A THREE LEVEL APPROACH FOR EXPLORING ICT IMPACT ON ARCHITECTURAL DESIGN AND MANAGEMENT APPLIED TO A HOSPITAL DEVELOPMENT PROJECT

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ABSTRACT
An understanding of how ICT impacts the building design process and the architect's role and contribution within it can be crucial for ensuring good architectural design and management of building projects. This paper is based on a possible approach of organizing and structuring design process actions and roles, and how ICT impact on them. The approach is founded on the recognition of three levels within the building design process and focuses especially on four essential, interdependent and iterative aspects: the generation of design solutions, the communication, the evaluation of design solutions and the decision-making. This approach aims to contribute to a better overview of how ICT impact the building design process in general, and the architect's role and contribution in special. The purpose of this paper is to illustrate how this approach can be used to explore several architects' experiences due to use and implementation of ICT in a large hospital development project in Norway. The main experiences regarding the ICT implementation and use are summarized within an ICT impact matrix.

Keywords: ICT impact, architectural design and management, three level approach

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 (Lawson 1997). Over the years, the ICT (information and communication technologies) impact has led to dramatic changes within the construction sector average working day, affecting both processes and roles (Wikforss 2003). The participants within the building design process face ICT related benefits and challenges at several levels. On the international IAI (International Alliance of Interoperability) conference "BuildingSMART" in Oslo June 2005, one of the key-themes was the ICT related paradigm shift within the AEC sector and which threats and opportunities this shift inherits for the architect. The architect has traditionally 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 involved with management tasks; leading, coordinating and administrating the design process as the building design- or even the project manager. Although the traditional leadership role of the architect within these management tasks partly has passed to other management oriented professions (Emmitt 1999). An understanding of how ICT impact the building design process and the architect's role and contribution within it can be crucial for ensuring good architectural design and management of building projects.

This paper is based on a possible approach of organizing and structuring design process actions and roles, and how ICT impact them (Moum 2005a; Moum 2005b). The approach is founded on the suggestion of three levels within the building design process and focuses especially on four essential, interdependent and iterative aspects: the generation of design solutions, the communication, the evaluation of design solutions and the decision-making. This approach aims to contribute to a better overview of how ICT impact the building design process in general, and the architect's role and contribution in special. The purpose of this paper is to illustrate how this approach can be used to explore several architects' experiences due to use and implementation of ICT (especially an IFC-based 3D object model) in a large hospital development project in Norway. This is one of the first attempts of applying the approach to a real-life building project. The resulting first and tentative impressions of the approach's adaptability on practice are intended to establish a basis for further development of the approach.

After a short description of the project, the three-level-approach will be explained and the four interview respondents introduced. All respondents are architects involved in management tasks on different levels in the project. The main points from the interviews regarding the implementation and use of ICT will be explored and described. The interview respondents' perception of the project processes, participants, and the use and impact of ICT, can deviate from how something really happened. Also, the intention of this paper is not to cover all aspects which came up during the interviews, rather some of the key points will be described to illustrate and discuss the adaptability of the approach on practice. At the end of the paper, an ICT impact matrix summarizes these key points (Table 1). 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 design and management of building projects.

INTRODUCING THE REAL-LIFE PROJECT: AHUS

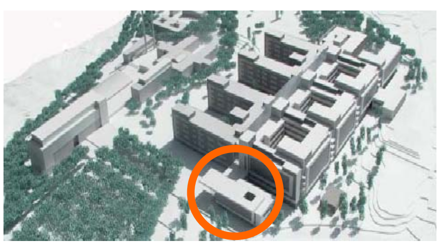
The new Akershus University Hospital (AHUS) is a major hospital development project in the suburbs of Oslo, Norway. The new hospital buildings comprise a total floor space of 116.000 m2 (Figure 1). After an architectural competition and several revisions, a final main outline of the project was presented in may 2003, and this outline became the basis for further design development and detailing. Full operation is planned during the autumn 2008 (www.nyeahus.no). The architect suggested early to implement a 3D object model (building information model or BIM) based on IFC (Industry Foundation Classes) and intelligent objects. The client's "go" for this suggestion, made the AHUS project to what Khemlani (2005) calls "*a front runner in Norway in the use of IFC-based BIM*". The project is divided into five main building parts, with their own teams of architects and consultants. The 3D object model has to a different degree become implemented in the five building parts. Only the architectural team developing and planning the front building uses the 3D object model to (almost) its full extent. This paper focuses on this front building part (2.500m2), which contains the main entrance, an auditorium and a cantina (Figure 2). The modelling of the front building started autumn 2004, and in the spring of 2005 the 3D object model was "completed", a little later as expected. Summer 2005 the front building project is going to be handed over to the contractor and the production of the building starts. All key participants of the total building project work collocated directly beside the building site.

