A three level approach for exploring the ICT impact on the building design process applied to a real-life project

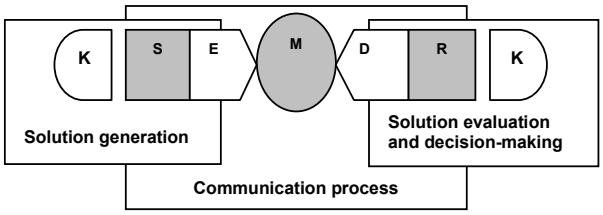
A. Moum
Norwegian University of Science and Technology, Trondheim, Norway

ABSTRACT: An understanding of how ICT impact on the building design process and the architect's role and contribution within it can be crucial for the building project success. This paper introduces a possible approach of organizing and structuring design process actions and roles, and how ICT impact on them. This approach is based on the definition of three building project levels and could contribute to a better overview of how ICT impact on the building design process and on the architect's role and contribution. The aim of this paper is to illustrate how this approach can be used to explore the ICT impact on a real-life project.

1 INTRODUCTION

A fundamental pillar of a successful building project is a good design process. The future and development of a good architectural design solution depends on complex and iterative processes on several levels and with different actors. Over the years, the ICT impact has led to dramatic changes within the construction sector average working day. Especially the network technologies, such as internet and e-mail, and the development of advanced visualization and CAD systems, such as virtual reality and building information models (BIM) have had and will further have an impact on both processes and role definitions (Wikforss 2003). The participants within the building design process face ICT related benefits and challenges at several levels. The architect has a distinct and important role within the building design process (Gray & Hughes 2001). His skills makes him adaptable for several roles, from being a design specialist, translating the many project constraints into physical form, to being a design generalist; leading, coordinating and administrating the design process as the building design- or even the project manager. An understanding of how ICT impacts the building design process and the architect's role and contribution within it can be crucial for ensuring building project success, due to quality, time and cost.

This paper introduces a possible approach of organizing and structuring design process actions and roles, and how ICT impact them. This approach is based on the recognition of three levels within a building project. The intention behind this approach is not to force aspects of the complex architectural design process into rigid categories, rather it aims to contribute to a better overview of how ICT impact on the building design process in general, and on the architect's role and contribution in special. The paper focuses on four essential aspects of the design process: the generation of design solutions, the communication, the evaluation of design solutions and the decision-making. These four aspects are highly interdependent and iterative, as figure 1 seeks to illustrate. The illustration is among others based on Kalay's description of the communication process (Kalay 2004).



K=knowledge, **S**=sender, **E**=encode, **M**=message, **D**=decode, **R**=receiver

Figure 1. Illustration of the relations between the four selected architectural design aspects

This first outline of the three-level-approach is based on the exploration of recent literature and research within the area. The aim of this paper is to illustrate how this approach can be used to explore the ICT impact on a real-life project. The first part of the paper will introduce and explain the three-level-

approach, illustrating the three levels using some theory examples. The second part is based on an interview with an architect involved in a housing estate project in Trondheim, Norway, which was completed in 2002. The three-level-approach was both used as a guideline throughout the interview and as a support of analyzing and presenting the interview respondent's perception of the project processes, participants, and the use and impact of ICT. Based on the very first and tentative impressions such an interview can give, the approach's adaptability on this specific real-life project and the challenges for further development will be discussed. This paper and the three-level approach contribute to a framework for further inquiry about the relation between ICT and the architect's role and contribution within the building design process.

2 INTRODUCING THE THREE-LEVEL-APPROACH

Three levels of operations and actions can eventually be recognized within the building design process. As a first overview of the three levels: the micro-level comprises individual and cognitive processes, based on what is going on in the head of the individual. The meso-level covers the mechanisms within a group and the macro-level comprises the mechanisms on overall organizational or sector level.

