the slow progress, as being too modest. However, the utopian social engineer sooner or later falls victim to the expedient of piecemeal improvisation – the „notorious phenomenon of *unplanned planning*". In other words, the larger and far-fetching a plan is, the more likely it is that the engineer loses control over its development. He has nothing left but to continue haphazardly and pray, that he has hit, not missed.

Some features of piecemeal social engineering and project management practice are akin to each other. The most prominent of them is their orientation to problem solving¹⁵. The biggest difference lies, however, in the actual implementation of the project, which will be conducted not according to the principles of piecemeal social engineering, but rather that of the currently typical practices of utopian social engineering.

7. CONCLUSIONS

In this paper, we have investigated some of the reasons why projects fail from a novel perspective by philosophically analyzing the method used in project management and looking for the theoretical principles of the method.

First, the tools used within the project management method in were initially not designed for universal use, but for a specific sector (semi-military structures). Second, these methods were not actually meant for planning, but primarily as visual aids for decision

¹³ It is important to notice that such traditional methods as work breakdown structure (WBS) do not correspond to the notion of piecemeal social engineering. An innate 100% rule in WBS states that WBS must include all activities and results, based on the implementation of the activities. The activities must include all elements that result in the completion of the activities (PMI 2000).

¹⁴ Hayek's remark against the use of the term "engineering" in connection with "piecemeal" activities is, of course, utterly valid. His argument can be used also while criticizing the planning process within the conception of organization: it is not possible to "possess all the relevant information" and that "the knowledge of the circumstances of which we must make use never exists in concentrated or integrated form but solely as the dispersed bits of incomplete and frequently contradictory knowledge which all the separate individuals possess" (Hayek, 1945). Involving as much as stakeholders does not really help, but rather obscures the process of planning (if carried out in the mind-frame of organization).

¹⁵ Thus we can state that project management, if properly implemented, serves as a tool for falsificationist approach.

makers. Last, these methods were developed to solve a specific problem and were not designed for universal use.

This uncritical approach towards the described methodology is – in our opinion – the main reason for the frequent failure in project management. Researchers have only recently started to look for the underlying theory in project management. Their research, however, takes place within the conception of organisation. We have proposed an alternative solution, i.e. to follow the conception of self-organisation as the philosophical framework for describing the project management environment.

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THE CONSTRUCTION MANAGEMENT FIELD: A BIT OF A DIG!

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ABSTRACT

Construction management has established itself as an internationally recognised area of research with an established and growing community of academics. This community interacts at a variety of levels and the outputs of activities take a number of forms. This study aims to explore and expose what constitutes the academic field of construction management. Drawing on the literature on field configuration and development, the paper focuses on institutional logics as a way to help explain underlying assumptions and embedded practices inherent in 'fields'. The paper presents the findings from a pilot study that has explored these logics through a content analysis of high-quality journal papers. A single volume of a construction management journal and management journal is reviewed and compared in order to explore and discuss the content, process, rigour and relevance of construction management research. The findings are of a tentative nature, but provide insights into the institutional logics that underpin the construction management field. Significant support is found for extending the study in the future to encompass other artefacts, rituals and events that configure the academic field of construction management.

1. INTRODUCTION

Construction management (CM) research is commonly perceived to be an applied science that lies somewhere in between the natural and the social sciences. Notably CM researchers have extensive interaction and long-standing relationships with the construction industry. Indeed, many researchers and research institutions pride themselves on developing and maintaining long-term relations with both research funders and industry partners. Thus, CM researchers, in general, are very good at working with industry and getting research funding. Yet, CM researchers, like many of their peers, are consistently subjected to a range of competing demands. Industry wants easy, directly applicable solutions and publications that can be read and understood by an industry audience. Research funders want both industry-engaged problem-solving research and publications in quality journals. Universities as employers, place pressure on researchers in the form of: winning funding; the quality dissemination of corpus knowledge through teaching; and publication of cutting edge research that both addresses industry problems and maintains and enhances the academic reputation of the institution.

The research reported in this paper takes these competing and inconsistent demands as a starting point for exploring construction management research. Inspiration is taken from the literature on field development and how a combination of artefacts, rituals and events act to configure a field and its associated logics over time (cf. McInerney, 2008, Oliver and Montgomery 2008). Particular interest is given to the recursive relationship between academic fields and the contents of high quality journals and papers (cf. Judge *et al.*, 2007). The position taken is that insights into academic fields could be gained by reviewing and analysing high quality academic journals. The published papers constitute repositories of research and provide a vantage point from where it is possible to view what shapes, interests and directs the research that is undertaken.

The paper draws upon a comparative analysis between a construction management journal and a general management journal. The intention is to open up and extend the debate on the content, process, rigour and relevance of construction management research. Notably, this research is in its early stages and the paper is an initial attempt to

get conference attendees to provide early feedback on the approach and initial findings. The statistics presented are rather crude but nevertheless provide enough insights to develop broad propositions for further discussion. The authors are also unashamedly attempting to be controversial as they view the extension and sharing of knowledge to be the product of debates around controversy.

2. BACKGROUND

According to Bourdieu a field consists of a set of objective, historical relations between positions anchored in certain forms of power (capital) (Bourdieu and Wacquant, 1992). Within the field an agent's actions are governed by a network of social relations. Similarly, within organisation studies 'field' is conceptualised as the domain where an organisation's actions are structured by the network of relationships within which it is embedded (Wooten and Hoffman, 2008). Thus, it relates to a community of organisations and actors that engage in common activities and are subject to similar reputational and regulatory pressures (Owen-Smith and Powell, 2008). 'Fields' are therefore not constrained by the boundaries and structures of a single organisation but rather by participants that partake of a common meaning system and that regularly interact. A 'field' is essentially a social arena that can be used for any number of purposes (Scott, 2008).

On this basis it is possible to conceive of construction management research as a field. Within various universities throughout the world construction management researchers coalesce to form recognisable organisations – e.g. divisions, departments, schools and faculties. They are also subject to similar reputational and regulatory pressures such as research assessment exercises, professional accreditation and promotion boards. Thus, we argue that construction management research is a field in its own right with a relatively easily defined membership. For the purposes of this paper we have adopted Bourdieu's label of academic field. As an academic field, construction management is an arena associated with particular 'co-evolved' logics that are representative of the configuration, coherence, interests and formation of a field over time (cf. Oliver and Montgomery, 2008). These logics are mediated by and through agents within the field. The CM academic field regularly interacts through multiple activities and events. For example: the refereeing process of journal papers and research proposals; national and international conferences; visiting professorships; edited books; co-authorship of books; the external examination system; membership of various committees and professional bodies and; numerous seminars, panels and events. A small but significant aspect of this interaction takes place through the medium of high quality academic journals.

2.1 Reviewing construction management literature

In accordance with the above, reviews of literature as the basis of exploring academic fields is common (cf. Kevork, 2009). These can take the form of content analysis exercises as well as attempts to ascertain impact and relevance. Indeed, contemporary work has given significant attention to citations as a means to ascertain measures such as impact and diffusion (e.g. Judge *et al.*, 2007). Whilst significant insights could be gained through the use of these kinds of measures they are clearly limited in generalisability.

Recent reviews of journal papers in construction management have chosen not to adopt citations as a measure in their analysis. It is generally recognised that the ISI web of knowledge does not favour multi-disciplinary applied fields such as construction management. Very few construction-related journals are listed in the ISI web of knowledge making judgements on the basis of ISI citations problematic. Instead focus has been on specific aspects of the contents of the papers (e.g. Betts and Lansley, 1993). Dainty (2007), for example, explored papers to determine diversity within the field regarding methodology. The conclusion drawn was that CM research is dominantly

positivist and that there is an apparent lack of methodological diversity. Another recent review by Pietroforte *et al.* (2007) analysed the abstracts of all the papers published in a single journal over a twenty five year period. Their key aim was to chart key trends in research and explore the evolving body of knowledge in construction management.

Here we seek to extend the work of Dainty (2007) and Pietroforte *et al.* (2007) to begin to explore and establish logics within the field of construction management. We do so by developing a line of inquiry that compares the content, process and focus of research in a construction management journal with a broader management journal. Such a comparison will provide a basis for understanding similarities, differences, constraints and future opportunities.

3. RESEARCH APPROACH

3.1 Journals of interest

Judging the quality of journals in the construction management field is a highly subjective exercise. In the absence of ISI indexes, several attempts have been made to develop journal rankings and associated factors for the field of construction research. The most recent of these is Bröchner and Björck's (2008) investigation regarding which journals are favoured as publishing outlets by the most influential CM scholars. Using a multi-criteria approach they established a list of seven journals they deemed to be CM researchers' 'journals of choice'. Of the seven journals listed three were ranked as 'best or leading journal in its field' by the Australian Business Deans Council (ABDC, 2008). Out of these three *Construction Management and Economics* (CME) is the journal with the clearest orientation towards construction management.

In 2008, this journal published 92 papers equivalent to 1 327 pages. During this year, 240 paper manuscripts were submitted. The journal had a relatively low desk rejection rate and over 700 individual reviewers were involved in the reviewing papers the papers with an acceptance rate of 45%¹. A strong case can be made that the reviewing process and the many reviewers used facilitates that the journal publishes the kind of papers that are of interest to the CM community at large. This leads us to conclude that CME is a leading journal within the construction management academic field that could be considered to play a small but important role in shaping the academic field itself. Reinforcing this view, CME was also chosen by Dainty (2007) and Pietroforte (2007) as the basis of their reviews.

Within management there is no shortage of indexes to draw from in developing a view on the quality of journals and rankings abound. The *Journal of Management Studies* (JMS) is one of the leading European management journals boasting an ISI impact factor of 1.926 (2007). The journal has a long-standing tradition as an independent, broad based management journal of international standing that attaches no priority to either the subjects of study or the theoretical and methodological approach adopted. The editorial mission has long been one of ensuring that the journal avoids 'being taken over by any one approach to management studies at the expense of others' (Clark and Wright, 2009).

3.2 Citations

Initially, although accepting the limitations of doing so previously described, the research focused on citations and the extent to which insights could be drawn from looking more closely at the extent to which papers in the two journals are cited. Citations are becoming increasingly important as a measure of research impact. This has long been the case in Asia and North America and Europe is following suite. In contemporary academia citations are argued to be used as:

"the formal accounting process of science, documenting the origin and evolution of research streams over time. If the most important outcomes of science are the creation and dissemination of new knowledge, citations not only document the history of an investigation or research area, but also project its future" (Judge et al., 2007:491)

A strong argument can thus be put forward linking citations of papers and the development of academic fields. Certainly, despite their limitations, citations cannot simply be ignored, as has largely been the case within the field of construction management. High-quality papers in high-quality journals will be cited (used) by the wider community to further develop or reinforce institutionalised logics and routines. The following discussion is based on the Scopus database².

Table 1 demonstrates the extent to which papers are used/cited by other academics once published. It should be noted that any analysis of this data is limited by the lack of detail surrounding who cites the work, which field they belong to, on what basis papers are cited and for what purpose. The data does nonetheless provide a starting point for analysis and an insight into potentially significant issues.

Table 1. Citation statistics for the period 2005-2008 (source: Scopus³).

Volume	<u>JMS</u> Most citations gained for a single paper	<u>JMS</u> Papers with no citations	<u>CME</u> Most citations gained for a single paper	<u>CME</u> Papers with no citations
2005	98	1.5%	11	25%
2006	28	5%	8	51%
2007	10	23%	5	64%
2008	15	37%	2	98%

The differences between the two journals in Table 1 are stark. It would seem that few papers in CME could be described as having had an impact on other researchers. The most cited paper has only 11 citations whereas the equivalent JMS statistic is 98. Even starker is the difference regarding how many of the papers that are cited and thus could be considered to have an impact on the development of knowledge elsewhere. Over 60% of the papers published in CME over the last four years have not been cited at all. In contrast, over 80% of the papers published in JMS have been cited at least once. It is of course not possible to tell from this data from what field citations are linked. It may also be the case that papers are further developed/used in other contexts not necessarily considered academic – practice for example. Despite these caveats, Table 1 presents a picture of knowledge development in management that is not replicated in construction management.

This raises the following broad questions for further consideration: why do CME papers in general fail to make an impact through a measure of citations; why are so many CME papers apparently ignored; and do CME papers therefore fail to provide the basis of future developments of knowledge in the field? Extending the analysis to a review of the papers themselves may help to answer some of these questions. Certainly, it may be useful to know what, if any, characteristics of the content and process inherent in papers differ between construction management and management. If there are any differences, do they provide explanations for field development and formation in the future?

3.3 Scope of the review

In order to review and compare the papers in accordance with the preceding discussion a broad framework was developed. This framework contained a number of key aspects considered to be indicative of the content and process of research described in the papers. Following the framework the review took the following steps: (1) the problem area that the paper addressed and any dominant and secondary literature sets that it draws upon. Each paper was assigned a single topic only. The most relied upon literature sets were recorded. (2) The theoretical lens through which the problem is addressed. This explored whether or not there are any identifiable theories employed. The two dominant theories were recorded. (3) The underlying research was categorised as either quantitative or qualitative. (4) The research paradigm. Any concession to an overt inquiry paradigm was recorded. Where none was conceded a reasoned decision was taken as to a suggested paradigm. (5) Research methodology. This included recording: whether or not the research was empirical; the research method; the data gathering techniques; and the applied data analysis techniques. (6) If the paper and the underpinning research were practice or theory orientated.

The journal issues were divided between authors so that each read and coded an equal amount of papers in both journals. To ensure a consistent interpretation the two authors initially individually reviewed the same three papers from each of the two journals. Differences in opinion were discussed until consensus was reached. This exercise was repeated a further two times during the review process on randomly chosen papers. In all, 86 CME and 46 JMS papers were reviewed and coded.

4. BASIC ANALYSIS AND DISCUSSION

It serves little purpose to list all the topics that were dealt with in the two volumes. More important is the clarity of the topics and how these are made explicit. In general, the JMS topics are less specific and more easily generalisable. CME topics are much more specific to country, sector and markets. The two journals also differ markedly in the how the literatures that the papers draw upon are presented. All the JMS papers have a clearly identifiable core literature against which they were positioned. In contrast, focus in CME papers is more on stating the problem area. Thus, rather than presenting current leading thinking in the particular area of investigation, information is provided setting out the context and particular sets of problems that the paper seeks to address.

In similar fashion JMS papers more explicitly present the theoretical backcloth against which the paper is positioned. Of the 46 papers reviewed all but 4 explicitly stated which theory or sets of theories the research had relied upon, one of which was a literature review. In contrast, determining the underpinning theoretical position of CME papers was a more difficult task. Indeed, the authors of this paper could not easily determine the dominant theories in 54 out of 86 papers reviewed. This could be considered a symptom of space prioritisation as the word restriction of 6000 words in CME not readily allows lengthy theoretical expositions. However, there was not sufficient evidence in the papers reviewed to support this claim. The main difference between the two journals lies in how theoretical concepts are presented not in the disposition of the papers.

4.1 Research approach

Not all research is empirically based and not all research draws on primary data. Of the 86 papers reviewed in CME 59 (68%) could be considered to be based on primary data acquired by the authors during the research process. In JMS the equivalent figures were 35/46 (76%).

Table 2. Breakdown of qualitative and quantitative research approaches.

Journal	Quantitative (%)	Qualitative (%)	Both quantitative and qualitative (%)	Neither (%)
CME	49	25	10	16
JMS	48	33	11	8

As could be seen in table 2 the two volumes were fairly similar in the division between quantitative and qualitative papers. It should be noted that on several occasions the nature of the descriptions of the data collected and the methods employed were ambiguous and/or minimal in content in the CME papers. The information provided in table 2 is therefore based on the reasoned judgement of the two authors, who by no means were in initial agreement.

4.2 Inquiry paradigms

Very few papers across the two volumes explicitly stated an overt research paradigm. Thus, the majority of the papers described the research design and the methods employed without presenting the philosophical and ontological assumptions that underpinned their research. In CME 3 out of 86 papers (3.5%) overtly stated a research paradigm. Out of these, two stated to be interpretive and one stated that it followed a positivistic approach. In JMS the equivalent figure was 6/46 (13%) stating an overt research paradigm; all of which were different.

In an attempt to classify the rest of the papers the dichotomy interpretive (constructivist) and positivistic research was introduced. But not even using this very crude categorisation was it possible to form an opinion of all the papers.

4.3 Research methods

Table 3 outlines the research methods that were used by researchers in each field. Notable is the similar dominance of surveys and case studies used by both construction management and management researchers. Clearly, these research methods are perceived to provide the greatest opportunity to explore research questions and provide a robust and reliable basis for high quality papers.

Table 3. Breakdown of the main research methods.

Research Method	% CME	Research Method	% JMS
Survey	27	Survey	36
Case Study	20	Case Study	26
Unclear	15	Reviews	13
Modelling	15	Data Mining	5
Multi-method	5	Multi-method	5
Review	5	Action research	2
Others	11	Others	14

What also stands out is the 15% of papers in CME that are unclear regarding the research approach taken and that 15% of the papers draw upon modelling as a research method. Modelling is absent within JMS and no papers remain unclear regarding the adopted research method. This is perhaps symptomatic of disparate processes and emphasis placed upon the development of papers within CME and JMS and the refereeing process. However, modelling may also be a legitimate research method within construction management as it is largely concerned with achieving industry relevance through applied research outputs. In this sense it reflects whether the papers seek to address, develop, test or extend practice or theory. This is quite clearly linked to the disparate institutional logics that underpin the way fields self regulate outputs and what is understood to need developing.

4.4 Data gathering approaches

On the surface it appears from the table above that there may be a greater range of data gathering techniques used by construction management researchers. However, 'multiple' as a category relates to papers where more than a single data gathering technique has been employed.

There is clearly greater significance given to employing multiple data gathering techniques in research that aims to be published in JMS. This appears to further strengthen the argument that disparate processes and emphasis are placed upon the development of papers within CME and JMS and that this is reinforced through the refereeing process.

Table 4. Breakdown of data gathering techniques.

Data Gathering Techniques	% CME	Data Gathering Techniques	% JMS
Questionnaire	26	Multiple	35
Interviews	17	Questionnaire	30
Unclear	12	Archives	11
Secondary Datasets	20	Secondary Datasets	11
Multiple	10	N/A	6
N/A	6	Interviews	5
None provided	6	Observations	2
Case material	2		
Expert panel	1		
Practitioner feedback	1		

4.5 Data analysis techniques

The picture emerging from the review of data analysis techniques is one that shows great similarity between the techniques used. There are notable differences though. The papers published in JMS to a much greater extent rely upon multiple analysis techniques. This is particularly apparent in the papers relying on statistical analysis. There is also a slightly greater emphasis placed upon qualitative rather than statistical techniques employed within JMS papers. Papers in CME are also more likely to omit any description at all of analysis techniques applied. What passes the refereeing process and the expectations of JMS and CME are clearly informed by disparate logics. By extension, these logics also have a story to tell with respect to the research content, process, rigour and relevance within construction management.

Table 5. Breakdown of analysis techniques.

Analysis Techniques	% CME	Analysis Techniques	% JMS
Statistical (Various)	46	Statistical (Various)	41
None described	16	Qualitative (Various)	25
Qualitative (Various)	9	Multiple	11
N/A	9	N/A	7
Simulation	6	Comparative	4
Descriptive	4	None described	3
Comparative	3		
Others	7	Others	9

Table 6. Breakdown of the orientation/focus.

Paper Orientation	% CME	Paper Orientation	% JMS
Practice	80	Practice	7
Theory	11	Theory	85
Theory and Practice	3	Theory and Practice	9
Unclear	6	Unclear	0

4.6 Theory or practice orientation

Part of the review of the papers in the journals was the intention to explore the orientation of the papers with respect to making contributions to theory or practice. Table 6 provides a rather striking view of the differences between CME and JMS papers.

From the table, we can see that the papers within JMS are strongly motivated to make contributions to theory. This is in stark contrast to papers in CME where the motivation seems to be shaping and influencing practice. This should perhaps not be so surprising given that the construction management community historically has been labelled an applied field. The field's strong connection to industry undoubtedly influences the focus of the research. Papers are therefore written and refereed in a way that is sensitive to industry relevance, at times at the expense of theory development.

5. CONCLUDING REMARKS AND THOUGHTS

The analysis and discussion presented above is the result of a pilot study at a very early stage of ongoing research. It is limited to a single journal volume and should therefore be considered as indicative rather than absolute. The process of analysis is also a focus of investigation within the pilot study and as such, still very much a work in progress. It should also be acknowledged that there are several limitations to a study of this kind and many valid objections can be made. One of these is whether or not it is possible to draw conclusions regarding academic fields on the basis of the publications in one journal. Whilst, CME would appear to be a pivotal touchstone for researchers seeking to publish research in the construction management field, questions could still be raised regarding whether or not the papers are typical for the CM field. It would for example be erroneous to assume that CM researchers share the same ontological and epistemological perspectives regarding the methods they mobilise and the products that their work generates. Accordingly there is no reason to expect universal agreement over how the products of research contribute to academic or practitioner knowledge. Indeed, a variety of different factors shape the efforts made by researchers to affect their surroundings. Nonetheless, the utilised mode of research influences and shapes the research outputs in the form of publications and *vice versa*. Thus, we remain convinced that the papers published in CME in 2008 reflect the constitution and configuration of the construction management academic field. The pilot study has certainly provided enough insights to support further research that draws on a more detailed analysis of construction management papers. In summary, it would be rather naïve to draw too many strong conclusions from this pilot study but, several insights can be derived from the preceding analysis.

First of all, there is little point in discussing the rigour of the research within each field. Clearly if a paper is published it has passed the criteria set by the publication in question. However, the acceptable criteria used within processes associated with exploring and maintaining standards of rigour in CME papers would appear to differ from that of JMS. To start, there is significant difference in the use of theory in the two journals. JMS papers are predominantly theory driven with most publications aiming to make a contribution to theory development. In contrast, CME papers are predominantly practice driven and emphasis is put on establishing the relevance of the findings. This greater focus on theory in JMS has clearly had a direct impact on the adopted research methodology. For example, JMS surveys are based on clearly stated theoretical propositions. These propositions guide the questions asked, data gathering technique used and the subsequent analysis. CME surveys on the other hand are less theoretically grounded. They typically rely on questionnaires with comparatively fewer respondents with the analysis tending towards providing description. Furthermore, looking more closely at the papers that could be considered to be 'qualitative' it is noteworthy that those published in CME relied much more heavily on semi-structured interviews than the JMS papers. This is in line with Dainty (2007) who similarly noted an over reliance on

interviews in qualitative research in construction management. It is worth pointing out that JMS papers that relied on interviews generally drew on a bigger set of interviewees.

What is clear in comparing the two journals is the greater level of detail, thought and structure within the development of theoretical lenses, research methods, data collection techniques and analysis. Despite not being considered an applied field, papers in JMS demonstrated that researchers in management are able to gain access to multiple sources of data and mobilise multiple data gathering techniques. The robustness of the analysis benefits from such pluralism. In comparison, much is made of CM being an applied field close to practice and, that the researchers in general have good connections with industry. Indeed, CM research is sometimes seen as an exemplar in the 'co-production of knowledge' debate. The papers in CME however provided a picture where such connections do not necessarily reflect the argument surrounding 'connection'. In essence, the papers in CME were predominantly quantitative and reliant on questionnaire surveys. They also exposed those studies of a qualitative nature to be associated with the use of a limited number of semi-structured interviews. Multiple sources of data and data gathering techniques were rare. Clearly, applied fields do not necessarily equate to ready access to data for researchers. There are either constraints placed upon CME researchers or, the institutional logics of the construction management field differ from management.

Addressing the above, a number of propositions are readily identifiable. The first is highly pragmatic in nature and is concerned with the practicality of attaining the necessary access to study change as it unfolds and the costs of the extensive resources that this would require. The second is the location of CM departments within science or engineering faculties with the inherent leaning towards a dominant engineering paradigm of research. Out of these two it is only the latter that holds up to any closer scrutiny. As argued above it ought to be easier for the CM field to get access than it is for those engaged in the wider field of management. It seems that the majority of the CM publications aim at achieving industry impact, preferably with quantified evidence of relevance and utility. The importance given to the relevance of the findings and industry impact is so well diffused that often no methodological or theoretical justification or positioning is given, or indeed required.

It is clear from the analysis that there are disparate logics and assumptions that underpin the content, process, rigour and relevance within the two fields. It is also clear that an analysis of papers alone is limited in scope and further studies should attempt to explore other instances and evidence of interaction within the field. The paper has provided enough evidence to support further research that more fully explores the institutional logics within the academic field of construction management.

A final note is required here in the author's experience: the intention of the paper is not to provide insights into 'best practice' within each field but to explore underlying assumptions and logics. In this sense, the authors are not setting up the management field as an exemplar of how an academic field should be configured. We are not making an argument that the construction management field should be more like the management field and, we are most definitely not attempting to mobilise an argument that views 'management as good' and 'construction management as bad'. We are simply trying to explore, explain, learn and make a contribution to the development of the field!

6. NOTES

1. Personal correspondence with *Construction Management and Economics* editorial office.
2. Scopus is a large abstract and citation database of research literature covering over 16 000 peer-reviewed journals from more than 4 000 publishers.
3. The statistics are based on papers published before 4 February 2009.

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CONSTRUCTION VERSUS ARCHAEOLOGICAL SECTORS: ENEMIES OR FRIENDS?

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ABSTRACT

The focus on archaeology and protection of cultural heritage is increasing – both for hidden elements in the ground and for the built environment. The legislation for the protection of cultural heritage states that in the case of building activity concerning such items, the client in most cases will have to pay for archaeological activities. As a part of the Leonardo daVinci programme, "Archaeology and Construction Engineering Skills (ACES)", we have studied a number of construction projects aimed at researching the interface between the construction and archaeological sectors. From the cases in question, we can discern matters of principal interest to be discussed on professional (and political) levels and thus contribute to a discourse on best practice. The ACES project will end in November 2009. This paper is thus based primarily on the case study for this programme although there is still more work to be done before conclusions can be drawn on best practice. The paper will discuss expectations of the construction sector in Norway as regards its multi-scalar co-operation with archaeologists, including protection of archaeological heritage at the planning phase, scope of archaeological excavations, restoration policies and the like. Initially, the construction sector seems to prefer that these two sectors operate separately. However, the best practice policy will also be discussed underlying that for a number of reasons 'good dialogue with archaeologists is necessary' at all the phases of a building process. This will probably be in the clients' own economic interest.

1. INTRODUCTION

The two sectors represent two different cultures in most aspects. In the case study referred to below, one of the informants described these differences as "two different clocks, two views on the value of money, and two views on the importance of the practical use of a building".

The construction sector must relate to a complex set of legislations and prescriptions, stakeholders, actors, economical elements/market, technical solutions and more. In addition, many of those factors will give contradictory advice. Archaeology is just one of several elements the professional participants have to relate to, and most of the actors are unfamiliar to the archaeological sector.

The archaeological sector must relate to a wide specter of archeological remains, from early prehistoric periods up to recent history, and the remains comprises both organic and non-organic findings, cultural layers and structures hidden in the ground, and more. Even the archaeologists do not know exactly what to find through the excavations, and they will have to decide whether the registered findings should be excavated, or preserved un-excavated.

In Norway, the 'user pays' principle is stated in the Law on Cultural Heritage and means that the construction sector will have to pay for both registrations, excavations and reports. The client will also have to pay the costs for the chosen solutions for preservation and the possible impacts on the construction projects.

The clients will in each new project often define the 'drivers' of the project, and identify the most important driver, whether it is time, money or quality (technical and/or functional). However, if the project will be in contact with archaeological interests, both time and economy will be affected, and so may also the qualities of the project. Dealing

with archaeological interests will then be an important part of the risk management of the construction project.

The construction sector itself is continuously changing, as a number of new models for enterprises, partnerships and other types of contracts or agreements for carrying out construction works are being developed and used. The traditional ways of co-operation between the actors are also changing; the planners, clients, architects/designers, developers, contractors and other actors/professional participants are working together in new and different ways, and their roles in the project in the different stages may also be changed. This may sometimes seem confusing to the archaeologists. At the same time, the actors of the construction sectors are most often unfamiliar to the challenges and the character of the archaeological sector. And sometimes legislation may even obstruct a complete and continuous communication between the parties (e.g. law on competition).

Some 'cultural differences' in their communication will remain. The two sectors have different professional terms, and may not understand each other completely. The construction sector would still prefer fewer words and clear advices pointed out in conclusions, while the archaeologists would perhaps seek more explanations, and thus a richer language. However, improvement of the communication will be the most important part of the risk management related to archaeology in construction projects.

2. STATE-OF-THE-ART REVIEW

In Norway, the interface between the archaeological and the construction sectors has not been the topic for a research project before, meaning the communication and understanding between the sectors, and the practical impact of archaeological excavations on the administration of construction projects.

However, there have been several projects on technical solutions for specific challenges connected to the interface between the sectors, but not studies related directly to the interaction during the construction period. But this project is not focusing on the variety of technical solutions.

In Norway, there are no written guidelines, handbooks or other instructions for this interaction – neither in the archaeological nor in the construction sectors. The practice in the construction sector today is dominated by individual procedures based on own experiences, or on 'first-time handling'.

To our knowledge, there are no research projects or written guidelines in the three other countries involved in this project (England, Poland and Turkey), or in other European countries. Thus, this lack of written guidelines has been the basis for the EU-project "Archaeology and Construction Engineering Skills" within the Leonardo daVinci Programme.

The project is aiming at developing e-learning programs / guidelines for this interface within each of the four involved countries, and the practical guidelines will probably differ between the countries. Then, the similarities will be discussed to derive some basic principles valid for more countries.

3. RESEARCH PROJECT

3.1 Project description and objectives

The project is aiming at finding best practice between the archaeological and the construction sectors, and finding suitable ways to implement knowledge (digitally) on best practice to the sectors.

The ACES project is an EU-project involving four countries (England, Norway, Poland and Turkey), two partners from each country: state authorities for archaeology and research

institutes for the construction sectors, and European parachute organisations for both sectors.

Each partner should first discuss views on best practice within its own sector in its own country, then there should be discussions between the two sectors in each country and, then, the similarities and differences between the countries should be discussed.

As this two-year project will end in November 2009, all results are not yet ready to be presented. This paper will then only present the views of the construction sector in Norway, partly including views from the archaeological sector here.

Important research questions have been to find the weak and/or strong points of the current practice in the field, regarding minimizing of costs for archeological activities within a construction project. This will also comprise reflections on the importance of communication/co-operation in the different stages of a project.

3.2 Research methodology

The views within construction on today's practice of the interface between the two sectors have been studied through an explorative case study. The case study comprised nine cases, with a wide range of challenges. The views displayed in the case study have then been discussed in workshops with representatives from both construction sector and archaeological sector.

3.3 Description of the research project

The construction sector in Norway

Norway has less than 4.8 million inhabitants, approximately 430 municipalities, large areas (12 p/km²) and scattered settlements. This is reflected in the structure of the construction industry. There are now about 40 000 construction companies, but around 90% of them have less than 9 employees and only 3 or 4 companies have more than 100 employees. Thus, the sector is dominated by small companies with some middle-sized companies. The structures of the architect/civil engineering companies and the clients show the same profile.

The small companies do not have many resources to spend on bureaucracy and paperwork, and they may have problems with keeping up to the requested skills on all subjects and for all kinds of construction works. In the latest major revision of the building legislation (1997), the authorities requested more formal theoretical skills by the companies, approvals of the actors, and more documentation on the projects. This was a challenge to the smallest companies, and some of those quitted or joined to bigger companies, which are still small.

However, the construction sector is very dynamic, especially in and around the bigger cities, and is there marked by high costs due to increasing urbanisation and a healthy and stable economy both in public and private sectors. This leads to a high demand for skilled workers. At the same time, competition from foreign companies is discernible.

The profiles of the actors in the construction companies and the dynamic processes in the sector will affect the ability to handle the challenges connected to archaeology. For the majority of companies, a project with interface to archaeology will be a 'first-time' project.

Description of the challenges

To the construction sector, the main challenges are related to the 'user pays' principle. Costs for archaeological investigations, registrations, excavations and reports for those activities shall be paid by the clients. The clients seem to have no influence on the

amount of the costs, and they then seem to have no appropriate tools to handle the risk management of such costs.

But in fact, the costs could be managed in better ways if the communication between the sectors was improved, and if the understanding of the importance of better co-operation in all stages of the projects also comprised the economical impact of the different archaeological activities, and of the ways the client can contribute to minimize the costs – which he has to pay for anyway.

The case study for the ACES Project

SINTEF Building and Infrastructure has carried out an explorative case study to gather opinions from the construction sector on their experiences with the interface between themselves and the archaeological sector.

The study comprised nine cases. The cases should together cover as broader scopes of experiences as possible – from all the stages (planning process, prefaces, design, construction, maintenance and rehabilitation), from different types of projects (infrastructure, small projects, big projects, cottages), from both urban and rural areas, and from different types of clients (public and private, big and small).

The Authorities for Cultural Heritage submitted a list of possible cases, as projects where archaeology were in demand. The organisations of the construction sector do not keep statistics for this kind of issues. Initially, the list comprised a great majority of public clients – and the authorities informed that approximately 90% of all excavations were done on behalf of public clients (including infrastructure projects). Nevertheless, some private clients were added to the list.

The communication between the construction sector and the archaeological sectors are taken care of by the projects managers, the site managers or the clients, so the choice of cases will reflect this. To get a more complete picture, we also needed planning offices. The cases are:

- Two municipal planning offices; one from a small municipality and one from a big city.
- Two public clients; one for waste water systems in city (Oslo) and one for public roads.
- Two private design companies working for public clients – different sizes and resources
- Three private developers; one big in Oslo, two from countryside – medium/small sizes.

From the case study we can discern expectations from the construction sector, aiming at finding best practice for the interface to archaeologists. The case study has also been followed up with workshops where also archaeologists were participating. The discourses on finding best practice will continue between the two sectors at least until the ACES project is terminated, but hopefully longer.

From the cases in question we can also discern matters of principal interest to be discussed on political levels and contribute to defining the best practice.

Table 1. The actors and the cases/projects.

Actors	Cases/projects
Small municipality Planning department Authority	Small municipality and 'bad practice'. Both the municipality and a contractor were given a penalty fee for disturbing archaeological objects. The digital maps were not correct because the County Authority for Cultural Heritage had not given information to the municipality. The contractor applied for digging for waste water, got an approval, dug – and disturbed the objects.
Oslo municipality Planning department (PBE) Authority	Planning of the complex new development in/around the Old City best practice (?). They made maps for 'archaeological risks' (with zoning), and they were accepted for delayed archaeological investigations – until a developer could pay directly (to avoid paying for this themselves).
Oslo municipality WWS-sector office Public client	Construction of complex wastewater system in/around the Old City – planning, design and building. 'Best practice' (?). They used their own and well experienced workers to all 'risk operations', and they had 'straight projects' to work on if there were 'stops'. (NB: This may not be possible in near future).
Public Road Adm. Project management Public client	Planning, design and construction of a main road (E-6) through lots of archaeological sites. 'Best practice'. The client wanted more investigations than the archaeologists because they wanted the best possible control in the construction period (no surprises!)
Private Architect Co Project management Public client	Rehabilitation of a building (440 m ²) – not legally protected, but with protected basements and severe fungus. +/- ? This small rehabilitation project seemed "easy" (after removing of the fungus). But the surveillance of a Building Archaeologist (BA) was leading to a steadily increasing project and too much influence from BA. Very expensive (> 2 x the estimate).
Private Consultants Design management Public client	Rehabilitation of the Royal Farm in Oslo – severe damages and well known history. 'Best practice' (but Rolls Royce?) The State Client had high focus on early. The archaeologists planned their work very exact, and they were sticking to their plans brilliantly (but it was expensive). They also had challenges of technical characters, mutually worked out.
Private Company Developer Private client (big)	Design / building of a project (80 000 m ²) on a construction site close to Old City. 'Best/interesting practice'. They ordered complete investigations very early – and the schedule was approved /worked out by the archaeologists (to be finished in September so construction work could start in March).
Priv. Company Developer Private client (medium)	Area with 400 cottages in the mountains. Relatively high costs for registration and excavations. 'Improvements possible'. They had to redesign after registrations, and they tried to sell the cottages as exclusive without really being so, because of the history of the place. But there were obstacles in using the result of the excavations in marketing, and they have still not received the reports and the final account.
Priv. Company Developer Private client (small)	Ski-lift/ski resort and area with about 40 cottages in the mountains. Relatively high costs for excavations, and they also paid for excavations outside their project. The developer's conclusion: "the best way to co-operate with archaeologists will be to pay and then keep your mouth shut"

4. RESEARCH RESULTS AND INDUSTRIAL IMPACT

4.1 Quantification of results

The aim of the case study has been to display views on the co-operation between the two sectors, and the results can not be quantified here – only described.

Co-operation with archaeologists in different stages

However, the multiscale co-operation could be related to the different stages of the planning phase and the construction works. The stages will be defined as: planning process, early stages/pre-phases, design process, construction period and facility management/rehabilitation.

Planning

Maps

Updated and correct maps are the basis for every planning process. For planners it would be obvious that this also should include information on archaeological substance. But so is not automatically the case. The example from the small municipality showed that the authorities for cultural heritage at the county level register all archaeological findings in a register (Askeladden), but the municipalities do not have access to this register today. The main argument for this lack of access is apparently fear of abuse of the information (by 'gold diggers'). There is no direct link or possibility for the municipality to check if there are any conflicts – and the system is based on awareness from the public officers at the county level; that they observe cautiously all comprehensive plans and local plan put on display from the municipal planning offices. However, the cultural authorities are now working on development to a better system.

The Oslo example focused on maps for archaeological risks, with zoning showing both the degree of the risk and the character of the possible findings. The use of such maps would be an example very useful for the planning processes and for construction sector, and can work as an example of best practice. The basic idea is that such maps can be worked out before investigations are carried out. There might then be a limitation connected to the degree of liability of the maps, or maybe they cannot be worked out all places.

The construction sector would also like to have precise information on the cultural layers as early as possible, and preferably marked on a separate layer on the digital maps, and with general (public) access to the maps. This could be of interest already in the planning process, but it is vital information before the design and construction works starts – the managers would need this information for detailed planning of the foundation works.

Archaeological investigations

In the case study, there were two contradictory views on best practice for archaeological investigations and these differences are primarily connected to money, and the roles in the process.

The Oslo Municipality Planning Office (Oslo PBE), stated that in case of complex situations best practice would be to apply for delay of the archaeological investigations until the developers may organize this and co-ordinate this with his construction works / machines. The planning process would then be based on 'risk maps' and be completed (and made legal) before the investigations started. This way, the Planning Office did neither have to pay for the investigations, nor organize it. And these motives were also initiating the work with 'risk maps' mentioned above.

However, the private developers want exact information on possible costs to archaeological investigations and excavations before they buy a construction site – to buy without knowing this may lead to a situation where the economical burden is too heavy and they will then not be able to carry out the project. From their point of view, best

practice would be complete investigations as early as possible, and at least be completed before the local plan is approved. This way, they could avoid the economical burden of archaeological activity if they don't have economical strength to bear it.

To help the situation for private developers, some of the county authorities for cultural heritage try to find a solution to such problems, by establishing a fund to provide prepayment for archaeological investigation. Thus, the risk may be minimized for the clients. But the clients will still have to pay back if they decide to build on a construction site where such investigations have been carried out.

Protected buildings/remains

In Norway, the classification of historic buildings will be marked at the local plans, and given two legal degrees of protection: "protected" according to the Law on Cultural Heritage, or "to be preserved" according to the Planning and Building Act. But in addition, the authorities also provide a "yellow list" of buildings which are not given any legal protection, but regarded as "historic interesting" in some way. In practice, many actors in the construction sector experience that if they try to rehabilitate buildings on the "yellow list", they will at some point meet a "resolution on extraordinary emergency protection".

This means that the developers should keep in mind that even a very modest classification on protection may/will be activated as a claim for almost complete protection in case of building activity concerning the building.

Lesson

Good dialogue with the archaeologists is necessary to define the risk zones and the protection strategy already in planning process.

Early stages

Interface in solutions

Except for the opinion of the planning offices, the construction sector want the archaeological investigations to be done as early as possible – before the project is defined completely and/or designed (to avoid surprises). They will then have a better possibility to find innovative solutions for taking care of the cultural heritage.

The planning process leads to formal categories of protection (for areas or buildings), but for practical use the decisions on *how* to protect are of equal interest: the archaeologists may use the terms: "visible protection", "covered protection", "none", and the construction sector would prefer early answers on "check out/release". These decisions may have vital impact on the design works, and of the concept for use of the site.

Interface in practical works

Initially, both sectors would prefer to work entirely on their own premises. For the construction sector, they would prefer that all investigations are completely finished before they start the design work, and that all excavations are completely finished before they start the construction works.

But economically, this will probably not be the best solution: this will cost much more in use of machines and more. Technically, this may not be possible; in some cases, it will be necessary to secure the area and to work in parallel processes.

But still, the recommendation will be to seek for solutions where both sectors may work on their own premises as much as possible, and to find flexible ways for both parties to co-operate if they have to do so.

In case of questions of principal interest

Priorities in "protection of historical remains" should also sometimes be a political matter – especially related to new big or important projects. In some cases, there may be

contradictory interests where both parties may have good arguments, and where “good solutions in the built environment” is set up against “taking care of the cultural heritage”.

There is then a possibility to take the case into political decisions – but this have to go through the Department of Environment (which is responsible for both cultural heritage, planning and for solution for built environment). However, such processes take long time, and need early initiatives.

The municipal councils do have formal possibilities to take decisions connected to local plans, but in reality, the cultural sector has formal authority to instruct. The construction sector gives signals that they would like to have better legal possibilities to try these kinds of political discussions on a lower level.

Schedule

The schedule is the most important tool for control – use energy on time planning! This is of vital importance to success for both sectors.

Lesson

Good dialogue with the archaeologists is necessary to work out the schedule and carry out archaeological investigations in economically best way.

Design period

Impact on functional aspects or design

If the early stages have provided conclusions regarding categories of archaeological findings, and to what extent they should be protected visible or not, the focus in the design phase will be to find the solutions – how to do it.

This must be an innovative process with unique solutions and no specific guidelines. But it will be important that the design process also foresees possible technical conflicts or conflicts related to time/schedule/construction works for the solutions.

Most often, the excavations are carried out parallel to the design process, and in some cases, there may be new findings in this period which will have impact on the solutions. In such cases, both sectors would have to be flexible and innovative.

Impact on technical solutions

In addition to solutions of functional/aesthetic/practical substance, there must be a focus on the strategies/technical solutions for:

- conserving the archaeological elements that should be visible and/or exposed in order to preserve them as much as possible
- covering/protection of archaeological elements that should not be investigated or exposed to provide dilapidation.

Lesson

Good dialogue with the archaeologists is necessary to find the good technical/functional solutions for both sectors.

Construction period

Enterprise models

The choice of enterprise model will have impact on the ability to secure archaeological interests. The Client must focus on securing necessary competence on protection also in the construction sector, and this may be done in three ways:

1. By choosing pre-qualification on the actors
2. By using types of enterprises that may give the client surveillance also on the

competence of the sub-contractors

3. By using own and well experienced workers on risky operations.

But this strategy may be difficult to use in practice because of other political trend for the construction sector. Public clients are allowed use own staff to perform construction works – and in such cases this strategy may work. But most public clients are for political reasons sizing down own staff, and must buy construction works from private companies – and then the Law on Competition prohibit (or cause obstacles) to the use of this strategy. It may still be formally possible to ask for requirements by the actors, but difficult to follow up.