The four ICT cornerstones of the project and some of the visions behind them

There are four ICT cornerstones in the front building project. Firstly, the 3D object model (AutoCad ADT 2004) which: *Given the huge size and complexity of the project (...), the main focus of the use of BIM was to keep track of all the objects—rooms, components, fixtures, furniture, and equipment—not just during design and construction but throughout the project lifecycle* (Khemlani 2005). This paper focuses mainly on the implementation and use of this 3D object model. According to the contract, the 3D object model is the property of the client. Secondly, in a document database (ProArc) all drawings and documents are archived and distributed, no parallel document archiving is allowed. Up-to-date project material is accessible to every project participant, independent of time and place and without the danger of working with or discussing obsolete material. Thirdly, a room database containing room lists, equipment lists etc. represents the users programme and requirements (dRofus). And finally, e-mail is an important tool in the everyday project communication. IFC-based BIM could eventually become a standard building process tool in some years, and an essential aim for using this tool within AHUS, is to collect experiences and build up competence around the implementation and use of this still quite new and untested technology within the AEC sector. Against the original intention comprising both architects and consultants, only the architect work directly with the 3D object model. Three IFC R&D projects are going to be and partly are implemented and tested within the planning of the front building. An IFC Model checker (Solibri) can check the consistency of the 3D object model through intersecting objects, doubles- and clash-detection etc. Another project is the linking of the room database with the 3D object model, with the possibility to check deviations between the users requirements due to rooms and equipment, and what is actually integrated in the object model. The last project is to transfer object information to Facilities Management (FM) systems (Bakkmoen, BuildingSMART conference in Oslo, 31.05.-01.06.2005). An open question in the project today, is to which extent the contractor will implement and use the 3D object model in the further realization of the project.

THE THREE LEVEL APPROACH AND THE INTERVIEW RESPONDENTS

Three levels of operations and actions within the building design process are suggested. The micro-level comprises individual and cognitive processes, as the creative processes in the head of the individual architect. The meso-level covers the mechanisms within a group, for instance the architect's interaction with other designers and consultants within the design team. The macro-level comprises tasks and mechanisms on overall organizational or project level (Figure 3), as e.g. architectural- or project management (Moum 2005a).



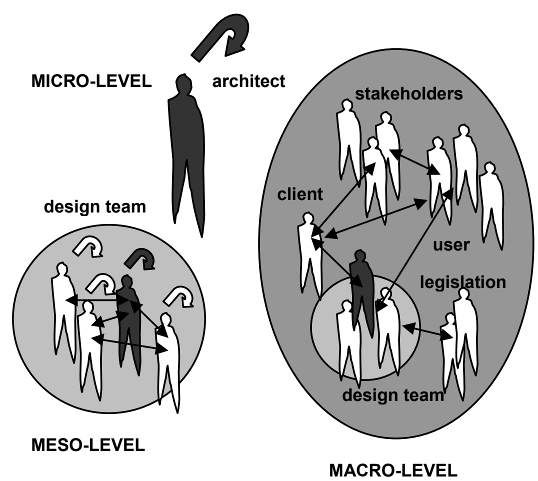


Figure 1 (left top): The new Akershus Universtity Hospital (from: www.nyeahus.no)
Figure 2 (left bottom): The front building (from: www.nyeahus.no)
Figure 3 (right): The three hierarchical levels

All four persons interviewed are architects, involved with management tasks on different levels and within different contexts.