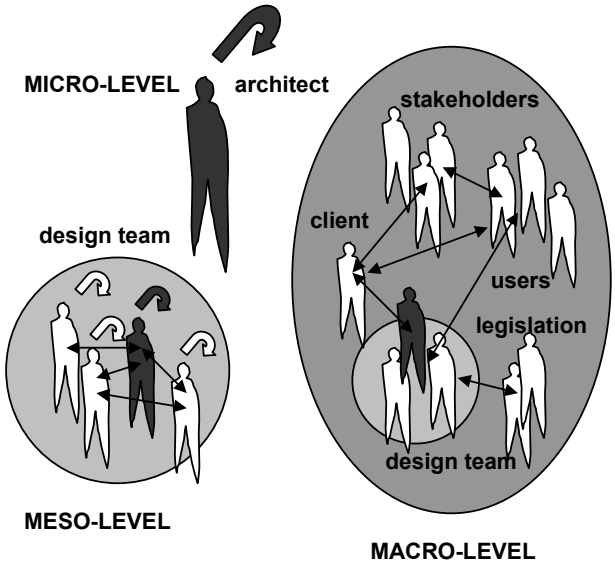


Figure 2. Illustration of the three levels within a building project

Different types of theories, as for instance individual theories (micro-level), group theories (meso-level) and organizational theories (macro-level) can be used to illustrate the processes on the different levels.

Many individuals are involved in a building project, each communicating, making decisions and taking actions based on "something going on in their head". Each of these individuals is himself a micro-level, as the client, the architect, the mechanical consultant and the manufacturer. However, at the same time, every individual operates within one or several contexts. The client is an individual operating within his own organization (meso-level) and within the overall project context (macro-level). The three-level-approach could thus be applied on different situations with focus on different individuals. The chosen individual can be the filter for defining the other levels. In this case, the chosen individual and the filter is the architect. Thus, in this paper, the micro-level is illustrated by the individual architect generating his ideas, the meso-level by the design team in which the architect interacts and the macro-level by the overall building project context and frame around the design process.

The architect could be seen to have different roles and contributions on the different levels. The creative processes in the head of the individual architect, take place on a micro-level. Within a meso-level context or the design team, the architect has to interact with other designers and consultants, as a design specialist and a hierarchical equal participant, or as a design generalist, with responsibilities within coordination and leading of the group. On the macro-level, the role and "visibility" of the architect depends on his function on the two other levels.

In an unpublished paper written for the CIB Symposium "Combining Forces" in June 2005, a literature based exploring of ICT related benefits and challenges within four essential aspects of the design process: the generation of design solutions, the communication, the evaluation of design solutions and the decision-making, was presented. An ICT impact matrix, based on the three level approach, was introduced as a frame for summarizing and gaining overview of the theoretical topic explored (Moum 2005).

2.1 The micro-level

The micro-level is in this paper illustrated by the architect's individual development of design solutions. According to Lawson (1997), the design process is a simultaneous learning about the nature of the problem and the range of the possible solutions, with no clear distinction between problem and solution, analysis, syntheses or evaluation in the design process. The designer juggles with several ideas at the same time, without forcing a premature precision or decision (Lawson 1997). Schön (1991) describes the design practice (e.g. sketching) as a

conversation or reflective dialogue between the designer and the design situation or design issue (Schön 1991). The designer conversation with the design situation allows a fluid thinking process without constraints like disturbing accuracy. The designer's conversation with the drawing, or what Kalay (2004) calls ideation or an intra-process role of communication are examples of micro-level processes.

Figure 3. How do ICT impact on micro-level?

2.2 The meso-level

The group processes within the design team illustrate actions on the meso-level. Heavily based on collaboration and communication, taking into account different constraints set for the project, the primary idea develops within a group context into something that can become the conceptual fundament of the building project.

The importance of collaboration is growing, as globalization and increasingly complex technique and products require more teamwork, and the complexity of the problem becomes unmanageable for one individual. Barrow (2000) introduces the term Cybernetic Architecture, which he explains as a "collective" body of knowledge and specialty skills found in many individuals (Barrow 2000). The focus changes from the individual to the collaborative design process, and this introduces a challenging dimension in the idea finding process: the interaction between the individual and the group (Lawson 1997).