In addition, the client/site manager should check that the role of the archaeologists is clearly defined and written down in formal agreements.

Digging/foundation works

All types of digging will disturb the environment in some way – both nature and built environment, and also possible archaeological sites – and co-ordination of digging may be economically best for involved parties.

Mandatory co-ordination of all types of digging will then be of benefit for all parties. A public office should be given a formal authority on this.

Construction works

The Client should have a strategy (plan B) for administration of construction works in case of stops or surprises caused by archaeological findings.

One such strategy for Plan B may be to combine projects with 'archaeology risk' with 'straight projects'. In the case study, this was the chosen strategy by Oslo WWS, and was regarded as successful – mainly because they could use own staff. But in the (near) future they will not have enough own staff to carry out projects themselves, and must have competition on the project – then this strategy will not work; it will be rather impossible to find a straight project to bear the extra costs for an inefficient schedule.

Another strategy for Plan B may be to organize projects with archaeology risks as big as possible, to secure this kind of flexibility within the project.

Lesson

Good dialogue with the archaeologists is necessary to find compromises and solutions that have to be solved on site

Facility management/rehabilitation

By use of these terms for the interface between archaeology and construction sectors, we mean the stages where a) there is a normal situation for both sectors with no specific activities, b) projects where archaeological remains have been integrated in new projects and must be maintained, c) archaeological remains / historic building structures are in danger of dilapidation and must be rehabilitated. The phases for facility management and for rehabilitation may be two sides of the same case, or be closely connected to each other.

Facility management

For *municipalities*: it is important to have good systems for up-dating of all kinds of information connected to archaeological sector. This includes a need for finding solutions to the obstacles based on principal attitudes regarding registers for archaeological findings.

For *public client /municipalities*: it is mandatory to have good plans for all facility management tasks for the cultural heritage in the municipality and have a surveillance program to secure that someone really take responsibility.

For *clients* in general (but especially for built constructions with claims for protection): Keep focus on maintenance / facility management – the law on Cultural Heritage is strong, and it will cost much more resources to rehabilitate than to maintain.

Rehabilitation

In rehabilitation projects: Seek very early contact with the archaeological authorities – this will provide good climate for dialogue, better help for finding solutions (in case of conflicts, the authorities for Cultural Heritage will have the 'best cards' anyway).

Lesson

Good dialogue with the archaeologists is necessary and will also be in the clients' own (economic) interest.

4.2 Implementation and exploitation

Comments on the impact of archaeology on construction projects

User pays principle and risk management

The Law on Cultural Heritage states that the basic principle for costs for archaeological investigations is that the user pays (often mentioned as: polluter pays) (= construction sector/clients pay for all). In the case study, some of the informants then concluded that the best way of co-operation would be to pay and keep the mouth shut.

But other informants pointed out that they use much energy on risk management in all their operations, and seek every possible way to get better financial management in the projects. But the costs for archaeological investigations/excavations are now completely out of their control, and they feel uncomfortable with this.

However, good dialogue with the archaeologists in both planning of work and planning of schedule will contribute to finding the best economical solutions for solutions, use of machines, transport and facilities for workers and more. The dialogue will for this reason be the most important way to get better control/insight in this economy and, then, also be the best way to minimize the economical risk elements.

Co-operation on construction sites

Initially, the case study indicated that the construction sector seems to prefer that these two sectors operate separately. They want to have a construction site where they can perform construction works on their own terms and with a high level of efficiency (which means without archaeologists).

The workshop with both sectors indicated that initially, the archaeologists also prefer that these two sectors operate separately. They want to carry out their excavations without the tight schedule given by a construction site manager. But at the workshop, both sectors agreed that for a number of practical and economical reasons (as mentioned above: use of machines, transport and facilities for workers and more) the best practical solution for both sectors would still be to work together, well co-ordinated.

Use of archaeological output

Some of the informants focused on the archaeological output. They pointed out that they used much money on archaeological investigations/excavations and, normally, they would expect to get something in return for an investment.

In some of the projects for private clients, the high costs for archaeological works resulted in higher costs for marketing for sale; they would have to sell cottages as exclusive without really being so, and they would then like to use the findings as a part of the PR profile. But there were several obstacles to do so, mainly that the authorities for cultural heritage wanted control over this information at the same time as they did not finish the reports on schedule. Such issues should be discussed further to encourage co-operation.

In addition, the final accounts are often very delayed, this means extra costs for the client, because he can not conclude his own final accounts and convert the construction loans.

5. CONCLUSIONS

In summary, it is possible to say that good dialogue with archaeologists is necessary during:

- planning to define the risk-zones and the protection strategy already in planning process
- the early stages to work out the time schedule and carry out archaeological investigations in the most economical way
- design to find the good technical/functional solutions for both sectors
- construction to find compromises and solutions that have to be solved on site
- FM/rehabilitation, where it will also be in the client's own (financial) interest.

In all the stages, a better dialogue between the two sectors will contribute to possible reduction of the costs for archaeological activities – and these costs will have to be paid by the client in any case. Focus on good dialogue with the archaeologists in all stages of the project will therefore be in the clients' own economical interest.

INNOVATION AND COLLABORATION FOR EMBEDDED TECHNOLOGIES IN DANISH CONSTRUCTION – THE ROLE OF THE CLIENT

Kresten Storgaard and Marianne Forman (Aalborg University)

ABSTRACT

In a Danish setting, clients are especially seen to have the potential to be the main drivers in the process of stimulating innovation and use of embedded technology in construction: the paper questions this. The paper presents the results of a study of embedded technology. The study revealed the needs and potentials of specific types of embedded technologies in different segments of the sector. The types of technology include especially (Radio Frequency Identification tags (RFIDs) and Micro-Mechanical Systems of sensors (MEMS)). The segments in the construction sector were clients, suppliers and contractors. The study also included Danish research institutions and teams in this field. The empirical data were based on desk studies and interviews with key persons in supply (R&D in embedded technology), in potential demand (clients, suppliers and contractors) and in regulation/government. The study revealed noteworthy potential for innovation in developing products with embedded technology for the construction sector. The study also analyses barriers for this R&D process. What are the barriers and their character – technical or social? Are there any indications of how these barriers may be overcome, and who are the main drivers?

1. INTRODUCTION

A study on embedded technology in Danish construction, which SBI conducted for the Danish Enterprise and Construction Authority¹⁶, demonstrated that each link in the supply chain in the construction industry may profit by solutions provided by embedded technologies. The basic technologies are developed! But still there is gap between these visions and available solutions for the construction sector. A process is needed that adapts the technology to the specific needs in construction. There is, in other words, a challenge for innovation and development - both in the fields of ICT and in the construction sector itself. Theoretically, the conditions for innovation seem obvious. Needs in the construction sector – comprising all links from supplier and contractor, to client and users - seem to be asking for solutions from the ICT sector. And the ICT sector has products and capability for innovation, which seem adequately to deliver the requests. Yet, this analysis concludes that the market *alone* seems to be inadequate as a driver for this process of innovation; at least not in the short term.

This paper will focus especially on the role of the client in the process of developing adequate technologies. In Denmark as in most western countries the client is seen as an agent or facilitator for change. As the end-buyer – the client has the potential capability to make demands not only to the built solutions – but also to the building process itself (for example to demand partnering elements in design and process). Therefore the client is seen as an effective gateway for facilitating changes even in the construction sector. A gateway because it is a much more simple policy to facilitate change through demands by public clients in tenders, than through programmes for innovation including research, private firms in construction and supply, users and clients. Such a client focused centred policy is also much cheaper for the state, and seems much less complex to implement.

¹⁶ Storgaard, K., M. Forman and T.V. Rasmussen, 2007: Indlejret teknologi i byggeriet. Potentialer og besparelsesmuligheder for offentlige bygherrer. Erhvervs- og Byggestyrelsen. (Title in English translation: *Embedded technology in construction. Potentials and savings for public clients.*)

But the study demonstrates that a strategy depending on only the client as the facilitator for change, does not work. If the process of developing embedded solutions is seen as a chain of communication and negotiations between the developers of technology and the supply chain, the client and the user, it becomes evident that it is a complex setting. To develop solutions adopted by the users requires development of methods that support a process of innovation, which in turn reflects the complexity both in the sector and in the products.

2. STATE-OF-THE-ART REVIEW

2.1 Embedded technologies in construction

ICT and construction has been on the agenda for several years. Concepts of the Intelligent House and the Smart House were established, as well as real-life experiments with smart technology in buildings, which took place in several projects (Moltke *et al.*, 1997; Ambrose and Nielsen, 1997). Potential for increases accessibility for disabled people has often been in focus (Bendixen and Christiansen, 1999). The perspective in many of these projects has had a rather technological focus, often with an implicit assumption that the technology has the capability to develop smart solutions which would be implemented and dispersed through the market, with a little help from the demonstration project themselves. But increasingly both user involvement and focus on the innovation process itself have been seen, as is the case with a project for stimulating the regional economy in the periphery of Denmark (Lindgren; Sarghaug, 2008).

The Internet has opened up the perspectives for smart solutions both in the building and on the building site as well, combining net-based information or management systems with local devices. In 2002 the European Commission funded Roadmap projects including the ROADCON (Hannus *et al.*, 2003), charged with the task of providing input for the RP 6, identifying key actors and preparing cooperation between them. Embedded and ambient technologies were seen as potential technological issues, and the construction sector should be involved in their development. ROADCON concludes that *the Challenge for RTD in Construction is to identify the opportunities to collaborate with and use results from other sectors while focussing its own resources on sector specific issues* (Hannus *et al.*, 2003:3). But despite such advice for further investment for the IST programme, the construction sector did not play an important role in developing new technologies – neither in RP6 nor in RP7¹⁷.

In 2005 the ECTP (European Construction Technology Platform) was formed to provide input to the RP7. Embedded and ambient technologies played a significant role in the recommendations by one of the subgroups¹⁸. And again strong recommendation for collaboration between the ICT sector and the construction sector was seen. Hitherto no major initiatives have been established in RP7.

The ERABUILD organisation¹⁹ took a position where especially the RFID technologies²⁰ were seen as a major technological feature with potential importance for the construction

¹⁷ The project ManuBuild (RP6) may be seen as a project that opens up for collaboration between ICT and the construction sector: *ManuBuild targets a radical breakthrough from the current 'craft and resource-based construction' to 'Open Building Manufacturing', combining ultra-efficient (ambient) manufacturing in factories and on sites with an open system for products and components offering diversity of supply in the market.* (Manubuild, 2005:1)

¹⁸ PICT (Process and ICT) was Focus Area no 7 in ECTP; see http://www.ectp.org/fa_pict.asp

¹⁹ ERABUILD (European Research Area in BUILDing) is an EU related strategic cooperation between national programmes promoting sustainable construction and operation of buildings between 8 EU countries, see <http://www.erabuild.net/index.html>

²⁰ RFID stands for Radio Frequency Identification. The technology consists of a tag that contains information and antenna or a radio-transponder and a reader, which can receive the radio signals

industry and for the built environment. A report²¹ from an international consortium was published December 2006.

As early as 1995 Jaselskis *et al.* pointed out that the RFID technology was especially promising for the construction industry because it *"can be integrated into systems that can track materials, identify vehicles, and assist with cost controls"* (Jaselskis *et al.*, 1995). The Era report was characterised by a rather technical view of the RFID subject, yet they *"acknowledge that there are also organizational and socio-political aspects of implementing RFID in an industry or organization"* (Erabuild, 2006:8). But they didn't include these aspect in their analysis as they see such aspects as *"not a special RFID technology issue but more or less and issue that will be important for any technology and in any industry"* (op.cit, p8).

Two technologies are central when speaking of embedded technology: RFID and MEMS²². It is the combination of sensor technology (MEMS) connected to RFIDs and the access to the web that widened the perspectives much more than the perspective of use of RFID as a potent barcode technology, a function that hitherto has been in focus. The technology implies that data from a building material (e.g. a roof) or a building functional unit (e.g. a room) can be read and combined with information on the net, transferred to the reader. This will make it possible to get information about the situation on the building site (e.g. about the material (authenticity, condition/ moisture), instructions for the placing and handling of building elements, on Health and Security – or information about the building in use e.g. the roofs (e.g. leaking roofs, snow loads) or about temperature and ventilation in rooms. Information which typically requires response such as maintaining operations, alarms for pre-mould growth attack, removal of snow etc. or for automatic regulation of temperature and ventilation.

2.2 Client driven innovation

In recent years, the policy and research efforts in both Denmark and abroad have emphasised the role of the client as a driver for change in construction. This has been the case in the Danish policy on government building projects (Erhvervs- og Byggestyrelsen, 2002), it is seen in the proactive strategy of CIB on revaluing construction (Haugbølle og Sørensen, 2008), and it is seen in the establishment of an International Construction Clients' Forum (ICCF), (Haugbølle and Forman, 2006). However, little effort has been put into understanding how clients have in fact been a valuable contributor to reforms in construction. Thus a gap seems to exist between knowledge and policy on the role of the client as driver for change.

and thereby the information. The RFIDs can be either passive or active. In a passive tag, radio waves from the reader induce power in the tag, so radio-signals here can be transmitted and be readable by the reader. The distance between the tag and the receiver ranges from a few inches to 30 feet, depending on the frequency of the radio waves (ERABUILD, 2006:13). The amount of data has to be few; often only identification as an easy-to-read barcode, or an address on the internet. The price is low allowing the tags to be scattered widely e.g. in a building material – e.g. in concrete. The active RFID tag has access to power – a battery or a connection to the power supply – allowing transmission of signals over a longer distance, typically 60 to 300 ft. The amount of information can be high and prices are higher (ERABUILD, 2006:14; Bassi and Parand, 2002).

²¹ ERABUILD, 2006, RFID in Construction. Review of the current state of Radio Frequency Identification (RFID) Technology, its use and potential future use in construction.

²² MEMS are sensor technology and it stands for Micro-Mechanical Systems. *A sensor is a device that provides information about the state of a physical system. A sensor is tailored to the physical system and operates on the premises of the system".* (<http://www.sensortec.dk>). The sensors might be reduced to a minuscule size where nano-technology meets sensor-technology, see fx the Smart Dust project at Berkeley (Pister, 2001), (Hsu *et al.*, 1998). The sensors taste the molecules so to speak. The sensor measures the state of a functional condition (heat, moisture, ventilation, load, frequency of mould, etc) and may communicate this information to an actuator, e.g. through RFIDs, so a response to change the situation if needed, may be carried out.

According to the Swedish Academy of Engineering Science (Swedish Construction Client Forum, 2006) the client must maintain a broad spectrum of competences in order to manage planning, execution and operation of a building. Thus, focus must be on the client's ability to handle the relationship with all stakeholders of the building, be they the owner, the customer, society or the building industry.

The Danish Association of Construction Clients (DACC) focuses on client's line of action for purchase and tender. They propose that the action changes from being based on project-specific assumptions to be based on company and strategic discipline, and they propose clients to develop strategies for purchasing and supply of buildings (Bygherreforeningen og Konkurrencestyrelsen, 2008). This growing focus on clients as change agents is among other things inspired by the concept of lead users developed by Von Hippel. Von Hippel defines lead users as: *"Lead users are users whose present strong needs will become general in a marketplace months or years in the future. Since lead users are familiar with conditions which lie in the future for most others, they can serve as a need-forecasting laboratory for marketing research. Moreover, since lead users often attempt to fill the need they experience, they can provide new product concept and design data as well."* (von Hippel, 1986:791).

2.3 Public procurement and innovation

Edler and Georghiou argue that public procurement as an innovation policy has a major importance for the development, an argumentation that may enhance the interest of the public client as a main driver for innovation. In the 1970s empirical studies showed that over a prolonged period of time public procurements motivated to more innovation than R&D subsidies. They define demand-side innovation policies as *"all public measures to induce innovation and/or speed up diffusion of innovations through increasing the demand for innovations, defining new functional requirement for products and services or better articulating demand"* (Edler and Georghiou, 2007:952).

They point to the fact that public procurement has to play a different role depending on the stage the product has been developed to. They make a distinction between commercial procurement and pre-commercial procurement. Commercial procurement is when the products are already developed (the products are on the shelves) and the public clients just have to demand and buy the products. Pre-commercial procurement is the situation where the products are not ready for sale, but are still in a pre-commercial stage, and there is still a risk connected with the innovation of the products and services. The idea behind pre-commercial procurement is that the risk is shared between the potential producers and users, here represented by the public. There is still a need for R&D. Edler and Georghiou formulated it this way: *"In practical terms the procurement in fact is an R&D service contract, given to a future supplier in a multi-stage process, from exploration and feasibility to R&D up to prototyping, field tests with first batches and then, finally, commercialisation."* (Edler and Georghiou, 2007:954). They argue that the justification for this more flexible approach in the innovation process is that interaction is necessary between R&D activities and formulation of user demands. Three rationales for applying public procurement as innovation policy tool are identified: 1) Local demand, 2) market failures and 3) improvement of public infrastructure and service.

Local demand

Edler and Georghiou are inspired by the concept of lead-users developed by von Hippel. They extended the concept of lead-users to the concept of lead market. The rationale behind local demand is a situation where early users take a risk by using a technology that not finished and in return get access to a solution that can give competitive benefits or quicker access to a problem's solution. Lead market is when more users adapt an innovation long before the innovation is finished and contribute to products diffusion or when a single user like a public client constitutes a market by himself. The producers'

advantage is a reduction in the investment-risk. Edler and Georghiou formulated the rationale for the public in the following way. *"The role of the state in creating or assisting in creating lead markets mainly lies in the provision of a means to combine supply and demand-side measures. This includes provision of appropriate framework conditions that include and enable innovative activity (infrastructure, sufficient R&D basis, support for co-operation, etc.)"* (Edler and Georghiou, 2007:956).

Market failures

Edler and Georghiou point out two aspects concerning market failures. Firstly, customers often do not know what there is on the market. There is a lack of information and traditional distribution channels are insufficient for spreading the information to the users. Secondly, the user-producer interaction and communication is often poor. The users do not voice their demands loudly enough for the producers to hear them (Lundvall, 1990; von Hippel, 1986). The result is a marked where demand and supply do not meet. Edler and Georghiou argue that public procurement can be a part of the solution of these market failures. Public procurement can reach critical mass and shape the incentive for the producers to innovate and to produce products that especially the public buyer demands.

Public procurement to improve other public policy and services

The rationale is that through public procurement the state can shape the direction for innovation and support certain policy goals such as sustainability, energy efficiency, e.g. In the case of embedded technology it could be goals as reduction of building damage or a more general a wish to maintaining buildings in a better way. It is argued that, it is shown that the state often is more demanding than private consumers in satisfying new societal needs and providing infrastructure and public service. The state will in this role often act as a lead user (Edler and Georghiou, 2007).

Implementation

Edler and Georghiou point out that a necessary condition for promoting public procurement is governmental management and coordination across the public sector. Simultaneously the suppliers have to realize the economic benefit they can achieve through this cooperation. They formulate the challenge in following way: *"The major requirement for a strategy procurement policy thus is to bring future needs and future supply together at an early stage"* (Edler and Georghiou, 2007:959). They point to the use of strategic forecasts as a way to develop common visions between producers and users.

This also shows the weakness in public procurement as a main driver for innovation on a national (European) scene. What was seen as a fruitful strategy for innovation is today more or less impossible – or at least difficult - to carry out, due to international agreements and regulations on competition and collaboration. In EU no major public procurement is allowed without tendering (EU, 2004/18/EF), which impedes strategic collaboration for innovation between public procurement agents and private firms. In DK and in many other western countries it is also the experience that management across governmental bodies seems simple but is a huge challenge in itself. These few empirical based facts weaken the assumption that the public body in collaboration with the industry in *an (politically) easy way* will be allowed to be agents for innovation in direct collaboration on innovation through purchasing.

2.4 Embedded technology in construction: a complex system

Buildings are often characterised as complex products and the production and supply system as a complex production systems (Gann and Salter, 2000). In this sense development and implementing of embedded technology in buildings and in the construction system may be perceived within the frame of innovation in complex production systems. Gann and Salter point to different central aspects that characterise innovation in complex production systems. In contrast to traditional industrial networks, the construction sector is project-organised. As a consequence of this, Gann and Salter point to the fact that: *"The project-based nature of work implies that firms have to manage networks with complex interfaces. Delivery of products and services requires collaboration between firms. Performance and competitiveness depends not solely on the single firm, but on the efficient functioning of the entire network"* (op.cit. p959). The created value and profits is in this way not connected to a single company but rather *"generated by project groups that tend to operate at the boundaries of the firm"* (op.cit. p957).

Often complex products and systems must be integrated in existing systems to function in the context. Gann and Salter point out that it appears that the level of technical complexity increases when new generations of technology must be integrated with older systems. Therefore the need arises for new specialisations to support system integration, which can be placed in different locations within companies or between companies in new firms (op.cit. p959). Furthermore project-based firms can position themselves in the role of system integrators. The development and placement of these new specialisations may have an impact on the production and use of complex products and systems itself. A key question concerning the development and implementation of embedded technology is how the system integration can be done? Which actors can be system integrators or develop into it, and what kind of framework has to be developed for this to happen?

For Gann and Salter not only clients and the regulation system are important single drivers; they add *"Governments and international agencies, financial institutions and insurance organisations are creating a new framework for the governance of technology in construction"* (op.cit. p960). Each stakeholder in the process might play an important role. And so must stakeholders in new businesses which may stem from the new solutions/ technologies, such as new services, financing bodies, insurances companies, etc.

Project-based innovation across organisations has at least two implications for the involved firms, customers and institutions e.g. first, innovation projects are characterised by having a lot of non-routine features. Second, *there is a need for integrity of information between suppliers, designers, systems integrators, engineers, contractors, clients and end-users* (op.cit. p961). Gann and Salter point to the fact that there is a growing need for developing services to support the owners and users of complex products and systems; both in relation to the management servicing and the maintenance of building systems. Services include financing, planning and design, consulting, customer support and training, supplier coordination, marketing and risk management, together with benefits in relation to facilities management. They conclude that *"Growing demand for packaged product and service delivery is blurring the traditional boundaries between manufacturing, design, construction and service sectors"* (op.cit. p962). Moreover a characteristic of complex products and systems is that the artefact generates added services and these companies earned money on the services instead of only on the artefact.

Following the argumentation of Gann and Salter we will conclude that in complex systems of innovation a single stakeholder is seldom seen as the main driver for innovation. If innovation has to be stimulated an innovation progressive policy must reflex the complexity among the stakeholders that must constitute the future technological solutions – that is stakeholders from ICT, from construction, from client, facilities

management (FM) operators, users of the building, and even from the regulative bodies, financing bodies and future service providers.

3. RESEARCH PROJECT

3.1 Project description and objectives

The objective of the research project was to investigate the potential of embedded technology in the Danish construction sector. It was carried out for the Danish Enterprise and Construction Authority. In a key report for the Danish construction industry published in 2006 a central scenario was that *Major developers should require the use of embedded ICT in building materials and construction. Smart building materials can enhance the construction process, helping to meet users' needs and manage the building business.* (Erhvervs- og Byggestyrelsen, 2006:11)

The research team at SBI was given the task of investigating how close the vision was to the actual state of the use of embedded technology in the sector. The analysis was carried out and in August 2007 the results were published (Storgaard, Forman and Rasmussen, 2007). The task included a definition of terms and concepts and a clarification of the future and current market for embedded technologies in the construction sector, an overview of research in the field and a clarification of the need to stimulate development in relation to public buildings and embedded technologies.

3.2 Research methodology

The project was carried out in five phases²³. The empirical data was based on desk studies and interviews with key persons in supply (R&D in embedded technology), in potential demand (clients, suppliers, contractors) and in regulation/government. Qualitative interviews with key persons were chosen as the main method for getting information on experiences from stakeholders. Surveys would add only little to the *understanding* of the use of the technology or of the process (or potential) for innovation and collaboration on R&D between the construction and the ICT sectors; although surveys may be suited for *mapping* the frequencies of use of embedded technology in construction and of frequencies of collaboration on innovation in the sector. Case studies would have been an option, which might have given a good understanding of how well the technology worked in the construction sector – and about the problems of daily use. But case studies would have brought only little experience to the explanation of processes that do not in fact take place – like for example the lack of collaboration on R&D, which, as mentioned in the introduction, was the assumption of the project from the beginning. Our conclusion is that the chosen methods are appropriate for outlining the patterns of use, potential use and potential savings as well as to give some indications to the understanding of the process of innovation. A total of 23 key persons were contacted and interviewed. All were stakeholders in the potential industrial complex between ICT, contractor and suppliers in the construction process, clients, research and

²³ Phase 1 - Conceptual Clarifications – based on desk studies. Phase 2 - Research into embedded technologies and construction. Desk studies, interviews with key players in research and research foundations. Emphasis was on identifying the Danish research, but also the EU research is described.

Phase 3 - Applications and saving potentials. Interviews with stakeholders in the construction value chain.

Phase 4 - Public clients and embedded technology. Special interviews with this type of user.

Phase 5 - Analysis of barriers and opportunities for the development of embedded technology.

consultancy and governmental bodies. The method used for finding the relevant people for interviewing was by the snowball method. Starting with a core group, then asking each person interviewed, whether they knew other people with experience in the area that it would be appropriate to interview.

4. RESEARCH RESULTS AND INDUSTRIAL IMPACT

4.1 Quantification of results

The analysis showed a construction sector with substantial potential for embedded technology that could contribute to solving its needs and an ITC sector with potential for delivering the wanted solutions. But the analysis also demonstrated solid barriers, which prevented demand and supply to meet.

Table 1 summarises the results. For each type of use, the state of use of embedded technology, the potential for further use and for possible savings are stated. The table shows that *clients* can benefit from embedded technologies especially through better FM functionalities for example improved energy management and operation, just-in-time repairs, warning against moisture and moulds, warning against break down of materials. Type of use that also the *end-user* (tenants, employees in factories and offices) may benefit from for example enhanced comfort and cost reduction of energy. In the building process as such, the *contractors* may benefit from better logistics, improved instructions concerning production and health and safety, information and management on logistics, condition and authenticity of delivered materials. The *distribution sector* may benefit from improved logistics that allows them to deliver just-in-time to their customers, i.e. the contractors. The *suppliers* may not only be the stakeholder that should embed the new technology in their products – to deliver products with higher value for their customers (clients, contractors, distributors) – they themselves can also benefit from added information to the single items (on RFIDs) with individual customer data, allowing a mass-customized automated production.

So far the construction sector has not shown any great willingness to use the new technology or to participate in the process of needed R&D to form the technology in accordance with their demands. This also applies the supplying industries. They were uncertain of how much demand there would be, and uncertain of the benefits, if any. It applies to the distribution and marketing stakeholders as well, reported to be on a stand-by, despite the benefits reported and documented by other industries. The picture seemed clear. Solutions to cover specific needs were developed – or could be delivered. In this way there was a potential for solutions to meet needs. But the technology has not fully matured yet – for commercial solutions. This means that specific solutions have to be designed for each customer. Volume in production is low, and prices high.

Table 1. Use of embedded technology in the construction sector and the potential types of savings.

		State of use today	Future use and potentials for savings and cost-reduction
Building materials		RFID for production management Prefabricated smart HVACs	RFID for the management of production RFID for warehouse management. Cost savings: Optimising logistics
Distribution		RFID for supporting logistic	RFID and sensors for supporting logistic, waste and the destruction of materials used for transportation and storage, and guarantee of authenticity. Cost savings: Optimising logistics.
Process of construction		RFID for the marking of construction equipment, etc.	RFID and sensors to support logistics, including losses of construction and destruction of building materials for the transportation and storage. RFID to support the building process itself with instructions, etc. for example with links to the websites of construction material manufacturers. The link between Digital Construction tools, the on-site digital hut, and tags on building materials. Cost savings: Reduction of waste. Increase of productivity. Reduction of industrial accidents
Use – Client, FM and residents	Operation	Local CTS building management system for managing energy	CTS – building management system for control of energy production and energy coupled to energy system. Using RFID to ensure proper cleaning through links to web based services managed by producer or service provider. Prevention of moulds, etc. through monitoring with sensors, etc. Cost savings: Optimising management of energy and ventilation
	Maintenance	Use of sensors for assessment of condition of concrete on bridges. Assessment of monitoring of moisture	Using RFID to ensure proper maintenance through links to the homepage of the producer. Using the wireless system (RFID and sensors) to the assessment of the condition of buildings. Cost savings: Optimising renewal - just in time.
	Use	Management of matters relating to comfort (light, temperature, humidity)	The use of embedded technology to support operations and new forms of cooperation. Control of lighting, heating, ventilation, humidity, etc. with CTS, sensors and RFID. Cost savings: Increase in the value of the buildings - enhanced comfort, improved energy balance.

4.2 Barriers and drivers

The overall picture of the innovation process was that many persons involved in the construction industry were reluctant and hesitant to implement embedded technology,

due to uncertainty about it, and lack of clarity about its impact on their market potential. The study also pointed out a general type of problems concerning the *standardisation* in relation to RFID. This has to do with identification of frequency ranges and power. The standards that are currently developed are the passive tags for use in logistics, where the sole aim is to identify the manufacturer and the product.

A gap between the speed of development of ICT and in technical/physical elements was mentioned as a barrier as well. Buildings etc. are characterized by having a long life, while ICT equipment is characterised by rapid development and rapid transitions to new generations. Uncertainty as to whether one *generation* of embedded technology would be able to communicate with the next generation also weakened the motivation for the construction sector to invest in the new technology. Furthermore *security* was seen as a barrier. Would it be possible for competitors to "read" the tags and view a company's purchases and investments, and in this way get information about some of its key parameters of competition? Investments in embedded technology in buildings may be seen as a minor investment in a *total economic perspective*. Even if cost saving on FM is judged to make a profit of the extra costs in investment, the client is reluctant to take on the role of facilitator for innovation in this field. That the tenants often directly pay the FM expenditures only weaken the motivation for client-driven innovation even more. The analysis showed clearly that the level of readiness and awareness of the new technology was low at the time of the study, and that the level of uncertainty concerning the impact on the user of the built environment was high. The clients believed that other parts in the supply chain, especially the contractors, might benefit more than the client. And therefore the clients were not motivated for being prime drivers. Our research also demonstrated that insurance organisations might play an important role in the innovation of embedded technology. Not only as a part of the framework condition but rather as an active part of either the supplier and service system or as a part of the market system.

The study demonstrated that each link in the supply chain in construction may profit from solutions delivered by embedded technologies. However, the technological solutions differ in accordance with the type of need of each link in the demand chain. If the process of developing embedded solutions is seen as a chain of communication and negotiations between the developers of technology and the supply chain, the client and the user, it becomes evident that it is a complex setting. In this way embedded technology in the construction sector has to be interpreted as integrated complex products that must interact, if high effects are to be achieved. But that requires development of methods that support a process of innovation, which reflects the complexity both in the sector and in the products.

Although the construction sector is known for a certain restraint concerning investing in strategic innovative activities themselves, the interview nevertheless revealed a growing readiness to participate in R&D activities concerning use of the new technology in the sector. The study point out that in collaboration with the technology sector (researchers, developers and producers of devices for this new technology), the construction sector has the potential to be a major partner in further innovation in the ICT sector on a national and international scene. It can be noted that there is a gap between the current R&D in embedded technology and R&D in construction.

Coupled with R&D traditions in ICT and high-tech funding bodies that do not give priority to collaborative innovation projects between the ICT sector and industries, which are certainly not perceived as high-tech, the construction sector's traditional inertia to invest in development can be a significant barrier. In settings where the user of buildings may be seen as advanced users²⁴, there will be a potential for strategic collaboration between the construction sector and R&D in embedded technology for developing solutions that

²⁴ Advanced users are users, who embody the need of tomorrow, e.g. families who want careers, children and lot of leisure time – a cocktail that today's everyday life, often cannot fit in.

are suited for future demands in other markets as well. This may be the case in a Scandinavian context, where dwellings and homes are very highly valued, and there are high demands for functional everyday dwellings, as well as for architectural performance. The same applies to non-residential buildings, where Scandinavian companies are inclined to invest in the building part of their production system. Architecture is not only symbolic capital, but real estate as well. In addition, the construction sector represents a potentially significant demand itself. The turnover in the building set-up is large in the national economy and a small additional cost for technology investment, may seem modest in the overall construction project. If the new technology can increase internal functionality in buildings while at the same time contributing to a better performance in the process of construction and even improve the quality of the finished construction, there should be opportunities to develop solutions that have great potential for marketing in the international market.

5. CONCLUSIONS

Innovative processes in which technologies mature and develop are characterised by a high degree of uncertainty about the outcome. Through a process of negotiations between stakeholders the span decreases – the new technologies (including the use of the technology) crystallise and the scope of future influence is dramatically reduced. In the case of embedded technology there still seems to be opportunities for stakeholders to participate in forming the technology in these years. The study clearly demonstrated that in the field of embedded technology, the client alone is not capable of assuming the role of the leading facilitator of innovation. The connection between extra investment and a direct pay-off in higher value is judged to be too weak and uncertain, even by public clients. The study also demonstrated that the different stakeholders in the construction sector – or links in the chain of delivery - have different demands to what the technology should deliver. This puts focus on the need for a dialogue with these actors across the construction segment to developers and producers of the embedded technology. While clients may not be the main driver for innovation, they will be an important part in the dialogue in the complex network for innovation. Such a network should include stakeholders from the embedded technology (e.g. RFID, MEMS) who deliver the technology, the building materials industry, which produces the elements where the technology is built in (or attached), the client, operators (FM) and users of the buildings. Also the constructors, designers/architects and consultants are significant contributors to a dialogue-based innovation process. And so is finance and assurance which may develop new budget models if higher quality in the produced buildings with fewer failures and insurance costs.

It is the conclusion of the analysis that a wide diffusion of the use of the embedded technology depends on the establishment of a process of communication and negotiations between the developers of technology and a complex of the stakeholders in the construction value chain. A (re)configuration of actors has to take place. A client-driven process alone will not stimulate the process of innovation.

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DISCREPANCY IN THE ASSESSMENT OF ATTRACTIVENESS AND USEFULNESS OF IT AND PLANNING METHODS BY BUSINESSMEN AND ACADEMICS

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ABSTRACT

Dynamic development and utilisation of construction management (CM) tools and information technology (IT) in the Polish construction sector are the objects of the research. Polish builders, real estate developers and academics based in technical universities are the subject of research. A significant discrepancy in the assessment of the attractiveness and usefulness of those methods by businessmen and academics has been highlighted and their respective viewpoints have been presented. The companies have primarily indicated such problems as: scheduling of resources, risk analysis, cost and budgeting. Decreased interest in mathematical methods and optimisation were some of the phenomena which have been observed. On the other hand, representatives of technical universities primarily indicated fuzzy and stochastic approaches. Academic preferences in recent research have been supplemented by the following: flexible management, advisory systems, as well as RFID, and combinations of GIS, GPS and GSM. A good financial situation in the construction industry is the context of discussion although, unfortunately, such a favourable situation does not have a positive influence on using new methods, IT in particular. The research was based on questionnaires and interviews carried out in 2000, 2005 and 2008. Regression and correlation were used to analyse the relationships between the degree of utilisation and usefulness of the methods in question and the type, magnitude (measured with the number of employees) and the type of company ownership. In all those cases such relationships have not been found. The reasons for such a situation are explained.

1. INTRODUCTION

Both in the world and in Poland, the end of the twentieth century has defined new economical conditions which, in fact, boil down to the following slogan: knowledge-based economy. Two trends have been present alongside: dynamic changes in production geared towards construction industry, and development in management methods which are primarily supported by the development of information technology (IT). The conclusion of the process of privatisation of Polish companies, and good economic atmosphere should foster more interest in new decision aiding and planning methods. Even brief observation shows that interest and, what follows – utilisation of new IT methods is below expectations.

A number of questions arise, for example:

- What is the relationship between usage of new solutions and assumptions of knowledge-based economy?
- What is the level represented by Polish companies, from the standpoint of new planning techniques?
- What is the relationship to good economic situation and prosperity in the construction industry?
- What stops Polish companies from acting towards introducing IT and sophisticated planning techniques?
- How do scientific achievements translate into practice?
- What phenomena occur, and is it possible to explain some of those occurring on the interface of science and everyday practice?

Searching for answers to some of those questions required using unconventional methods, but produced surprising results.

2. STATE-OF-THE-ART REVIEW

2.1. Bibliography of the subject

In order to answer the above questions it is, first of all, necessary to know the parameters of good economic situation or prosperity in construction industry, as well as barriers blocking the construction and assembly sector. There is innovative economy in the background of our discussion. Strong economy, including the introduction of new technologies, materials and services to the market, is also an effect of collaboration between the worlds of science and business. In Poland, approximately 2.7 patents are claimed per a million inhabitants, whereas the average in Europe is as much as 133 (GUS, 2007). There are some countries which intensively invest in research and development. Poland is still one of those countries that attracts investors with low labour costs. It is a fact that, in the long run, such strategy does not pay off and, moreover, it can be disastrous.

There still lingers a popular stereotype. An academic or scientist is a person very often distanced from real life, focused primarily on research on extremely difficult subjects. A businessman is a representative of a fast growing, ever wealthier group, disinterested in acquiring knowledge and developing a competitive edge through expert advice and know-how, or IT.

Research on collaboration between businessmen and academic centres was carried out by the Ministry of Science and Higher Education (MNiSzW, 2006), but concentrated on industry, not building companies. Nonetheless, some characteristic conclusions can be presented here. The Internet is a source of information for 30% of businessmen. As many as one-fifth of Polish businessmen do not know that such collaboration is at all possible. Only 10% of companies see a chance to increase their exports thanks to collaboration with academics. Businessmen criticise reality for the lack of legal incentives and specific offers. On the other hand, as many as 62% of scientists declare that they are the authors of solutions that can be commercially implemented in the world of business. Nearly every single one of them declares willingness to find businessmen who would be interested in collaboration.

The Ministry report (MNiSzW, 2006) indicates a need to introduce internet communication platforms where both communities may meet, virtual stock exchanges where information could be swapped, and other places in cyberspace. According to the author, it is nothing more than institutionalising collaboration using yet another label. The report, though suggests conclusions, is quite shallow: it indicates areas of anxiety, but does not analyse the causes. What it means is that research on construction should be carried out differently.

It should be expected that good economic situation in construction industry should foster a better usage of IT tools. The major crisis in Polish construction industry in this decade is over (2002). In those times, companies may not have invested in IT systems. Since 2002, fast growth of profitability of construction sector can be observed, cf. ASM, 2007; Forum, 2007; GUS, 2007; Kapliński, 2008a; Zdyb, 2007. It may seem that increase in profitability will determine the increase in new planning methods, as well as developed methods of decision making, and IT systems. Unfortunately, research done by the author only partly corroborates this hypothesis.

Therefore, it is worth noting again the existence of some barriers in construction and assembly activity. Such reviews are regularly carried out by GUS (Central Statistical Office). 10 factors are usually analysed. The most recent September 2008 review indicates that the percentage of businessmen not feeling any barriers in their business activities is around 4.3%. Major difficulties encountered by construction companies who

claim that they, indeed, encounter barriers, were related to labour costs (60%). Competition from other companies as a factor, is at the level of 57%; shortage of qualified workforce 55%; costs of materials 36%; costs of financial services provided for construction 36%. Other six barriers are felt by fewer companies (28% to 4%), GUS (2008).

In the review, GUS do not ask problem questions about decision making, management, computer software, and so on. Other research, carried out in the Kujawsko-Pomorski Region (Bizon, 2005), compared to similar research from Russia (Kovalenko, 2005) indicate characteristic differences: while Polish companies seek capital (50%), workforce (81%) and managers (62%), the Russian ones are largely interested in sheer accumulation of capital (priority at the level of 58.3%). The interests (priorities) are similar with respect of IT implementation, i.e., 25% and 29.2%. The synthesis of those comparisons has been presented by Kapliński (2008a).

There are some interesting international comparisons. Oladapo (2007) compares data related to Nigeria from 2005, Sweden – 2000, Singapore – 2003 and Canada – 1999 with regard to information and communications technology. Goh (2005) compares research in Singapore with data from Denmark and Sweden with respect to interactive applications of IT resources. Samuelson (2008), in the paper typical for Nordic countries, analyses resources aiding the design process (including CAD) and business. Rezgoui and Zarli (2001) present an attempt at synthetic discussion of IT usage in construction industry from the European standpoint. A review of different models solving specific problems has been presented by Ginevicius and Andruskevicius (2004), Hewage *et al.* (2008), Khamkanya and Sloan (2008), Kapliński *et al.* (2002), Salem and Mohanty (2008). Besides, web-based construction project management systems are highly estimated by different authors.

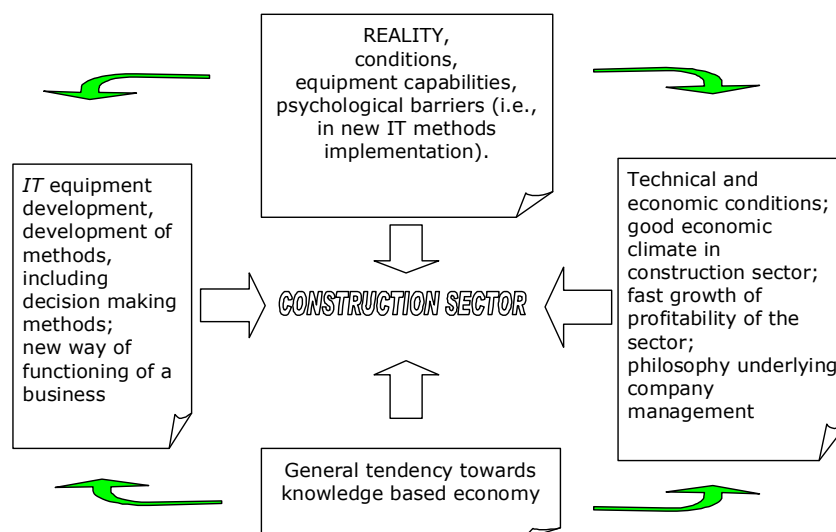


Figure 1. Technical and economic conditions of development and utilization of IT in the Polish construction sector.

The papers mentioned above deal mainly with software utilisation, including its usage by different groups connected to the investment process. All above quoted publications have a defect with respect to assessment on an international scale, namely they do not account for specific character of a given country, though economic and cultural conditions may vary considerably between the countries. Moreover, they do not reach out to find the causes of such a state, neither do they analyse the utilisation of the indicated planning techniques or specific IT resources, but most of all, they do not analyse the

relationship between the two communities: businessmen (building contractors) and academics.

The review of bibliography indicates increase and abrupt interest in IT. It is a result of changes in the ways decisions are taken and production is planned. There is a clear general trend to replace institutions by research. An order of steps in the development of foundations of decision making can be indicated, i.e. intuition, personal experience, self analysis of the problem, and then, recommendation of the staff. With respect to more developed steps, there are expertise, experiment and research. Artificial intelligence also appears in this area. It is a clear cut sphere of IT influences. Naturally, intuition can fail you, and experience is gathered over the years. The development of IT tools supports this tendency. This phenomenon is also typical for Poland. The reason is not only general technological advancement, especially in construction industry, but it is also because foreign capital and the process of ownership changes intertwine. The results of the author's research covering the 1990s and 2005 have been published in a variety of forms: see (Kapliński, 1994; 1997; 2008a).

Though it is easy to illustrate the trend in foundations of decision making, i.e. from intuition to IT, it may be much more difficult to present the evolution of development and usage of a variety of techniques, methods, and IT programmes. The difficulty stems from the sheer number and variety of the techniques and, primarily, from the dynamics of change in general. There have been attempts at systematic approach to the area – see Kano, 2005; Kapliński, 2008b; Kim *et al.*, 2005. A question arises: which of those IT elements is of special interest for companies and which is preferred by academic centres focused on research?

The usage of specific methodologies or software depends on the knowledge of the methodology and procedure of management in company. Generally, it depends on a number of both technical and economic conditions. Figure 1 presents basic factors influencing the development of IT in Polish construction sector. The claims illustrated by Figure 1 will accompany us to further sections of this paper.

2.2. Remarks on research methodology

Below are the most popular sources of information on the subject matter:

- a. three professional institutions (GUS – Central Statistical Office; ASM – Market Research and Analysis Centre Ltd.; PMR Ltd. – a British-American company providing market information). There are also other, smaller research sources:
- b. websites
- c. individual research.

The following methods are applied: ad-hoc (custom designed), omnibus, syndicate, distribution, and panel. Professional firms usually apply syndicate methods. Data derived from those firms, quoted above, have been acquired using that method. Data presented in the MNiSzW (2006) report was obtained using computer assisted telephone interviews (CATI) method. Individual research (even involving PhD dissertations) is obtained through surveys (questionnaires) which are not always approved of by faculties at universities of technology.

In research presented below, the author applied two types of methods: ad-hoc and surveys. The most credible data acquired by the author came from direct interviews.

3. RESEARCH PROJECT

3.1. Description and objectives

Taking into consideration the question asked in section 1 and conditions presented in a condensed form in Figure 1, research was divided into three separate parts.

The first group of research activities was intended to indicate a degree of utilisation of IT resources in construction sector. Further, detailed research depends on the level (degree) of using IT, namely finding the relationship depending on magnitude, ownership category, and specialisation of a company. The majority of companies have been defined according to the classification generally accepted in Poland: 5 classes were taken into account (see Figure 2 for details). In the largest class (>1000) no such company was found, therefore, zero was indicated as the degree of utilisation. As far as ownership category is concerned, three classes were analysed (private, public companies, and foreign capital companies). Analytical research into the type of specialisation was the most difficult, as there are no such companies in the region. As many as eight classes were analysed, 4 data in each class, which were then averaged (for each class).

The second group of research activities aimed at indicating the 'attractiveness' of various methods and techniques from the standpoint of construction companies. The decisions about taking up such research stemmed from a low level of utilisation of IT techniques and methodology. The context for the research was created by barriers that companies encountered, discussed in section 2.

The third group of research activities can be called counter-research with respect to the analysis of IT utilisation in companies. The same category of questions was addressed to academics. This research was supposed to indicate which of the methods are attractive from the standpoint of current dissertations, and which could be recommended to businessmen, i.e. building contractors.

3.2. Applied research methodology

Research on the degree of utilisation of IT methodology was carried out over three periods: 1990, 2005 and 2008. Research in the second and third group was carried out in 2005. The latter research was enriched with observations and interviews done in 2008.

The first batch of research was based on questionnaire surveys. Unfortunately, the questionnaires did not indicate a potential method; therefore, it was necessary to ask additional questions about some items.

Further research (within the framework of the first and second group of research) was based on collaboration with Wielkopolska Building Chamber which indicated companies best fit for being researched and made some data available. Employees of the Chair of Construction Engineering and Management at Poznań University of Technology participated in the research. The answers gave options of selecting some items. Furthermore, our staff collected questionnaires in person, often fine tuning the details (answers and indications). This is how nearly 100% of questions were answered!

Regression and correlation calculations were used in further analysis. Information acquired from participants of Poznań BUDMA 2008, the major Polish construction fair, was very useful. In this case, the author personally carried out the interviews. He talked with fair participants presenting and distributing information systems for construction industry, constituting a so called IT island. Thanks to this data, it was possible not only to add onto previous results, but also to define the phenomenon of saturation of the market with IT resources. (cf. Kapliński, 2008b).

The third group of research based on answers from members of the Section of Engineering of Construction Projects (formerly Construction Management). The Section is part of the Civil Engineering Committee (Division IV, Polish Academy of Science). Two questionnaire surveys were designed and distributed in 2000 in 2005. The 2000

questionnaire embraced only members of the Section, i.e., 22 people (62%). The 2005 questionnaire involved 17 members (48%) who represented 11 academic centres in Poland (number of answers from individual centres was 1 to 8). Several items could be indicated in the answers. The results could be confronted with the profile of papers presented for annual conferences of the said Section, whose problem range, to some degree, reflects Nordic conferences on construction economics and organization.

Difficulties in acquiring data, or flaws in research, are presented under the discussion of results (section 5).

4. RESEARCH RESULTS

The degree of utilisation of specific IT techniques and methods was the foundation for further analysis. The research indicated that the degree of practical utilisation of IT methods is insufficient. The 1990 results were compared with 2005 and 2008 results. The initial conclusions were as follows: The interest in mathematical programming decreased from 27-50% to 18% in 2005, and 15% in 2008. Similarly, the interest in digital simulation: from 20% in 1990 to 7-15% and 10% in 2008.

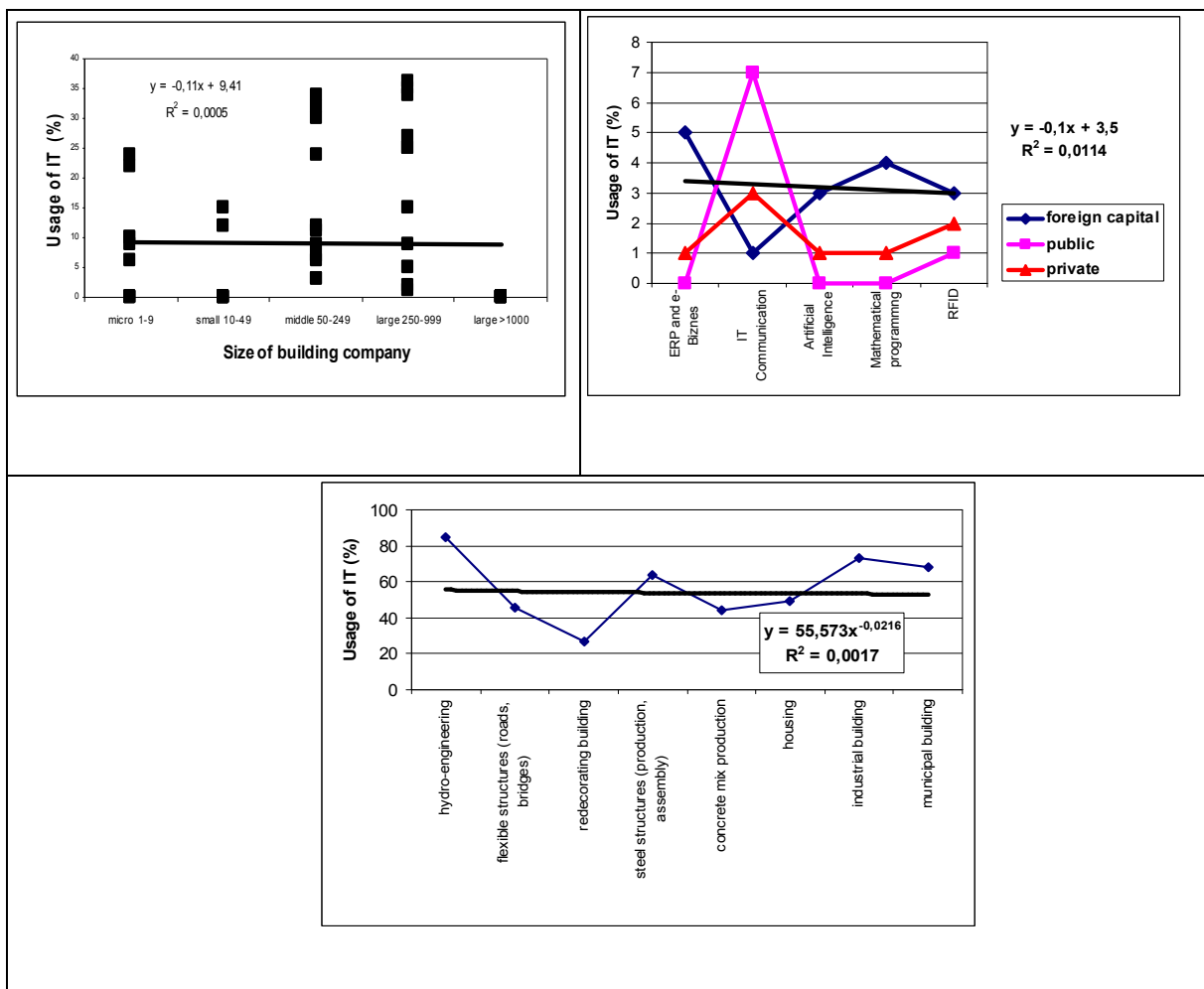


Figure 2. Relationships between of IT usage and the characteristic of a building company.

It was surprising to discover the degree of practical utilisation of MCDA (Multiple Criteria Decision Aid) methods. In this case, the utilisation of MCDA fell from 22% to 10% (and to nearly 5% in 2008), though interest in those methods in Lithuania (international collaboration of academics) is extensive, and the indications of their attractiveness by Polish academics are clear. The said degree, regarding expert systems stayed at its level (2-5%, 5% and 2%). There have been increases in: scheduling 4D (modelling of space + time), respectively from 0% to 5-20% and 10-25%; web-based project management systems (0%, 2-13 and 15-25%; and RFID (radio frequency ID) (0%, 5-7%, 10%). In 2008, the position of advisory systems (0%, 0%, 25-30%) was taken into account in research. It may be expected that in forthcoming research, a 5D modelling item (cost analysis) will appear.

Poor research results presented above gave a stimulus to analysing the relationship between the degree of usage of the above mentioned methods and techniques and type, size, and properties of a building enterprise. The results are presented in Figure 2.

Unfortunately, as Figure 2 shows, R^2 coefficient was nearly equal to zero in all cases. The lack of such a relationship proves scarce utilisation of IT tools (including planning methods).

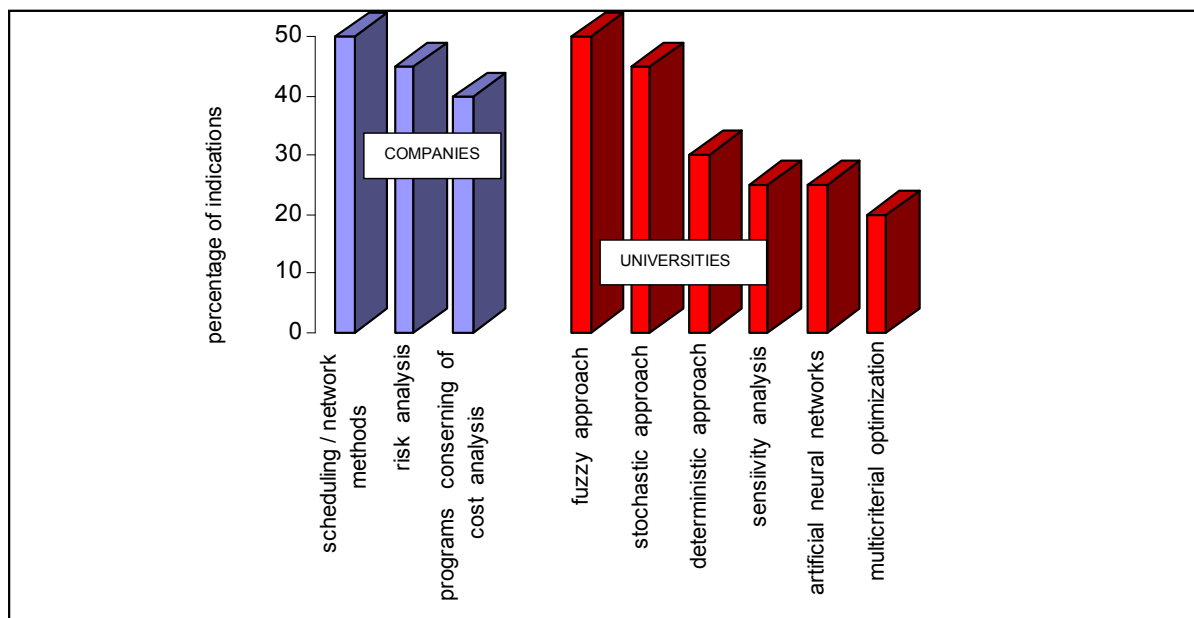


Figure 3. Recommendations by Polish building companies and academic teachers and research institutes (2005).

The results of subsequent research were merged. Indications regarding attractiveness of recommended or used methods between academics and businessmen in 2005 have been presented in Figure 3. The differences in indications are quite significant. Planning departments and building contractors pointed at, first of all, the methods dealing with scheduling tasks, including network planning. Second, they pointed at computer software and risk management methods. On the other hand, academic centres pointed at something completely different: fuzzy and stochastic approach. It was in keeping with current subjects of PhD dissertations worked on at civil engineering faculties. High position of deterministic approach results from the fact that some of the research participants represented ITB – an industry institute dealing mostly in technological approvals which are deterministic by nature.

Similar research, but dated January 2008, has been illustrated in Figure 4. This is data added to earlier results presented in Figure 3. What it says is that earlier indications were supported, and the list of items was extended. The first items to be listed were tools used in integrated management (ERP). It seems that the indication of ERP, as well as further items was a result of the flow of time. The situation is similar in the indications made by the academics who first mentioned such tools as RFID, as well as combinations of GIS, GPS and GSM. It is easy to notice that during our conferences mentioned above, and in PhD dissertations, those problems were also given high priority.

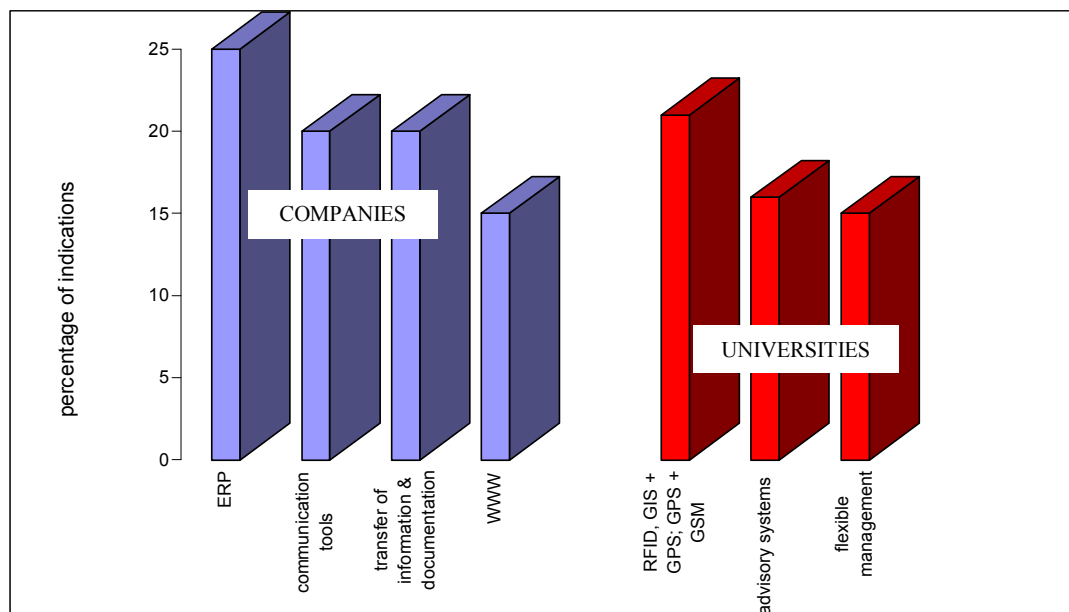


Figure 4. Requirements on IT tools by Polish building companies and academics (2008).

5. DISCUSSION OF RESULTS

What calls for a reflection is a lack of correlation between the indicated relationships which indicated a low level of utilisation of IT technologies. It was especially clear from the 2005 research. Poor utilisation of those techniques by Polish enterprises can be explained by a limited range of research and too sophisticated questions. Representatives of companies are reluctant to answer such type of questions, often hiding behind arguments of commercial secrecy, privacy, and competitiveness. It all happens when circumstances for development of IT tools and in this CM tools in Poland are favourable: free market, competitiveness and, first of all, favourable PMR-index of economic situation in construction industry.

It may seem that good economic situation in the construction sector should foster IT implementations. The good economic situation is one of the most important conditions listed in Figure 1. The profitability of the sector should be analysed more closely. The profitability trend in construction sector has been evident since 2002. In the years of stagnation, building companies rarely invested in IT systems. A specific paradox can be observed, namely that favourable market conditions in the sector and rapid development of construction companies makes IT solutions implementation more difficult, especially ERP class systems. It can be explained by the fact that the choice between distant benefits (which an IT system may bring in the future) and a short term profit resulting from the number of implemented projects is difficult. In Poland at the moment, we have the contractor market.

Let us take a closer look at the second subject. One of the reasons for such significant discrepancy (cf. Figure 3 and 4) is parameter based assessment of accumulated work of the academics, which decides about promotion. In Poland, in practical terms, there are still three academic degrees: a PhD, a post-doctoral degree (*Habilitation*), and professorship (*Sc.-Title*). Preferred publications should appear in periodicals on the so called Philadelphian List, i.e., those listed on ISI Master Journal List. Another preference is a high Impact Factor (IF). What it means is that research papers should be highly theoretical, whereas papers with a large practical component are slightly disrespected. Such situation, though forces the scientific level up, worsens relationships with the world of practice, and disregards current needs of construction companies. Furthermore, such papers which are largely published abroad, are often inaccessible to the Polish reader.

In spite of the tendencies to setting parameters, there have been papers presented in our environment, during the above mentioned annual conferences, with less theoretical rendering, for example on pre-qualification, selection of a contractor, tender systems, role of a manager. We have also seen papers more fitted to the profile of economical schools or departments, for instance on value and risk management, or on earned value. On the other hand, the following phenomenon is to be observed: a lack of papers on mechanisation of building processes. Such research requires larger teams, they are labour consuming, and the system of financing (grants) prefers short-perspective research subjects. Perhaps it is for the same reason that academics are reluctant to design and implement integrated management systems (ERP), in such demand in everyday practice.

It should be expected that, alongside with changes in economic situation in construction, business interest in IT solutions will change. Autumn 2008 indicates that prosperity for companies who do not use IT aid is coming to an end.

5. CONCLUSIONS

On the one hand, it is clear that development of IT tools is dynamic, while not all the solutions account for the specific character of construction industry. On the other hand, the present degree of utilisation of IT resources is unsatisfactory. Generally speaking, prosperity in the construction sector is good, nonetheless the investment in IT tools is not enough.

It can be seen from observations of the construction market in Poland, as well as from the presented research, that discrepancies between indications of the need and attractiveness of IT methods on the one hand, and recommendations made by universities of technology on the other, are substantial.

This discrepancy in the assessment of attractiveness and usefulness of IT and planning methods by businessmen and academics can be primarily ascribed to two reasons. Firstly, companies at present still manage to be highly profitable and do not need to invest in IT resources or introduce abrupt changes in management. Academic centres, on the other hand, are subject to thinking along the line of parameters, thus research work saturated with theory is, in fact, preferred. The more the academic world will accentuate thinking and assessing according to parameters, the bigger the gap between science and practice will become.

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UNDERSTANDING PROJECT COMMUNICATION IN A CONSTRUCTION PROCESS: THE IMPORTANCE OF PROJECT LIAISONS

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ABSTRACT

Research regarding project communication and ICT (information and communication technology) in the construction industry has, until present times, mainly focused on information modelling and standardization issues. However, in the quest for a more profound understanding of the current challenges and opportunities, a wider scope needs to be taken that also includes non-ICT related parts of the communication process. Therefore, this paper draws on traditional organisation theory literature and seeks to investigate the communication practice within the operational phase of a construction project. Based on an ongoing case study this paper investigates the parallel sub-processes within a partnering project's operational phase. When looking at the communication process and analyzing the integrative link between the formal and informal communication levels an essential information reduction process was discovered facilitated by the liaison function of the local branch coordinator (the project liaison). The paper concludes that the project liaison constitutes a very important part of the communication process within the project. Moreover, the paper concludes that the need for extensive information and ICT support, at a practitioner's level, is limited and scrutinized through a lens of situation based practical usefulness – resulting in the information reduction process, supported by the project liaison which enables flexibility and facilitates project completion.

1. INTRODUCTION

Research regarding project communication and ICT (Information and communication technology) in the construction industry has, until present time, mainly focused on information modelling and standardization issues (Wikforss 2006; Wikforss and Löfgren 2007). Although the acceptance and adoption rate of ICT in the industry has been slow, a major increase of both scope and depth has been identified during the last decade (Samuelson 2002, 2008). The use of ICT among large building and construction companies is today an essential part of the coordination and management of information flows (Molnár *et al.* 2007). It also plays a role in supply chain management, planning, control, and cost estimation (Cutting-Decelle *et al.* 2007; Dainty *et al.* 2006).

Within construction projects, however, the use of ICT for intra and inter-organizational coordination and information exchange in the planning, design and production processes (i.e. the operational phase) has been limited, even if it is claimed to have recognized potential (see e.g. Wikforss and Löfgren 2007). The fragmentation of the industry and the lack of integration between the design and production processes is often claimed to create barriers for further integration and development (Dainty *et al.* 2006). Moreover, in contemporary research a number of additional aspects have been identified to explain the challenges of project communication and the present adoption and use of ICT within the construction companies, i.e. both hinders and driving forces. Some of the aspects discovered are competitive advantages, external and internal forces, management support, user's individual characteristics, and the project based mode of organizing within the industry (see Mitropoulos and Tatum 2000; Peansupap and Walker 2006; Rowlinson 2007; Linderöth and Jacobsson 2008).

In an attempt to further address the dilemmas regarding construction ICT and project communication, Wikforss and Löfgren (2007) suggest a number of areas in need of further research. One of the areas put forth by the authors relates to formal and informal communication and focuses on how project members are able to handle the unexpected situations that occur during the construction processes. In accordance with Wikforss and Löfgren (2007), and in a quest for more profound understanding of the current hinders, challenges and opportunities, a wider scope needs to be taken. That is, not only focusing on ICT and the technological aspects of the communication process but widen the scope and also include formal and informal communication and thereby also analysing organisational aspects of the communication practice.

Given this short introduction, the aim of this paper is therefore to investigate the project communication and the practice that arises within the operational phase of a construction project, linking the formal and informal communication together. Essentially address the question; *how are formal and informal communication processes integrated and linked together within the operational phase of the project?*

Based on an ongoing Swedish case study within a construction project and drawing on traditional organization theory literature in general – more specifically on Mintzberg's (1980, 1983) role related liaison devices, i.e. the liaison positions and integrating managers – this paper scrutinizes the communication practice within a partnering project and the activities carried out by the subcontractors and the local branch coordinators. To be more specific, it investigates the link between the informal and generally non-technologically supported communication and the formal and often, as to be shown, technologically supported communication within the sub-processes of the projects operational phase.

2. THE CONTEXT OF CONSTRUCTION PROJECT COMMUNICATION

In order to follow the suggestions from Wikforss and Löfgren (2007) and take a wider scope on project communication and the mentioned organisational difficulties related to adoption and use of ICT, the construction context and its built-in communicative challenges needs to be considered. In the following section a number of central aspects of the construction context will therefore be outlined followed by a discussion concerning collaboration and communication in the project setting.

According to Harty (2005) there are five central characteristics of construction work that are important to understand in order to grasp the challenges of the contemporary construction context, and through that the arena for construction project communication. These characteristics are; the collaboration upon which construction work is based, its organization around particular projects, the importance of inter-organizational relations, the way power is distributed, and the centrality of communication to its performance (Harty 2005).

More or less regardless the type of construction, there is an extensive need of collaboration to finalise the undertaking in question. From the perspective of the single company the undertaking is managed in a traditional (single firm) sense, acting on its own interest and sometimes at the expenses of others (Harty 2005). Seen in a wider scope, the actual building process is characterized by being largely fragmented, with many different actors that have different cultural backgrounds, tasks and responsibilities yet in need of working together. The projects can therefore be seen as complex undertakings (Baccarini 1996) since there is an underlying necessity to incorporate interests and needs from the varying professional groups to make the project function. Given that this complexity is grounded in a varying set of principles, rules and knowledge domains, the context at hand is likely to cause difficulties in co-operation due to the risk of communicative problems (Söderholm, 2006). Moreover, partly caused by strong shared conceptions among the participants and different actors, change, or 'renewal' as

the authors terms it, is also likely to be slow (Ekstedt *et al.* 1992), i.e. an aspect that also originates from varying knowledge domains both within the sector and the projects.

Closely linked to the extensive need of collaboration and the importance of inter-organizational relations, the construction process is often organised in a project form. It could be said that projects are the natural form of organising construction, even if some activities are handled outside the projects. In addition to the need for close collaboration between different professions and firms (for example: architects, general contractors, subcontractors, manufacturers, and suppliers), the project "as a natural form of organising" can be linked to the geographical site (Harty 2005). Since most of the activities concerning the actual operational phase creates a geographical centring of interdependent activities around a particular physical site (or several sites), the need for efficient communication and coordination among the involved actors arise. This inter-organisational joint coordination between the different professions and firms makes up the basis of the project, even though time, task, team and transition are seen as the basic theoretical concepts that set the boundaries of the project/temporary organisation (Lundin and Söderholm 1994).

Moreover, power and control within construction is an important aspect that can have a major impact on the communication and coordination of the project (Harty 2005). The work within the project can for example either be coordinated by one main contractor or in a partnering form that promotes more openness and less hierarchical relationships. Depending on the contractual form, the power and control over the project can vary and therefore influence the communication and coordination, an aspect that (in section 4) will be further elaborated on in relations to this specific case. It has been suggested that the impact of power and control, together with the varying knowledge domains and set of principles could lead to "a battle over the communication"; referring to the different professions and firms striving to influence the project communication in their own preferred way (Wikforss 2006; Söderholm 2006).

Since efficient collaboration and coordination (whether intra or inter-organizational) relies on effective diffusion of information throughout a project (Harty 2005), the given organisational context adds up to obvious consequences and involve challenges for the concerned participants regarding the communication and coordination of the project. These are therefore challenges that somehow need to be handled in order to have a successful outcome from the construction process, i.e. an efficient and well functioning project.

Previous research has moreover shown that the described production environment (the operational phase of the construction project) and the handling of problems and other work related activities result in natural communication patterns that are dynamic, spontaneous and informal (Dainty *et al.* 2006). It has been claimed that that there are two different levels of communication that each have different functions and characteristics within the projects, one formal and one informal (Wikforss 2006; Wikforss and Löfgren 2007). The formal level is where the planned, deliberate and organized information exchange is taking place and the informal is where the dynamic, spontaneous and active problem solving is handled. As Wikforss and Löfgren (2007) express it, *"...communication was going on at two levels at once. The formal, controlled exchange of documents took place on one level, while informal, interactive problem solving took place on the other"* (Wikforss and Löfgren 2007:341).

Since the collaboration relies on effective diffusion of information throughout the project, the flow (or diffusion) therefore has to cross, be translated, or be bridged from the formal to the informal level and the other way around. Even though the levels are represented by different actors having different cultural backgrounds, tasks and responsibilities, one should understand that the two levels proposed by Wikforss and Löfgren (2007) are not altogether static and only bound to different actors but also to different activities within the project. However, even with an understanding of the context, the central

characteristics, and the built-in communicative challenges of construction work, the question of how these communication processes are linked together is still unanswered.

3. LIAISON DEVICES – AN INTEGRATIVE LINK

Looking at collaboration and communication between different groups of people within or in between organisations (i.e. in this case within the project organisation), and drawing from traditional organisation theory literature, the theoretical concept of coordination is central to understand. Coordination is generally described as collaborative mechanisms linking activities, i.e. tasks and/or people together, in order to accomplish a collective set of undertakings (Van de Ven *et al.* 1976). This also involves managing uncertainty and dependencies between the activities (Malone and Crowston 1994). It could be claimed that depending on the type of dependencies and level of organisational complexity and uncertainty, different types of coordination mechanisms are more frequently occurring and more appropriate than others (Jacobsson 2008). For a more thorough review of coordination mechanisms and coordination theory see Hage *et al.* (1971), Malone and Crowston (1994), Dietrich (2007) or Jacobsson (2008).

In an attempt to outline some basic means that explain the fundamental ways in which organisational work could be coordinated, Mintzberg (1980, 1983) proposes five different types of coordination mechanisms. These are mutual adjustment, direct supervision, standardisation of work processes, standardisation of work outputs, and standardisation of worker skills. Although Mintzberg (1983:4) refers to these mechanisms as "*coordination mechanisms*" he furthermore explicitly expresses that they are "*as much concerned with control and communication as with coordination*". Hence, central to understand in order to grasp the organisational aspects of the communication challenges.

When neither direct supervision nor forms of standardisation are sufficient to manage the complexity of the dependencies, Mintzberg (1983:82) puts forth what he calls *devices* (or *liaison devices*) to handle the mutual adjustment needed to manage the situation. According to Galbraith (1973) the liaison devices can occur in several different forms, stretching from direct contact between managers, via liaison roles, task forces, teams, integrating roles, to managerial linking roles, and matrix organisations. Mintzberg (1980, 1983) has condensed Galbraith's (1973) classification and gives four basic types of liaison devices. Two of which can be linked to specific individuals or roles, *liaison positions* and *integrating managers*, and two that can be linked to groups or structures, *task forces* and *matrix structures*. Given that individuals and roles are in focus – which is the case in this paper – one need to distinguish between the role related liaison devices, the *liaison positions* and *integrating managers*. In reference to Mintzberg's (1980, 1983) argumentation when distinguishing between them, formal power and authority is of special interest.

Mintzberg (1983) describes the liaison position as follows; "*When a considerable amount of contact is necessary to coordinate the work of two units, a 'liaison' position may be established formally to route the communication directly, bypassing the vertical channels*" (Mintzberg 1983:82). Furthermore, he points out that the position has no formal power, even though it is formally established. The power of the liaison position is in that way completely informal and only derives from knowledge and not status. According to Mintzberg (1983) the liaison position emerges as a nerve centre that functions as a communication crossroad, linking different fields together, providing information and understanding that facilitates the communication and integration between the different knowledge domains. The position is moreover physically located in-between two groups/knowledge domains or sometimes placed in the opposite knowledge domain to the original in order to more easily and efficiently achieve the objectives (Mintzberg 1980, 1983).

The integrating managers on the other hand are described in terms of superimposed formal liaison positions with recognised authority. As Mintzberg (1983) puts it; *"When more coordination by mutual adjustment is required than liaison positions, task forces, and standing committees can provide, the organisation may designate an integrating manager – in effect, a liaison position with formal authority"* (Mintzberg 1983:83). The integrating managers are commonly appointed from existing managers that are given supplementary responsibilities in the form of integrating functional activities. The mentioned authority is hence not linked to formal power over concerned personnel, but always over some specific type of decisions or aspects of the decision process. The decisional authority therefore, as the only type of authority, results in a need for proficient negotiation and persuasion skills of the integration managers. Mintzberg (1983:84) moreover concludes that a successful integration manager also must have an ability to balance and handle pressure from conflicting groups without, as he puts it, *"being absorbed into either"*, referring to the groups and their different interests. Furthermore, he stresses that the role of the integrating manager is not an easy one since there is a lack of formal authority over the concerned people which makes it hard to influence behaviour (Mintzberg 1983).

All in all, in spite the differences described it could be concluded that both the liaison position and the integrating managers have the same overall purpose – to achieve work-flow coordination amongst different knowledge domains by facilitating the communication between them. Or, as it was suggested earlier, assist the communication flow or diffusion of information throughout the project.

With an understanding of the context, central characteristics, and the built-in communicative challenges of construction work, along with Mintzberg's (1980, 1983) terminology and definition of liaison devices, we can now continue to investigate the operational phase of the project and the integration between the formal and informal communication processes. However, before we do this there is a need to present the method used and the project in focus.

4. METHOD

The empirical study this paper is based on is an ongoing case study of a construction project in the province of Jämtland, Sweden. The project is a partnering project that involves Skanska and a local corporate group of companies (Jämtkraft) which produces, distributes and sells electric power and district heating.

This paper scrutinizes the operational phase within a partnering project and the activities carried out by the preparation team, site workers and the local branch coordinators. As described, the paper focuses on the link between the informal and generally non-technological communication and the formal and often technologically supported communication. In order to understand the processes of the operational phase, the information flow and the activities carried out, a qualitative case study approach was taken. Case study research allows for obtaining rich insights of processes (Yin 1994), therefore a combination of participant observations, semi structured interviews, and document analyses including reports and public material were conducted.

In line with recommendations from Yin (1994) and Eisenhardt (1989) the data for this study was collected from a variety of sources stretching from personnel of the two main contractors, the subcontractors, and branch coordinators to observations and public material. The paper is based on a total of 18 semi-structured interviews with a variety of people from the project, three days of observation including meeting participation and document analysis, all gathered over a period of six months. All interviews conducted were recorded, transcribed and presented as a full case description in Jacobsson (2008). The empirical material and the case descriptions presented were analysed using theoretically supported inductive categorisation (Andersen 1998; Jacobsen 2002).

5. DESTINATION 2011

The project in focus, called Destination 2011, is a partnering project in the municipality of Jämtland, Sweden. It was initiated in August 2006, involving approximately 150 employees and has a planned termination in 2011, hence the name. The aim of the project is to secure the regions power distribution from severe weather conditions, signifying a substantial infrastructure investment (approximately €100-110 million over a period of five years). In total, the project includes securing of 3 500 km cable, out of which approximately one-third is ground based, i.e. involves digging. The two main contractual partners in the project are Jämtkraft, a local group of companies supplying district heating, electricity and broadband internet connection in the region and Skanska, a multinational construction company. In addition to these two, about a dozen small, local subcontractors are involved in different parts of the project. In contrast to what is most common in partnering projects – were it is only the project owner (the orderer) and the main contractor that are a part of the contract – it should be noted that the partnering contract of Destination 2011 also involves the subcontractors.

Jämtkrafts' permanent organisation produces, supplies and sells electric power and district heating to the main city in the county of Östersund, including surrounding municipalities. Additionally, they provide broadband internet connections through optic fibres in the area. The vision of the company is to be a driving force for the development and success of the region. Skanska was founded in 1887 and is today one of the largest construction companies in Sweden. Originally, Skanska offered Jämtkraft two forms of contract; a more traditional contract and the partnering alternative, out of which the latter was accepted as the form of cooperation. The partnering contract includes close contact between the two companies with detailed interaction and development work already in the planning phase. In addition to close cooperation it also includes shared responsibility for the economical outcome of the project. Since the cooperation between the companies began early in the project the opportunity for influence and mutual adjustment is considered to be large for both parties. The permanent organisation of Jämtkraft acts as the orderer although the project organisation consists of personal from both companies.

It needs to be stressed that the studied project is a partnering project, which implicitly implies that there is a unique opportunity for mutual adjustment and early influence between the involved parties. Moreover, the overall purpose with the partnering form is to improve innovation, communication and performance and also in a more efficient way utilize resources (Gray and Larson 2006; Bresnen and Marshall 2000; Packham *et al.* 2003). All which are characteristics that differentiate partnering from regular contractual forms. However, when addressing the communication process – in the way it is done in this paper – the importance and potential implications of the contractual form (i.e. partnering) are limited since the need for extensive and well functioning communication is equally important independently of the contractual form used. That is if the project consists of different actors with different cultural backgrounds, tasks and responsibilities which are the case in this kind of construction project.

5.1 Activities and processes in the project

As a part of the overall project process, three separate and partly parallel sub processes can be identified. The first one, and the one in focus in this paper, is the most complex and extensive of the processes and involves planning for a new route, required deforestation, digging of the cables, site restoration, and dismounting of the old overhead lines. The second one involves deforestation in connection to the existing overhead lines and changing of the old lines, and the third and final one only involves deforestation in connection to the existing lines. All the activities conducted during these three processes occur both within and across the various companies involved.

As previously mentioned the permanent organisation of Jämtkraft acts as the orderer and initiates the process. A digitalised order (using Tekla Xpower – a software system designed for operational asset management of energy utilities) with supporting electronic documentation is sent from Jämtkraft to the project organisation initiating the activities related to land issues and the design of the new route – including negotiation with land owners, gathering of information, getting building permits, and contacting concerned authorities and institutions. Moreover, the design of the new route includes addressing questions such as; how to dig, where to dig, and how to outline the electrical stations and electrical installations. During a period of approximately 2-4 months information, documentation, maps and decisions are generated, gathered and stored in an electronic format, i.e. using Xpower, GIS applications (geographical information system – an information system for capturing, storing, analyzing, managing and presenting data which are spatially referenced) and traditional file structures. When all essential information regarding the route is at hand, the electronic information is printed and put into a physical binder. The binder, shown to be a central communication tool, is later presented at a coordination meeting where the preparation group, the subcontractors and the local branch coordinators are represented, together with personnel responsible for quality and environmental control.

At the coordination meeting, central aspects of the new route are discussed and the responsibility is handed over from the preparation team to the subcontractors and the concerned local branch coordinator. The local branch coordinator, subcontractor(s) and a person from the preparation team thereafter physically inspects the outline of the new route. When the inspection is done and the responsibility is in the hands of the subcontractor and the local branch coordinator, the actual digging starts.

The subcontractors, with support from personnel at Jämtkraft and Skanska, carry out the physical site preparations including digging and cable-laying. Personnel from Jämtkraft (project members) are responsible for electric installations and procurement of material (cable, lines, stations and manufacturing supplies). The electrical staffs work parallel to the digging with installation of the stations and with connecting the cables. All in all, this is coordinated and supported by the local branch coordinator and personnel at the projects office. When the new cable is installed, and the site is restored, personnel from Jämtkrafts' permanent organisation use GPS to measure where the cable is located for future mapping. Thereafter, the deconstruction of the old overhead power lines takes place and the subcontractors start all over, at another route.

The process briefly described above, from the initiation until it is restored and measured, takes approximately 3-6 months to carry out. Within the ongoing project several partly parallel processes are conducted at the same time, overlapping and integrating each other i.e. as is generally termed, concurrent engineering (Terwiesch *et al.* 2002; Ford and Sterman 2003).

6. SCRUTINIZING THE OPERATIONAL PHASE

Using the dimensions proposed by Wikforss (2006), and later Wikforss and Löfgren (2007), a formal and an informal communication process can be identified within the described operational phase. The following section will begin with an empirical supported description and an analysis of the two communication processes. Thereafter the integrating link between these two will be scrutinized and related to Mintzberg's (1980, 1983) liaison devices – the liaison position and the integrating managers. Since the aim of this paper is to investigate the communication practice which arises within the operational part of the construction project, linking the formal and informal communication together, the main focus will be placed on liaison functions between the two processes. Through this, the posed research question of this paper will be addressed and answered.

6.1 The formal communication process

Starting off with the formal communication process, described by Wikforss (2006), and Wikforss and Löfgren (2007) as the controlled exchange of documents, one can identify extensive formalised communication activities related to the early part of the operational phase and the preparation team.

A vast part of the planning and design activities – including negotiation with land owners, gathering of information, getting building permits, and contacting concerned authorities and institutions – are highly formalised and also ICT supported. Most of the communication in this part of the process has formal channels i.e. dedicated contacts at the various institutions involved and formalised procedures to acquire the different permits and information needed. Everything from the initial electronic order (from Jämtkrafts' permanent organisation) to the calculation and drawing of the new route is moreover supported by software applications (Tekla Xpower and GIS applications). The procurement of material (cable, lines and stations) is also mainly ICT supported and follows a formal and predetermined pattern, although some purchasing activities are generated by upcoming problems.

Even though not all of the communication in the early part of the operational phases and related to the preparation team is formal and technologically supported, it is predominantly where the planned and controlled information exchange is taking place. Apart from the preparation activities, the work where personnel from Jämtkrafts' permanent organisation use GPS to measure exactly where the cable is located is also highly formalised. Since the project could be described as concurrent engineering one needs to understand that 'the early part' of the operational phase is constantly occurring, parallel to other activities i.e. not only in the beginning of the project cycle. This means that the two communication processes are taking place at the same time and parallel to each other creating a need for simultaneous integration.

6.2 The informal communication process

Moving on to the informal communication process, we need to look elsewhere than among the early part of the operational phase and the preparation team. As described by Wikforss (2006), and Wikforss and Löfgren (2007) the informal communication is characterised by being dynamic and spontaneous, with a focus on interactive problem solving.

Even though there is problem solving needed among the design and planning activities, much of the dynamic and spontaneous communication originates from upcoming problems related to the physical site preparations, the digging and in some aspects the cable laying. Although the physical binder (mentioned earlier as a central communication tool) in many aspects give important guidance to the activities executed – giving the subcontractors information about how to dig, where to dig, and the electricians guidance regarding how to outline the electrical stations and the electrical installations – certain aspects of these activities are nevertheless hard to plan.

One central area, always hard to foresee, is for example the ground conditions of the new route. Even if the preparation team thoroughly tries to identify and avoid unsuitable areas, rocks and other sudden obstacles are still likely to appear during the digging. These obstacles are crucial to handle in order to be able to continue the work, which means that there is also a frequent need for a dynamic and spontaneous communication. The communication among the subcontractors and in-between the subcontractors and the local branch coordinators are therefore naturally often informal, dynamic and spontaneous. In addition to this, the communication is also due to its described nature generally non-technologically supported, even if the mobile phone is a central tool which arguably could be seen as digital communication – however all in all verbal, dynamic and spontaneous.

Taken together, in order to manage the upcoming problems, to facilitate the dynamic, spontaneous problem solving, and to link the communication between the formal and the more informal communication processes, the local branch coordinators are of great importance. The following section will be devoted to function of the local branch coordinator and their liaison and integrative role.

6.3 The local branch coordinator as a liaison device

The function of the local branch coordinators is in several ways central to the project outcome and the activities performed within the operational phase. In line with Mintzberg's (1980, 1983) description of the liaison position, the local branch coordinators also emerge as a nerve centre, functioning as a communication crossroad that links different fields together and provide information that facilitates the communication and integration between the different knowledge domains.

The local branch coordinators use their extensive experience to guide and control the activities and at the same time, in other situations, they create space for the subcontractors to solve the emerging problems in line with their own knowledge, competence and experience. That is, in some situations they allow the subcontractors to have their way without involvement.

In order to create the space needed for the subcontractors, and in order to be able to determine when to interfere and when not to, the local branch coordinators need to have extensive understanding of the different knowledge domains. They need to understand both the work processes of the subcontractors, the electricians and the preparation team – an aspect that is heavily stressed during the interviews. *"...you can't do this type of work without practical experience, it would never work. Preferably you should have seen and been a part of the building of a whole power net, if possible you should have worked your way from being a subcontractor so you know the practical work by first hand. Moreover you also need to understand the electricians and maybe even have worked within the preparation team"* [Expressed by a local branch coordinator].