Successful teamwork is among others based on shared understanding. If the group participants have similar background and a common base of experiences, with the opportunity to learn about each other over time, to communicate, share information, and to develop a team spirit, this will be ideal conditions to ensure a shared understanding of goals and tasks (Hinds & Weisband 2003). Within a design team, much of these will not be the case. The actors come from different companies and organizations, have different interests and experiences, have often never worked together before and will perhaps never work together again. However, the project team consisting of specialists with different competences, as architects and consultants, has a long tradition, especially by middle-sized and large projects. Hence, handling team processes and communication is nothing new for the building process participants. The degree of shared understanding as the basis for a good teamwork can on the one hand be seen to depend on the skills of the manager, such as the facilitating and monitoring of information exchange and interpretation (Cramton & Orvis 2003). On the other hand the informal "rules" of how to structure the building process, partly defined in different professional guidelines as the German HOAI (Honorarordnung für Architekten und Ingenieure) or the Norwegian AY (Arkitektytelser), contributes to establish routines and an understanding of the work to be done.

Figure 4. How do ICT impact on meso-level and the architect's role and contribution within it?

2.3 The macro-level

The design team is a part of an overall context, the macro-level. The building project comprises many organizations, representing different interests. The client organization, the users, the building authorities and the contractors are some of the actors, which establish the overall building project frame and the constraints and requirements influencing the design process. Decisions are made on all three levels. The architect will on the micro-level make his decisions about which design solutions are worth being put on the paper. But on the macro-level the client will be responsible for the crucial decisions regarding which proposed concept should be developed further.

There are several challenges due to decision- making within the field of architecture. The building design process is in addition to the measurable, quantitative and conscious based on the qualitative, intuitive and tacit (Kiviniemi 2004, Lawson 1997). Explicit knowledge can be articulated and is thus accessible to others while tacit knowledge cannot be articulated (Griffith et al. 2003). Wittgenstein's language game theory is one illustration of this problem area (Lundequist 1992). The crucial question within

evaluation of design solutions is how to measure or judge the qualitative, tacit and intuitive aspects? "Is it possible to say that one design is better than another and, if so, by how much?" (Lawson 1997, p.62). The client's understanding of the qualitative aspects depends essentially on the communicative skills of the architect and the design team.

Failed communication can cause conflicts and misunderstandings, negatively influencing the building project if not recognized and solved at an early stage. As illustrated in figure 1, the sending and receiving of a message (e.g. design solution) depends on the competence, knowledge and previous experiences of the participants in the communication process. The architect must encode the design solution in the form of some symbolic language, which is then transmitted, through a suitable medium (e.g. paper drawing scale 1:100), to the client, which must decode the design solution to understand it. Both the client and the architect decode and encode information based on their knowledge, or frame of reference (Kalay 2004). If the client does not know the symbolic meaning, or the level of abstraction used, he will not understand what the architect or the design team tries to communicate.

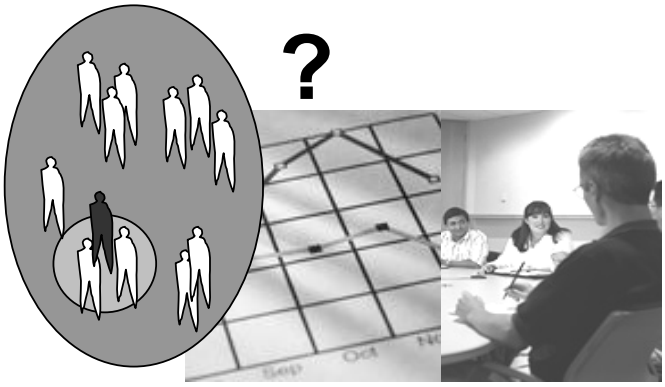


Figure 5. How do ICT impact on macro-level and the architect's role and contribution within it?

These were some theoretical key points related to each of the three levels, which seems to inherit different challenges and difficulties to be handled. Processes and actions on all three levels could be seen to impact on the successful design process and the generation and development of good design ideas.