As the local branch coordinators create space for the subcontractors to solve the situation without interference, the subcontractors are able to manage the unexpected situations that occur during the construction processes, while still focusing on the work at hand. When this is not working the local branch coordinators step in – helping and supporting the subcontractors in the problem solving, taking control over escalating or potential problems – thereby assisting in managing the unexpected situations. Often the evaluation, whether to assist or not, seems to be dependent on the difficulty of the problem and the time span estimated to solve the problem. When it comes to whether the local branch coordinators tries to manage the problem on their own, or get assistance from other parts of the project organisation, it mainly seems to be dependent on the time span estimated to solve the problem and not the difficulty. If there is a fast solution they will try to manage the problem themselves and if there is not, they try to assign the problem to an appropriate part of the project organisation in order to disengage themselves from the problem.

As previously mentioned both the liaison position and the integrating managers have the same overall purpose i.e. to achieve work-flow coordination amongst different knowledge domains (Mintzberg 1980, 1983), a purpose that also corresponds with the local branch coordinators. In order to achieve this purpose the local branch coordinators reduces and channels the information. The documentation, maps and decisions that are generated and gathered in the preparation activities is often 'translated' and reduced into a minimum amount of information presented to the subcontractors. In some cases it is presented as drawings on a laminated map only, suitable for the subcontractors to always carry with them. This information reduction activity seems to be highly appreciated by the subcontractors as they do not see themselves in need of extensive information to execute the tasks at hand. *"We only need to know what route we should dig, what potential*

obstacles like crossing cables there are, and what material we are supposed to use, that is the type of cable and size – apart from that we manage ourselves” [Expressed by a subcontractor]

Even though the mentioned binder, containing all the available information, is physically placed at the site of the digging the subcontractors are only occasionally in need of the information. Apart from the initial, and very important, guidance of what is planned (i.e. supporting the inspection of the outline of the new route) the binder only communicates static information whereas the concerned local branch coordinator instead facilitates the dynamic and informal problem solving and communication needed.

In comparison to Mintzberg's (1980, 1983) liaison positions and integrating managers, proficient negotiation and persuasion skills are not one of the central characteristics of the local branch coordinator. Instead there is, as mentioned, an extensive need for knowledge and understanding of the ongoing activities and the challenges facing the different knowledge domains. The knowledge of the local branch coordinator is, in line with the liaison position (Mintzberg 1980, 1983), the main source of power since the position carries no 'real' formal power apart from some delegated decisional power regarding emerging problems. Regardless of the delegated decisional power and the knowledge at hand, the position does not have any recognised power with the project managers and is rather seen as a control and administrative function. Hence, the local branch coordinators are not project managers themselves. The lack of recognition could be linked to the fact that the local branch coordinator is not a formal manager, as Mintzberg (1983) describes the integration manager, and have no personal responsibility at all.

All in all, the local branch coordinators or 'project liaison' are still acting as a communication gateway, connecting the formal dimensions to the more informal using their extensive knowledge and tacit power to filter, reduce and adjust the information, and to support the dynamic problem solving through informal and spontaneous communication.

7. CONCLUSIONS

With a starting-point in the contemporary construction context and based on a case study of a partnering project, this paper has addressed important aspects of project communication and coordination. Focusing on the most comprehensive process of the studied case (i.e. planning for a new route, carry out necessary deforestation, digging of the cables, and dismantling of the old overhead lines) and using the dimensions proposed by Wikforss (2006) and Wikforss and Löfgren (2007), two partly parallel sub-processes were identified – the formal communication process primarily existing among the preparation and administrative support activities, and the more informal, interactive problem solving, taking place within the actual field production.

Drawing on traditional organization theory literature in general and more particularly on Mintzberg's (1980, 1983) liaison positions and integrating managers, the position of the local branch coordinator was described and analysed – a position that is shown to be of central importance to the communication and the progression of the project.

The liaison function of the local branch coordinator – tentatively termed *project liaison* – has been shown to serve as a communication crossroad that makes integration between different knowledge domains, formal and informal communication easier. The function guides and controls the ongoing activities and creates space for the experience of the subcontractors. Furthermore, the local branch coordinators assist in managing unexpected situations and arising problems. A central part of the project liaison is nevertheless the reduction and translation of information, activities highly appreciated by the subcontractors. In order to facilitate the communication processes and in order to act as a communication crossroad, the local branch coordinators (project liaisons) are in need of extensive understanding and knowledge regarding the ongoing activities. Since

the position carries no formal power, apart from some delegated decisional power, the knowledge is also important as it brings authority and thereby makes the work easier.

This paper therefore suggests that from a field-production (i.e. the subcontractors) point of view, the value of extensive information and ICT support is scrutinized through a lens of situation based practical usefulness. The need for ICT support is consequently limited and the information is therefore reduced, filtered and cut away from the supporting systems. An activity facilitated and supported by the liaison function of the local branch coordinator (the project liaison). This activity could be seen as a way for the participants to reduce complexity and thereby enable flexibility and project completion based on the experience of the subcontractors i.e. the site workers. One could say that the project members at the field production level of the organization are on a need to know basis – and consequently they don't need or want to know.

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A MODEL-BASED DESIGN APPROACH WITH THE FOCUS ON ENERGY

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ABSTRACT

The purpose of the research is to investigate how a model-based design approach can facilitate the decision-making process in the early design phase. The construction client is in a key position to affect the outcome of a construction project by proper decision making during the design. Different design options can rapidly be analysed to assist the client in making informed decisions in the early design phase. The research approach is based on a theoretical framework for a model based design, decision-making methods and the case of a property in Finland in the early design phase with focus on energy performance. The result of this study is to provide guidelines on how a model-based design process in the early design phase can help decision-makers influence the energy performance of a building. The framework is believed to be generally applicable for decision-making in the design process.

1. INTRODUCTION

The building stock in Europe accounts for over 40% of the final energy consumption in the European Union (ENERDATA, 2003). Since, roughly 50% of the energy is based on fossil fuels the building sector also contributes substantially to the green house gas emissions.

Today, minimizing the investment cost is in focus for new buildings. However, the focus on production cost do not improve the service life performance (Öberg, 2005). Wise initial investments can decrease the total LCC (life cycle cost) for a building significantly. It is particularly important to show the relation between design choices and the resulting life cycle cost such as energy, maintenance and operation cost (Kotaji *et al.*, 2003). An office building will cost about three times its initial investment cost, to operate and maintain, over a 25 year period (Flanagan and Jewell, 2005).

Therefore, a model based approach for life cycle design could be a tool for construction client and the design team to considerate and simulate all sustainable aspects of a building in the early design stage.

2. THEORY

2.1 Life cycle design aspects

An ideal sustainable design process has to include the life cycle design perspective where all solutions are optimised for the entire design service life of the building (Sarja, 2002). However, to improve the service life performance for a building several aspects need to be included in the early stages of the design. Sarja (2002) introduced four main aspects in his integrated life cycle design approach human conditions, financial cost, culture and ecology.

Outgoing from these main aspects, the most dominant aspect with regards to cost and environmental issues is the operating energy. Junnila (2004) shows in his study that the operating electricity causes most of the environmental impact during the life cycle of office buildings, also the operating heat and maintenance have significant impact on the environment. The statistic from the Swedish construction industry (2007) shows that one

of the major components of the life cycle cost during the operating time of a building is the energy.

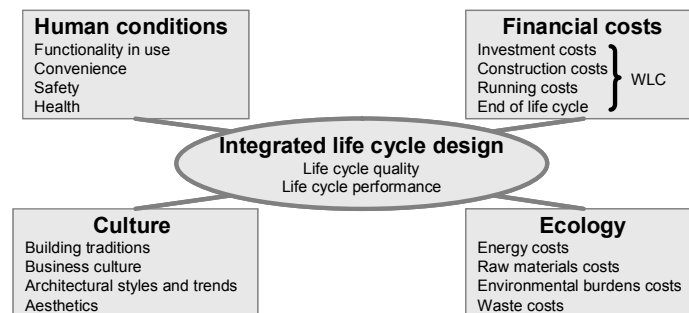


Figure 1. Main aspects of integrated life cycle design (adapted from Sarja, 2002).

By optimising the design parameters such as building shape, the building envelope and orientation the heat consumption can be reduced up to 80% (Feist *et al.*, 2005). According to Clarke (2001), energy simulations for buildings result in a cheaper, better and quicker design process, the outcomes will better match society's aspirations for sustainable practices and environmental protections in particular with regards to the global warming.

2.2 Building Information Modelling

Building Information Modelling (BIM) is the process of creating object-oriented and parametric 3D CAD models. The verb BIM describes the process to create, store and use the noun BIM (Building Information Model). The noun BIM is a static representation of a building that contains multidisciplinary data that defines the building from the point of view of more than one discipline.

BIM applications generally operate on shared databases which enable them to capture, manage, and present data in an appropriate although coordinated way for each discipline. Such downstream applications start with capturing and managing the required information, and present that information back in appropriate way, and thus making it available for use and reuse during the project (Ibrahim and Krawczyk, 2003). Laiserin (2007) defines BIM as a process to support communication (sharing data), collaboration (acting on shared data), simulation (using data for prediction), and optimisation (using feedback to improve design, documentation and delivery). This definition makes no reference to any software at all, but software can automate and improve that process.

Virtual Design and Construction, VDC, is another acronym used to describe the model-based technology and working methods (Kunz and Fisher, 2008). According to Kunz and Fisher (2008) three levels of implementation of VDC methods in the building sector can be recognized:

- **Visualisation:** 3D models are routinely created and used to predict performance metrics. Especially, gains in clarification of project objectives for stakeholders and resolving of coordination issues between different design disciplines can justify the relative inexpensive investments made in the project.
- **Integration:** projects develop computer based methods to exchange data among different modelling and analysis application either using standard formats such as IFC (International Foundation Classes) or propriety formats. For integration to work well vendors need to agree on exchange formats The implementation costs in the integration phase are more expensive compared to the visualisation phase

and cannot be justified on project level. Therefore the benefits need to be derived on company level over several projects.

- **Automation:** routine design task or manufacturing of assemblies (CNC - Computer Numeric Control) for on-site installation are automated. Enables a dramatic increase in design efficiency and effectiveness and dramatic decrease in construction duration. The automation phase need more long term strategic partnership since the implementation costs are high and need to be depreciated over several projects.

For VDC to work well the contracts need incentives to encourage sharing of information between stakeholders in the projects (ibid).

Several research projects and national programs have been launched over the past years in Europe in order to develop model based design guidelines and exchange strategies of BIM data (InPro 2008, DBB 2008, Senatti 2007, Norska BIM). A common approach is that the degree of detailing, the information level or model maturity is increasing through a number of phases from the early stages to detailed design and construction where the required functionalities gradually are mapped onto technical solutions. According to (Delivery D4), a concurrent engineering approach is recommended where the design maturity needs to be synchronised between the involved design disciplines. These maturity levels will form the framework for the design trades and reflect the growing detail level of the design, e.g. BIM maturity A, B, or C, depending on how many different maturity levels are required for the design process. The quality gates will define the level of maturity of the model information and make sure that this information is according to the technical requirements of the design as translated from customers needs.

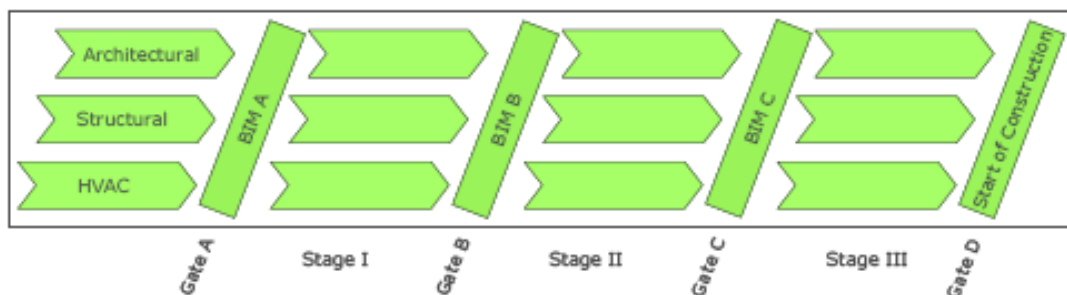


Figure 2. A concurrent engineering approach with increasing maturity level (Delivery 4).

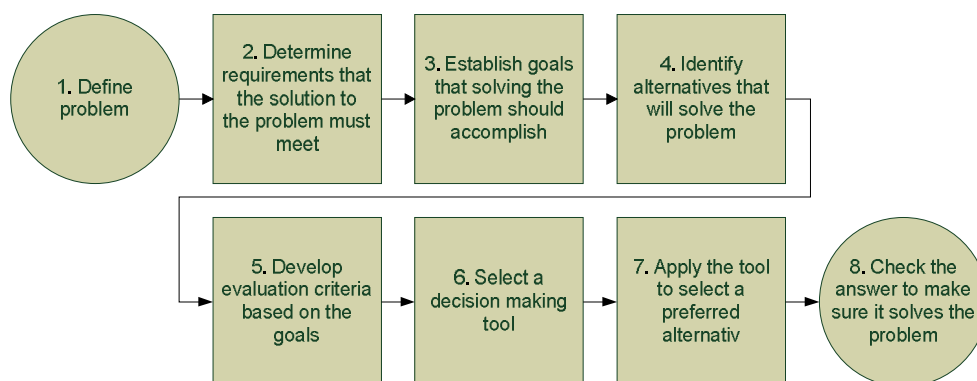


Figure 3. A formal decision making process (after Baker *et al.* 2001).

2.3 Decision making in building design

A formal decision making process can be decomposed in the following steps – see Figure 3 (Baker *et al.* 2001).

However, in any design situation the designer has to capture the users requirements in order to provide design alternatives that can fulfil the needs and intended use. These requirements or needs are expressed in the user's language, often difficult to translate to specifications of a technical solution. The performance concept presented in Figure 4 offers an intermediate language that makes it possible to match demand and solution – the use of a 'performance language' (Jasuja 2005).

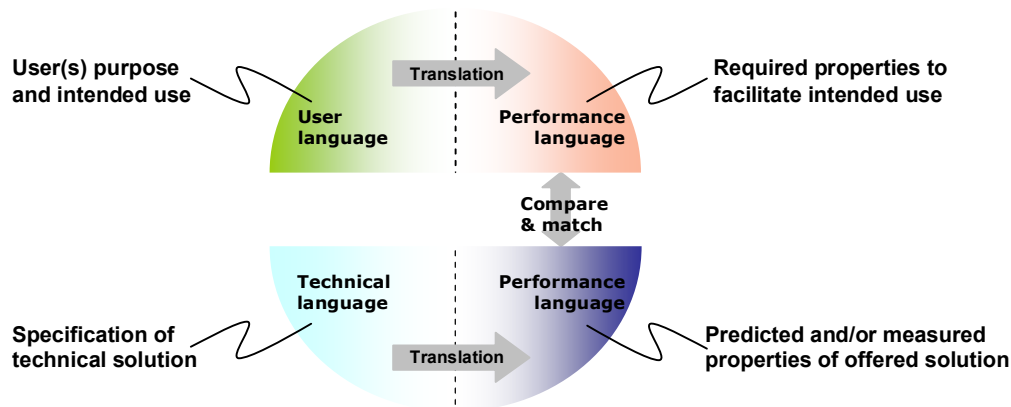


Figure 4. The performance language – a solution to match demand and solution (adapted from Jasuja 2005).

Looking at the requirements originating from the evaluation criteria, design evaluations generally are a multi-criteria decision problem of a high complexity. The criteria themselves are also manifold. They range from subjective criteria that can be described using qualitative statements to precisely measurable criteria, all measured originally with different dimensions or scales. Another challenge for the evaluation methodology comes from the increasing level of detail of the design model along the design process. As a consequence the decision making methodology will have to cope with gaps in the produced design information during the different design phases. A number of formalised decision making methods have been proposed:

The Analytical Hierarchy Process (AHP) developed by Saaty (1990) emphasizes the quantitative comparison of alternative solutions. The core of the procedure is that the preferred solution is identified using pair-wise comparisons of alternatives based on their relative performance against the criteria. The method is most useful to support group decisions in teams where people with different specializations are working on complex problems.

Consider All Facts (CAF) and **Plus Minus Interesting (PMI)** have been introduced by Edward De Bono (De Bono, 1985) and represent relatively simple, techniques for logic and problem-solving. CAF is a method to possibly take all criteria relevant for a decision into consideration. The PMI method focuses more on the potential impacts of a decision.

Multi-Attribute Utility Theory (MAUT) developed by Keeney (Keeney and Raiffa, 1993) is a quantitative comparison method used to combine dissimilar measures of costs, risks, and benefits, along with individual and stakeholder preferences, into high-level, aggregated preferences. Unlike

AHP, MAUT uses utility functions to define how the diversely dimensioned criteria will be transformed into one common, dimensionless scale or metric with a range of 0 to 1.

SMART developed by Edwards and Barron (1994) is a simplified variant of MAUT. The main difference is in the rating of each criterion. Unlike MAUT where the rating has to be calculated with the transformation or utility function, the decision makers directly assign a value between 0 and 1 using the utility function in a qualitative way. By directly assigning the rating values to the criteria, the availability of quantitative data from the alternative becomes optional and the calculation effort is reduced.

The Multi-Attribute Collective Decision Analysis for a Design Initiative (MACDADI) is another multiple criteria decision making method under development by Haymaker and Chachere (2006) with the objective to support the decision process related to design alternatives. According to its developers the MACDADI procedure is inspired by established methods of Decision Analysis, in particular MAUT.

3. RESEARCH PROJECT

3.1 Problem definition

Within the context of InPro we assume that one or more Building Information Models (BIM) build the decision bases on which the decision making method will be applied. The existence of such a structured and data rich model which exceeds a mere graphical 3D representation of the building geometry by additionally containing semantic building elements information offers significant advantages to facilitates the data analysis required using a formal evaluation method (Figure 5).

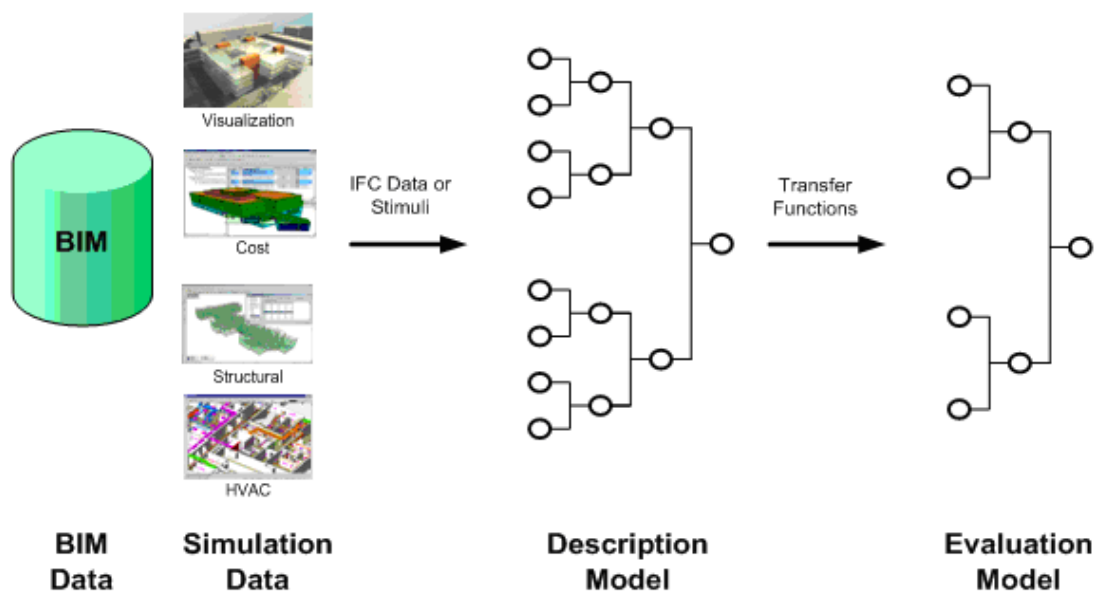


Figure 5. Design evaluation using Building Information Models (BIM).

For the design evaluation from a BIM, two different opportunities exist:

- Indirect measurement: stimuli from visualizations classified as ordinal, interval or ratio level scales
- Direct measurement: values are taken from the BIM or from analysis/simulations based on the BIM and then transformed into dimensionless scores.

An example of an indirect measurement is the ranking of the architectural appearance of different design alternatives. A direct measurement is the energy performance as calculated from an energy analysis tool. These measurements need to be transferred or normalized from dimensional quantities into dimensionless evaluation results, which can be combined and prioritized into an aggregated result using a traceable mathematical method.

Facing the variety of different methods and strategies offered in the decision theory, it is necessary to further define the characteristics and restrictions of the decision problem. Table 1 summarizes the characteristics of evaluating BIM-based design alternatives.

Table 1. Characteristics of the decision problem to evaluate BIM-based design alternatives.

Characteristics of design alternatives	Characteristics of evaluation criteria
<ul style="list-style-type: none"> • Reasoning about existing design alternatives available as BIMs • Number of design alternatives is generally 2-4 or up to 15 (design competition) • Alternatives differ either significantly in geometry or just in details • Explicit data available from BIMs 	<ul style="list-style-type: none"> • Generally multiple criteria have to be evaluated • Criteria from different domains lead to complex decisions • Subjective and objective criteria has to be considered • Criteria have different dimensions

3.1 Objectives and limitations

The objective is to define a model based design process that includes life cycle aspects into the early design phase. The model should include a decision making framework to support the decision makers to select the most appropriate design solution based on defined project goals. The study has been limited to energy performance of office buildings.

3.2 Research methodology

The research methodology used is a combination of four distinct methods:

1. Literature review: state-of-the-art of energy analysis, building information modelling and decision making methods.
2. Unstructured interviews with clients, contractors and energy consultants: the interviews have been conducted to investigate how energy performance is taken into account in today's model based design process of office buildings.
3. Workshops and project meetings within the InPro consortium: several workshops and project meetings have been conducted to define and select suitable methods for a model based design process in the early phase.
4. Development of a motivating case: an energy design scenario has been developed in order to demonstrate the developed concept.

This paper describes only the developed framework. The proposed framework is going to be tested and further developed in demonstrations in the InPro project.

4. RESEARCH RESULTS

4.1 Early design phase

The stakeholders in the building process have different interpretation of the term 'early phase', Ryd (2008). For the client the 'early phase' starts when a business opportunity or a societal demand arises. The initiation of a building project often include a business planning phase for the client where goals, budget, timeframe and organisation is determined before other stakeholders from the AEC (architectural, engineering and construction) sector is involved (see Figure 6). The design of a building is traditionally done in two steps; first a system design of the architectural, structural and installation systems before the solutions is further detailed for construction. After realisation the building is handed over for operations.

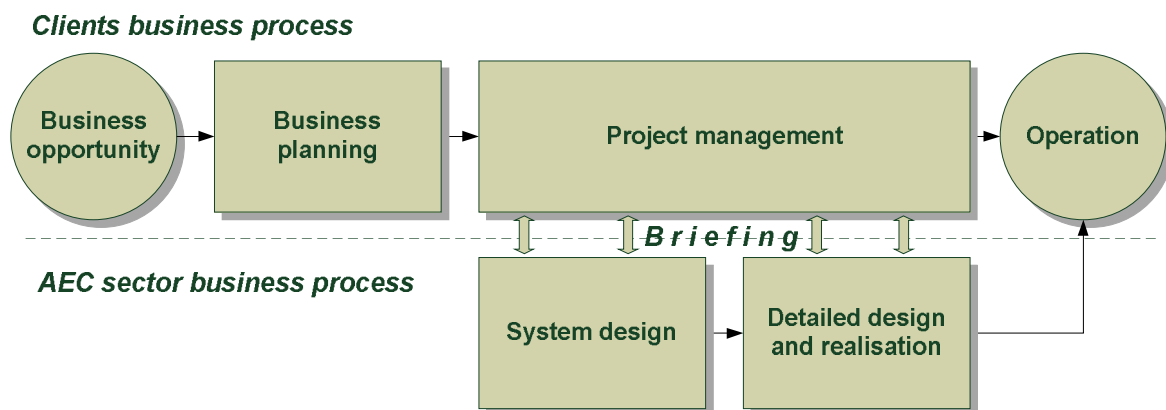


Figure 6. A building project from the perspective of the client and stakeholders from the AEC sector.

One of the main goals of the InPro project is to shift focus from the detail design to the early design phase where the majority of the decisions are taken that influence the final costs. From a client's perspective the AEC sector need to be involved earlier in the building process. The AEC sector also needs to involve the client more in the design process to ensure that project goals as expressed by the client are met by the proposed design.

One of the issues that the clients were complaining about *"...is that even if we ask for three solutions from the architect in the sketch stage one. We usually just get one usable solution as the architect just put effort into one solution and do the other tow with less effort. There is just one solution which we can try to energy optimised but that mean often optimising windows which cost a lot instead of optimising the design."*

Figure 7 shows the InPro definition of the early design phase. It contains besides business planning and building design (cf. system design in Figure 6) a feasibility design phase where the development team, which includes the client, translate the client's project goals expressed in user language into values and design requirements expressed in performance language. In this phase it often becomes clear that different design requirements can influence each other or even be conflicting.

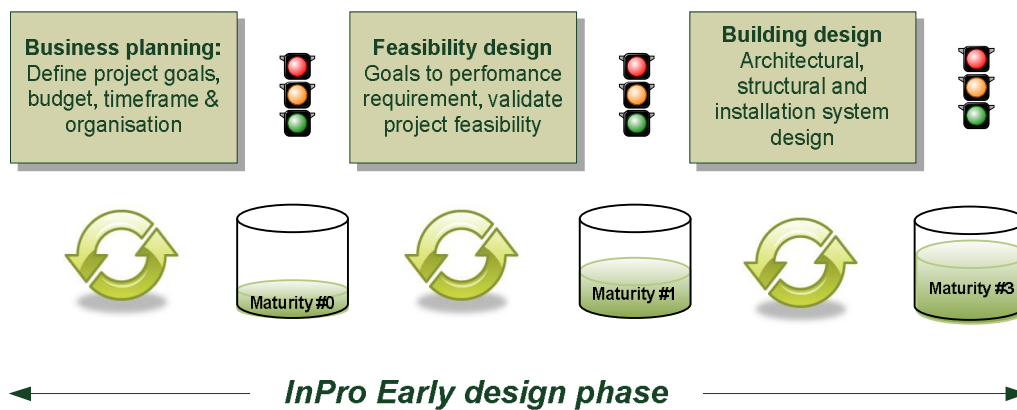


Figure7. Definition of InPro early design phase.

Each stage in the early design ends with a quality gate, i.e. go/no-go criteria, where the result is evaluated using a formalised and traceable decision making process. Approved design information, here denoted maturity level, are stored and put under change management control after each quality gate. The circular arrows in the figure indicate the iterative nature of the design process where the design solution is gradually more detailed in each stage during the early design phase.

4.2 The decision making framework

With the characteristics of decision problem we can define the required components or functionalities of a framework to support design decision making as follows.

First, it is essential to know the target values which the design should fulfill from the stakeholders, in particular the client. These values, typically expressed in different dimensions, are often contra dictionary to one another. Second, in order to be able to later comprehensively analyze these critical target values, the stakeholders have to transfer them into dimensionless key performance indicators. To solve the dilemma of multiple and contra dictionary target values, we further need a method to transparently prioritize these KPIs and a mathematical evaluation method to combine KPIs into an overall alternative ranking. Finally, charts or diagrams to visualize the performance of the alternatives regarding each single target value will be required in order to communicate and explain the method's results in a self explanatory way.

Figure 8 shows a schematic overview of the required components and input for the decision making framework. The following methods have been used in the InPro Smart decision making framework:

- Evaluation method – the MAUT family of evaluation technique for multi attribute decisions problems.
- Prioritization method – the AHP process using pair wise comparison.
- KPI – key performance indicators are normally used to benchmark the success of building projects. In the Smart framework, the KPI has been extended to represent the utility functions used in the MAUT framework.

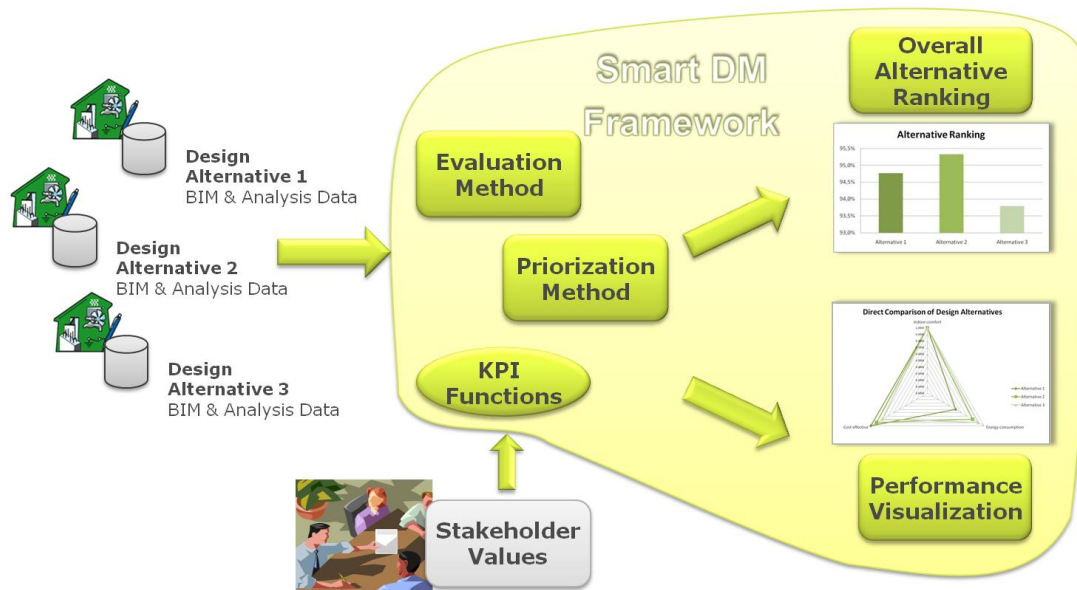


Figure 8. The Smart decision making framework (Smart is an abbreviation for Simple multi-attribute ranking technique).

4.3 Modelling concepts

The InPro model based process is divided in information maturity levels adapted to the decision making process for a specific purpose in a buildings lifecycle. The decisions are based on a specific level of information in the InPro Open Information Environment, here denoted OIE maturity, from which performance indicators can be presented for the main decision makers. This makes it possible for decision makers to make informed decisions throughout the buildings lifecycle matching solutions against functional needs. The InPro modelling concepts for the proposed model based design process can be summarized as follows:

- The InPro Open Information Environment (OIE) contains the minimum required information needed to support the decision making process at the quality gate in question. The content in the OIE contains in general of a mix of documents, models (design discipline models and aggregated models) and evaluated performance indicators.
- The use of information for e.g. derivation of performance indicators through visualization, simulation, analysis, etc in a specific stage will determine the requirement of information content in the InPro OIE.
- An InPro OIE maturity level defines the approved content of the InPro OIE. Change management procedures are applied on approved maturity levels of the OIE.

InPro defines by default eight lifecycle maturity levels, where levels 0–3 are part of the early design phase. The default OIE maturity levels are:

0. *Goals*, where the business case is identified and normally developed by the client. In this level the overall goals, timeframe, budget and location of the building project are formulated. Also, space program and specific requirements from authorities, client and end-users can be stipulated.
1. *Layout design*, where alternatives regarding building envelope and placement on the premises are selected with regard to constraints given by authorities, the client and geotechnical conditions. Also, gross areas for different functions, room types and relation between functions and alternative use of the building in the future are developed.

2. *Functional design*, gross areas are further detailed into functional spaces in the building (e.g. location of office rooms, meeting rooms, fire compartments, etc). Location of installation shafts and structural parts.
3. *System design*, design of main structural and installation system. Development of building program for approval from local authorities.
4. *Detailed design*, detailing of structural, installation and finishing design and planning information for the realisation stage.
5. *As built*, the OIE level 4 is updated with information from the realisation of the building.
6. *Operation*, normal operational stage where the OIE is updated with information from facility management. If during the operational stage the facility is rebuilt, the OIE maturity levels are repeated starting with as built condition as input.
7. *Demolition*, planning for the demolition and recycling of building parts.

The default mapping of OIE maturity levels versus the building lifecycle phases and quality gates can be fuzzy and overlapping and must be adapted to the specific project.

4.4 Design workflow

The design workflow is coordinated between the involved speciality design/analysis disciplines using OIE maturity levels and quality gates for decision making. Figure shows a proposed methodology for the decision making process at a specific stage of the design. It starts from an approved level of maturity set by the previous quality gate (level m). If the previous stage was the layout design (level 1) we now have a basic design of the building envelope and its placement on the site. In the current stage, the target is to create different interior alternatives and select the best alternative from the customer perspective, i.e. to reach maturity level 2.

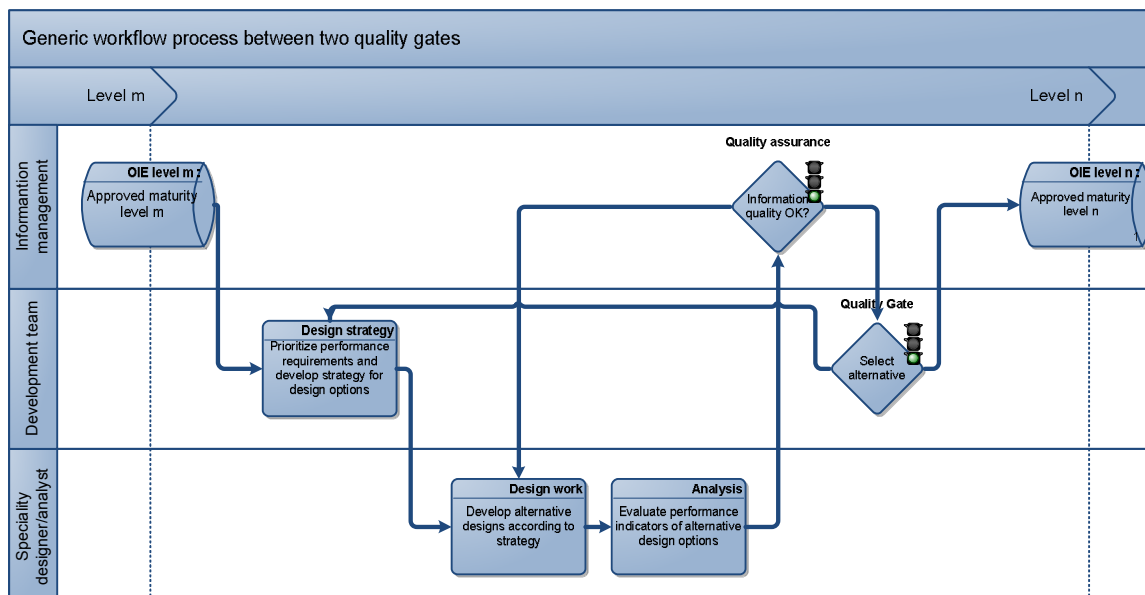


Figure 9. Generic workflow process between two levels of maturity.

First the development team, the client and different design specialities, decide the mapping of performance requirements from the client(s) goals and requirements that can be evaluated using key performance indicators (KPI) of the design. The KPIs are then

prioritized to guide the team in developing a design strategy. Also the dependencies between the different design specialities must be resolved in the design work using process maps or dedicated design spaces to manage the concurrent design process (Eppinger 1991). After different design alternatives have been created and evaluated, the developed design information and analysis must be checked for consistency, completeness and correctness in the quality assurance gate, c.f. Figure. If the information developed do not pass the QA phase the design information needs to be updated and checked again at the QA gate. The KPIs for the different alternatives are presented together with the overall ranking of the alternatives using the smart decision making tool at the quality gates. If one of the alternatives is selected at the quality gate the new approved set of design variables is added to the model and the design moves to the next stage, otherwise the design loop starts again.

In the example the design workflow started at OIE maturity level 1 and ended with OIE level 2. However, the ending level of OIE maturity is project specific, e.g. the design could very well encompass more than one maturity level ending in this example at level 3.

4.5 Motivating case

The scenario

For the rebuilding of a warehouse to an office building in Helsinki an environmentally conscious Client requests his project team to deliver a very efficient, low-energy consumption design. Having heard about the new energy consumption classes he suggests evaluating the options to create an 'Energy Class A' design. During the feasibility design the client is informed, that for the climatic conditions at the building location, such an energy class cannot be achieved without paying tribute to the indoor climate. From the project team's experience, the energy target 'Energy Class A' is hard to combine with the required 'indoor climate class S1'. Additionally they suggest balancing the energy savings of various design options with their investment costs. The Client and future building owner agrees to continue with an investigation of different design options during the building design phase. The project manager summarizes the goals for the building design (see Table 2).

Table 2: Client goals expressed in user and performance language.

Client Goals	Value (for Client)	KPI	Target value(s)
Healthy and comfortable indoor climate	Best Indoor Climate	Indoor Climate Class	S1
Low energy consumption	Energy efficiency	Energy Certificate Class	A - C
Cost effectiveness (moderate rent level)	Lower operational cost	Payback for investment	Payback time 5-10 years

Design strategy

As a next step the project team starts the discussion of priorities among the above goals with the client. In order to formalize the discussion, the project manager prepares the following evaluation table for the team.

Table 3. Prioritisation of design goals.

KPI	Priority	KPI
Indoor Climate Class	<i>More important</i>	Energy Certificate Class
Indoor Climate Class	<i>More important</i>	Energy Certificate Class
Energy Certificate Class	<i>Equally important</i>	Payback for investment

The priority corresponds to weight values in the evaluation matrix in Table 4 according to a nine-point scale (Saaty, 1990):

Equally important 1
 More important 3
 Strongly more important 5
 Very strongly more important 7
 Overwhelmingly more important..... 9

Table 4. Evaluation matrix for calculation of the priority vector.

Evaluation Matrix	Indoor Climate Class	Energy Certificate Class	Payback for investment	Eigenvector
Indoor Climate Class	1	1/3	3/1	0,60
Energy Certificate Class	1/3	1	1	0,20
Payback for investment	1/3	1	1	0,20
Total				1,00

When the first criterion in the left column is less important than the second criterion, the weight value becomes reciprocal. The normalized eigenvector of the weights matrix give the priority vector. After having set the priorities, the target values with tolerances and therefore the boundary conditions for the design alternatives have to be discussed among the project team. The Smart decision making method requires assigning a utility function for each KPI respectively criterion to relate values measured for the different design alternatives to a performance scale between 0 to 100% fulfilment of the client demands/desires (see Figure 10).

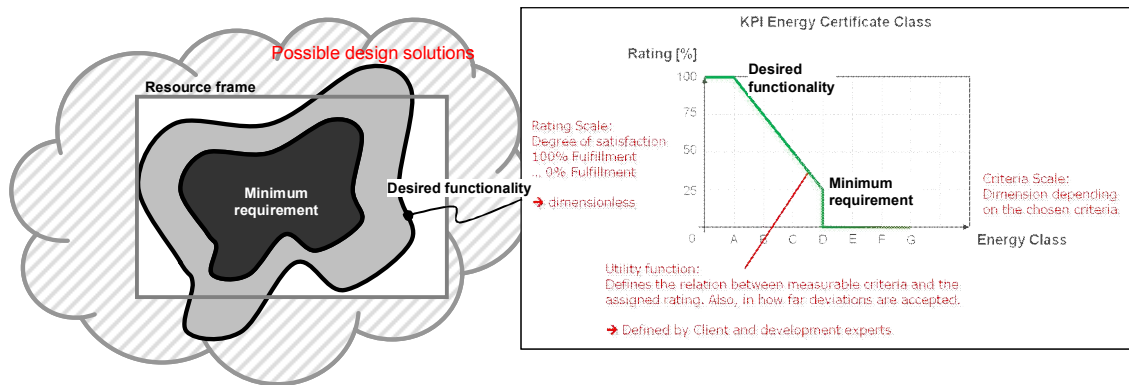


Figure 10. Rating of target values between minimum and desired functionality using utility functions (adapted from Ryd (2008) and Schreyer *et al* (2009)).

Together with the project team the following ratings to optional target value ranges are determined by the client, see Figure 11. An important criterion for the Client is the indoor climate class since he is convinced that the productivity of his company will be strongly influenced by an excellent indoor environment. He is willing to allow some tolerance below class S1 but not lower than S2. For the criterion 'Energy Class' class A would fulfil the desired requirements fully. The rating for values B to D is decreasing disproportional and values beyond class D were not accepted by the Client. Regarding the payback time for the total investment, the Client is willing to spend more if the additional investment doesn't exceed a payback time of 15 years. The optimum rating for the economically most sustainable design is therefore assigned when the payback for investment will not exceed 5 years.

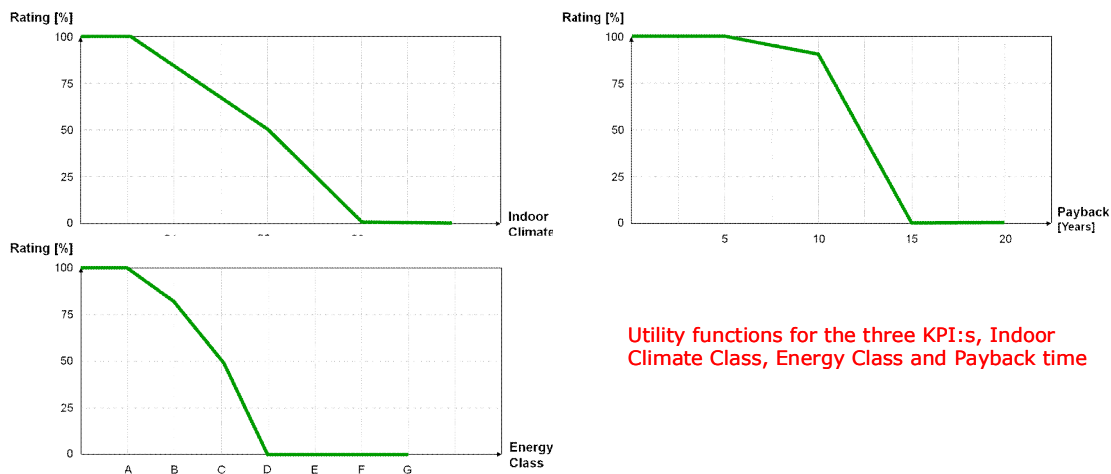


Figure 11. Utility functions for the KPI in the energy design scenario.

Design and analysis

At the design kick-off meeting the team reflects the consequences of the design requirement analysis for the design strategy and the technical solutions that have to be investigated. Taking the Client priorities into consideration, the preference of the indoor air quality will govern the design strategy. However, at the same time the requirement for an economical reasonable design solution within the boundaries given by the Client will have to be fulfilled, a criterion, which is also influenced by finding technical solution with low energy consumption. A couple of days later, the design team have created and analysed the three Building Information Models summarized in Figure 12.

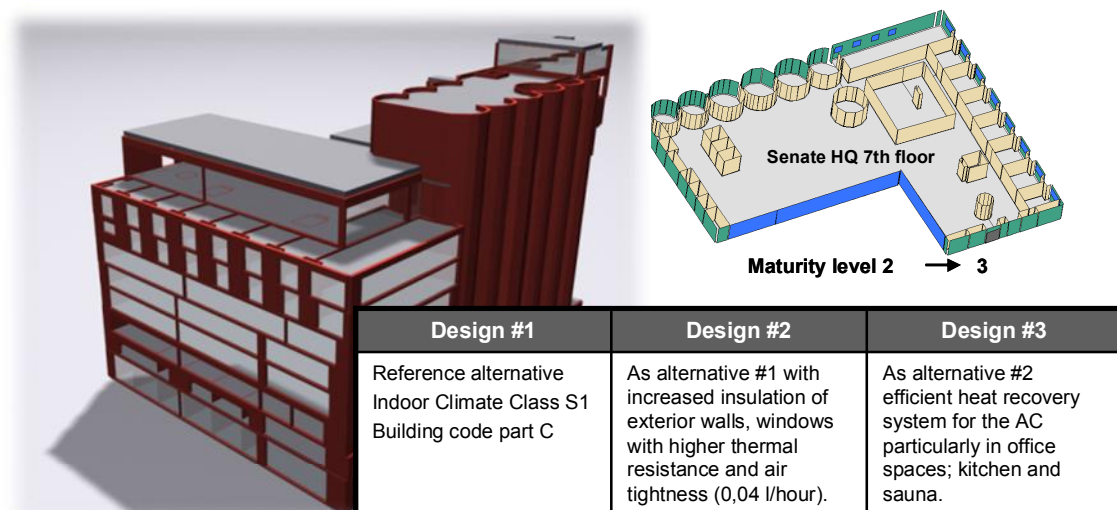


Figure 12. Design alternatives of the Senate headquarters in Helsinki.

The result of the energy analysis is summarized in Table 5. The three alternatives have the same Indoor Climate Class and the Payback Time for the investment in energy saving design #2 and #3 was estimated to 8 and 12 years respectively, (design #1 is the reference, i.e. 0 years payback).

Table 5. Results from energy analyses of the three design alternatives.

Design #1	Energy cons. [MWh/a]	Design #2	Energy cons. [MWh/a]	Design #3	Energy cons. [MWh/a]
Space heating	528,5	Space heating	307,2	Space heating	306,9
AC-heating	321,4	AC-heating	310,7	AC-heating	180,7
Hot water heating	66,2	Hot water heating	66,2	Hot water heating	66,2
Total. heating energy	916,1	Total. heating energy	684,1	Total. heating energy	553,4
Equipment el.	23,5	Equipment el.	23,5	Equipment el.	23,5
Lighting el.	211,1	Lighting el.	211,1	Lighting el.	211,1
HVAC el.	212	HVAC el.	211,5	HVAC el.	211,4
Total electricity	446,6	Total electricity	446,1	Total electricity	445,9
Cooling energy	29,5	Cooling energy	36,5	Cooling energy	36,6
Total energy consumption	1392,2	Total energy consumption	1166,7	Total energy consumption	1036,4
Energy efficiency rate [kWh/m ²]	123	Energy efficiency rate [kWh/m ²]	103	Energy efficiency rate [kWh/m ²]	92
Class	C	Class	B	Class	B

Decision making at the quality gate

After the model information been quality assured by the information management the project manager prepares the project meeting at the quality gate and calculates the KPI ratings for the three alternatives from the utility functions. The result is also visualised in a spider diagram – see Figure 13.

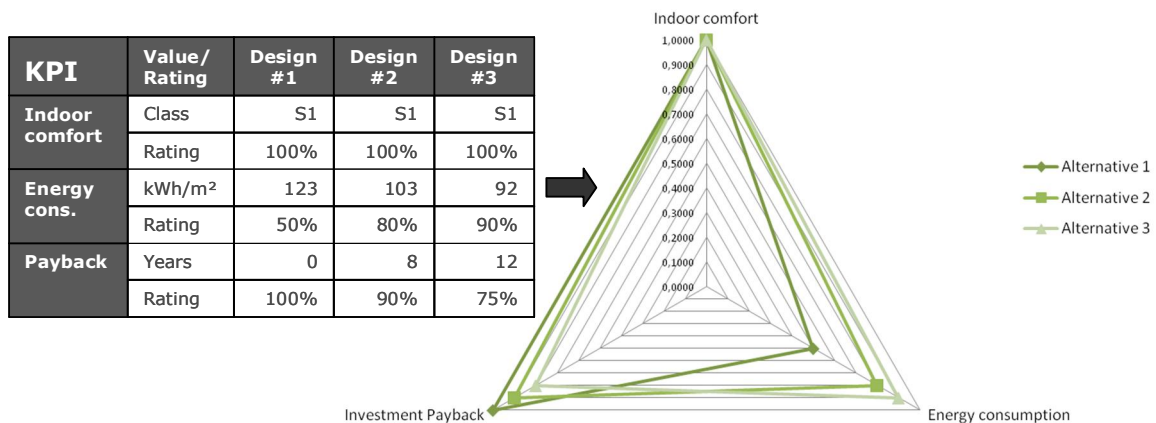


Figure 13. Calculation and visualisation of the KPI ratings for the different design alternatives.

After the individual KPI performance results have been calculated and visualized, the priorities are taken into consideration in order to calculate the total evaluation result for each design alternative (see Table 6). In the final design meeting the team discusses the results of the analysis with the Client. Under the conditions given, alternative 2 which fulfils the design requirements with a rate of 95%, offers the best performance. The improvements for lower energy consumption by the heat recovery systems in alternative 3 do not payoff fast enough to balance the additional investment. On the other hand, the improvement by a higher insulation and tightness of the building shell on the energy consumptions results in a payback period which is still within the tolerance level of the Client.

Table 6. Total rating of the three design alternatives.

KPI	Rating/priority	Design #1	Design #2	Design #3
Indoor comfort	Rating	100%	100%	100%
	Priority	0,60		
Energy consumption	Rating	50%	80%	90%
	Priority	0,20		
Payback	Rating	100%	90%	75%
	Priority	0,20		
Total rating	$\sum \text{Rating} \times \text{Priority}$	80%	95%	93%

The total performance chart together with the individual KPI results for each alternative help the design team to transparently explain the evaluation results, their design decisions and recommendations to the Client, thus enabling him to make an informed decision or, if necessary, to reconsider the initial priorities.

The total rating, here 95%, can also serve as a KPI for the design process as it reflects the fulfilment of the client goals/values.

5. CONCLUSIONS

The InPro lifecycle model-based framework offers a new methodology for communication energy consumption through each stage of the building lifecycle. The benefits with this

BIM-based lifecycle design include that such information as building geometry, structure, material, installation and functional use is stored in the BIM model. This reduces time and cost for analysis of energy lifecycle for the building. Furthermore, the flexibility of design changes increases as the changes are easier to arrange. Analysing and optimising the energy performance of the design at the early stage is a significant advantage of this framework.

The benefit of adapting the decision making framework into this model-based process is the transparency of the design decisions with regard to the set goals at the beginning of the project. The construction client is more involved in the early design process. With the help of the decision making process the decision rational during design is based on a more formal, hence transparent procedure than the biased process we often find within project teams, today. The possibility of including different criteria in the decision making process makes this framework very flexible. This process further reflects the necessary compromises during the design and interdependences of the different goals. However, it does not uncover the interdependences and influences of the parameters. These parameters must be still interpreted further by the specialists. By choosing appropriate KPIs, a long-term improvement process for the enterprise can be possible. The software conversion of the decision making framework is relative trivial.

The InPro life cycle model-based process is a theoretical framework that needs to be further tested in practice.

6. ACKNOWLEDGEMENT

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ENERGY USE IN MULTI-FAMILY DWELLINGS – REQUIREMENTS AND VERIFICATION

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ABSTRACT

Energy use at nine properties containing 200 apartments erected during 2001 located in the south of Sweden has been studied. Before obtaining a building permit, the developers had to present calculations that proved that their building's energy use fulfilled specific requirements. The energy use was measured and compared to the requirements regarding energy use and predicted energy use. Despite of the specific goal of the projects, resulting total energy use varied by a ratio of three between the lowest and the highest and only one property out of nine fulfilled its goal. This stresses the importance of higher quality energy predictions, clear requirements, verifications and appropriate legal options to ensure that buildings achieve low energy use.

1. INTRODUCTION

The building industry is facing a great challenge. Energy efficiency has to be significantly improved in new, as well as existing buildings in order to reduce CO₂ emissions. This calls for actions from all involved in the building process, from architects and designers to construction workers and operation managers.

During 2001, the international housing exhibition Bo01 was held in Malmö, in the south of Sweden. This housing exhibition had an ecological and sustainability focus and the area was supposed to be self supporting in regards to energy with 100% being locally supplied renewable energy. There was also supposed to be an annual balance of energy supply and energy use at the area (Lövehed, 2005). To achieve this balance, all buildings were designed to use a maximum of 105 kWh/m² energy annually including space heating, domestic hot water, common electricity and household electricity (Quality Programme Bo01, 1999). The developers used different techniques to achieve the restrictions regarding energy use. Before receiving a building permit, the developers had to submit calculations that proved that their building's energy use was predicted to be less than 105 kWh/m². The Quality programme (1999) requires that the energy used at the properties were measured during two years after inauguration. The results from the measurements are presented with the intention of helping decision makers during the building process and to be a source of feedback to the building industry.

2. STATE-OF-THE-ART REVIEW

2.1 Reduction of greenhouse gas emissions

Sweden has to reduce the greenhouse gas emissions by 17%, excluding sectors included in the carbon emission trading system, before 2020 in relation to 2005 in order to meet the goal of reducing EU's greenhouse gas emissions by 20% before 2020 (Commission of the European Communities, 2008).

The Directive²⁵ on energy end use efficiency and energy services states that the energy use should be at least 9% more efficient by 2016 in relation to the time period 2001 to

²⁵ Directive 2006/32/EC of the European Parliament and of the Council on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC, *Official Journal of the European Union*.

2005. According to the Directive, the mitigation of CO₂ and other greenhouse gas emissions will be reduced if the efficiency of energy end use is improved.

The energy use in the sector dwellings and service that consists of residential buildings, commercial buildings excluding industrial buildings, service buildings, agriculture, street lighting, sewage and power stations stands for 36% of the total energy use in Sweden. Within this sector, 87% is used in residential and commercial buildings for space heating, domestic hot water heating and operation of installations. (Swedish Energy Agency, 2006)

According to Klimatberedningen (2008) there is a need for more powerful means of control in the Swedish building regulation that should also include renovation, if the EU climate goals should be possible to achieve.

2.2 Regulations and requirements in Sweden

According to the Swedish building regulations (The National Board of Housing, Building and Planning, 2008), residential buildings must not use more than 110 kWh/m² in the south and 130 kWh/m² in the north regions of Sweden, for bought energy including space heating, domestic hot water heating and electricity for operating the building. Within two years after the inauguration, the energy use must be measured during at least one year to verify that the requirement regarding energy is attained. In addition to this, there are many initiatives for energy efficient buildings in Sweden. The Bygga Bo project represents collaboration between companies, municipalities and the government (Glaumann *et al*, 2008). The project aims to promote development towards a sustainable building- and property sector. The projects have classification of buildings, new and existing, based on different environmental factors. Regarding energy use, the project defines three different levels. Level A, B and C corresponding to annual bought energy less than 110, 135 and 171 kWh/m² including space heating, domestic hot water heating and electricity for operating the building.

The Swedish specification of requirements for a passive house (Forum för energieffektiva byggnader, 2007a) have recommended a highest annual bought use of energy excluding household electricity, 45 kWh/m² in the south and 55 kWh/m² in the north. However the specifications require that the installed power for space heating shall not exceed 10 W/m² in the south half of Sweden and 14 W/m² in the north half. In buildings that have a heated floor area less than 200 m², the installed power shall not exceed 12 W/m² and 16 W/m² respectively.

The Swedish specification of requirements for a mini energy house only exists as a preliminary document (Forum för energieffektiva byggnader, 2007b). The document recommends that the highest annual total use of bought energy excluding use of household electricity shall be 45 kWh/m² in the south and 55 kWh/m² in the north. The total annual bought energy is calculated with a formula that favors district heating and biomass fuel meaning that a building that uses these can have a higher energy use and still fulfill the requirements. The specifications require that the installed power for space heating shall not exceed 15 W/m² in the south half of Sweden and 19 W/m² in the north half. In buildings that have a heated floor area less than 200 m² the installed power shall not exceed 17 W/m² and 21 W/m² respectively.

'Miljöbyggprogram syd' (Malmö Stad, 2008) is a program developed by the municipalities of Lund and Malmö, Sweden in cooperation with Lund University. Regarding energy use, the program defines three different levels: A, B and C. For residential buildings level A corresponds to a 'passive house', level B corresponds to a 'mini energy house' and level C corresponds to the requirements regarding energy use in the Swedish building regulations.

2.3 Predicted and measured energy use

To design a building that fulfils the requirements regarding energy use in the Swedish building regulations, it is crucial to perform energy simulations of the building in question during the building process (Bagge, 2007). The simulations must represent the building during operation and the calculated result shall be verified within two years after the inauguration by measurements of the energy use in the actual building during operation. According to Elmroth (2002) it is too common that measured energy use exceeds predicted use. Elmroth refers to a number of residential buildings in Stockholm, Sweden, built during the 1990s that have measured energy use exceeding the predicted by 50 to 100%.

Lindén (2006) studied the energy use at a housing area built in 2001 in Stockholm, Sweden. The buildings were designed to use no more than 60 kWh/m² annually, including all electricity. During operation, none of the buildings fulfilled that goal. Lindén concludes that the energy restriction set to 60 kWh/m² was impulsive and not based on what could be achieved in reality. Nilsson (2003) studied the energy use in the multi-family dwellings built for the housing exhibition Bo01 after the first year of operation. The use was about 50% higher than predicted. This was partly because an energy simulation program that was not appropriate for the actual buildings was used. (Bagge *et al*, 2006)

Karlsson *et al* (2007) studied energy use in passive houses built in Lindås, Sweden. The measured energy use during operation was 50% higher than the use predicted during the design phase. According to Karlsson *et al* this is partly due to higher indoor temperature and less efficient heat exchangers than predicted. Elmroth *et al* (2005) studied energy use in an energy efficient single family house in Malmö, Sweden. The measured total energy use agreed very well with the predicted use. However, the use of household electricity was higher and the use of space heating was lower compared to the predicted use. Karlsson *et al* (2007) stresses the importance of accurate input data for energy simulations. The building users' behaviour is very important in low energy buildings and also the hardest to model according to Karlsson *et al*.

2.3 Measured user related energy end uses

Energy related building user behaviour is, for example, use of household electricity, use of domestic hot water, occupancy rate and window airing. Time resolved data on these parameters are needed to perform accurate simulations of energy use (Bagge and Johansson, 2008a). Tso and Yau (2003), Riddell and Manson (1995), Capasso *et al* (1994) and Paatero and Lund (2006) studied the daily use patterns of household electricity in different projects in Japan and Europe during time periods of different length varying from 22 days to one year. Common for the different projects was that there were generally two peaks during the day, one during the morning or noon and one during the evening.

Papakostas *et al* (1995) monitored domestic hot water heating in four apartment buildings in a Solar Village in Greece. Average domestic hot water use patterns by day of the week were analysed. During weekdays, the patterns showed equal characteristics. There was one peak during the evening and one at noon. During weekends the peaks appeared earlier and the use was more uniform. Vine *et al* (1987) monitored domestic hot water use in four apartment buildings in San Francisco. During a typical day, there was a peak in use during the morning and another peak in the evening. Different usage patterns were observed for weekdays and weekends.

Lech *et al*. (1996) measured the amount of time spent indoors and Papakostas and Sotiropoulos (1997) studied occupational and energy patterns for 158 families living in the outskirts of Athens, using questionnaires. Occupancy rate patterns during the day were described for different family members and typical families, and activity patterns for different electrical appliances are presented.

There seems to be a lack of Swedish building user related data, showing both annual and daily variations, particularly for many parameters that can be correlated, including many apartments. Based on this shortage Bagge and Johansson (2008a; 2008b) started a study of household electricity use, domestic hot water use, indoor temperature, moisture production and CO₂ production with hourly measurements. Preliminary results show that the studied parameters have peaks at the same times during the day.

2.3 Decisions during the building process

Johansson (2005b; 2007b) discusses life cycle costing from the perspective of the energy use of a building and its climate system. It was shown that the life cycle cost can be decreased by the right system choice (Johansson, 2007a; 2008a) and optimisation (Johansson, 2005a; Johansson, 2008b). At the same time, in almost all cases, an optimisation means that the energy use is decreased since the commonly used level of energy related measures is low.

Nässén *et al* (2008) interviewed eleven persons who had experience from energy issues in the Swedish building sector including public authorities, construction and housing companies, architects and consultants. Nässén *et al* raised the question of the absent incentive to reduce life cycle costs of buildings when the building companies acts as their own client and sell directly to the housing market. According to one answer this is not a problem "since any client would simply stick to the energy performance which is defined by the building standards". The most common basis for decisions on energy efficiency investments in new buildings was, according to the interviews, the standard in the building regulations and most clients focus on minimising initial investment costs rather than life cycle costs.

Wijk *et al* (2005) sent a questionnaire to 345 random picked households that were prospective investors in a single family house. The response rate was 83%. According to the answers in the questionnaire, 57% preferred lower operation costs over lower investment cost.

3. RESEARCH PROJECT

3.1 Project description and objectives

The objective of this research project was to study the measured energy use in the multi-family dwellings built for the housing exhibition Bo01. This shows whether or not the different properties fulfilled the requirement regarding energy use in the Quality programme (1999) after the first years of use. The key values concerning energy use provided can be used to critically examine different designs and systems, and results from calculations. Energy use for space heating, domestic hot water heating, assimilation of solar heat gains, common electricity and household electricity is presented to give input that helps designers of buildings to fulfill requirements concerning low energy use.

3.2 Research methodology

When energy use in buildings is to be analyzed, the only method with reasonable accuracy is measurements of the physical parameters in a positivistic research approach. It would be interesting to combine these measurements with a hermeneutic approach with for example interviews and questionnaires for the building users, but in this research project, the focus has been limited to measurements. The energy use measurements were outlined before this research project was formed. The energy use and outdoor climate data were collected hourly. Data about the buildings, their construction and technical systems, were collected from the developers. To be able to analyze the energy use, a number of models and assumptions based on other studies and theories were used (Bagge, 2007).

4. RESEARCH RESULTS AND INDUSTRIAL IMPACT

4.1 Measured energy use

All the developers designed the buildings to achieve the same goal concerning energy use. The measured total energy use varied with a ratio of three between the lowest and the highest use during operation. The measured use was higher than the predicted in all but one case. Only one out of nine properties, fulfilled the requirement in the Quality program (1999), with total annual energy use below 105 kWh/m² heated floor area. Three properties used more than 190 kWh/m² annually, five properties used between 110 kWh/m² and 140 kWh/m² and one used 100 kWh/m². The total average annual energy use of all properties was 157 kWh/m² during 2005. Table 1 presents the average, lowest and highest use of; district heating, domestic hot water heating, common electricity and household electricity.

Table 1. Average, lowest and highest measured annual use.

Energy use (kWh/m ²)	Average	Lowest	Highest
District heating	104	58	234
Domestic hot water heating*	23	19	25
Common electricity	20	6	52
Household electricity	35	22	47

*Domestic hot water heating is a part of District heating

The three properties that had the highest total energy use have three particular characteristics. They were the three properties with the highest window area in relation to heated floor area, they all had under floor heating as primary heat distribution system and they had the highest use of district heating.

The two properties that had the highest use of heat did not have any kind of exhaust air heat recovery. These properties had the highest and the third highest window area in relation to the heated floor area and under floor heating as the primarily heat distribution system. This indicates that a combination of the three characteristics; under floor heating, large window area and no heat recovery might be unfavorable from an energy use perspective.

The average use of district heating at properties that used under floor heating as primary heat distribution was 173 kWh/(m²·year) compared to 70 kWh/(m²·year) at properties that used radiators. The average use of district heating at properties without ventilation heat recovery was 145 kWh/(m²·year) compared to 72 kWh/(m²·year) at properties with ventilation heat recovery.

All the examined properties have a large ratio of windows in relation to heated floor area, varying between 22% and 38%. During the design phase, the useful solar heat gains were predicted to between 35% and 50% of the annual total heat losses. The measured annual useful solar heat gains was on average 14 kWh/m² and varied between 3 kWh/m² and 22 kWh/m² at the different properties. On average, the useful solar heat gain was 17% of the annual use of district heating.

4.2 Same function, different systems

A building that appears to have a low use of heating might have that because the domestic hot water was heated by, for example, electricity. This is the case at two properties where the domestic hot water was heated in each apartment by an exhaust air heat pump included in an air handling unit run by household electricity. These properties

also had relatively low use of common electricity since each apartment had its own air handling unit run on household electricity.

Persson (2005) reported that electrical under floor heating and towel dryers in bathrooms could increase the use of household electricity by 2000 kWh annually per apartment. The difference between average annual use of household electricity at the Bo01 properties with and without electrical heaters in bathrooms run by household electricity was 2100 kWh per apartment. At properties with air handling units run by household electricity and electrical heaters in bathrooms, the annual use was on average 1300 kWh higher per apartment compared to the average use at properties with electrical heaters in bathrooms. At the properties that had the highest use of district heating, one reason for the high use might be that towel dryers and under floor heating in bathrooms were heated by district heating. These properties have lower use of household electricity compared to the other properties where towel dryers and under floor heating in bathrooms were run by household electricity.

To be able to analyze the energy use of a building, the entire picture of the different types of energy is needed. When it comes to money and environmental impact, different types of energy is also usually valued differently. It is apparent that it is not possible to rate a building with only one parameter regarding energy use.

4.3 Different use at different times

At places where the outdoor climate varies during the year, the use of space heating will also vary since it depends on the outdoor temperature. The use of space heating will be largest during the winter and lowest during the summer. Other types of energy use such as use of household electricity and use of domestic hot water were also different at different times of the year.

During December, the measured use of household electricity was almost twice as high compared to the use during July. The variations during the day were also high. All properties had daily household electricity variations with common characteristics. The use was least during the night, increased during the morning and was constant during the afternoon where after there was a peak during the evening. During weekends, the use increased later during the morning compared to weekdays. The use was higher during the afternoon during weekends compared to weekdays.

Assuming a constant use of household electricity in energy simulations of residential buildings can result in incorrectly calculated space heating since excess heat from the household electricity is an important internal heat gain, especially in low energy buildings.

The variation in use of domestic hot water heating had equal characteristics as the use of household electricity. At all properties there were two peaks during the day. However, during weekends these peaks were not as high as during weekdays. The first and largest peak occurred during morning and the second peak during the evening. The peaks occurred at about the same time as the peaks in use of household electricity.

4.4 Implementation and exploitation

The Swedish building regulations requires that predicted energy use shall be verified by measurements in the actual building. According to the Swedish building regulations, it is recommended that safety factors are used to assure that the energy use during operation aligns with the predicted use (The National Board of Housing Building and Planning, 2008). No guidelines regarding the safety factors are given in the building regulations. The energy predictions for the examined properties were executed by consultants that make energy predictions on a regular basis. Yet the actual energy use was much higher than predicted. Several other studies have found equal differences between measured

and predicted energy use. If these results are representative, a safety factor of at least two should be appropriate to ensure that the actual energy use does not exceed the predicted energy use. However, a safety factor that high is unrealistic and pinpoints the necessity of better knowledge for the designers and the construction workers. It is of greatest concern to have energy simulations done carefully and with suitable input data and critical examination of the results to get realistic predictions. The construction work needs to be carefully done so the buildings' different elements and technical systems match the design data.

5. CONCLUSIONS

To enable a detailed analysis of a buildings energy use and to find reasons for deviations between calculated and measured energy use, the measurements of energy use need to have a high time resolution and they need to be divided into suitable end uses of energy. This was partly done at the examined properties but not enough. It was, for example, not possible to split domestic hot water from space heating, and in many cases, common electricity or household electricity was apparently a part of the heating system without separate meters.

The result stresses the importance of a detailed analysis of the energy use in order to rate a building or a property. Studying just a few parameters, for example use of heating and common electricity, might result in an inappropriate rating of the energy use.

A specific goal concerning total energy use in the newly built multi-family dwellings resulted in a ratio of three between the lowest and the highest total energy use during operation and only one property out of nine that fulfilled the goal. This result stresses the importance of higher quality of energy predictions to enable design of buildings that fulfils requirements for low energy use, regardless whether the deviation is due to insufficient usage of energy use simulation tools, unqualified consultants or imperfect construction work.

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ENVIRONMENTAL MANAGEMENT IN CONSTRUCTION COMPANIES: DECISIONS, TECHNOLOGIES AND EFFECTS

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ABSTRACT

Understanding of environmental management and sustainability practices – issues that have gained a significant momentum in the construction industry all over the world – requires consideration of multiple factors and of the interplay between these factors. This study examines the scope and number of the environmental decisions made, the availability and use of ICT to support these decisions, and the implications of the increased environmental pressure placed on the building and construction sector. The empirical section of this paper is based on the analysis of 483 survey responses from mid-sized and large construction companies in Sweden. The main contribution of this paper is that we empirically describe environmental-related decision making in the Swedish construction sector on multiple levels. We see that the frequency of use of ICT systems that support environmental-related decisions – environmental management system (EMS) and quality management systems (QMS) – is relatively low in relation to the use of other ICT systems. Nonetheless, approximately 60% of our respondents perceive the EMS and QMS to be functioning quite well, even though they do not use them so often. At the same time, the majority of our respondents also think that these systems are not so well integrated with their companies' other ICT systems and only 33% agreed that these systems actually help them in their decision-making. Finally, we studied how our respondents perceived the effects of increased environmental considerations. There is a quite large consensus that while increased environmental considerations are costly and potentially time-consuming, they do not lead to lower quality, are beneficial for the end-user and create goodwill for the company.

1. INTRODUCTION

The building and construction industry is one of the economy's largest sectors (Sveriges Byggindustrier, 2008), activities of which have a major impact on our lives and on the society as a whole. Consequently, this sector is often the subject of much attention and discussion. These discussions have frequently been critical towards the industry and its practices (see, for example, Ekstedt *et al.* 1992; Lutz and Gabrielsson 2002; Andersson *et al* 2003; Gluch 2005).

The bulk of the criticism raised has been two-fold. On the one hand, the industry has been criticized for being too conservative and slow in adopting new technologies. On the other hand, the sector's environmental scandals, the subject that has caught most of the attention during the last years, have been seen as a consequence of embracing new ideas or technology too quickly and without proper control. In the latter, the lack of systematic communication and effective IT systems has been seen as a major cause to several of these problems (Wikforss 2003).

Just because of the size of the construction industry, it is obvious that decisions taken by the firms in this industry can have a high impact on the overall sustainability of our society. At the same time, the sector a very fragmented one with a vast number of actors that make decisions and interact with each other. Environmental decision making, or decisions that have an environmental effect, can be taken at many different levels during a construction project (Gluch 2005). The buyer, the architect, the superintendent, the purchaser, the site manager, they all have the capability to make decisions that will determine the project's environmental impact.

As the discussion above implies, the understanding of the environmental management practices of the building and construction sector requires consideration of the multiple factors and answering several questions: What, where, and by whom are the environmental decisions made? How can the information and communication technology (ICT) support these decisions? How will the increased environmental concerns affect the cost, quality, and timing of the construction project?

Thus, the purpose of this paper is to examine the scope and number of the environmental decisions made, the availability and use of the information and communication technologies (ICT) to support these decisions, and the implications of the increased environmental pressure placed on the building and construction companies.

2. BACKGROUND

2.1 The Swedish construction sector: an overview

Of about 920 000 companies registered in Sweden in 2006, 68 000 (7%) were active in the construction sector. The Swedish construction industry is characterized by a large number of very small firms (88% of all firms had less than five employees), a group of middle-sized firm with 10-50 employees (in a national perspective these could be viewed as unimportant but on a local level could have considerable market share and a few very large firms. The three largest construction companies in Sweden (Skanska, NCC and Peab) had roughly 32 000 employees in Sweden, which accounts to 30% of the total workforce in the Swedish construction industry (Karlsson, 2008; Sveriges Byggindustrier, 2008).

The entire construction sector in Sweden, including architects, designers and installation companies had a turnover of over SEK 450 billion in 2007. Counting only building and construction companies, the total turnover was around SEK 150 billion. Skanska, NCC and Peab accounts for roughly half the turnover (see Table 1 below). Furthermore, the construction sector is still largely local and national, although a few international actors have entered the market in recent years (Sveriges Byggindustrier, 2008).

There is no doubt so that these companies' activities and how this industry chooses to handle environmental concerns have a major impact on the entire society. Environmental management in a broad variety of aspects in those companies is therefore an important issue to address.

2.2 Environmental management with a focus on communication and technology

Our study relates to the two most comprehensive surveys on sustainability in the construction sector in Sweden 'miljöbarometern' (Bauman *et al.* 2002, Gluch *et al.* 2007). Those studies examine the development of sustainability management and attitudes towards sustainability and environmental issues. At an overall level, these studies have provided a good overview of the attitudes and strategic work in the industry as a whole. However, both studies mainly focused on the environmental managers and their perception of the construction companies and their environmental management work. Some conclusion, important for our investigation, from 'miljöbarometern' studies, are that companies in the sector are more and more aware of the environmental effect they have and that the environmental management systems has been highly emphasized during the last years and are now implemented in over 90% of the companies in the sector. Nonetheless, the knowledge on how these systems actually work and who uses them is scarce. Gluch *et al.* (2007) also expresses concern over the development of inertia with respect to some environmental issues they have obtained from the latest 'environmental barometer' study.

Other studies that have specifically looked at the construction companies and at how they deal with environmental management in general and with EMS in particular also show that there are significant problems and difficulties in a broad spectrum. Gluch (2006) has, based on studies of a large tunnel project, specifically pointed out the problems with communication and information flows concerning environmental decisions. Several studies (e.g. Selih 2007, Christini *et al.* 2004, Oforo *et al.* 2002) have focused on more technical solutions like environmental management systems based on ISO14000, hence come to the conclusion that those solutions are a necessity, and while they are useful in some parts, actual implementation of these systems is a major challenge for the companies; also, these systems do not solve the entire environmental management problem.

A common reflection made in nearly every study made on environmental management is that the communication aspect is an essential problem area. Enhanced environmental consideration and an increased focus on green building process, requires, among a number of other factors, well functioning information and knowledge flow in an organisation. In that process ICT is a necessity and basic condition (Björk 2003, Wikforss and Löfgren 2007). In this paper, as earlier stated, we draw attention to the communication aspect. Under investigation is the use of ICT in construction companies and in their day-to-day activities to both ensure and develop more environmentally friendly and sustainable products and production processes.

Our study relates to earlier studies of IT use in the Swedish construction sector the IT barometern (Samulesson 2000, 2008) and Samuelson (2008). In summary, the ICT studies give an overview of the IT use in general in the Swedish construction sector. However, it is not possible from these studies to draw conclusions in any detail of what systems are used or on what level in a specific construction company those systems are used. When it comes to environmental management related ICT this has not been specifically investigated at all in these studies. Wikforss and Björk (2007) have pointed out the need for studies that not only focusing on technical solution but also see to more social related aspects, which necessitates studying where decisions are taken and how ICT supports those decisions.

Thus we argue that it is essential to know what (and for what) IT solutions are actually used by actors at all levels in an organization, i.e. actors in different levels and on different stages during a construction project; where in an organizational hierarchy decision are taken that could affect environmental issues and what role IT plays in this process.

3. METHOD

The primary data collection tool for this study is a self-completed questionnaire. The questionnaire was sent to decision-makers in different levels at construction firms in Sweden: superintendents, site managers, foremen, purchasers, estimators, and project managers. However, a number of interviews, discussions and meetings with decision-makers at different levels preceded the survey construction process.

The process of questionnaire development and administration involved several steps. First, the draft questionnaire was developed and then tested and revised through interviews with decision makers at different construction sites and head offices in a region in south Sweden. Seventeen questionnaires were collected manually during this pre-testing phase. In a second step, a web-based questionnaire was distributed to 215 decision makers in construction sites all over Sweden that was identified from an internet search among mid-sized and large construction companies in Sweden. That process gave a response rate of 51% (89 responses). At the third step, we obtained permission from two regional offices of one of the largest construction company in Sweden to investigate their employees. The process of identifying respondents and

sending out the surveys was handled by the company. However, that step gave us another 627 responses to our questionnaire.

In total 733 persons have responded at least in part to our questionnaire. However, the internal loss is quite high, i.e. some respondents did not answer all the questions. We also filtered out only those respondents that fit our target population, decision makers. After this process a total of 483 responses have been used in our analysis.

Table 1 below reports the specific organizational position of the respondents. The classification on-site/at office will become important in the further analysis. Some of the returned questionnaires contained non-systematic missing values for some of the variables of interest. These questionnaires were used only when relevant, that is, when the analysis did not involve these variables.

Table 1. Respondents by position and location.

Position	Location	#	%
Superintendent (at the office)	At office	51	11
Purchaser, estimator etc	At office	120	25
Other	At office/on-site	31	6
Site manager	On-site	161	33
Assistant site manager (foreman)	On-site	120	25
Total		483	100

4. RESEARCH RESULTS

The questions we were seeking an answer were: In general, to what extent and how do the actors use ICT solutions and what are their general perception of those systems? We especially wanted to identify how environmental systems were perceived and used in relation to other systems. In addition, we need information and knowledge about what influence and power concerning decision-making during a project different roles related to in the organization have, i.e. how do they perceive their own, as well as other actors', possibilities to influence and make decisions concerning production process, material and suppliers – all factors related to environmental decision making.

The first part of the questionnaire focused on ICT and identified the frequency of ICT use in general both at work and at home. Further on, we examine what specific *communications technology used* and what ICT based *systems implemented* in the organization and the *frequencies of use* of different management systems and *the attitudes and perceptions* of those systems.

4.1 The scope and number of the environmental decisions

Environmental related decisions during a construction project are not limited to the obvious handling of waste or managing hazardous chemicals. Almost all decisions that are made during a construction project, from the selection of what materials to use to the choice of transportation and logistics, could have environmental implications.

In order to get an approximation of to what degree decision makers in a construction company make decisions with environmental effects, we constructed a list of decisions that incorporate environmental considerations. The respondents where then asked to indicate if they, during the last week, have made any of these decisions. The result of this question is presented in Figure 1.

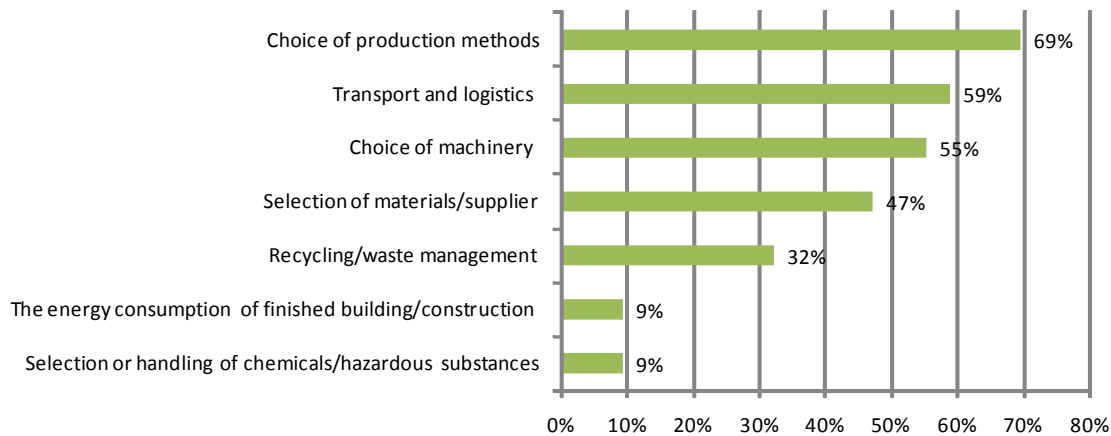


Figure 1. Environmental-related decisions made by the respondents.

The percentages represent those respondents who said that they made such a decision during the past week of answering the questionnaire. This question is further used for the intensity of decision making index.

The obvious, as well as logical, implication that falls out of the figure above is that the frequency of decision making is rather high. The most common decision made was related to the choice of production methods (69% of the respondents indicated that they have made such decisions during the last week). The last in the decision intensity list were the decisions related to energy consumption (9%) and the selection or handling of chemicals/hazardous substances (9%).

Even though this list is by no means an exhaustive one, it shows that the kinds of decisions that have immediate and clear sustainability implications (e.g. hazardous substances) is rather limited in the light of the everyday decisions (e.g. selecting materials). Hence, this discrepancy can explain why many individuals do not always recognize that they are involved in the decisions that could have an environmental impact.

4.2 Quality and Environmental System Use

In order to investigate the use of environmental and quality management systems the respondents were asked to indicate the frequency with which they used these systems, as well as other ICT systems. Table 2 gives the results to this question. Respondents were asked to estimate their use on a scale from 1 (never), 2 (rarely) to 5 (very often, i.e. daily).

In the table we can see, among other things, that environmental management systems are the ICT systems that are used least frequent by the decision-makers. Only 13% of our respondents indicated that they used environmental management systems often or very often.

The results from this question can be linked to the previous question. It is probably the obvious environmental decisions (e.g. handling of chemicals/hazardous substances) that the environmental management system are tailored to, and these decisions are much rarer than the day-to-day decisions that the other ICT systems are supporting.

Table 2. The use of ICT-systems by decision-makers in the construction industry.

ICT system	Never/ Rarely 1-2	3	Often/Very often (daily) 4-5
Management of project-related documents	19%	23%	57%
Purchasing Management Systems	35%	22%	43%
Drawing Management Systems	36%	23%	42%
Accounting, cost control, budget etc systems	49%	17%	34%
Quality management systems	35%	38%	27%
Project Management Systems	58%	18%	23%
Environmental Management Systems	61%	26%	13%

4.3 Perceived Functionality of the Environmental Management System

Next, we investigated the perceived functionality of the ICT systems that supports environmental management decisions. We regard the environmental management system and the quality management systems as the two major ICT-systems that are supplying this support. Respondents were asked to state to what degree they agreed to a number of statements assessing these systems functionality. The results are presented in Figure 2. For comparison, in the figure we also added the perceived functionality of the project management system.

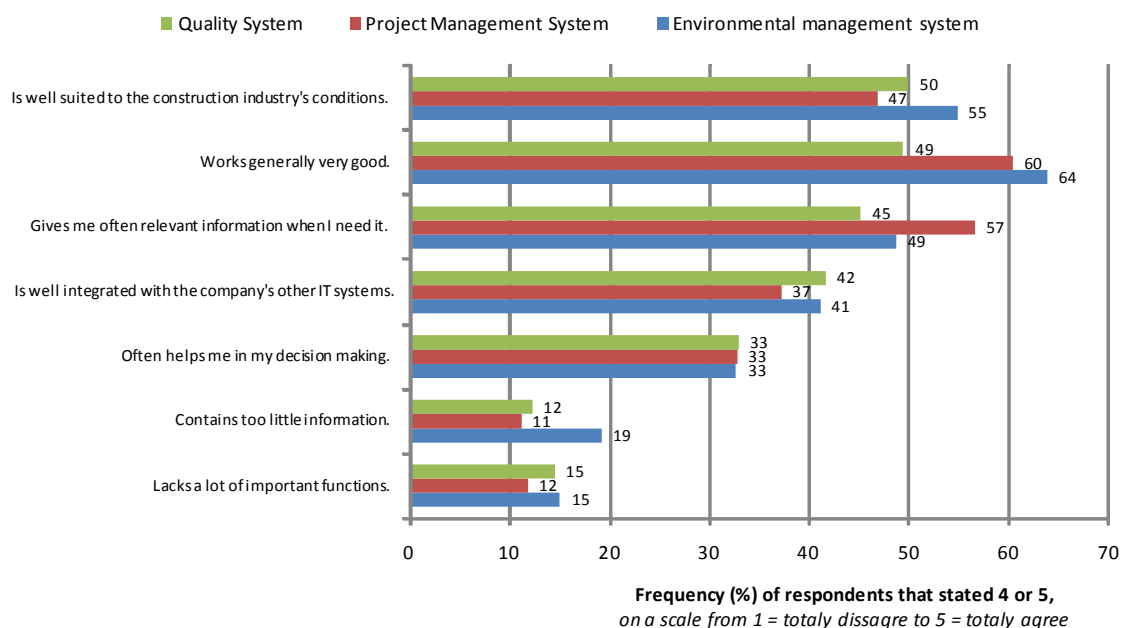


Figure 2: Perceived usefulness and functionality ICT systems by decision-makers.

The results show that the perceived usefulness of the environmental and quality management systems is approximately at the same levels as the project management system. However, in many cases a quite large percentage of our respondents did not perceive the systems as very useful. For instance, only 55% of our respondents thought that the environmental management system was "is well suited to the construction industry's conditions". Interesting are also the statements with a reverse scaling: "Contains too little information" (19% agreed or totally agreed for the environmental management system), "Lacks a lot of important functions" (15% agreed or totally agreed for the environmental management system). Thus, while the usefulness of the systems is questioned by many, very few think that the systems lack any information or important functions.

4.4 Perceived effects of increased environmental considerations

Finally, we investigated our respondent's perception of the effects of increased environmental considerations that the building and construction industry is exposed to. We asked the respondents on a scale 1-5 to react to a number of statements measuring how the increased environmental considerations will affect various aspects of the firm's operations. The statements and the answers about how the requirements for increased environmental considerations (sustainable buildings) generally affect the projects are illustrated in Table 3. Numbers indicate the percentage of responses to a scale from 1 (strongly disagree) to 5 (strongly agree).

Table 3. Affects of increased environmental requirements on projects.

Statement	Do not agree (1-2)	Uncertain (3)	Agree (4-5)
Increased environmental considerations leads to higher costs	21%	31%	48%
Increased environmental considerations leads to reduced costs	53%	37%	10%
Increased environmental considerations lead to lower quality	62%	24%	14%
Increased environmental considerations lead to longer production times	30%	36%	34%
Environmentally-friendly production creates goodwill for the company	3%	9%	87%
Environmentally-friendly production is beneficial for the end user	6%	22%	72%
We often lack the knowledge to make environmental friendly choices	39%	30%	31%

The most important effect of the increased environmental friendliness that our respondents perceive is that it creates goodwill for the company, 87% agreed (4-5) to that statement. It also seems to be a quite large consensus that while increased environmental considerations are costly and potentially time-consuming, they do not lead to lower quality and are beneficial for the end-user.

Table 4. Mean of responses by decision making intensity and the location of the respondent.