3 THE THREE-LEVEL-APPROACH APPLIED TO A REAL-LIFE PROJECT

The three-level-approach was applied in different ways within the exploration of the real-life project. A matrix (Table 1) established a frame for exploring the relationship between ICT and the four design process aspects on each level. This matrix was intended to guide the interview and to structure the questions to be asked. Further, the three-level approach and the matrix were used to analyze and structure the interview material, with the intention to present an understandable overview of the key points concerning the project design process and the ICT used.

Table 1. Outline of the ICT impact matrix.

	Micro-level	Meso-level	Macro-level
Generation of design solutions			
Communication			
Evaluation of design solutions			
Decision-making			

3.1 Background and context of the real-life project

Trondheim is a middle-sized old university town in Norway. On a site directly by the waterfront, the development of a housing estate, including a home for elderly people, was started in 1998.

Figure 6. Housing estate project "Ilsvika"

The client, a professional organization, offered services within project development, real estate, contracting and module manufacturing. These different client departments played different roles during the building process. This client commissioned in 1998 a middle-sized architectural company from Trondheim to do the introductory negotiation with the building authorities, resulting in a development plan, and the following building design. This paper focuses especially on the building

design process. The housing project was divided into four stages of construction, in the size from 850 to 6400 square meters usable area (total 22,000 square meters). The design of the first construction stage started in 1999, the whole project was completed for sale in 2002.

One of the main requirements from the client was to use a prefabricated modular system, which made the short construction period of two years possible. In addition, there were influential design constraints based on the legislative regulations, regarding e.g. environmental-, noise- and day-light conditions to be handled. Both together established a narrow frame around the design, and had a distinct impact on both process and result.

3.2 Actors, processes and the use of ICT on micro-level

Within the design process, the construction stages had own groups of architects, and an internal design manager coordinated each of these groups. The interview respondent was the internal design manager responsible for two of the four project stages, in addition he kept the overview of the project in total to ensure the transfer of experience between the different construction stages.

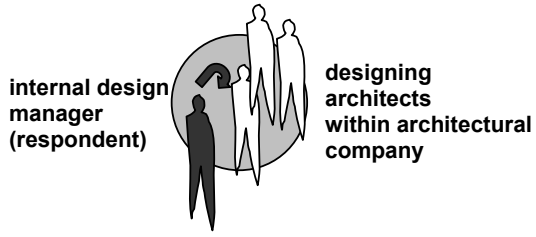


Figure 7. Micro-level actors

Each of the architects working with the design used the VektorWorks CAD program as a 2D tool. A specialist within the company developed the 3D models. In the beginning of the design process, the architect was sketching with pen and paper. But very soon the hand-sketches had to be transformed into computer-generated drawings. According to the respondent, there were several reasons for this. The project was to be built up of several identical units of accommodation. In addition, a modular system was to be adapted also on e.g. facades and construction system. Thus, as soon as the sketch of one unit was put on the paper, its potential as a repetitive element had to be tested. The computer was a valuable support within this task. Furthermore, the solutions should as early as possible be transferred to the module manufacturer, which controlled the usability and adaptability of the suggested components. In addition, the architects consequently used computer-generated drawings as basis for communication and discussion with other participants. ICT was in this project more a tool for evaluation as a partner supporting the creative processes. The respondent perceived the time available and used for sketching and modeling by hand as too short, and according to him, this could negatively have influenced the quality of the design solutions.

The applied CAD system did not allow more than one person to work with one file at the same time. This made it difficult to delegate tasks and, according to the respondent, led to a less efficient working day.

3.3 Actors, processes and the use of ICT on meso-level

In the beginning of the design process, there were not many participants within the design team. Only structural, acoustics- and fire-technical consultants supported the architects with the outline design stage. The architectural company offered itself the traditional mechanical and electrical services until later in the process. As the mechanical and electrical consultants finally joined the process, both as planner and as manufacturer of the technical systems, the main design concept was almost fixed. Thus, there was little activity around collective design solution generation at the meso-level. The respondent emphasized several times the drawback of this situation, since the knowledge of these participants would have been a valuable contribution within the generation of the design concept. The independent design manager joined the design process first at the end of the scheme design, and at this time also the formal design team meetings started, coordinated and leaded by this independent design manager.