	Overall Mean	Decision making intensity			Primary location of the respondent		
		Low	High	p	Office	On-site	p
Intensity of Decision Making Index	2.66	<i>1.98</i>	<i>4.66</i>	<i>.00</i>	<i>2.27</i>	<i>2.91</i>	<i>.00</i>
Integral Quality and Environmental System Use ^a	2.67	<i>2.59</i>	<i>2.87</i>	<i>0.01</i>	<i>2.81</i>	<i>2.57</i>	<i>0.02</i>
The perceived usefulness and functionality ^a							
Gives me often relevant information when I need it	3.52	<i>3.46</i>	<i>3.69</i>	<i>0.04</i>	<i>3.48</i>	<i>3.55</i>	<i>0.51</i>
Works generally well	3.58	<i>3.54</i>	<i>3.68</i>	<i>0.21</i>	<i>3.61</i>	<i>3.56</i>	<i>0.66</i>
It is well suited to the construction's industry conditions	3.62	<i>3.58</i>	<i>3.73</i>	<i>0.16</i>	<i>3.68</i>	<i>3.59</i>	<i>0.38</i>
Often helps me in my decision-making	3.18	<i>3.12</i>	<i>3.34</i>	<i>0.07</i>	<i>3.15</i>	<i>3.20</i>	<i>0.65</i>
Contains too little information	2.71	<i>2.72</i>	<i>2.66</i>	<i>0.57</i>	<i>2.77</i>	<i>2.65</i>	<i>0.27</i>
Lacks a lot of important functions	2.70	<i>2.73</i>	<i>2.64</i>	<i>0.49</i>	<i>2.75</i>	<i>2.67</i>	<i>0.47</i>
Is well integrated with company's other IT systems	3.42	<i>3.38</i>	<i>3.54</i>	<i>0.16</i>	<i>3.42</i>	<i>3.42</i>	<i>1.00</i>
Perceived effects of increased environmental considerations							
We often lack the knowledge to make environmental friendly choices	2.88	<i>2.89</i>	<i>2.85</i>	<i>0.80</i>	<i>2.86</i>	<i>2.88</i>	<i>0.89</i>
Increased environmental considerations leads to higher costs	3.30	<i>3.30</i>	<i>3.30</i>	<i>0.99</i>	<i>3.25</i>	<i>3.34</i>	<i>0.46</i>
Increased environmental considerations leads to reduced costs	2.51	<i>2.53</i>	<i>2.45</i>	<i>0.46</i>	<i>2.58</i>	<i>2.47</i>	<i>0.29</i>
Increased environmental considerations lead to lower quality	2.29	<i>2.31</i>	<i>2.24</i>	<i>0.62</i>	<i>2.38</i>	<i>2.23</i>	<i>0.19</i>
Increased environmental considerations lead to longer production times	2.98	<i>2.90</i>	<i>3.22</i>	<i>0.01</i>	<i>2.79</i>	<i>3.12</i>	<i>0.00</i>
Environmentally-friendly production creates goodwill for the company	4.36	<i>4.37</i>	<i>4.36</i>	<i>0.92</i>	<i>4.38</i>	<i>4.35</i>	<i>0.70</i>
Environmentally-friendly production is beneficial for the end user	4.00	<i>4.03</i>	<i>3.90</i>	<i>0.27</i>	<i>4.05</i>	<i>3.97</i>	<i>0.46</i>

Notes. Significant differences are *italicized*. To check for robustness, the tests reported in the table were replicated using non-parametric techniques free of distribution assumptions (not reported in the interest of brevity). The results were nearly identical to those above.

^a Equal-weight summated scale. The correlation between Environmental and Quality management system use is .86, $p=.00$

^b Significant in non-parametric test

4.5 Further examination

Finally, we examined the patterns in how construction firms use the ICT systems and approach the increased environmental concerns. Table 4 reports the mean responses to background and environment-related ICT use measures. The first column is an overall mean for the total sample. The remainder of the table presents the mean responses depending on the decision making intensity (low/high), the location of the respondent (office/on-site), and the *p*-values of the *t*-test for mean difference.

The decision making intensity index is a number of the environment-related decisions taken during past week, reported in section 4.1. The low and high-intensity groups correspond to the index being above or below the median. The location measure (office/on-site) captures whether the respondent is located primarily in the local, regional or head office or on the building site. For exact classification we refer the reader to Table 2 in the method section.

Given that quality and environmental management systems are closely integrated, the various aspects of the perceived usefulness and functionality environmental and quality systems was computed as a simple average of responses. The significant results can be summarized as follows:

- There is a significant difference in the number of environment-affecting decisions between on-site and office decision-makers, with number of decision taken on-site being higher. An important caveat is due, however: such conclusion assumes that each decision listed in the Figure 1 carries the same weight.
- Quality and environmental ICT systems are used more intensively by office employees and by individuals who make more decisions.
- High-intensity decision-makers perceive the environmental and quality management ICT systems as providing more relevant information when needed
- High-intensity decision-makers consider the ICT system helps in decision-making.
- Compared to the office respondents, on-site respondents expect that higher environmental requirements will result in increased time to complete the project.
- Similarly, high-intensity decision-makers, when compared to the low-intensity ones, expect that higher environmental requirements will result in the increased time to complete the project.

5. DISCUSSION AND CONCLUSIONS

A well functioning and efficient information and communication flow is the heart in a construction company. Construction projects are complex and involve a huge number of actors both within the company as well as outside.

In this study, we have focused on the actors within the construction companies boundaries. All these actors are related to each other in a multifaceted system of information flows and decision-making processes. The main contribution of this paper is that we empirically describe environmental-related decision making in the Swedish construction sector on multiple levels. We see that the frequency of use of ICT systems that support environmental-related decisions (e.g. environmental management system, EMS, and quality management systems, QMS) is quite low in relation to the use of other ICT systems. Environmental and quality management systems are the ICT systems that are used least often by the decision-makers. For instance, only 13% of our respondents said that they use the environmental EMS very often.

We continued to measure the perceived usefulness and functionality the EMS and QMS. Interesting results here are that approximately 60% of our respondents perceive that the EMS and QMS works quite well, even though they not use them so often. At the same time a majority of our respondents also think that these systems is not so well integrated with the company's other IT system and only 33% agreed to that these systems actually help them in their decision-making. Moreover we studied how our respondents perceived

the effects of environmental considerations. There is a quite large consensus that while increased environmental considerations are costly and potentially time-consuming, they do not lead to lower quality, are beneficial for the end-user and creates goodwill for the company.

In a final analysis, we investigate if these conclusions are dependent upon the number of decisions that our respondents are making or whether the respondent is positioned in the head office or on the construction site. First, we discovered a difference in the decision making intensity between the head office and on-site respondents. Furthermore, we did not find any major differences between high or low decision intensity makers or between respondents that are positioned at the office or on the construction site. Exceptions is for instance that respondents with high decision intensity perceive the ICT systems as giving them more relevant information and more beneficial in their decision making. We could also see that respondent's working at the office to a higher degree perceived that environmental considerations lead to longer production times.

We have concluded that decision that could effect environment is taken with the same, or even higher, frequencies at the construction site as at the office. On paper, or as perceived by top management in the organisations, decisions concerning building-material, production-processes, choice of suppliers etc. to a higher degree are supposed to be taken earlier on in the project and by actors such as managers, suppliers and project planners. In reality, a lot of decisions are taken during the project execution at all levels and with same frequency by actors at the office as by actors at the construction site. Furthermore, the site manager is the actor which is seen to have the highest degree on influence on a project which further strengthens the conclusions concerning where and by whom important decisions are taken.

The implication is that the information that ensures that decisions are taken in line with the companies' sustainability and environmental policies, as well as knowledge that ensure a efficient decisions from an environmental perceptive, must be easily accessible for managers at all levels during the entire project process. However, this is not necessarily the case.

From our study we can conclude that ICT is used at strategic, tactical and operational level in construction companies by all actors involved, often on a daily basis. The number of different systems available is considerable, and EMS and quality management systems are implemented in nearly all companies. In general, managers are satisfied with their companies IT strategies and policies, as well as with their environmental and sustainability policies.

When it comes to the use and perceived usefulness of EMS in relation to environment-related decisions, there are clear indications that there are may be hidden problem areas with especially EMS systems. Even if a lot of actors perceive the systems as being at least acceptably integrated with other IT systems and useful, when scrutinized the results are more worrisome. The EMS is a system that is used least frequently. Moreover, there is an indication that if you take fewer decisions, you tend to be less satisfied with the system than actors that take more decisions. In addition, managers working at the office find the systems more useful than managers at the construction sites; they also perceived the effects of the environmental concerns in a different way.

In summary, there is reason to suspect that environmental decisions to a large extend are made outside the controlled information systems of the company, without knowledge of what is the optimal decision from a sustainability perspective, and by actors that were not originally expected to make these decisions. It is clear that there is a need for more studies in these areas in order to get a deeper knowledge of what these decisions include and what the consequences are from the eco-efficient perspective.

5.1 Limitations

It is important to note that, while self-contained, this section reports the tentative findings from 483 responses. Undoubtedly, a further investigation will reveal more interesting patterns. It is important to point out that our sample is not simple random or stratified. A large proportion of the answers comes from a single large construction firm, thus the results may be biased, even though the face validity of the results is acceptable. These and some other deficiencies will no doubt be remedied in future work.

6. ACKNOWLEDGEMENT

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SUSTAINABLE REFURBISHMENT: LOW CARBON STRATEGIES AND THE ROLE OF STAKEHOLDERS

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ABSTRACT

It is expected that greenhouse emissions will continue to increase if consumption of resources are not managed. Hence, facilities have an eminent role in some of the most important issues of today: global warming, energy supply and carbon emissions. Unless measures are taken, the construction sector will keep on contributing to these crises. The aim of the study presented here is to address the issues of low carbon strategies in order to identify future challenges that face the construction sector in this regard. A review has been undertaken about the current state-of-the-art concerning low carbon strategies within the scope of stakeholder impacts, carbon footprint, energy use, quality and change management. The results are a reflection of future studies that need to be undertaken from a variety of perspectives in order to achieve facilities that substantially reduce their carbon footprint. How do we identify and classify stakeholders from the perspective of their potential carbon footprint on a facility? What tools are there, or could be developed, to determine the carbon load over the operational life? The research that was undertaken is seen as an initial study that raises questions about the challenges that construction researchers and practitioners face in the near future in regard to low carbon strategies. The result of the study aims at raising the question of how to reduce the carbon footprint of facilities. This is ensured by the identification of stakeholders and development of strategies that allow a real reduction in carbon emissions. Designs that fail to take into account the carbon load imposed by all stakeholders will similarly fail to meet sustainable development criteria.

1. INTRODUCTION

The holistic nature of environmentally sustainable development is not well embraced by the property and construction industry as compared to other industries. Many players in the industry tend to focus on certain component of environmental sustainability for example energy use and heritage conversion (Robinson, 2002). Currently it has become popular to market or advertise a proposed building as being environmentally sustainable if it incorporates even a single environmentally design feature despite the building itself breaking most of the environmental sustainability rules in terms of its configuration, material and services (Robinson, 2002). In Sweden, buildings consume more than 40% of energy and produce over 40% of the direct and indirect carbon emission (European Commission 2007). It is expected that these greenhouse emissions will continue to increase if consumption of resources are not managed. Hence, buildings have an eminent role in some of the most important issues of today: global warming, energy supply and carbon footprint. Unless measures are taken, the building sector will keep on contributing to these crises.

Inventories of greenhouse emissions (e.g. calculation of carbon footprint) have greater uncertainty than is often recognised (Markland *et al.* 2009). Carbon foot-printing has not been driven by research, but rather has been promoted by non governmental organisations, companies and various private initiatives (Weidema *et al.* 2008). This has resulted in numerous definitions on how to calculate the carbon footprint, which could add to the uncertainty. The information provided by carbon footprint models is inconsistent and often contradictory, to enable individuals and organisations to calculate

their greenhouse emissions accurately there is a need for credible and regularly updated sources that are transparent and country specific (Kenny and Gray, 2009).

Refurbishing of older buildings to modern standards of carbon emissions is generally a major project and is often more challenging than building a low carbon home from new. This is because previously, energy performance was not featured at all in building regulations, and it's only recently that serious attention has been focused to ensuring properties are designed and built with minimising carbon emissions as a high priority. According to the Swedish Statistic Bureau, between 2000 and 2007, the yearly average number of refurbished housing is 30 100 units and demolition of housing is 2 500 units in comparison with new housing with only 15 000 units. Obviously, the focus on refurbishment would definitely be a worth investment for carbon emission.

This paper presents arguments and ideas on carbon reducing refurbishment in buildings. This paper will also define and examine the role of the stakeholders in terms of their potential impact on low-carbon refurbishment including the supporting infrastructure. In summary, the paper aims to identify a broad set of stakeholders to actively address the benefits of low-carbon refurbishment (low running cost, low carbon dioxide emissions, comfort and health) in their decision making.

2. SUSTAINABLE REFURBISHMENT

"The built environment, i.e. the production, operation, maintenance and disposal of buildings, infrastructures and, to a certain degree, cultural landscapes, is the largest part of the physical and economic manmade capital. It is, however, also an important part of the social and cultural capital of a society. This gives it, by definition, a central position in all attempts to achieve sustainable development, both in industrialised and emerging countries." (Kohler and Yang, 2007:351)

The essence of the sustainability debate is that reuse and refurbishment is likely to be more firmly on the agenda than ever before (Ball, 1999). Refurbishment can take many forms, ranging from simple redecoration to major retrofit or reconstruction, and if a function is no longer needed building may be converted to a new purpose altogether (Langston *et al.*, 2008). What is needed is a coherent strategy for the existing building stock that mirrors the successful approach for new buildings (e.g. zero carbon new homes by 2016 in England and 2011 in Wales and the Germany's PassivHaus Standard)(Killip, 2008). Indeed each country manages sustainable refurbishment differently. Scandinavian countries like Denmark and Sweden have started ahead in developing different strategies of integral renewal of buildings (Mickaityté *et al.*, 2008).

Mickaityté *et al.* (2008:56) had rigorously summarised factors such as economic, social and environmental influencing refurbishment sustainability from various studies. Among the studies adopting decisions on economic efficient refurbishment to new technology methods are: general theories of expert systems to construction by Adeli in 1998, theoretical model of several modular stages in the decision process by Henkett in 1990, frame based decision support model by Reddy *et al.* in 1993, multi-criteria 'knapsack' model by Alanne in 2004 and XENIOS methodology by Dascalako and Balaras in 2004. Various studies also focus on integrating IT supported knowledge management, decision support, expert model for building life cycle management as well as refurbishment project assessment. The energy efficiency activities during refurbishment take into account the economic feasibility of possible measures (Chwieduk, 2003). There have also been studies focusing on polluting affecting decision support system for innovation (Mickaityté *et al.*, 2008). Meanwhile, Zavadskas *et al.* (2008) summarised a study by Sobotka and Wyatt that considered the rules for sustainable refurbishment must refer to the building throughout its life cycle, starting with choice of raw material for the production and their evaluation, through to demolition of the building. The link between

different types of service life and effective lifetime of buildings resides in differences between planning decisions and the interest to use the complex resources of the building stock in a sustainable way (Kohler and Yang, 2007).

In summary, sustainable refurbishment is mostly related to technical-ecological aspects of building life cycle. This include the satisfaction of social (health housing) and economic (energy savings, low maintenance costs) needs. The integration of these needs makes the concept of sustainable development (Zavadskas *et al.*, 2008). Ideas about good practise from a sustainability perspective are filtering into the decision-making process, even when developers do not have a clear conception of what sustainability actually involves (Ball, 1999). As cities expand, improving the quality of the existing building stock is important for all stakeholders, occupiers and policy makers (Reed and Wilkinson, 2005).

3. STAKEHOLDERS' DIMENSION

Freeman (1984) traces the modern use of the term stakeholder to a memo from Stanford Research Institute in 1963, which states that a stakeholder is a person or a group of people without whose support the organisation would cease to exist. Freeman (1984) expands from this and defines stakeholders as those who affect or is affected by the achievements of an organisations purpose. In project management the term stakeholder can be defined as any individuals or organisation who are actively involved in the project or whose interest may be affected as a result of project execution or completion (PMI, 2004). Olander (2006) had discussed thoroughly on the identification of stakeholders and formulates a defined definition of the term as a person or a group of people who has vested interest in the success of a project and the environment within which the projects operates. There are two categories of stakeholders, internal stakeholders – those who are actively involved in the project and external stakeholders – those who are affected by the project.

Regardless of what the definition is, the key aspect of stakeholders' engagement is the issue of participation and empowerment (Mushove and Vogel, 2005). Meaningful needs to be coordinated with decision-making power so that there emerges an inverse relation between the level of community participation and the level of decision-making power by those in power. A study by Gilkinson *et al.* (2006) suggested that in order to encourage the construction stakeholder to 'buy into' the sustainability agenda, the best method would be to provide short construction site seminars that will inform the operative and manager of the impact that the inefficient use of the construction product has upon the ecological system.

According to the environmental dispute resolution model by Smith (Mushove and Vogel, 2005), the degree of participation of stakeholder commitment should be directly proportional to the extent of their bargaining power for any meaningful resolution to be brokered. All successful climate change must identify and engage relevant stakeholders that understand and acknowledge the need to respond to climate change, develop an understanding of the science and access useful data and gain support from a wide spectrum of decision makers and implementers within an organisation (Justus *et al.* 2007)

In summary, acceptance and participation from stakeholders can be gained through acknowledging their needs and concerns. Their input can be analysed using different decision-making models such as STURE model (Persson and Olander, 2004) and Proposed Building's Refurbishment Knowledge-based Decision support System (BD-DDS) by Zavadskas *et al.* (2008). It is important to gain understanding of the potential impacts of climate change throughout stakeholder followed by drawing on stakeholders' expertise and local knowledge. This approach can successfully engage broader stakeholders across a range of sectors on the need for climate change in refurbishment.

4. SYNERGY OF STAKEHOLDERS TO FORMULATE CARBON REFURBISHMENT STRATEGIES

The Kyoto Protocol is an international treaty on climate change, presided over by the United Nation (UN) and subscribed to, currently, by 164 countries worldwide. The treaty demands that full signatories reduce their carbon emissions (their carbon footprint) as part of a common initiative. This is achieved either by a reduction of emissions, or by 'carbon offsetting' (European Commission, 2007). In response to growing anxiety over the climate change issue, the European Union (EU) has issued directive to reduce 20% of greenhouse emissions in buildings by 2012 while Sweden's own ambitious target to cut carbon emissions in buildings by 17% (Björklund, 2008). With regard to the international standards,

ISO 15392:2008 identifies and establishes general principles for sustainability in building construction. It is based on the concept of sustainable development as it applies to the life cycle of buildings and other construction works, from their inception to the end of life. However, this standard does not provide the basis for assessment of organizations or other stakeholders.

Collecting information about carbon emissions can be extremely informative to the stakeholders and act as the first path to carbon management strategies. Nonetheless, in the face of the Kyoto Protocol's expiration in 2012, partnerships with stakeholder groups have emerged as crucial tool for companies to manage the risk and exploit opportunities posed by climate change and to participate in setting a post-Kyoto agenda. However, many companies are not communicating their effort to all stakeholders (Hull, 2007).

Hoffman (2007) identifies three stages in a climate-related strategy development process:

1. Develop a climate strategy
 - a. Assess emissions profile
 - b. Gauge risks and opportunities
 - c. Evaluate action options
2. Focus inward
 - a. Develop financial mechanisms
 - b. Engage the organisation
3. Focus outward
 - a. Formulate policy strategy
 - b. Manage relations with external stakeholders

There are essentially three key drivers that will hasten the transformation to a carbon-constrained world (Hoffman, 2007). The first driver is the establishment of regulations. When new policies are set, the business landscape will change. The second driver is rising energy prices, which will create incentives for choosing more energy efficient alternatives. The third driver is growing interest within the investment community to invest in environmentally friendly schemes where carbon reduction and energy efficiency are key issues. Hoffman (2007) further added that the motivations for undertaking climate actions, such as carbon reduction strategies are cost savings, social responsibility and reputation.

Kenny (2008) presented four advantages of managing carbon emissions. First, a comprehensive emission inventory involves most aspects of business manufacturing process, energy use and transportation infrastructure. Thus by measuring emissions, business realise opportunities to improve efficiency and generate cost savings and reduce energy use and emissions. The second involves getting ahead in the race of climate change. Companies that develop and implement climate change strategies will gain a competitive advantage as economy adjusts. Thirdly, developing climate change strategies now will help identify the risk stakeholders' face – and the opportunities for

new markets and products. Lastly the carbon footprint policy can improve the business public image and enhance corporate social responsibility.

Successful low-carbon refurbishment strategies depend on stakeholders' support and cooperation. Consultations with stakeholders – residents in particular – provide the best, and above all a pre-emptive opportunity to identify objections to the refurbishment and potential barriers to achieving the projected energy savings. Therefore it is important for stakeholders to understand and agree on the concept of 'buildability' idea. As explained by Killip (2008), key elements of 'buildability' idea are that building work needs to be made of products and methods that have the following characteristics.

- Practical – solutions need to be relatively simple and quick to implement.
- Replicable – a refurbishment package needs to be something that can be installed many times over by the general population.
- Affordable – unit costs may well come down over time and be influenced by policy, but there is no point in promoting items that is difficult to find in the market.
- Reliable – products and systems need to work well and be robust, including being easily understood by the building user.
- Sellable – the costs and benefits to both customer and installer need to be readily understood.
- Available – specialist products that take week to order will not be favourable among the mainstream; developing product supply chain is key.
- Guarantee-able – products that work will be accepted without the need for call-backs and complaints.
- Profitable – firms need to make a living from it.

Therefore it is anticipated that a strong stakeholder coalition is required to promote and mainstream low-carbon refurbishment. Strong partnership among stakeholders will be able to fulfil the ambitious aim of reducing the carbon emission. In addition, effective climate change depend largely on effective local scale response, since local attributes, including social and economic characteristics and the physical environment, will significantly determine the extent of risks and opportunities posed by climate change , as well as the nature of the community (Justus et al., 2007).

A preliminary conceptual model (see Figure 1) is formulated based on the work of Mickaityté *et al.* (2008), Hoffman (2007), Persson and Olander (2004) and Olander (2006). Micro and macro environments can form the base for identifying the specific and general conditions for a refurbishment project. The project can then be evaluated from the following dimensions: technological, cultural, ecological, social, architectural and economic. With further input from stakeholder analysis information can be obtained about stakeholders involved in the decision-process and these will affect carbon use. From this results can be obtained about the most appropriate refurbishment alternative from a wide array of perspectives. The bottom line is that carbon, just like capital, human resources and products, is now a strategic part of the new competitive game (Schultz and Williamson, 2005).

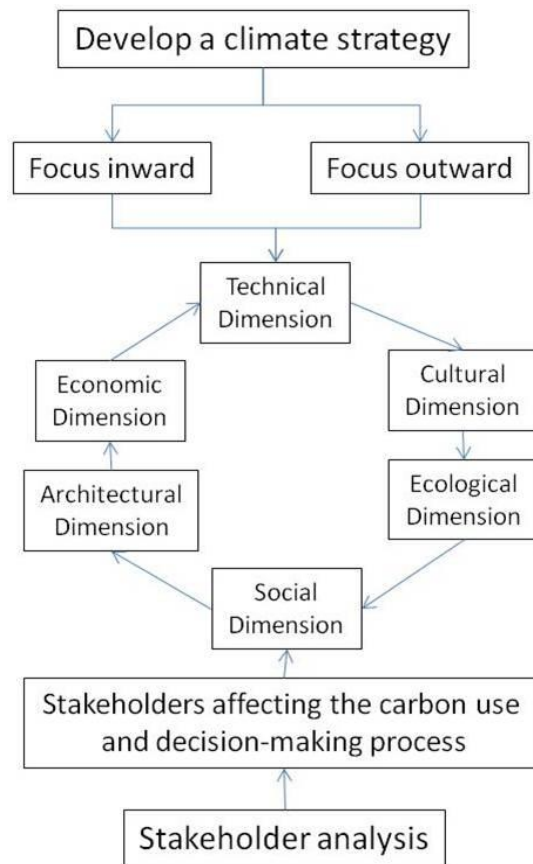


Figure 1. Preliminary conceptual model for evaluating refurbishment from a sustainable perspective (adapted from Mickaityté *et al.*, 2008; Hoffman, 2008; Persson and Olander, 2004; and Olander, 2006).

5. CONCLUSIONS

It is a challenge to find the methodological questions with regard to existing buildings. Although the importance of low-carbon refurbishment, due to the large amount in relation to new housing, is commonly recognised there is a lack of reliable tools for the description and assessment of existing buildings. The models used have to be acknowledged at a meso or macro level to gain enough transparency and creditability.

The stakeholders' involvement in refurbishment is quite different to that of new building, with smaller businesses in the construction industry being typically involved in repair, maintenance and improvement. Generally, the small and medium sized enterprises (SME) construction firms who undertake refurbishment work and these enterprises need to be ready and equipped to offer low-carbon options as part of that service. Apart from the SME contractors, other stakeholders for example the owner, occupants and customers/visitors also play an essential and critical role in developing policy ideas and strategies for making low-carbon refurbishment mainstream. A coordinated strategy to communicate the benefit of low-carbon refurbishment to stakeholders must take place. In addition knowledge needs to be obtained of the impact various stakeholders will have on greenhouse emissions, primary and secondary, before and after refurbishment. This would be an integral part of the decision-making process in the planning of a refurbishment project. The coordination of the information from the stakeholders has to become an important component of a project's quality control over time. Such coordination could have implications for stakeholder learning and continuous improvement throughout the project's life cycle.

Since the life cycle of a building is rather long, compared to other products, the term stakeholder could require a development of its definition. It must not only contain the current stakeholders but in some way it must include the 'next generation stakeholders' and that is a challenge for research. Thus, sustainable refurbishments not only introduce energy efficiency, but simultaneously improve the building condition, adding commercial value, prolonged life cycle for the current and future generation users.

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INVESTMENT PROJECT SELECTION BASED ON MULTICRITERIA ANALYSIS

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ABSTRACT

One of the basic tasks of a developer is an evaluation and selection of building investments in the initial phase of the planned undertaking. The problem of selection of investment undertakings arises mainly due to their specific character. The need to plan different solution variants concerns mainly the elements determining the success of the project. The aim of this paper is to address the issues of the selection of building investments from investor's viewpoint and to present the procedure based on Analytical Network Process. The presented method allows both quantitative and qualitative (social, ecological) factors to be considered in the analysis. Different variants of investment realization were compared according to the profitability and the applied technical, technological and organizational solutions. The reliability of the final result from the adopted market strategy of a developer was indicated.

1. INTRODUCTION

The economic situation in the housing market in Poland contributed to the increase in the number of developers. There was a sudden growth of competition in this sector. However, in the ensuing situation the problem could have involved the quick sale of flats. Undoubtedly, the major factor determining investment from developer's viewpoint is the maximization of profits. There are, however, many factors which, to a greater or lesser extent, may be considered in the phase of investment preparation. It is confirmed by the literature studies and the questionnaire surveys conducted amongst Polish developers. In the face of occurring changes, there is a growing demand in the housing market in Poland for formalized procedures providing rationale behind decisions.

The aim of this study is to systematize the knowledge about the choice of the final variant of the planned investment, to detail and determine the weights of criteria with their simultaneous organization into groups. First step in this research project is create a procedure which shall enable to rank projects (variants of the prepared investment) from the most to the least desirable. Moreover, it is important to establish the interrelation between the criteria.

One of the available methods which enable to determine the weights of the criteria via the comparison between pairs (also alternatives, projects) is the *Analytical Network Process*. The ANP method was developed by T.L. Saaty for problems which due to correlation (interdependence) and mutual influence between elements of higher and lower level cannot be arranged into hierarchical structure. According to ANP (BOCR) methodology, the criteria as well as individual projects (or variants) were subject to preliminary evaluation via pairwise comparison.

However, from the perspective of developer's market strategy we may consider two possibilities: the maximization of profits or minimization of costs. I will try to give some answers relate to influence of the final result (the choice of the best variant investment) from the adopted market developer's strategy. This study is a first step, aimed at finding a procedure for investment project selection.

2. LITERATURE REVIEW

2.1 Housing market in Poland

Developer's activity in Poland has developed mainly in the housing construction sector. A small percentage of companies offer so called commercial buildings, such as hotels, aqua parks or public buildings. The results of the observation of the housing construction market indicate that the realization of building investments in developer system is being more and more eagerly undertaken, especially by subjects having wide experience in building production. Developer's activity undertaken by typically building companies is more beneficial and less risky as the companies have considerable experience in realization of building investments, organization of a building process and very often they have their own equipment and material basis at their disposal.

The appearance of real estate development companies as one of the subjects of building market inspires to more detailed analysis of the success of the undertakings realized in this system. It is quite hard to provide an unambiguous definition of a developer. However, analysing the activity of developers in Poland, it should be noticed that they perform mainly the role of an organizer and coordinator of the investment process (mainly in the field of supervising the works executed by contractors during the building process). They start the building undertakings at their own risk and the resultant multi-family buildings put up for sale at the beginning of the investment process in order to make a profit and enable the partial cofinancing of the investment by a potential purchaser.

2.2 Crucial success factors in realization of investment project

The success of the undertaking is determined to a greater or lesser extent by many factors. Major factors profoundly influencing the success of the developer's undertaking include: location of the investment, the offered price of the apartment, the quality of the project and the quality of realization. The results of the research conducted in the form of a survey (additionally supplemented by an interview) (Dziadosz, 2006) among 15 developers indicate that a reputation and a favourable market opinion on a developer were recognized as key factors in success of building undertakings. The factors ensure greater stability of the company operations and may reduce the risk resulting from e.g. a slump in the economy (Figure 1). Undoubtedly, the location of the investment was acknowledged the most important by respondents as it is one of the basic features of any property, determining its market value.

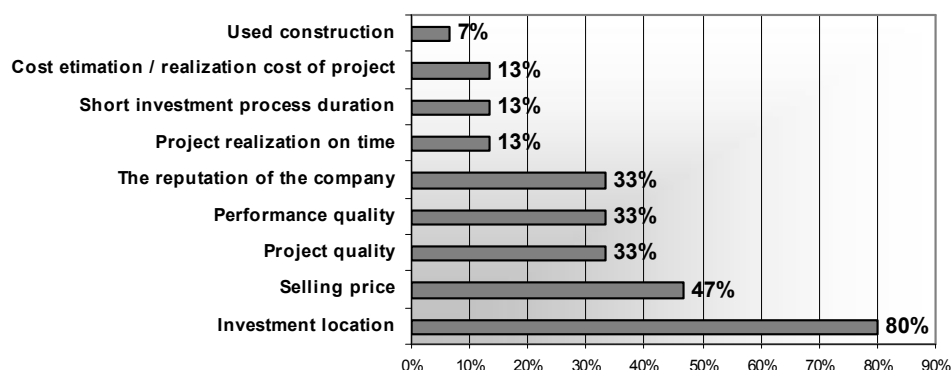


Figure 1. Critical success factors of investment project (Dziadosz, 2006).

As far as the location is concerned, the customer pays attention to the following factors: the immediate environs, accessibility and proximity of schools, shops, parks, convenient transport connections, neighbourhood, the journey to the building, a recreation area etc. (Dziadosz, 2008; Viteikiene and Zavadskas, 2007; Kauko, 2007). Similar criteria may be taken into account during the evaluation of the location and the choice of project when it comes to commercial buildings. However, here such criteria as a number of parking places, visibility of the building from the main street or usable floor area acquire greater significance (Zavadskas *et al.*, 2004). Continuing the deliberations of Polish housing market, the decision of a potential flat purchaser is influenced also by a price of a square metre (selling price), architectural style of a building or a heating system and the resultant cost of usage. All these factors determine to a greater or lesser extent the market value of the property (Kaklauskas *et al.*, 2007).

2.3 Investment project selection

The selection issues are relatively often addressed regardless of the type of the subject of selection and not only in the area of investment. However, in the field of investment the attention is focused on an evaluation and creation of ranking of undertakings according to previously determined criteria (Babic and Plazibat, 1998; Cheng and Li, 2005; Wong *et al.*, 2000; Ustinovichius, 2004; Kapliński, 2007). The main motive of this paper is a selection of investment projects from a developer's viewpoint. The process of planning the future investment starts far earlier, often in the phase of realization of the previous investment. Obviously, it is connected with the duration of individual phases of planning and preparing the investment, from the moment of purchasing the building land to obtaining necessary planning permission. A developer makes choices in each phase of the investment process, among others: a choice of one of many investment possibilities, a choice of the final variant of investment realization, a choice of the contractor for building works and so on, therefore it seems necessary to develop methods which will enable the developer to make the rational decision. The acceptance of the final variant of the realization of the future investment has major significance for further activities of a developer and influences their profitability. The proposal to use the multicriteria methods in the decision-making process results from the possibility of a comprehensive and thorough evaluation of the projects, offered by the methods.

2.4 The criteria of choice and their weight

The first phase, regardless of the adopted procedure and subject of the selection, begins with specifying possible alternatives and determining the set of criteria according to which they will be evaluated. The part of criteria is constant, i.e. regardless of the type of the undertaking the attention is paid to: profit, duration, cost of realization and the like. The literature on the subject places particular emphasis on financial analysis of the undertakings (Ginevicius and Podvezko, 2006). Therefore, undoubtedly, among financial criteria there will be included: rate of return, period of capital return or NPV level. However – according to the results of questionnaire surveys conducted in the Polish housing market – developers take into account also other factors (Dziadosz, 2006). A developer may consider such criteria as: the technology of realization, a reduction in financial risk or ensuring financial liquidity (Figure 3). The criteria should consider the requirements of the developer, the specificity and degree of complexity of the undertaking, legal requirements, the type of the building and preferences of potential customers. Then, the possible subcriteria should be determined. The next phase should include the determination of weights for individual criteria in order to establish their influence on the decision made. The level of risk connected with realization of a certain building should be also acknowledged an important criterion. The duration and complexity of the investment very often determine the inclusion of risk management in

the decision-making process during the realization of the investment (Gehner and Jonge, 2007). It is also connected with a decision-maker's attitude to risk.

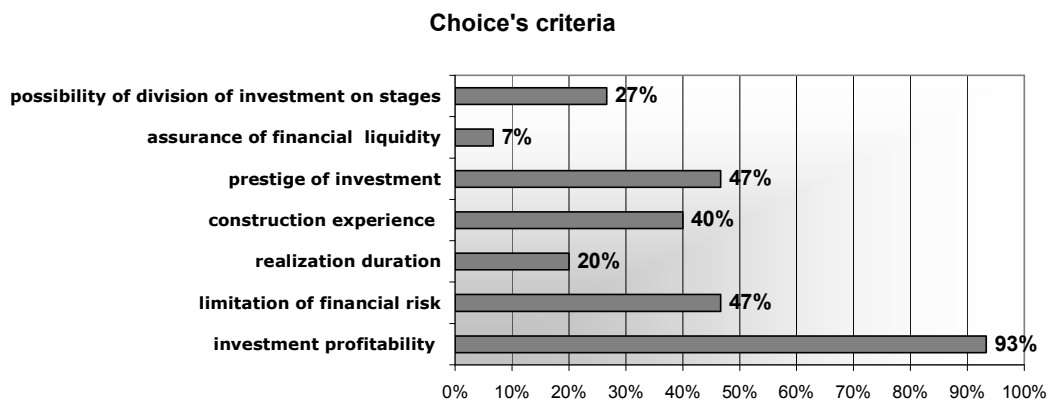


Figure 3. The criteria of choice of the final variant of planned investment realization.

3. RESEARCH PROJECT

3.1 Project description

Previous research confirmed that such factors as the level of risk or internal rate of return are significant during the process of planning the investment (the choice of the final variant). However, the companies consider also other factors reflecting their requirements, preferences and possibilities. Obviously, it is not possible to measure all the criteria on account of their character. There is a significant part of qualitative criteria influencing the final result of a decision. When it comes to such criteria, it is essential to determine their numerical scale. The next issue is to determine the criteria which enable to compare two projects. Continuing, the following phase consists in create a procedure which shall enable to rank projects (variants of the prepared investment) from the most to the least desirable. Moreover, it is important to establish the interrelation between the criteria, e.g. the influence of a degree of technical complexity of the building on the duration and cost of building. Nevertheless, it should be assumed that there are a number of independent and incomparable criteria. However, from the perspective of developer's market strategy we may consider two possibilities: the maximization of profits or minimization of costs.

3.2 Research methodology

The main stages of the evaluation of the project should be focused on (Figure 4):

- detailing possible variants (alternatives) of the undertaking;
- detailing criteria in strategies adopted by a developer (the maximization of profits or minimization of costs);
- determining the weights for individual criteria based on experts' opinions (considering a consensus of opinions);
- analysing possible projects (variants of investment realization) with a simultaneous arrangement from the best to the worst one; and
- analysing the main factors and their influence on the final result of selection.

Therefore, in the first phase a decision-maker creates a set of possible variants of the investment in order to choose the optimal project for realization, basing on the adopted criteria of choice. The second phase consists in detailing the criteria (or, additionally,

subcriteria) of selection. The set of criteria in this paper is created based on the analysis of literature and previously conducted questionnaire surveys. Taking their character into account, the criteria are appropriately assigned to two clusters: benefits and costs (Saaty, 2005; Saaty and Ozdemir, 2003). The division of the criteria into two clusters in this paper results from possible market strategies adopted by a developer. Moreover, the authors suggest considering opportunities and risks in a decision-making process. Benefits and opportunities are positive (their increase is profitable for a developer); whereas costs and risks are negative (their increase is disadvantageous for a developer). It is caused by a character of the criteria, e.g. for the criterion: *city center is close*, the high value of this factor is more profitable in the evaluation of the given variant (Kaklauskas et al. 2007; Viteikiene and Zavadskas, 2007).

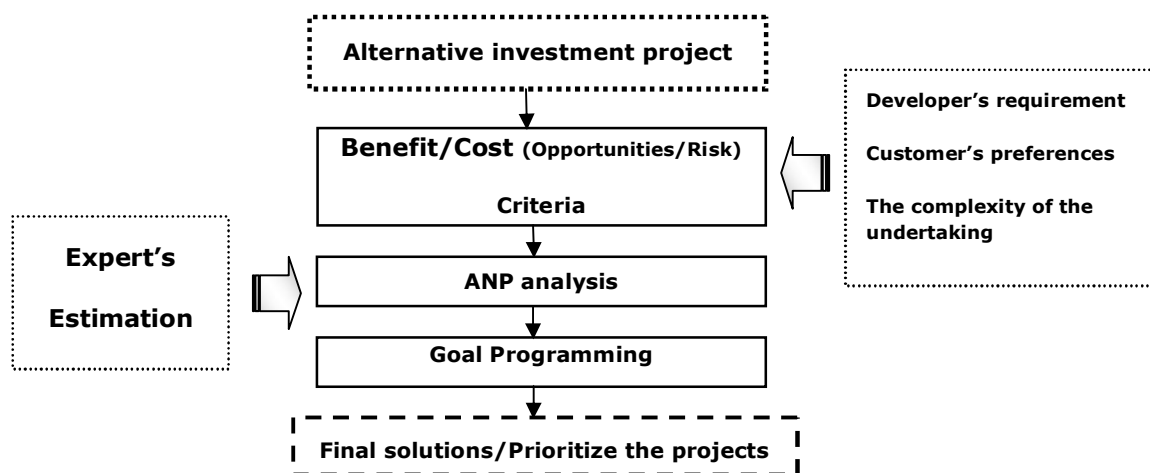


Figure 4. The overview of the proposed procedure.

It is essential to determine the weights of the individual criteria (subcriteria) taking into account their influence on a global evaluation of the selection. One of the available methods which enable to determine the weights of the criteria via the comparison between pairs (also alternatives, projects) is the *Analytical Network Process*. The method is frequently used in solving problems connected with choosing the contractor, financial crisis, strategy of company's operation, conflict resolving, job performance evaluation, etc. (Cheng and Li, 2004, 2006; Saaty and Vargas, 2006). One of the first works dedicated to the use of ANP in the selection of projects is the paper written by Cheng and Li (2005).

The ANP method was developed by Saaty for problems which due to correlation (interdependence) and mutual influence between elements of higher and lower level cannot be arranged into hierarchical structure. First, Saaty developed the *Analytic Hierarchy Process* method which is suggested for problems with a simple hierarchical structure. The aim of the mentioned methods is to rank the considered variants from the best to the worst one. The author of AHP/ANP introduced a 9-degree scale for pairwise comparison, where 1 means the equivalence of two criteria (factors, alternatives and the like), whereas 9- the absolute superiority of one criterion over the other. In order to ease the calculations the considered pairs are compared in matrix, i.e. the elements from the first column are compared one by one with the elements of the upper row. The superiority of ANP over AHP consists in considering in the analysis the interdependent relationship among individual elements (e.g. criteria).

Next, the system consisted of individual comparison matrices (in clusters and subclusters) have to be transferred into the supermatrix. Afterwards, there comes the

process of transformation of the supermatrix into the limit matrix (Saaty, 2004; Cheng and Li, 2005). The weights of the model criteria are obtained based on preliminary evaluations of 8 experts. It is worth emphasizing that each of the obtained evaluation matrices of experts is checked according to a consensus of opinions with the use of consistency ratio – CR, where $CR < 0.1$ means that the matrix is consistent. However, it should be mentioned that research on criteria and their weights are being still conducted among developers by the author of this paper in order to clarify the procedure.

The next phase of the procedure consists in the evaluation of possible variants (especially the allocation of available reserves to individual projects) using Goal Programming approach. GP is a technique of multiple objective programming developed by Charnes and Cooper. The technique consists in minimization of deviations between the achievement of goals and these acceptable aspiration levels (Chang, 2008). In the case where there is a possibility of realization by a developer more than one project, there arises a problem of optimal allocation of reserves (financial, time, equipment, etc.). Then it is possible to replace coefficients of objective function with suitable weights obtained from ANP analysis. In conventional GP approach the objectives are specified exactly. However, in reality there may appear imprecise aspiration levels such as 'somewhat larger than'. Therefore, there is the Fuzzy Goal Programming approach, offered in literature, enriched by fuzzy set theory.

4. RESULTS OF RESEARCH

4.1 Quantification of results

The analysis of literature and preliminary questionnaire surveys enabled to notice the lack of formalized methods in the area of choosing the final variant of the planned investment (project selection). Moreover, the use of ANP or GP methods in the area of real estate development is less common. Therefore, the structure of the procedure is proposed in this paper (Figure 5). According to ANP (BOCR) methodology, the criteria as well as individual projects (or variants) were subject to preliminary evaluation via pairwise comparison.

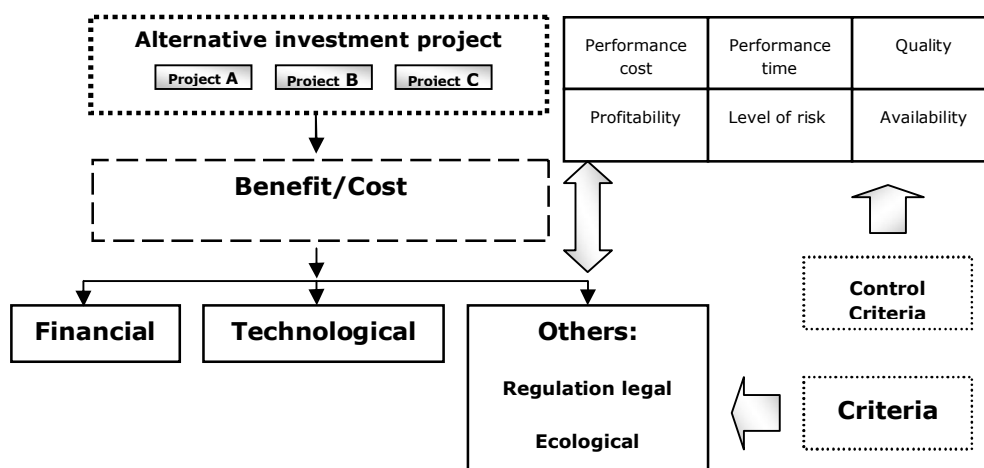


Figure 5. The framework of the proposed procedure.