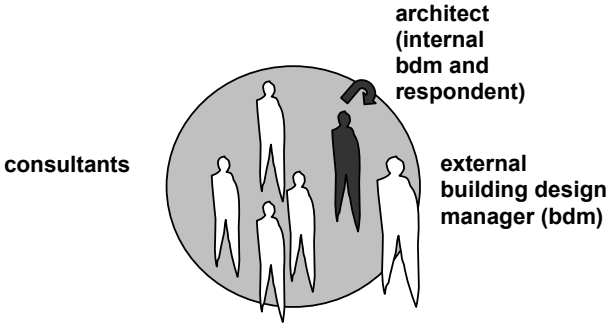


Figure 8: Meso-level actors

Originally, the client wanted to use a project-web system for documentation and file exchange, which would have been quite unusual and innovative at that time in the Norwegian AEC industry. These plans were stopped as the main person behind this idea left the client organization. Instead more

"traditional" ways of documentation and information exchange were used. The information, which was not exchanged face to face within the regular meetings, was communicated using telephone, fax or e-mail. The consultants were working with AutoCad as CAD system, and all file exchange was based on e-mail using dwg-format. The respondent mentioned the tendency that some participants, after receiving the files from the architect, redrew the computer-generated drawings from scratch with their own CAD system, which meant double work and inefficiency.

According to the respondent, the use of ICT in this project did not lead to central advantages due to accelerating the processes in the first stage of the construction. But as the design team started with the further parts of the project, ICT supported the possibility to reuse solutions and experiences in a most efficient way. Especially since the project was based on modular systems. The previous experiences were used as basis for improving the solutions. Thus, according to the respondent, the processes behind the later building stages went without most of the problems characterizing the first construction stage. This improved the quality of the design. However, another essential issue for reuse of knowledge was that the main participants remained the same throughout the whole project. This made it easier to build up a common knowledge and understanding of the project and what was to be done, which again supported the collaboration and the transfer of knowledge from one building stage to another.

3.4 Actors, processes and the use of ICT on macro-level

From the very beginning there was a very close collaboration between the architect and the client organization. The main actors within the outline design process and the design generation was thus the client and the architect, but also the building authorities and the module manufacturer indirectly or directly influenced this early stage of the planning. Thus, most of the processes due to idea-generation, evaluation and decision-making were taking place at this macro-level.

For communicating their ideas to the client, the architect used mainly 3D models, QuickTime movies and flyovers, all made with VectorWorks. The exchange format was pdf-files. The respondents experience was that this kind of illustrations supported the effort of making the qualities of the design solutions better understandable and visible to the client. The architect used this way of presenting ideas deliberately to influence the client's decisions. The same CAD system was used to simulate daylight conditions in the area, as this issue was seen to be critical from the side of the building authorities. The 3D models were made only from parts of and not from the whole project. The architect did not participate on the main client decisions and there was no forum or meetings around these decision processes. The decisions made were given further to the architect and the design team as new requirements or green light for further action. Because of this, the possibility to visualize the project in a convincing way without the support of verbal explanation was crucial for the architects' indirect influence on the client's main decisions.