According to BOCR methodology (benefits, costs, opportunities and risk) (Saaty, 2005), model criteria are divided into two clusters – benefits and costs – on account of their character and influence on a global evaluation of the project (Table 1). Obviously, the weights are estimated according to ANP taking into account a relation between criteria and control criteria. Afterwards, three hypothetical projects A, B, C are evaluated according to criteria mentioned above (Table 2). There is applied one of the four methods of results aggregation: $[B*b+(1-C)*c]$ (Saaty and Ozdemir, 2003), where B and C mean data obtained from the analysis for each of the considered alternatives, whereas b and c – mean weights for each of the clusters respectively. A short example shows an influence of the adopted weights for individual clusters of criteria on the final result of the selection (Figure 6). However, in order to notice the mentioned influence, different scenarios are adopted for individual clusters of criteria (Table 3).

Table 1. The example estimate criteria.

Control criteria					
Performance cost	Performance time	Quality	Profitability	Level of risk	Availability resources
Criterion	Benefit		Cost		
Financial	<ul style="list-style-type: none"> * Internal rate of return * Net present value 		<ul style="list-style-type: none"> * Level of initial expenditures * Necessity of giving the investment credit * Pay-off period 		
Technical	<ul style="list-style-type: none"> * Degree of utilization of useful area * Possibility of division of investment on stages * Degree of utilization of area land development * Number of floor 		<ul style="list-style-type: none"> * Construction complexity * Material solution complexity * Range of preliminary works on site 		
Others	<ul style="list-style-type: none"> * Friendly surroundings of investment, neighbourhood * Infrastructure of communications and number of cars for parking * City center/ green area is close, etc. 		<ul style="list-style-type: none"> * Range of works connected with investment preparation 		

Table 2. The example of project estimation.

	Benefit (B)	Weight	Project A	Project B	Project C
Financial (0,45)	* Net present value	0,55	0,15	0,06	0,04
	* Internal rate of return	0,45	0,09	0,06	0,05
Technical (0,35)	* Degree of utilization of useful area	0,65	0,10	0,10	0,03
	* Possibility of division of investment on stages	0,35	0,04	0,04	0,04
Others (0,20)	* Infrastructure of communications and number of cars for parking	0,59	0,05	0,06	0,02
	* Friendly surroundings of investment, neighbourhood	0,41	0,03	0,03	0,02
Final evaluations of projects			0,45	0,36	0,19

Table 3. Scenario benefit (cost) ratio.

Scenario									
	9/1	7/1	5/1	3/1	1/1	1/3	1/5	1/7	1/9
b - benefit	0,90	0,88	0,83	0,75	0,50	0,25	0,17	0,13	0,10
c - cost	0,10	0,13	0,17	0,25	0,50	0,75	0,83	0,88	0,90

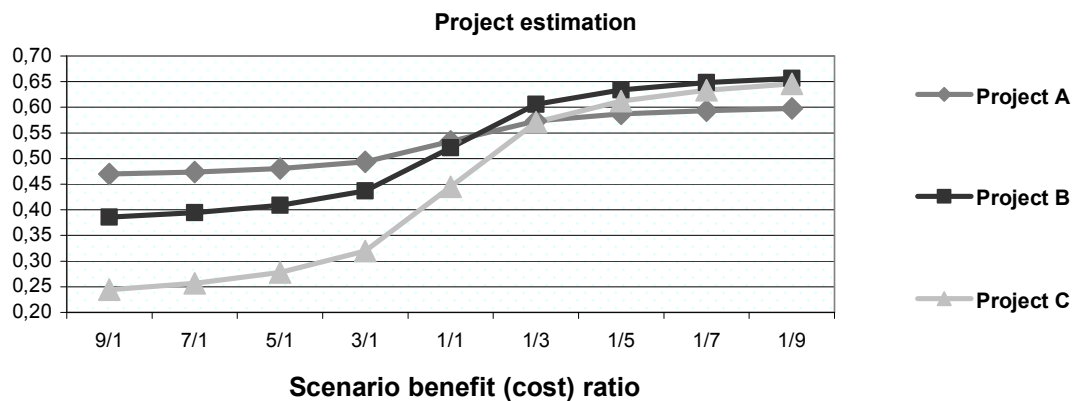


Figure 6. The sensitivity analysis of project estimation.

The analysis indicates that alternative A is beneficial from the perspective of financial criteria and greater possibility of utilizing usable floor area. Assuming that the investor is guided by cost minimization, then investment B seems to be more appropriate: the level of risk is relatively low but the benefits are medium. The further phase is the development of the procedure in the direction of optimization methods, namely Goal Programming. This method will enable to make an efficient allocation of developer's available reserves (time, and particularly financial ones) as part of the evaluation and choice of projects for realization.

4.2 Implementation and exploitation

Analysis to date constitutes the basis for further research into the optimization of investment decisions in the phase of planning the undertaking from the developer's viewpoint. The research on the factors and the degree of their influence on decision making process in the area of planning the investment is being still conducted. It will enable to supplement the knowledge in the area of choosing the optimal variant based on a suggested procedure. The use of ANP approach enabled a comprehensive evaluation of three hypothetical projects owing to the consideration of qualitative factors as well (Table 2). The proposed division of criteria depending on their character is also vital: benefits and costs and their influence on a global evaluation of the project. It is connected with the adopted market strategy of a developer.

5. CONCLUSIONS

In order to better adjust the offer to meet the needs of a purchaser, developers consider many factors influencing the shape of the final variant of the planned investment. The choice of the certain variant is not always determined by the sole financial benefits, but also by the degree of difficulty of the undertaking and the desire to minimize the inherent

costs and risk. Therefore, the possibility of using the approach of multicriteria analysis seems to be justified. This approach enables to address the issue in a comprehensive and multifaceted way. The possibility to provide the investor with the proper methods and procedures which facilitate making rational decisions in the phase of investment preparation shall allow for a thorough analysis of selected solutions. It will ensure the consideration of additional quantitative and qualitative factors determining the efficiency and feasibility of the investment.

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BeReal: TOOLS AND METHODS FOR IMPLEMENTING BENEFITS REALISATION AND MANAGEMENT

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ABSTRACT

The need to identify, monitor and manage benefits throughout a programme/projects lifecycle is being accepted as a way to ensure the success of that programme or project. Major capital investment programs and projects within both the private and public sector are conventionally measured upon their performance relating to tangible outputs such as cost, quality and time of delivery and not on the benefits they deliver. Benefits Realisation and Management is a method which is changing this way of thinking and focuses upon using benefits to drive, manage and measure the performance of a programme or project. Since 2006, The Health and Care Infrastructure Research and Innovation Centre (HaCIRIC) has been working towards developing a Benefit Realisation Management process (BeReal) which uses both ICT in collaborative environments and tools and methods to meet the above demands, by providing facilitation for evidence-base decision making, aiming to promote continuous improvement and organisational learning. BeReal has been developed focusing upon capital investments within healthcare infrastructures. The research project presented is a result of a literature review and action research which involved a close working relationship and dialogue with an advisory group and multiple case studies. The paper will present the importance of managing the realisation of benefits throughout a programme's or project's lifecycle by adopting BeReal during the planning, development, delivery and operational phases. The paper also argues why appropriate ICT tools using collaborative environments are developed to facilitate a simple and 'user friendly' implementation of the BeReal methodology.

1. INTRODUCTION

Complex public and private organisations, programmes and projects are driven by the need to realise benefits throughout their life cycle. A vagueness to identify as well as define these benefits at the conception stage makes it difficult to achieve and manage benefits which can result in the failure of the organisation, programme or project (Payne, 2007; Bartlett, 2006; Reiss *et al.*, 2006). With a growing understanding that the lack or inadequate use of benefits realisation and management can lead to failure the use of benefits realisation and management practices has risen. This seeks to move forward from the traditional investment appraisal approach and focus on the active planning of how benefits will be realised and measured (Glynne, 2007).

Healthcare programmes are classic examples of complex systems (Carruthers, 2005; Sweeney and Griffiths, 2002). They are also notoriously long, with a great number of different stakeholders involved this along with changes in policy during the lifecycle of a project mean that what is delivered seldom matches the vision set out at the initial stages of a programme stage. This can result in the need for changes which were not anticipated leading to an increase on the budget and time spent on the project. This failure can be due to either a lack of or poor benefits management (Sapountzis *et al.*, 2007). Benefits Realisation and Management is a method that can be used to stop this kind of failure (Glynne, 2007) through monitoring reporting and measuring benefits throughout the life-cycle of a programme or project.

This paper presents the process HaCIRIC has been through to develop a Benefits Realisation and Management (BeReal) framework with tools to help the planning,

development and delivery of successful healthcare infrastructure projects. The research project presented is a result of an initial literature review in Benefits Realisation and Management, a review of the literature on ICT tools used, an ongoing dialogue through workshops with an advisory group which includes: MaST LIFT, Community Health Partnerships, CABE, SHIFT, Eric Wright Group, NHS Confederation, Skanska Technology, OGC, NAO, Salford PCT, Tribal, Salford RHT, Trafford NHS, ActivePlan Solutions Ltd, Sir Robert McAlpine, Urban Vision, Manchester City Council and multiple case studies at different stages of a healthcare programme lifecycle. Initial discussions around the tools have been focused upon the penultimate stage of a healthcare programme lifecycle which is the Post Occupancy Evaluation stage. This has been generated from a case study at MaST LIFT.

The paper presents the importance of managing benefits throughout a programme's whole lifecycle using a process such as BeReal and how the adaptation of an IT collaborative environment can assist to easily implement such a methodology and facilitate a new way of thinking.

2. BENEFITS REALISATION AND MANAGEMENT

There are many different definitions given to the term benefit, with even more meanings being provided due to the different classifications these are discussed in depth in Sapountzis *et al.* (2008a). For the purpose of this paper a benefit is defined as 'an outcome whose nature and value are considered advantageous by an organisation' (OGC, 2007b; Thorp, 1998; Ward *et al.*, 1995) which are owned by individuals or groups who want to obtain value from an investment (Glynne, 2007). Whilst a 'disbenefit' in generic terms can be said to be the opposite to a benefit, disadvantageous to an individual (Merriam-Webster, 2005; Encarta®, 2005).

Benefits realisation and management also have a number of definitions, example could be seen in Farbey *et al.* (1999), Bradley (2006), Reiss *et al.* (2006), Lin and Pervan (2001), OGC (2007b) and Ward *et al.* (1996). Although some of these differ in their context for example Ward *et al.* focus around benefits that arise only from IS/IT and Farbey *et al.* identify the importance of recognising unexpected benefits. Most follow the same line of thinking that Benefits Realisation and Management is a process that realises, prepares and manages for planned benefits through change. HaCIRIC, like Farbey *et al.*, believe that the process should realise, prepare and manage for unplanned benefits, disbenefits and impacts throughout the programme/project's lifecycle.

Benefits realisation and management was first developed and quickly emulated into the field of IT in the late 1980s and early 1990s (Farbey *et al.*, 1999). Most of what was developed were practical guides around the investments these predominantly private IS/IT organisations made (Ward *et al.* 1995; Leyton 1995; Thorp 1998; Bradley 2006; Bartlett 2006; Payne 2007). Since then the importance of managing benefits has become increasingly recognised 'Projects and programmes can only be regarded as successful if the intended benefits are realised' (CITU, 2000). Recently the topic has been theoretically linked to healthcare through organisations such as OGC (2007a) and writers such as Bradley (2006).

2.1 Benefits Realisation and Management Approaches and Models

Since 1995, due to the recognition of the importance of benefits realisation and management within different sectors, various approaches and models have been developed to help organisations identify, monitor and ultimately achieve the benefits they originally set out to do so. These 'Benefits Management/Realisation' approaches are described in Table 1.

Table 1. Benefits realisation and management approaches and models (adapted from Sapountzis *et al.*, 2008b).

Approach/Model	Details
Active Benefits Management (Leyton, 1995)	Sets the benefits management activity in the context of business change. Identifies continuous flow between change and benefits
The Cranfield process model of Benefits Management (Ward <i>et al.</i> , 1996)	Key feature of this model is benefits monitoring this compares project results with the benefits realisation plan during the project and assesses if any internal or external changes have occurred that will affect the delivery of planned benefits. Potential benefits are identified, a plan is devised for their realisation, the plan is executed, the results reviewed and evaluated and feedback occurs.
The Benefits Realisation Approach (BRA) (Thorp, 1998)	Is based on two cornerstones: 1. The shift from stand alone project management to: Business Programme Management, Disciplined Portfolio Management, Full cycle governance. 2 The three necessary conditions for the successful implementation of the BRA are Accountability of activists, Relevant measure as in measuring the things that really count and Proactive management of change to give people ownership stakes in programs.
Active Benefit Realisation (ABR) (Remenyi and Sherwood-Smith, 1998)	A process for managing information systems' development through a continuous evaluation approach. ABR requires a direct and continuous focus on business benefits realisation and is based on a contingency philosophy, this is that information system outcomes development activities, tasks and participating roles of the stakeholders are dynamic throughout the duration of the project principle stakeholders of the information system are identified at the onset and that they accept and agree their continuous involvement.
Towards best practice to Benefits Management (Ashurst and Doherty, 2003)	In this approach benefits realisation is a continuous process through an evolving organisational context. But it does not into account influences that external factors may have onto a project
Managing Successful programmes (MSP) (OGC 2007)	MSP represents the UK Government's view on the programme management principles and techniques MSP identifies benefits management as "a core activity and a continuous 'thread' throughout the programme" (OGC, 2007a), and fundamental to the realisation of benefits from new capabilities delivered by projects within the programme. Emphasis is placed on identification, quantification, assignment of owners and tracking, it has been heavily influenced by Cranfield's Benefits Management model and Bradley's Benefits Realisation Management 2006.
The Gateway tm Process	The Gateway Review Process indicates, at a high level, dependencies between a typical Benefits Management process and the steps for managing a major delivery programme. It also maps the main benefits management steps onto the standard delivery stages described in both MSP and OGC Gateway Reviews, but the approach can be used for any type of more specialised change initiative. This process contains identification of potential benefits their planning, modelling and tracking, the assignment of responsibilities and authorities and their actual realisation.

Table 1. Benefits realisation and management approaches and models (continued).

Benefits Management in the Handbook of Programme Management (Reiss <i>et al.</i> , 2006)	This approach focuses the benefits management model in the delivery of benefits by projects (Nogeste and Walker, 2005). Reiss (2006) define the scope of benefits management as "the management and monitoring of benefits during and after execution phase" and depicts the "value path" relationship between benefits and projects as a Hierarchical Benefits structure (Nogeste and Walker, 2005)
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Table 1 shows that there are already a number of different models and approaches that exist for realising and managing benefits, however these do not drive projects through benefits, many occur at the end of a project acting only as an evaluation, from which lessons are not learnt. Sapountzis *et al.* (2007) discuss that there is a need in the healthcare sector for a process that is integrated into business planning as well as:

- appropriate for those who operate it and those that use the information produced;
- robust enough to withstand change;
- balanced in its assessment of hard and soft benefits;
- cost effective by producing performance information that realises benefits in proportion to the investment required to collect it; and
- simple to implement.

As a result of Advisory group consultations and workshops outcomes within UK healthcare organisations the need of a simplified, accessible and easy to follow process is evident. The use of a collaborative IT environment will be explored for this purpose.

3. COLLABORATIVE ENVIRONMENTS

Collaborative environments present an environment whereby various construction professionals involved in a construction project could come together and meet in the environment (Vlosky *et al.*, 2000). This environment presents a standard platform for all parties involved for communication, data and information exchange, data storage and replication, archiving and much more. Most of all, it initiates a drive for IT integration through data and information interchange and reuse (Alshawhi, 2007).

The internet, computing and information technologies are the main infrastructure used in collaborative environments. Users of the collaborative environments need a computer to access to the internet and in some cases, collaborative environment software. A 'virtual' working space is created for all members involved in a project and all information are shared in the environment are available 24 hours a day, 7 days a week as long as the user has the proper authorisation (Wilkinson, 2001). As the collaborative environments are based on the internet, it writes off the geographical factor whereby members of the project could access information from anywhere in the world – in office or at home (Jackson, 2004). Disputes and legislation cases could also be solved through user and programme archiving throughout the construction project life cycle.

The concept of collaborative environments have been around for quite some time but it is the wide availability of internet access, which is starting to transform them from expensive, difficult-to-use bits of complex software into cheap and user-friendly business tools (Kumaraswamy *et al.*, 2004). This environment also delivers a complete integration of information service for asset owners and operators, capturing all information associated with the respective projects or programmes (Oh and Pinsonneault, 2007). This is extremely helpful within healthcare programmes which as previously discussed are complex for various reasons. Through this virtual environment, owner and project managers could operate and maintain facilities more efficiently. One of the main

advantages of using collaborative environments is that it ensures that all members of the project team have access to the most up-to-date versions of the various project documents. This means that traditional mistakes generated from someone working from an old document or drawing are removed in theory or at the very least reduced. More crucially project collaboration can reduce the opportunity for mistakes and disputes, the biggest causes of waste and inefficiency.

Collaborative environments can help in achieving maximum impact on benefits realisation. The website is open to the general public, making information readily available to potential users and interested parties. This is the main tool to publicise awareness, engage in potential, information dissemination and provide the link to the collaborative environment. The collaborative environment itself is a secured area, which is open to registered project partners. Sub-domains are created for specific user groups or organisations participating in the benefits realisation exercise. These sub-domains also maintain a level of secrecy and security for the users. A security hierarchy is imposed on all members. Within each sub-domain, the benefits realisation exercise will go through a series of process protocols – users providing data and information through the system. The proposed collaborative environment architecture is as shown in Figure 1 as below.

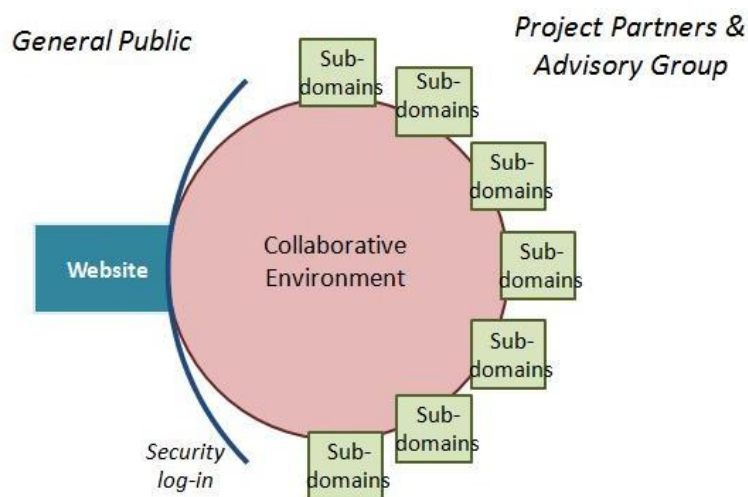


Figure 1. Proposed collaborative environment architecture.

Collaborative environments have the opportunity to significantly improve the way the healthcare industry works, without needing to make real changes in the structure or practice of the industry. The simplification of the process with customised software tools and processes will help enhance work automation, realise specific benefits, and in hope to remove the bureaucracy which often comes with modern working practices.

4. PROJECT DESCRIPTION AND OBJECTIVES

The BeReal framework is currently being developed to be adapted within the healthcare sector although it will eventually be applicable to other sectors. It is because of this that the framework is mainly aligned with healthcare investment, development and decision making processes, including OGC's Gateway process, the Capital investment manual by the Department of Health, a traditional PFI development process and the LIFT project development process (Sapountzis *et al.*, 2008b) as illustrated in Figure 2.

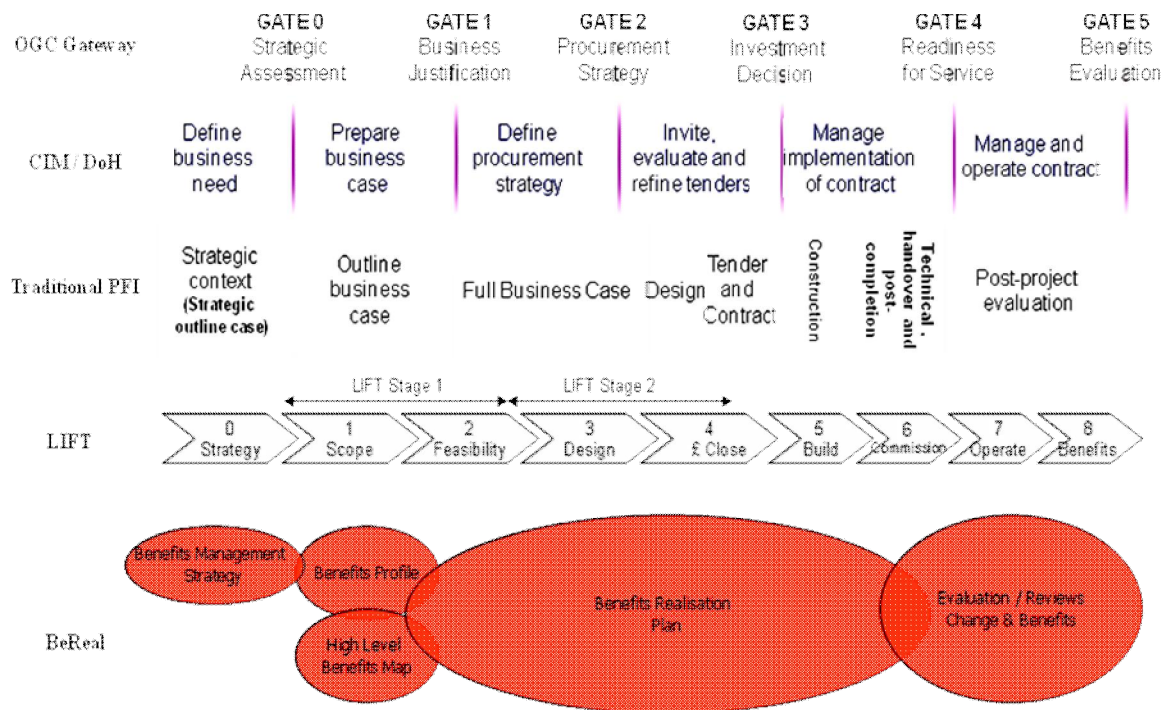


Figure 2: BeReal framework.

The framework aims to integrate with a collaborative tool that will assist in managing both healthcare programmes and projects driven by benefits. The tool aims to promote the knowledge sharing and organizational learning for successful monitoring of the benefits as they were originally conceived throughout the programme and manage new/reviewed outcomes (Sapountzis *et al.*, 2007). Figure 2 presents the four main phases of BeReal and how this can be aligned with traditional investment/development processes.

The tool is being informed and tested through case studies at different stages of the lifecycle of a healthcare programme. It would have been difficult to undertake one case study for the whole framework given time constraints, as the whole lifecycle of such projects spans from 20 to 30 years. The decision was made to undertake case study snapshots of the development of a healthcare infrastructure programme aiming to inform the framework in phases and by using different procurement routes within the healthcare sector (i.e LIFT for Primary Care, P21 for acute, Express LIFT for community ventures). The table below illustrates the how the different case studies inform the BeReal framework and its correlation with a traditional development process.

The findings from the different stage case studies will assist in better future planning, so that policy setting can be adequately informed by evidence with a fuller appreciation of potential outcomes and impacts.

The project is formed on the underlying assumption that benefits planned at the initial stage of healthcare programmes/projects are not monitored throughout the project. That often these benefits are forgotten about once the business case has gone through because traditional programme/project management approaches are often inflexible. The focus of the project is to develop, implement and evaluate a tool (BeReal) which goes beyond these traditional methods, and monitors benefits through a continuous improvement (CI) review cycle, generates knowledge and facilitates organisational learning. This has partly been done through, extensive literature reviews, consultation with the Advisory group and through interactive workshops with key stakeholders of the organisations mentioned in Table 2.

Table 2. BeReal case studies.

Development Phase	BeReal Phase	Case Study
1. Policy Setting	Benefits Management Strategy	Community Health Partnerships
2. Programme Development	Benefits Management Strategy	Cumbria PCT (Community Ventures)
3. Business Case Approval	Benefits Profile & Benefits Mapping	Stockport PCT (Community Hospital); Brighton & Sussex NHS Trust (3Ts Hospital)
4. Construction	Benefits Realisation Plan	
5. Post Project/Occupancy Evaluation	Benefits Evaluation/Review & Change	MaST LIFT
6. Operational 5yrs, 10yrs	Benefits Realisation Impact	

4.1 Research methodology

The overarching research philosophy adopted for this research project is an actor based research philosophy (Berger and Luckmann, 1966) as used in the development of the Generic Design and Construction Process Protocol (Kagioglou *et al.*, 2000) and it consists of the pre-understanding – understanding hermeneutic spiral (Odman, 1985). An action learning dimension is taken to enhance the research vision; this follows a cycle of planning a change, acting, observing the consequences, planning further action and repeating (Kemmis and Wilkinson, 1998). Action research is an interactive approach (Susman and Evered, 1978) and provides the platform where HaCIRIC's research team and the industrial partners can agree on the issues, monitor the present situation, analyse data, identify process improvements and subsequently reflect and evaluate upon impact.

Within this action research, multiple case studies are used to provide an area where the framework can be developed and the tools and techniques within it tested. Multiple case studies allows findings to be compared between the different cases, which allows the study to be more robust than if a single case study were to be used (Herriott and Firestone, 1983). This multi-site approach enables the transferability of the research findings to be measured at the same time as capturing wider user perspectives (Yin, 2003; Kagioglou *et al.*, 2000). Inside the case studies a variety of quantitative and qualitative methods will be adopted, these include questionnaires, interviews and interactive workshops. These will be used to develop, implement and evaluate BeReal from the perspective of both service providers and users. It is anticipated that the combination of techniques will capture the perspectives of the case study target population and the activity inside of the case study site to measure the effectiveness of the framework. The advantages of using two methods is that claims for the validity of conclusions are improved if the findings support one method can be counterbalanced with the strengths of the other another (Bryman, 1988; Punch, 2005).

5. RESEARCH RESULTS AND INDUSTRIAL IMPACT

Through the literature reviews on benefits realisation and collaborative environments and dialogue with the advisory group, the BeReal process and its integration within an ICT collaborative environment has been attempted. The case studies have been the most important factor in further refining and testing the BeReal framework and implementation tools. The framework differentiates the benefits management and realisation activities into four main phases, these phases have been aligned with other investment phases, this can be seen in Figure 2. Each phase has had aims, objectives, methods and deliverables assigned to it: each of these phases is described below.

- Phase 1 - Benefits Management Strategy & Benefits Realisation case. This first phase is concerned with identifying desired top benefits and developing a benefits management strategy in order to share and communicate these to the wider stakeholder group. The benefits management strategy forms the base of the development of a benefits realisation case of support should form the nucleus of the project's business case.
- Phase 2 – Benefits profile & benefits mapping. Project group meetings and benefits mapping workshops with the appropriate group of stakeholders are critical for the success of this phase. The benefits mapping and profiling form the basis of an ongoing benefits realisation plan.
- Phase 3 – Benefits realisation plan. This phase focuses on the execution of a benefits realisation plan as that is developed and formulated in the first two phases it consists of measuring and tracking the benefits previously identified and incorporating emerging ones, through data collection and measurement.
- Phase 4 – Benefits evaluation and review. This phase consist of the evaluation of the benefits as these have been identified or emerged through the previous phases.

Most of the approaches reviewed in the literature tend to focus on the continuous improvement cycle of Plan–Do–Check–Act (PDCA). The same logic is adopted by the BeReal framework adding to the PDCA cycle the Evaluation entity and extending in to an EPDCA cycle. The process begins with an evaluation of the current situation, the stakeholder's requirements and the aim of the programme. The BeReal framework is designed to be flexible and adaptable to a key decision making process.

The BeReal framework being used within an ICT based collaborative environment is still at its early stages. However some of the activities within the different phases of the framework have taken place through different case studies, these include:

- Development of BeReal Project team
- Benefit identification workshops
- Benefit Relationship Mapping – to identify the relationship between the different relationships
- Benefit Dependency Mapping – enhanced relationship map to include methods of measurement, changes and enablers
- End user questionnaires – to assess if the benefits identified have been realised by different end-users

With Benefits Realisation becoming increasingly recognised as an important method of successful programme delivery, ensuring that what it sets out to do is achieved. By following an action research methodology which facilitates the development of a 'user community' as the project evolves it is envisaged that BeReal will have a real impact upon future programme delivery and policy making. BeReal, once automated through the ICT collaborative environment, could be a tool that governmental organisations such as the DoH, NAO and OGC and other organisations will direct people to for undertaking Benefits Realisation. In the long run using such a methodology and tool could help to direct funding for private and public infrastructure programmes towards delivering products and services that provide value for money.

6. CONCLUSIONS

ICT is an enabler for the success of benefits realisation, but without an agreed and common understanding from all stakeholders involved BeReal will become another add-on process that people will gradually neglect and subsequently it will fail to achieve its full potential. ICT tools, such as the collaborative environments do not present a complete answer for benefits realisation. However, the development of collaborative

environments shall provide a common platform to share, store and reuse information shared within the project team or organisation – the use of collaborative environments must be process-led, and not ICT led. The logical processes within the environment will enable the beneficiaries to “do less and get more”. BeReal is based on the key principal that effective communication and information flow within the organisation is vital. Team working, informed decision making and transparency of information are keys to its success and the use of an IT collaborative environment is believed to simplify BeReal’s implementation and enhance its possibilities for success.

The next important step for the project is to further test the integration of BeReal with an IT collaborative environment within current case studies and to explore the strengths and weaknesses the integration and identify more robust ways of its implementation. In parallel other activities that will be facilitated by this model include the development of a benefits quantification method (in collaboration with Herriot-Watt University) that will consist of a identifying a common currency, score and weighting of benefits.

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MANAGEMENT SYSTEM IDEA FOR INDUSTRIAL LARGE-AREA FLOORS

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ABSTRACT

The paper deals with the problems of decision making support systems (DSS) in the management of industrial large-area floors. These large-area floors at the moment of finishing the building become a very important element. Eventual damages may, in a negative way, affect the functionality of the whole object, causing uncontrollable production stoppage and resulting in measurable material losses. The essence of the proposed management system is assistance in decision making in the field of technical and economic management, from which it will be possible to make a correct choice of following strategy and avoiding negative results of particular situations. The technical management means a cycle of actions in the field of exploitation, maintenance, modernization or repair. Economic management is directly connected to technical management costs and the analysis of economic effectiveness of eventual strategies. The social aspect was also noted, in which the mutual influence between the user and the owner/manager of the object was considered. It can define mutual trust, readiness and reliability of the surface or the preferential policy. The proposed research connected to building the management system is research at the border between knowledge engineering, methods of artificial intelligence, economics and techniques. An aspect of the management system is an elaborated hybrid advisory system for repairs of industrial floors which will operate as a subsystem in the management system. The application possibilities are also promising because in the situation of repetitive problems they will allow for significant unloading of the decision-maker as well as for simplification of the decision process by solving partial problems.

1. INTRODUCTION

Industrial large-area floors are an essential element of many buildings such as production halls, logistic centers, storehouses, workshops, parking halls and shopping centres. As opposed to standard floors, the industrial large-area floors are specific. They are, above all, under different types of influences such as mechanical, thermal or chemical (often extreme).

The appropriate functioning of the object always depends on proper large-area floors management. This is reflected in a number of measurable advantages for the owner/user of the object. Having this in mind, this paper presents an industrial floors management system as a potentially valuable tool assisting the technical services associated with the object maintenance. The system concentrates on three aspects: technical management, economic management and social management. The technical management is connected with ensuring proper technical state of the large-area floors which means caring about the maintenance and eventual repairs. Economic management is responsible for proper financial strategy and first of all, for caring about profits and minimalizing the losses and controlling necessary expenditures. Social management reflects the influence of numerous factors on the large-area floors user, beginning from aesthetics to readiness and floors reliability.

In this paper, the industrial large-area floors are presented as an element of the building in its life cycle beginning from the design stage, through realization, maintenance and recycling. During each of these stages there are decision problems; however, the paper concentrates on the maintenance and exploitation phases as the longest stages of the life

cycle. The main research problems move towards the elaboration of the management system assumptions, then analysing its frame and proposal of tool solutions with special impact on the artificial intelligence methods and the use of knowledge.

2. KNOWLEDGE REVIEW

One of the known classifications of management advisory systems considers the problem with the respect to the type of made decisions and the level of organization (Turban 1993). Let us think about the types of decisions we have to deal with in the case of industrial large-area floors and on what level they are made. Analyzing all the factors we come to a conclusion that the decision problems can be divided for classes partially or weakly structured, but the decision level covers the strategic as well as the operational level. According to the mentioned classification, the appropriate assisting management systems for these conditions are the ones, which are based on ES (Expert Systems), DSS (Decision Support Systems) and ANN (Artificial Neural Networks). These systems are definitely classified as intelligent systems.

Management systems based on intelligent models are known and willingly used in many fields, especially in fields connected with economics and management. Their practical advantages are commonly known – they assist man's works and in case of trivial and repetitive problems they can also replace him. Such an idea should also be implemented into the problems associated with the construction field.

2.1 The essence of large-area floors' management

The aim of industrial large-area floors' management is to build a harmony between the technical aspects associated with the floors, the economic aspects associated with profit maximizing and expenditures control for the owner of the floor and the social aspects influencing the owner and the user of the large-area floor. Analyzing the state of knowledge in this particular field one may conclude that the problem is a novelty and so far there have not been any attempts to solve it. Up to date solutions known to the author, concerning the industrial floors, consider only the technical aspects i.e. designing, production, operation and repairs (Czarnecki and Emmons 2002, Eddy 2005). The state of knowledge regarding the technical aspects is wide and is the subject of constant development due to the development of new production technologies as well as the development of materials used for building or repairs. Seidler (Seidler 1999) presented a certain attempt at a wider look at the industrial floors, where apart from technical aspects the nontechnical ones were also dealt with. He formed a program aiming at ensuring the quality control on particular stages of the industrial floor life cycle – starting from design, continuing with realization, maintenance and exploitation. Another equally interesting view was the problem considering the choice of reactive resins in the production of the industrial floors (Seidler 2003). Here, similar as previously, a set of nontechnical aspects was considered being difficult to define and express (e.g. experience and the renown of the producer). These works indicate an important fact - in case of management assisting models for technical problems it is necessary to consider apart from the technical aspects – often priorities – a wider range of nontechnical factors. Economic factors have a big impact among them. They are often perfectly measurable and thus simple to interpret. The factors which are more difficult to define are, as mentioned above, the social factors. Their impact, often unrecognizable, has a strategic significance for the user and the owner of the large-area floor. We speak here about such aspects as trust, readiness and operational reliability of the floor.

Figures 1 and 2 present the dependence between the value of the costs and income on the life cycle stage. These relations are elaborated on the basis of the data concerning the industrial floor in a large logistics centre (31 700m²). Two situations have been presented where the operational stage has a particular significance.

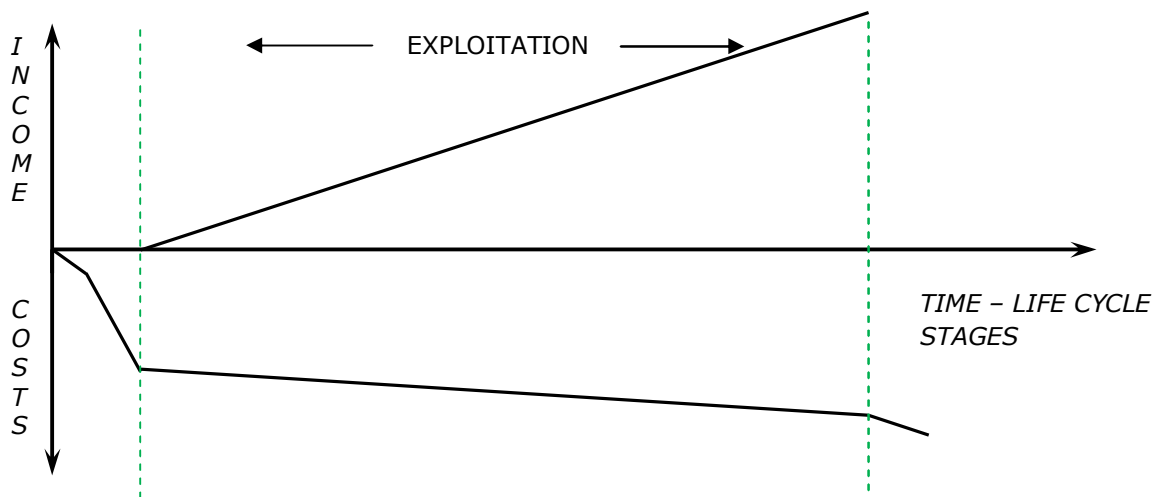


Figure 1. Example of correct management in the exploitation life cycle stage.

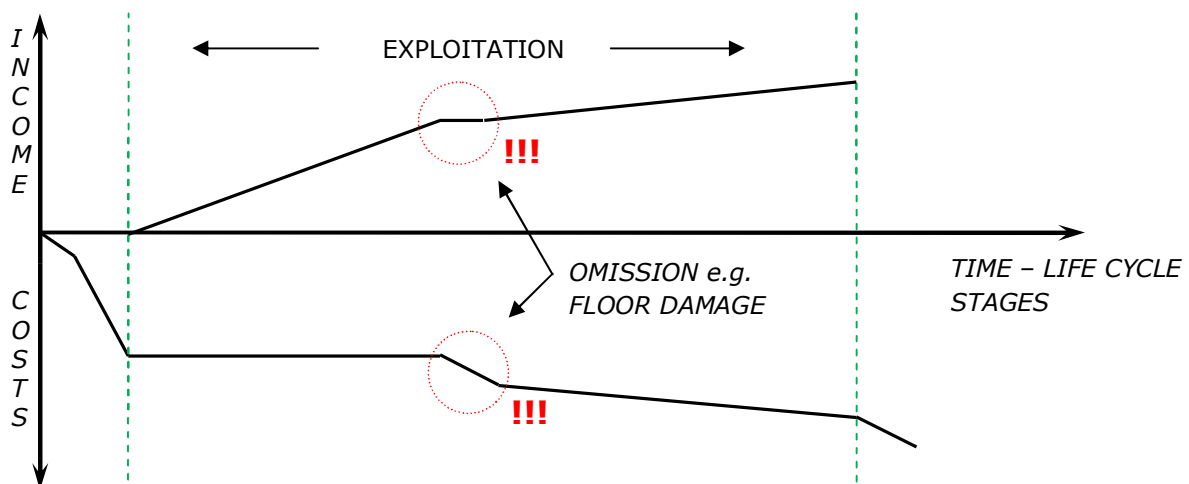


Figure 2. Possible situation (technical omission) as an example of the incorrect management.

First of the situations (Figure 1) indicates the proper industrial large-area floors management. After defined expenditures regarding the design and manufacture of the floor, which guarantee that the product would have a defined quality, at the operational stage special precautions have been taken in order to maintain as well as to make necessary repairs, having incurred certain expenditures. Thanks to this, no major breakdown has been recorded. This allowed for continuous profits from the floor and thus building proper relations between the owner and the users and not disturbing their trust (the social aspect).

Figure 2 shows a hypothetical example of a certain omission, a result of incorrect management. Due to the lack of proper technical maintenance of the industrial floor a major breakdown occurred. This resulted in a necessity to switch off a fragment of the floor from use and repairing it. The analysis of the graph shows how drastically the curve of expenditures grows with a stagnation of the income at the same time. It is definitely a

disadvantageous phenomenon from the financial point of view of the floor owner as well as the user, because it forces him to look for other storage or removal. A negative social significance is present apart from negative economic result. As the owner's mistakes continue, he loses his credibility, renown and finally a faithful customer.

2.2 Intelligent management systems

The essence of intelligent management systems is generally known and common. More and more fields implement them, wanting to cope with contemporary trends and, first of all, expecting an effective cooperation between the man and the system on the way to accomplish the set goals. In construction industry these solutions are also applied.

Analyzing a wide range of literature concerning the intelligent management systems one can notice different tools referring to particular management levels – from the strategic level to operational (Zavadskas 1995, Gal 1999). The most advanced systems are based on the methods of artificial intelligence (Kaplinski 2007). Often builded hybrid systems with varied complexity can be noticed which include many different cooperating intelligent techniques in themselves. The essence of such systems lies in the use of necessary features which are offered by the techniques included in them as well as harmonious cooperation between these techniques (Medsker 1994, Goonatilake 1995, Khosrowshahi and Howes 2005, Chen and Hsu 2007). Nowadays, one can observe a constant evolution of these systems, therefore their settled classification is difficult to present.

Out of the intelligent methods which are applied most often in management systems one can list: artificial neural networks, fuzzy logic and expert systems. Different connections of these methods give a basis for building of a range of hybrids, e.g. neural fuzzy expert systems, neural expert systems with fuzzy representation or fuzzy neural networks. The methods themselves, which have been known for years, are currently in their renaissance. The development of IT and programming techniques makes their application more accessible. This allows for the creation of clear interfaces, thanks to which even a non-professional is able to operate the system and use its advantages.

The building of industrial large-area floors management system will be based on previously presented assumptions. As assumed it will be an intelligent system, thus generating particular conclusions on the basis of the input information, which will be used in the decision-making process. The intelligent profile of the system will be reflected in intelligent techniques applied in it. The system architecture will be modular and each module will be responsible for specialized decisions. A certain forecast of such a module is the hybrid advisory system elaborated by the author used for making technological and material decisions with the repairs of industrial floors (Gajzler 2008).

2.3 Hybrid advisory system for industrial floors repairs

Shortly characterized advisory system in the aspect of a complex large-area floors management system building is supposed to function as a previously mentioned module on a subsystem level. This module will be responsible for the assistance of the decision-making person in selection of material and technological solutions for repair of an industrial floor. Despite the operational profile of the decision made, the advisory system is intelligent and complex in the aspect of tools. Generated answers are above all connected to technical aspects, as a priority during repair, as well as economic aspects (costs) and partially – social (renown and solution brand). As the tool solution of the system is a 'technical' matter, building the system resources – data and knowledge, is a far more complex problem. This problem also regards the large-area floors management system. What is the basis of building the database and knowledge base? They are necessary for the proper functioning of the system. In the advisory system of industrial

floors repairs this problem was solved by the use of the verbal model of the previously selected field-expert and on this basis the knowledge acquisition was made. Current researches concerning the building of the industrial large-area floors management system are directed towards the methods and knowledge-acquiring sources from the 'data and text mining' group.

3. RESEARCH PROJECT

Realization of ambitious tasks such as the attempt at building an industrial large-area floors management system requires elaboration of a wide research program. Analyzing the experience gained at building the advisory system connected to industrial floors repairs, one can conclude that the current research project will cover several problems and will integrate several fields; therefore, it will have a nature of an interdisciplinary profile.

3.1 Project description and objectives

The principal result of the research project is the building of an industrial large-area floors management system. The next milestones can be connected with the following problems:

- the building of the substantial system frame
- the building of the system resources
- the elaboration of the tool system frame
- physical system building – procedures, software
- testing and verification.

As we see from the presented items, the occurring problems have been formed in a very general way and require to be made more specific. The basis of the success of the idea of the industrial large-area floors management system is a question about the content and sense of the elements included in the system. This question leads to a substantial frame, which shall provide answers to the following questions: what function will the system be responsible for? To what extent the information generated by the system will be useful for the user and what is the extent of the operations performed by the system? The basic functions and the substantial content of the system are shown in the Figure 3. The basic scope of system operation is the top layer usage stages, where, in practice, within a very long period of time several problems arise repeating themselves at a specified interval. Due to this – problem repetitiveness – building of such a system seems to be wisely and economically justified.

The aim of resources building is to create a data and knowledge base as a base of the system functioning. The source of data and knowledge acquiring is an essential problem as well as sensitivity to being obsolete quickly and the openness for the update possibilities. Many solutions of the management systems have modules responsible for data acquiring in the real time. Contemporary technology, based to a great extent on mobile and wireless techniques (also in construction industry), gives such opportunities. An example is monitoring of concrete maturing process with the using of GSM/GPRS technology (Karlowski and Paslawski 2008).

Elaboration of the tool frame is the next milestone. Its aim is to find an optimal tool, which would allow for the effective system functioning. The author's experience (hybrid advisory system) indicates the majority of intelligent hybrid tools, in which functioning of several techniques was connected over the use of independent tools. Currently observed trend of return to artificial intelligence methods tends towards the implication of these methods into hybrid tools.

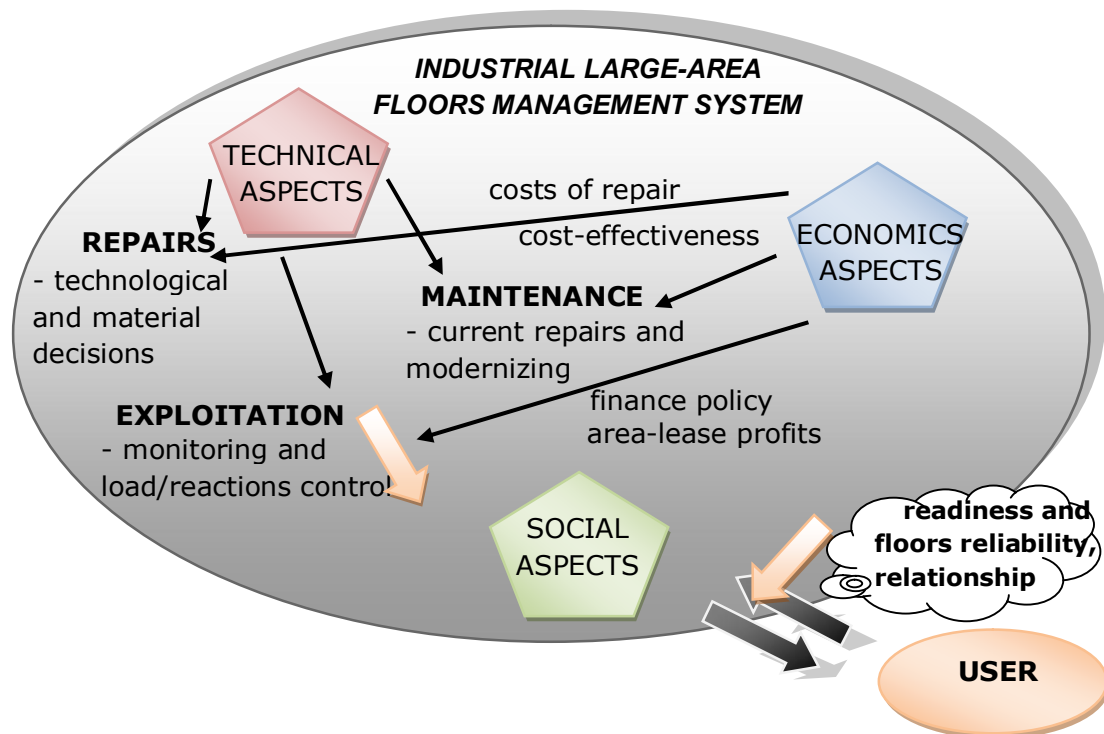


Figure 3. The idea of Industrial Large-Area Floors Management System.

The rest of the items are related to the realization aspects (software solution) and verification and implementation of the system. It is a kind of the finalization of the research program in a form of a ready product. Contemporary development of IT technologies, software tools as well as programming environments gives a chance for creation of a transparent user interface and the core of the system responsible for system management and information circulation. System implementation through making it available for the user will point out advantages of its application and will detect its eventual drawbacks.

3.2 Methodology

Having the elaborated model of advisory system for industrial floors repairs one can determine the applied methodology and indicate their distinguishing marks. Exploration techniques (data & text mining) and direct techniques (interview, survey) have been used in the range of data and knowledge acquiring. This was due to a fact that there is a large number of verbal or text sources in use connected to the particular problem. On the other hand, access to historical data is difficult or they are often subjective (e.g. information about carried repairs of the industrial floors with consideration of material solution or repair costs, informal agreements). It is much easier to obtain general information, not connected to particular object and – after some processing – use it with relation to the particular solutions. A certain hindrance in knowledge acquisition lies in a possible data fuzzyfication. Appropriate techniques (defuzzyfication, e.g. COG method) allow for transformation of this data into quantitative form, which enables their use in formal models. One must notice yet another aspect here. Namely, the acceptance of

certain fuzzifying is a certain guarantee of the terms generality (low sensitivity to being not up-to-date).

Another field where the peculiarity of the accepted approach is visible is building the tool frame of the system. Here the intelligent techniques and their mutual compilation in the hybrid model were used. In the quoted model of the advisory system a connection of three different elements is used: fuzzy rule knowledge base as an element of the expert system, fuzzy logic responsible for data and knowledge transformation and communication compatibility and artificial neural networks responsible for the inference. This connection resulted from the need to use the characteristics represented by the mentioned elements. As a result a hybrid system was created, but this hybrid was classified as immersion.

4. RESEARCH RESULTS AND THEIR SIGNIFICANCE FOR INDUSTRY

The fragments of research results presented in the subsequent part are connected to already elaborated model of advisory system for the industrial floors repairs. This system will become the element of the management system and the results themselves can be probably related to those, which will be obtained at the stage of management system creation.

Table 1. Qualitative and quantitative values for rule of knowledge base.

If...	and...	and...	and...	and...	and...	and...	Then...
<i>Damage type and depth</i>	<i>Mechanical loading</i>	<i>Chemical environment</i>	<i>Thermal loading</i>	<i>Interaction time</i>	<i>Repair temperature</i>	<i>Repair time</i>	<i>Solutions (R1, R2,..., Rn)</i>
<i>surface scratch</i>	<i>low</i>	<i>neutral</i>	<i>low</i>	<i>constantly present</i>	<i>low</i>	<i>long</i>	<i>disqualification or acceptance</i>
A	G	J	0,125	0,887	0,126	0,874	1 / 0

4.1 Results quantification

The presented results are connected to the use of artificial intelligence (fuzzy logic, artificial neural networks) in selected system modules. Fuzzy logic has been used in the transformation task. Thanks to defuzzification by means of gravity centre (COG method) an input set of artificial neural network in a strict form from each fuzzy rule of knowledge base was obtained.

The obtained above sets of inputs and corresponding outputs (two-state representation) have been used in the process of neuron network learning. Thus the transfer of knowledge included in rules of fuzzy database in neural network structures related to the module took place. The below mentioned results present the effectiveness of the applied neural network. Promising results in form of high learning, validation and testing coefficients were obtained. This proves the correctness of choice of the neural network for the problem model.

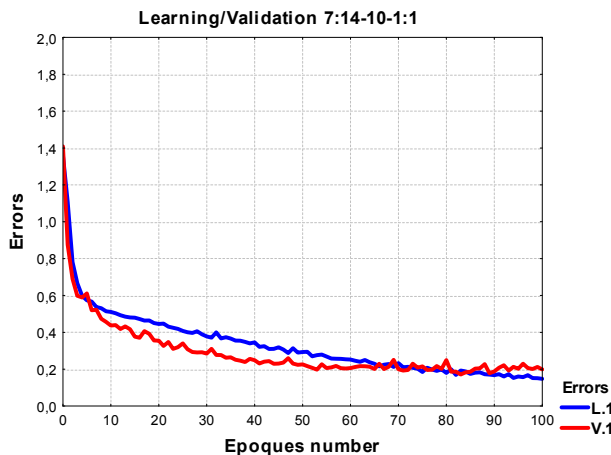


Figure 4. The learning/validation graph of MLP network.

Table 2. Test data of networks learning/validation processes.

ANN type	Learn. error	Valid. error	Learn. quality	Valid. quality
MLP 7:14-10-1:1	0,178	0,171	0,979	0,992
MLP 7:14-4-5:5	0,248	0,253	0,859	0,851
RBF 7:14-37-1:1	0,298	0,326	0,886	0,837
PNN 7:14-246-2:1	0,146	0,151	0,979	0,976

4.2 Implementation

The worked out advisory system, as well as the intention of industrial large-area floors management system is directed towards practical application. The addressees are technical services, which manage the industrial objects including the industrial floors. The idea of the supportive systems, which include management and advisory systems, is to decrease the load of the deciding person in case of standard repetitive problems. In this range automation of certain decisions is expected. In case of complex problems the presented system will be responsible for solving the partial ones.

The management system is only an intention; however, its practical abilities and advantages are unquestionable. The elaborated advisory system, connected with industrial floors repairs and being a part of a management system was practically verified. Basing on the existing floors damages, existing conditions in the object, preferences and limitations, an input vector was elaborated. For such an input vector the system drew conclusions and generated an output vector. The output vector contains system suggestions concerning the material and technological solution and connected to it information necessary for decision making (repair algorithm, costs, technological regimes, essential limitations). This way the system partially helped out the deciding person preparing decision alternative, this had a strong influence on shortening the time of the decision process.

5. CONCLUSIONS

Despite the fact that the management system of industrial large-area floors is in the building stage, even today, basing on the results of the exploitation of the advisory system for repair of industrial floors one can spot its practical abilities. From the point of view of the deciding person it is necessary to work out a comprehensive supportive tool, which would consider a wider spectrum of management aspects. A management system is a proposed tool whose functions would concentrate around technical, economic and social aspects. The management system itself will be a set of modules connected by appropriate functions and placed in particular places of the industrial large-area floors life cycle. Taking into account the potential tool solution of the management system it is advantageous to base the system on the intelligent techniques, including hybrid solutions resting on their mutual compilation.

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A CONTINUOUS FLOW SIMULATION MODEL FOR PROBABILITY REPETITIVE PROJECTS

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ABSTRACT

Continuous flow is one of the main focuses of scheduling repetitive projects. Construction practitioners and researchers have proposed approaches to maintain continuous flows. However, many of these approaches only consider deterministic activity durations or have some other methodological limitations. Accordingly, a continuous flow simulation model is presented in this paper in order to overcome aforementioned limitations. The proposed model integrates simulation and buffering to consider the probability of activities durations and for proper sizing of buffers. Instead of having the same activity duration distribution on different units as is common, the proposed model allows for different activity duration distribution between units. The proposed model is tested and validated on a case study and the results show that the model can provide practical contributions in scheduling that effectively maintain continuous flow for probability repetitive project. Possible further research directions in this regard are also discussed in the paper.

1. INTRODUCTION

Repetitive projects are common in construction where similar units require repetitive work from unit to unit. Typical repetitive projects include multi-story buildings, housing projects, highways, and tunneling projects. For such projects, the objective of scheduling methods focus on maximizing flow continuity by enabling crews to finish work in one unit of the project and then move promptly to the next in order to minimize interruptions.

A major in-depth study of seven Swedish construction projects reveals that only 15-20% of a construction crew's time is spent on direct work. Approximately 45% is spent on indirect work. The remaining 35% is spent on interruption, waiting, etc., i.e. a complete waste of time (Josephson, 2005). Productivity related studies also indicate that crew interruption in construction ranges from 20% to 45% (Thomas, 1991).

Flow continuity provides room for an effective resource utilization strategy by minimizing interruption. Some researchers involved in the construction industry have identified the benefit of continuity in recent years (Rongyau and Kuoshun, 2006; Vanhoucke, 2006). Yang (2002) used simulation to show the cost savings gained through continuous flow to be 30% for the small case project.

Many scheduling technologies, such as Line of Balance (LOB) and Repetitive Scheduling Method (RSM) have been proposed to maintain continuous flow for repetitive project. These repetitive scheduling techniques are deterministic methods in which activity durations are represented by a single number. The single number alone is insufficient to capture the behavior of actual construction for the probability of flow productivity (Tommelein *et al*, 1999). Accordingly, these deterministic methods could not provide practical scheduling for probability repetitive project.

This paper presents a continuous flow simulation model to provide practical contributions in scheduling that effectively maintains continuous flow for probability repetitive project. The next section discusses the literatures that are most relevant to this research project. The third section proposes a continuous flow simulation model for probability repetitive projects, which integrates simulation and buffering to consider the probability of activities

durations and for proper sizing of buffers. The case study is presented in the fourth section. The last section describes key conclusions and opportunities for future research.

2. STATE-OF-THE-ART REVIEW

This section of the paper first reviews the existing approaches for repetitive project scheduling. Followed by the detailed description of construction simulation model developed so far, this section highlights two simulation models for getting continuous flow under probability activities duration and points out the limitations of them. Finally, to make a clear understanding of research project, buffers are also discussed.

2.1 Repetitive Project Scheduling

Construction projects that are generally characterized as repetitive projects may be divided into two categories: (1) nonlinear project that are repetitive due to a uniform repetition of a unit work throughout the project (e.g., high-rise buildings and multiple housing construction); and (2) Linear projects that are repetitive due to their geometrical layout rather than uniform repetition of a unit work (e.g., highway, pipeline and railroads projects) (Hegazy and Wassef, 2001). El-Rayes and Moselhi (1998) distinguish between typical and atypical repetitive activities. Typical repetitive activities are characterized by identical durations over all units, while atypical repetitive activities assume variation of duration from one unit to another. This variation can be attributed to variations in the quantities of work encountered or crew productivity attained in performing the work of these units.

Flow continuity improves the overall productivity of construction works due to: (1) minimizing their idle time during their frequent movements on site; and (2) maximizing their benefits from learning curve effects (El-Rayes and Moselhi, 2001). The application of network scheduling techniques, such as the critical path method (CPM), to repetitive projects has long been criticized for their inability to maintain continuous flow in scheduling (Adeli and Karim, 1997). Recognition of the drawbacks of traditional CPM in scheduling repetitive projects has led to the development of several scheduling methodologies, such as, line of balance (Arditi and Albulak, 1986), Repetitive Scheduling Method (Harris and Ioannou, 1998), Repetitive non-serial activity scheduling (Hegazy and Wassef, 2001) and non-unit based repetitive project scheduling (Rongyau and Kuoshun, 2005), to name but a few.

Arditi *et al.* (2002) refer to those alternative scheduling techniques, developed over the last 30 years, by the generic term of 'linear scheduling methods' and claim that those methods have proven to be well suited for projects of a repetitive nature. Kenley (2004) points out that the repetitive scheduling methods strongly suggest locations or places and, consequently, he introduces the comprehensive term of 'location-based scheduling' (LBS). As a result of two decades of research and development, a comprehensive line-of-balance-based planning, scheduling and control system, has been developed and implemented among main contractors in Finland (Seppänen and Aalto 2005).

Nonetheless, many of these scheduling methodologies only consider deterministic activities durations and activities durations represent with a single number. The single number only represents an average and the actual production rate will vary (e.g., with some standard deviation if a Normal distribution appropriately characterizes variation) because of variation in the weight and size of components, ease of reach and access to their final installation location, fabrication and erection tolerances, skill level of the workers etc. (Tommelein *et al.*, 1999).

2.2 Construction Simulation

Discrete-event simulation has been used as a tool for scheduling since the development of CYCLONE (Halpin, 1977). Ever since, the application of simulation to support decision making in construction management was popularized. The CYCLONE framework provided the foundation for construction simulation researchers to develop a number of construction simulation tools in the past 25 years. Martinez and Ioannou (1999) examined the characteristics of discrete-event simulation systems used in construction and grouped them into three general approaches, i.e. activity scanning, event scheduling and process interaction. They claimed that activity scanning is the natural and effective approach for modeling complex construction operations in detail. Hajjar and AbouRizk (2002) proposed Symphony which allows for the creation of new special purpose simulation (SPS) tools in the form of modeling element templates and provides a highly flexible, yet user-friendly, environment for the simulation modeling process.

González *et al.* (2008) developed a discrete event simulation approach to design work-in-progress (WIP) buffer for repetitive project. Discrete-event simulation software, ExtendTM, was selected to perform simulation modeling. Figure 1 illustrates the simulation modeling architecture for two linear sequential processes, which is made up by two kinds of hierarchical blocks: processes and WIP Buffer. Inside these blocks, there are individual blocks, logical decision processes and stochastic inputs (e.g. process duration or production rate). For the simulation modeling architecture, work units as houses or floors for building projects are the entities flowing through the system from INPUT to OUTPUT states. However, with proposed ExtendTM simulation model, units must follow the same distribution types during process. This practice ignores the difference between typical repetitive activity and atypical repetitive activity (El-Rayes and Moselhi, 1998).



Figure 1. Simulation modeling architecture showing two linear sequential processes and the corresponding WIP buffer (González *et al.*, 2008).

Ioannou and Srisuwanrat (2006) presented a sequence step algorithm developed in Stroboscope simulation platform, as shown in Figure 2. The sequence step algorithm addresses for the first time the problem of scheduling repetitive projects with probabilistic activity durations while maintaining continuous resource utilization. The precedence relationship (link) between A and B is implemented through the semaphore (i.e., the logical start control) of the successor activity, B. In particular, the logical expression for the semaphore of activity B_CrewPerform compares the number of completed units in B_WorkDone to the number of completed units in A_WorkDone, as follows:

$$B_WorkDone.CurCount < A_WorkDone.CurCount$$

Nonetheless, the proposed model relies on complicated semaphore to erect the logical relationship between activities, which is not very easy to use in practical simulation process.

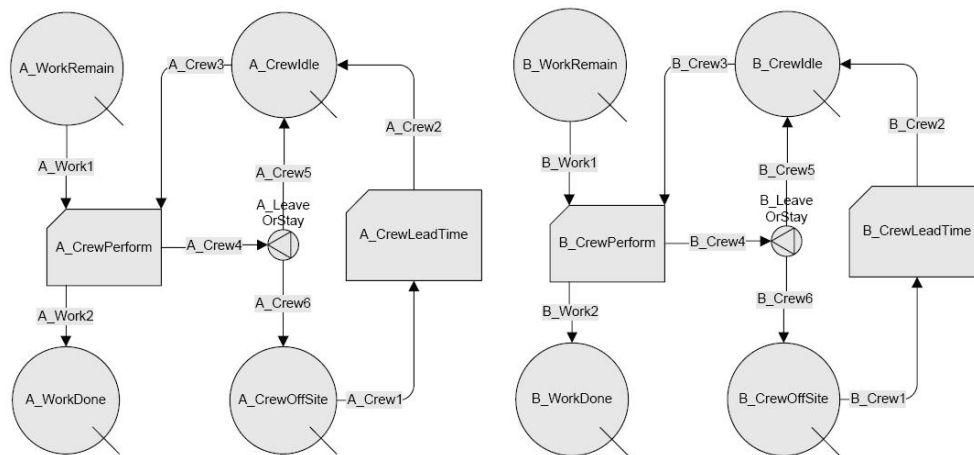


Figure 2. Sub-networks of simulation model (Ioannou and Srisuwanrat 2006)

Nasereddin *et al.* (2007) describe elements commonly found in modular manufacturing and summarizes an approach for automating the model development process using ProModel and Visual Basic. However, study reveals that construction-oriented resource-driven simulation platform is found to be more flexible and straightforward than manufacturing simulation platform (for example ProModel) in addressing construction systems (Ming and Lap-Chi, 2007).

2.3 Buffer

Buffer is a common approach to handle variability and to shield production system from its negative impact. By using a buffer, a production process can be isolated from the environment and the process depending on it, and the negative impact variability can be reduced in the production chain (Koskela, 2000). Buffers can avoid loss of throughput, wasted capacity, inflated cycle time, larger inventory levels, long lead time and poor customer service shielding a production system against variability (Hopp and Spearman, 1996).

Buffers are understood as resource cushions, i.e. money, time, materials, space, etc., used to protect processes against variation and resource starvation (Alves and Tommelein, 2004). Buffers can be used to protect a system against variability through the use of inventory, capacity, time, or a combination of the previous. Hopp and Spearman (1996) define three generic types of buffers for manufacturing, which can be applied in construction.

1. Inventory: in-excess stock of raw materials, work in progress (WIP), and finished goods, located in the supply chain.
2. Capacity: allocation of labor, plants, and equipment capacity in excess so that they can absorb actual production demand problems.
3. Time: reserves in schedules as contingencies used to compensate for adverse effects of variability – float in a schedule is analogous to a buffer for time since it protects a critical path from time variation in noncritical activities.

The size of buffers should be carefully managed, if oversize, buffers are waste and can impede on the continuous flow principle. On the other hand, if not sufficient, crews cannot realize their full production capacity due to starvation of upstream resources causing interruptions in the production flow. Ballard and Howell (1995), in looking to apply just-in-time to construction, called for research into the sizing and location of buffers and argued that a schedule buffer should be placed at the end of unpredictable processes, with a buffer size based on the degree of uncertainties involved.

However, the size of a contingency buffer is normally decided based on individual experience and assigned in a uniform way (e.g., 10% of activity duration) instead of taking into consideration the characteristics of each individual activity (Park and Peña-Mora, 2004).

3. RESEARCH PROJECT

3.1 Research Objectives

The objective of this research is to propose a method to validate a continuous flow simulation model for a probability repetitive project. To reflect the variability of a crew's productivity on different units, varying activity durations from unit to unit are incorporated into the model. To facilitate implementation of the proposed simulation model, a hierarchical structure is applied to avoid a complicated simulation network. Also, through proper sizing of buffers using the proposed simulation model, the method could provide practical scheduling information for obtaining continuous flow in repetitive project.

3.2 Continuous Flow Simulation Model

After considering the review points in section 2, a continuous flow simulation model for repetitive projects is developed using Symphony, as shown in Figure 3. The proposed model, in which four crews (A, B, C and D) pass through four units (1, 2, 3 and 4), applies an hierarchical modeling method. The model consists of two levels of hierarchical structures. The parent level is shown in Figure 3 and every unit elements possess a child level sub-model, as shown in Figure 4. The parent level contains three types of elements explained as follows.

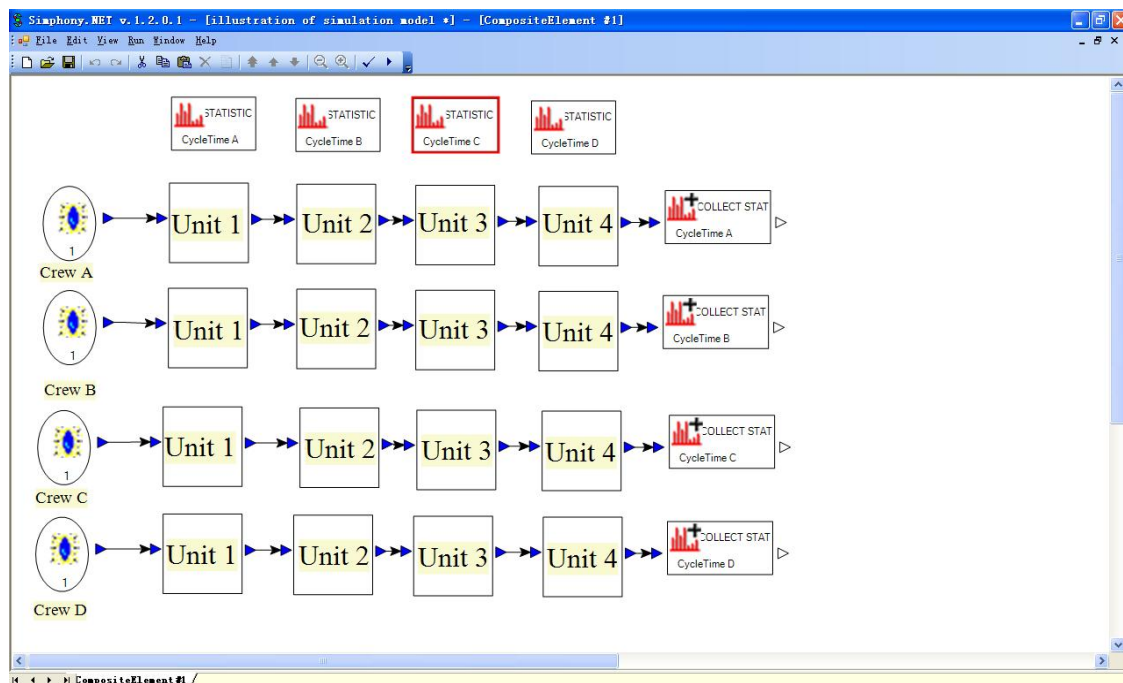


Figure 3. Continuous flow simulation model.

1. Crew elements represent available crews for the construction process. For example, four crews perform the construction activities on four units. Accordingly,

the model has four crew elements which represent these crews respectively, as shown in Figure 3. The user can specify the start times of a crew, which denotes the buffer for the crews. It must be emphasized that the size of buffers are measured from the start time of the project to the start time of a buffered crew. For instance, the start working time of crew B is set to 7, which means that crew B moves into the construction site 7 days after the project starts.

2. Unit element is the working unit required to be performed by the crews. With the progress of a project, crews need to flow through unit1, unit2, unit3 and unit4 sequentially. Unit elements have a children-level model describing the behavior characteristic of that unit, which are explained in detail below.
3. To collect cycle time in the model, CycleTime element is used to declare the collection of such statistics and distinguish it from other CycleTime elements. The declared CycleTime element can then be used by CollectStat elements to add observations to it. CollectStat elements add observations to the declared CycleTime elements.

The child level model consists of five modeling elements and two types of files, as shown in Figure 4.

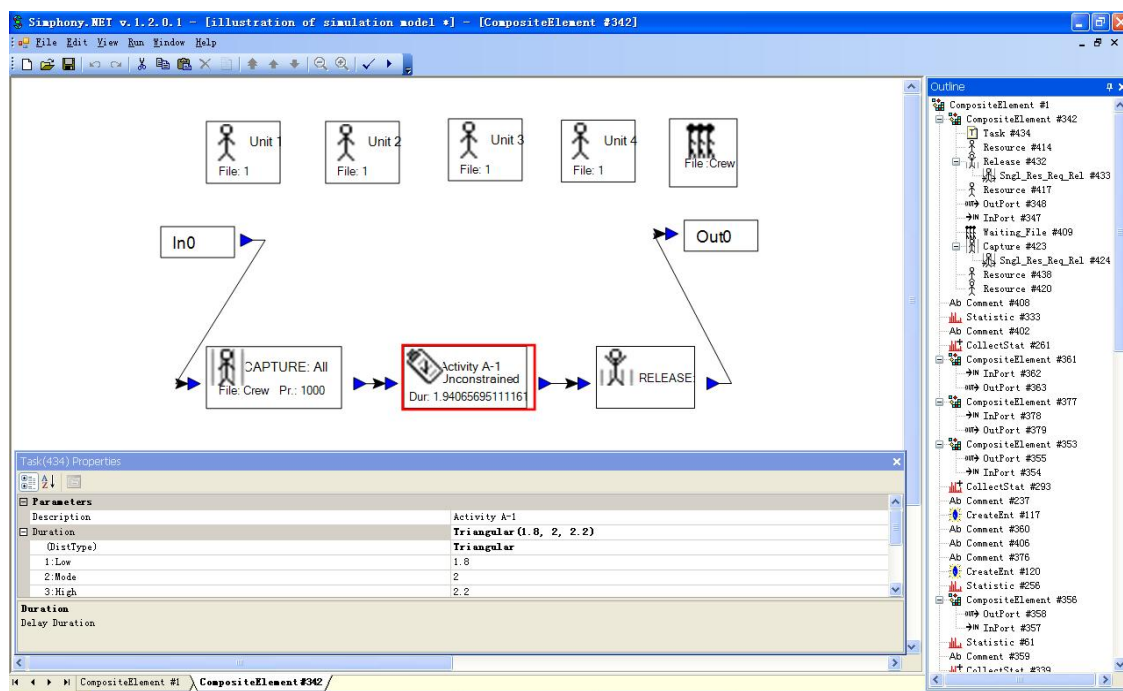


Figure 4. Child level continuous flow simulation model.

Crew elements that flow through a unit element, by firstly passing the In0 element, which works as the input link from the parent-level model to the child-level model. Similarly, when crews flow out of the unit elements, they finally pass the Out0 element which works as the output link from the child-level model to the parent-level model. To use unit elements in the capture and release elements, the unit element need to be declared through the declare files, such as unit files. Once unit elements are declared, they can be captured or released by the capture or release element. In order to be processed by an activity element, the unit elements need to be captured by the capture element. The capture element declares the occupancy of unit elements for the activity duration specified in an activity element. After the crew flows through capture and activity elements, it is released by the release element and can be used by other capture

element. When several capture elements require the same unit element at the same time, the set priority number determines the priority of that capture elements. The higher the number of priority, the higher is the priority of occupancy of the unit element. A crew file defines a waiting file for the crews. The activity element describes the activity duration which follow a specified distribution, such as beta distribution or normal distribution.

The whole process of simulation can be described as follows: when crews move in to the construction site, all crews first wait in a crew file. All crews are related with a corresponding capture element. The capture element with a highest priority number captures the unit resource. The related crew flows into the unit element, processes the activity on unit for the activity duration, and then releases the unit. Finally, according to the priority number, remaining crews pass through unit elements sequentially. This process continues until all the crew elements move out of the construction site.

Using the proposed continuous flow simulation model, schedules with proper sized buffers for repetitive project can be generated. The flowchart of designing buffer size and scheduling are illustrated in Figure 5:

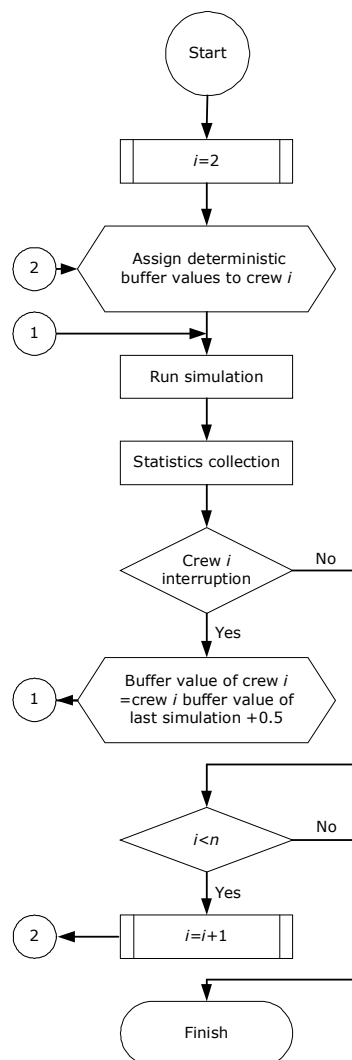


Figure 5. Flowchart of design buffer size and scheduling.

Since the first crew has no precedence crew, it can be processed continuously. So at the beginning of the flowchart, the i value with 2, which implies the successive crew of the first crew. The second step in the flowchart is assigning a deterministic buffer value to crews to start as soon a unit been released. As illustrated in Figure 6, when activities start as early as possible as is in typical in CPM, the difference in productivity between the activities in the deterministic scheduling observes interruptions. In order to eliminate the interruptions and ensure continuous flow, the start time of activities should be delayed by adding buffers between the activities, as shown in Figure 7. This situation is well suited for deterministic activity durations. While at the initial stage of a continuous flow simulation model, the deterministic buffer values can also be assigned to crews.

By running the simulation and collecting the statistics, the buffers can be adjusted. If crew 2 is interrupted, the buffer value can be incremented by 0.5 day, for each simulation, until no interruption exists for crew 2. When crew 2 maintains the continuous flow, the flowchart transfers to the next activity until all activities have been simulated. The schedule and buffer sizes ensure the continuous flow of crews.

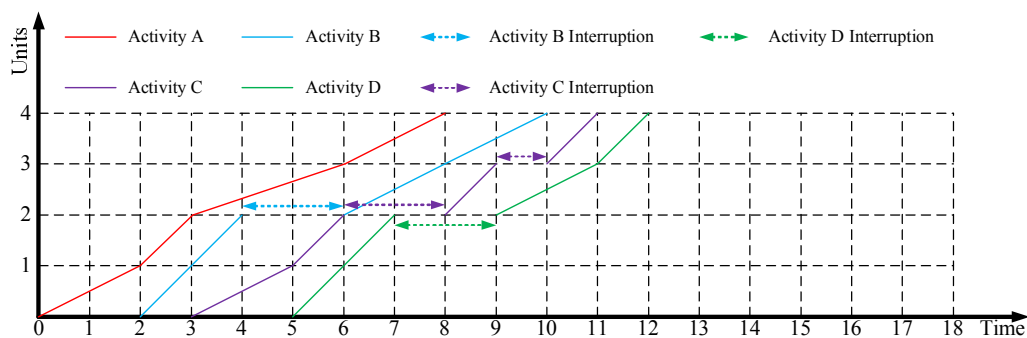


Figure 6. Initial scheduling of deterministic activity duration.

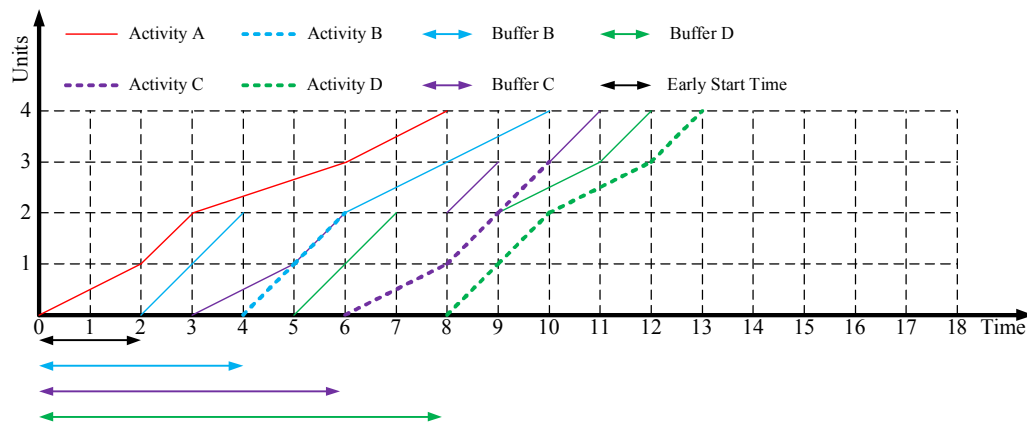


Figure 7. Continuous flows scheduling for deterministic activity duration.

4. CASE STUDY

A repetitive project consisting of 4 units, with 4 activities, is used to test and validate the effectiveness of the proposed continuous flow simulation model. For repetitive project, the objective of scheduling such type project is to maintain work continuity. However, most case studies so far only consider deterministic activity duration. The case study of this section introduces probability of activity duration. Table 1 shows the activities and their duration distributions. The proposed continuous flow simulation model takes into

account not only optimistic activity duration but also pessimistic duration. The initial scheduling of the case study is shown in Figure 6.

Table 1. Activities and durations in case study.

	Crew A	Crew B	Crew C	Crew D
Unit 1	Triangular(1.8,2,2.2)	Normal (1, 0.3)	Triangular(1.9,2,2.2)	Normal (1, 0.3)
Unit 2	Uniform (0.8,1.2)	Uniform (0.8,1.2)	Normal (1, 0.2)	Uniform (0.5,1.5)
Unit 3	Uniform (2.8, 3.2)	Triangular(1.7,2,2.2)	Normal (1, 0.2)	Uniform (1.8,2.1)
Unit 4	Normal (2, 0.2)	Normal (2, 0.1)	Uniform (0.8,1.2)	Normal (1, 1)

The numbers of simulation is set to 1000 within each simulation process and the initial sizes of the buffers are set to a deterministic value. The collected distribution of completion days is shown in Figure 8. Note that the confidence level of project completion due date (12 days) is below 20%. From the probability of activity duration, on unit 2, unit 3 and unit 4, there exist to some extent interruptions, as shown in Figures 9, 10 and 11. From observation of the simulation results, it should be emphasized that the buffer sizes and initial scheduling according to deterministic duration can not ensure the continuous flow of crews.



Figure 8. Cumulative distribution functions of project duration.

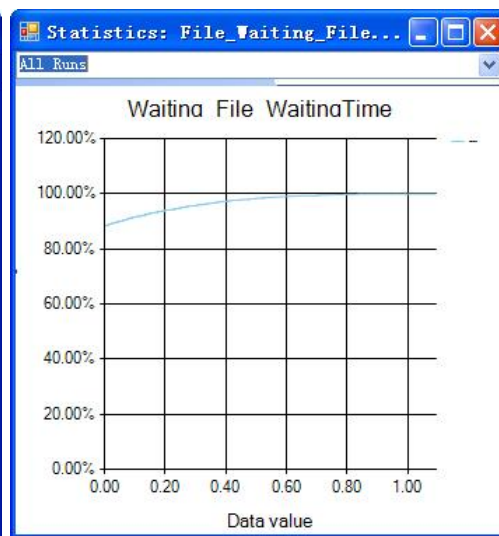


Figure 9. Cumulative distribution functions of interruptions on unit 2.

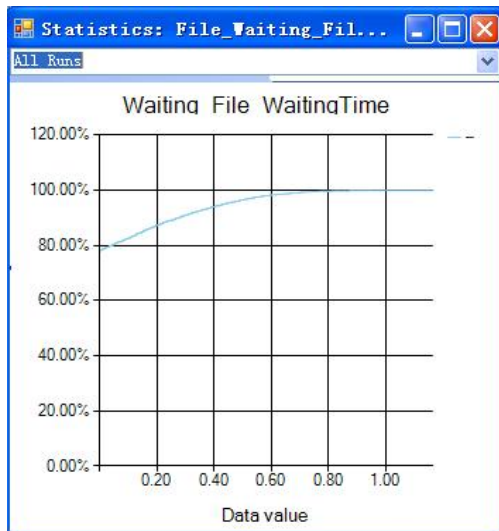


Figure 10. Cumulative distribution functions of interruption on unit 3.

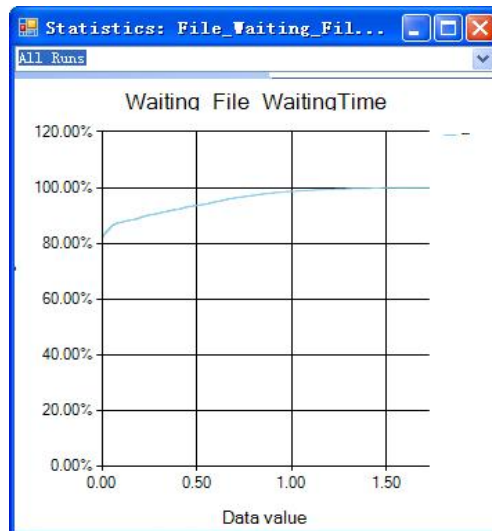


Figure 11. Cumulative distribution functions of interruption on unit 4.

Figure 12 shows the interruption days on unit 4 when buffer B equals 5.5 and buffer C equals 6.5. There still exists interruption to some degree. However, comparing Figure 12 with Figure 11, the increase in buffer size alleviates the degree of interruption on unit 4. Application of the simulation model and following the flowchart of generation scheduling, the project distribution for case study is shown in Figure 13. Notice that in Figure 13, where the size of buffer B equals to 9.5 and buffer C equals to 13.5, the crews maintain a continuous flow during the whole construction process. The scheduling of project is shown in Figure 14. In contrast to Figure 8, the confidence level of project completion due date (19 days) is above 70%.

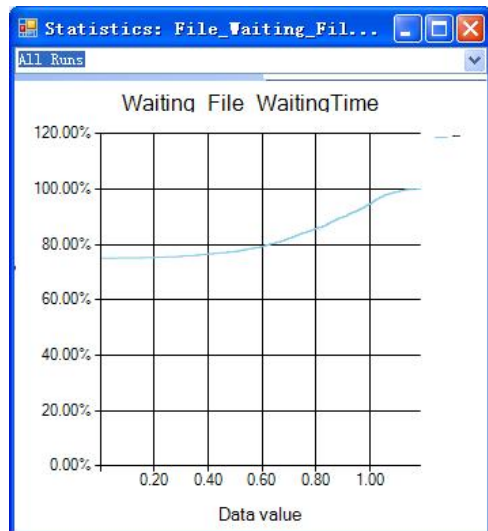


Figure 12. Cumulative distribution functions of interruption on unit 4.
(Buffer B=5.5, Buffer C=6.5)

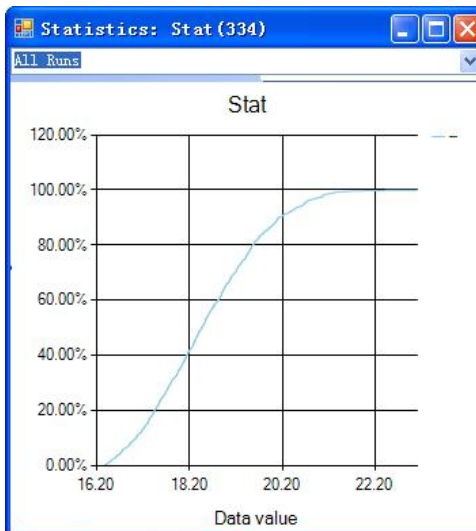


Figure 13. Cumulative distribution functions of continuous flow project duration.

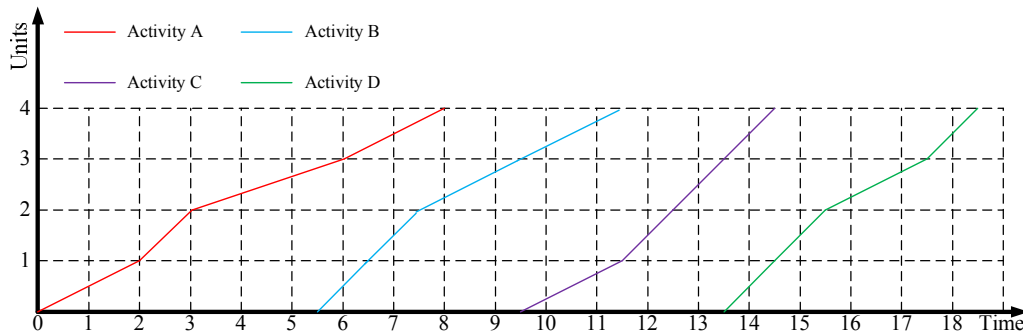


Figure 14. Continuous flows scheduling for probability repetitive project.

The case study reveals that deterministic assigned buffer values to crews used in deterministic scheduling method of repetitive project can not maintain a continuous flow. For the interruption and probability during construction process, the confidence level of project completion due date is not satisfying. Application of the proposed simulation model, the generated scheduling of repetitive project with probability assigned duration values can better ensure a continuous flow during construction process. Furthermore, the confidence level of project completion according to scheduling is greatly enhanced.

5. CONCLUSIONS

Within the context of this paper, a new continuous flow simulation model for probability repetitive project is proposed. The proposed model integrates simulation and buffering to consider the probability of activity durations and for proper sizing of buffers. Instead of having the same activities duration distribution on different units as is common, the proposed model allows for different activities duration distribution between units. The proposed model applies a hierarchical modeling method which avoids a complicated simulation network and maintains continuous flow for probability repetitive project.

This paper investigates the relationship of time buffer with continuous flow. Future research in this regard will give insight into other type of buffers, such as WIP, CONWIP and capacity buffer and how to use these buffers to ensure the continuous flows. Note that strictly maintaining continuous flow induces prolong of project duration which causes the increasing of indirect cost, while maintaining continuous flow decreases direct cost. So there exit the trade-off between project duration and continuity in terms of cost. Detailed analysis of this trade-off will be focus of future work.

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