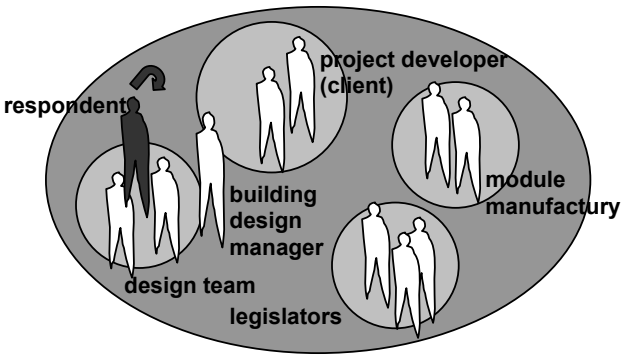


Figure 9. Macro-level actors

Another essential action on this level was the collaboration and communication with the modular manufacturer. As already mentioned, the client's requirement to use prefabricated modular systems directly influenced on both the design process and -product. The manufacturer participated already in the design process, and the communication with him was mainly based on the exchange of dwg-files. This made the architects digitalizing their ideas on a very early stage. The manufacturer controlled the files and gave feedback on the constructability of the suggested solutions. The ICT made it thus possible to integrate the production very early in the process. The only communication problem general within this building project was inherited in this contact, since the areas of responsibility for the design was, informally, not clearly defined. According to the respondent, these problems could have been more efficiently solved if the manufacturer and the architects have had more face-to-face contact.

3.5 Actors, processes and the use of ICT: summary

The project studied is not especially innovative due to the use of ICT, it is rather a typically example of a building process in Norway today. Of course within every project there are "specialties" which impact on both processes and the built result. In this case, such "specialties" are the late appearance of central consultant services, and an outline design process,

taking place on the macro-level. The traditional design team and meso-level activities appeared as the main concept of the project already was fixed. Another specialty was the rigid design frames due to building authority constraints and the client requirement of using prefabricated modules, which impacted the design process on several levels, from the individual design generation to the overall communication structure.

These "specialties" could in fact be seen as independent of the use of ICT. But ICT was in this project used to handle the emerging challenges resulting from these "specialties". In summary, ICT influenced especially four main issues. At first, ICT was used in the individual architect's design generation to test the ability of the hand drawn and tentative idea to fit into a total modular system. Within the matrix, this impact could be placed on micro-level design solution evaluation. Second, ICT supported the communication and exchange with the manufacturer, and made it possible to integrate production aspects already in the design process. This led to a blurring of the boarder between planning and production, and the border between the designer's and the manufactures responsibility. Within the matrix, this could be placed both on macro-level communication and design solution generation. Third, ICT contributed to the reuse of experience and solutions from one construction stage to another, which can be seen as both meso- and macro-level communication. And fourth, the ICT supported the architect in his effort to convince the client of the qualities of his suggested ideas. Within the matrix, this could be situated within macro-level evaluation, communication and decision-making.

Since the main consultants and the independent building design manager, who was a civil engineer, joined the process later on in the design process, there were not any participants "between" the architect and the client. The respondent regarded the architect's influence on the design process as high, especially on the meso-level. At the macro-level, the architect's influence and role was as strong it could be, taking in account the narrow frames of design and the client's overall control of the processes. The respondent further emphasized that the influence on the building concept was higher in the beginning of the building process, as changes did not cost much time, money and effort. The architect was commissioned for only doing the planning, not the production. Thus, the architect could not influence on the decisions made on the building site.

Today, the architectural company has changed from using VectorWorks to Archicad as main CAD device. The respondent gave two reasons for this. In the first place, Archicad offers the possibility of parallel working with the same file. Secondly, Archicad offers the possibility to work with IFC and product models, which could become relevant within other projects. Till now, this has not been the case.

4 THE THREE-LEVEL-APPROACH AND THE ADAPTABILITY ON PRACTICE – FIRST IMPRESSIONS

This first step into the real world has given some tentative feedback concerning the adaptability of the three-level-approach on a specific building project. In the interview situation itself, it became clear that using the matrix as a direct guideline as intended was very problematic. It was difficult to separate between the four design process aspects, especially due to the partly unconscious cognitive processes on the micro-level. There was also challenging to spontaneous handle all the "specialities" and the irregularities within this specific project. Both resulted in a freer interview form, leaving the more structured interview guide beside. However, the three-level-approach itself helped the interviewer to keep the big picture and not to get lost. Thus, to use the three levels as orientation points during the interview situation functioned very well, especially as the respondent himself easily recognized that he was working on different levels. It should be emphasized that the respondent gave answers reflecting his attitudes, experiences and interpretation of a situation, process or action, which can deviate from how something really happened. Still, as he was working both as a designing architect and an internal building design manager, he could give a good overview of processes and actors on all three levels.

However, within this case the main support of the three-level-approach was in the analyzing and presenting of the key points of the interview. In this case it was not quite clear on which level the actions within the group of architect's should be seen. It can be found arguments for both. In this case, the respondent gave information about how the architects, including himself, were working with ICT as individual designers, which led to the choice to place these actions on the micro-level.

5 CONCLUSION

This paper has illustrated how the introduced three-level-approach can be used to explore the ICT impact on a real-life project. The tentative impressions of the approach' adaptability on practice, is the potential as support for both guiding the collecting, analyzing and presenting the

empirical data. Within the project presented in this paper, the approach helped keeping overview of actors and processes, and which role and influence the architect had on the different levels. There are of course still several aspects to be further developed and clarified, especially regarding the definition of the levels and the understanding of the interactions between them and the four design aspects. In a next step, this approach could be applied to a case study of a large project using more "up to date" technology than the Ilsvika project. Within such a project, several architects working within different levels could be interviewed to get a more detailed impression of how ICT impact on their work and role. Interesting interview respondents could be an architect working on macro-level as a project manager, an architect being responsible for the design-team (architect as design generalist) and an architect developing design ideas (architect as design specialist). Such a case study could give further impressions of the three-level-approach and the matrix' adaptability on practice, and throw light on how ICT impact on different architects' working day within a developing building project.

6 ACKNOWLEDGEMENTS

This paper is a part of a PhD study and doctoral scholarship financed by the Norwegian University of Science and Technology (NTNU). The writing of this paper would have been cumbersome without the support and good advice from professor Tore Haugen (main supervisor of the PhD-project) and associate professor Birgit Sudbø. A thank goes also to Jørund Andreas Kjærem from Svingen Arkitekter AS, for his willingness to sacrifice time to contribute to the interview, giving interesting answers on many questions.

REFERENCES

Barrow, L. R. 2000. *Cybernetic Architecture, Process and Form. The Impact of Information Technology,* Doctor of Design Thesis, Harvard University, Cambridge, Massachusetts.

Cramton, C. D. & Orvis, K. L. 2003. Overcoming Barriers to Information Sharing in Virtual Teams. In S. G. Cohen & C. B. Gibson (eds), *Virtual Teams that Work, Creating the Conditions for Virtual Team Effectiveness*: 214-229. San Fransisco: Jossey-Bass.

Gray, C. & Hughes, W. 2001. *Building Design Management* Oxford: Butterworth Heinemann.

Griffith, T. L., Sawyer, J. E., & Neale, M. A. 2003. Virtualness and Konowledge in Teams: Managing the Love Triangle of Organizations, Individuals and Information Technology. *MIS Quarterly* 27(2): 265-287.

Hinds, P. J. & Weisband, S. P. 2003. Knowledge Sharing and Shared Understanding in Virtual Teams. In S. G. Cohen & C. B. Gibson (eds), *Virtual Teams that Work, Creating the Conditions for Virtual Team Effectiveness*: pp. 21-36. San Fransisco: Jossey-Bass.

Kalay, Y. E. 2004. *Architecture's new media principles, theories, and methods of computer-aided design* Cambridge: MIT Press.

Kiviniemi, A. 2004. 3D Modeling in Architectural Design. Ref Type: Unpublished Work

Lawson, B. 1997. *How Designers Think, The Design Process Demystified* (3 edn) Oxford: Architectural Press.

Lundequist, J. 1992. *Designteorins kunskapsteoretiska och estetiska utgångspunkter*. Stockholm: KTH Reprocentral,.

Moum, A. 2005. ICT and the architectural design process - introduction of an ICT impact matrix, in *11th Joint CIB International Symposium. Combining Forces - Advancing Facilities Management and Construction through Innovation*. Ref Type: Unpublished Work

Schön, D. A. 1991. *The reflective practitioner how professionals think in action.* Aldershot: Ashgate.

Wikforss, Ö. 2003. *Byggandets informationsteknologi så används och utvecklas IT i byggandet.* Stockholm: Svensk byggtjänst,.