Respondent A: female architect, employee of the architectural company, 20 years practical experience. Her main tasks are the individual generation of design solutions regarding the front building interior (micro-level) and the development and coordination of these design solutions within the design team (meso-level). Since she is the vice manager of the architectural team, she also to some extent takes part in the discussions with users and clients (macro-level).

Respondent B: male architect, employee of the architectural company, 9 years practical experience. He has the formal responsibility of managing and representing the architectural front building team (meso- and macro-level), in addition (since the team only comprises three persons) he designs and develops the front building envelope (micro-level).

Respondent C: male architect, employee of the architectural company, 27 years practical experience. He is the vice building design manager for the total project from the architect group, responsible for the administration of the work processes and the production of planning material (macro-level). He is also the key-person behind the overall project systematization and the implementation and development of the 3D object model and the R&D programme.

Respondent D: male architect, employee of the client organization, 24 years practical experience. He is one of five project managers, with responsibility for the planning part of the overall building project and the management of the contracts with the architect and the other consultants (macro-level).

The presented data from the interviews are intended to give a rough picture of how ICT impact on all levels and all four design aspects, thus demonstrating and illustrating how the approach can be applied to a real-life project. Therefore interview respondents were selected representing experiences perceived from different levels, views and positions within the front building project. Respondent A is a frequent user of the 3D object model, without a direct influence on the implementation and development of the model. This is the responsibility of respondent B and C, who both administrate and facilitate the implementation of the model in the front building team and on project level. Respondent D has no special knowledge about how to use or develop the technology, but as a client he has strong and obvious interests in a successful implementation leading to a successful building project.

AHUS: USE AND IMPLEMENTATION OF ICT ON MACRO-LEVEL

On macro-level there are formal structures for communication and decision-making. Regularly there are arranged meetings for different purposes (every 1-2 weeks). The front building planners meeting is the operational instrument of the project. Every decision regarding the design and development of the front building is made here. The participants in these meetings are, in addition to a person representing the user and the client (project part manager), the responsible persons from the different building planning disciplines. Thus, both respondent A and B participate in these meetings. Another meeting forum is the total project meeting, which focuses on strategic and administrative aspects due to the total project. Meeting leader is the respondent D. Respondent C participates in some of these meetings as a vice leader of the architectural discipline. Finally, the future users of the new hospital have a central position in the definition of requirements. The extensive degree of user participation required regular meetings between the users, clients and the planners autumn 2004.

Macro-level experiences from implementation and use of ICT- some examples

The 3D object model is not used directly in the formal meetings. Evaluation of the project development and decision-making are based on views or cut-off drawings (2D) generated from the model, partly projected on a screen using a beamer. In the total project meetings, every participant brings their own laptop. Once a week a cut-off of the 3D object model is laid out into the document database, thus every relevant and up to date drawing or document is easy and fast accessible, which respondent D regards as a huge advantage of ICT. In comparison, within the front building planners meetings the pen, sketch paper and physical models are still central tools supporting ad hoc solution generation and decision-making. Regarding the user meetings, the 3D object model became a valuable support for preparing discussion and decision-making material. Around 1000 unique rooms on total project level made a huge amount of drawings necessary as basis for the discussions and decisions. All these drawings (sections, plans and elevations) were generated directly from the 3D model.

An interesting aspect, which came up in the interview with respondent D, was the rigidity of the ICT tools regarding presentations. He perceived that perfect, static and almost finished looking drawings and illustrations presented in the meetings did not lead to dynamic, open and flexible discussions. Rather the presentations paralyzed the meeting participants and made it difficult for them to suggest changes.

The implemented IFC based 3D object model version does not support rendering of the objects. Thus, it is not possible to generate realistic visualizations and walk-throughs directly in the 3D model environment, which could be used for more dynamic and interactive presentations of design solutions in e.g. the users meetings. However, the 3D object model of the front building has now reached a stage where calculations and simulations regarding indoor climate, energy consumption etc. are possible. But the model is "heavy" to use and change in this late stage of design. Therefore, to work directly in the 3D environment in meeting situations demonstrating e.g. "live" simulations seems to remain being difficult since more rapid simulations or visualizations of results are required.

From the client's view (respondent D) ICT offer good possibilities for better could follow, control and evaluate the development of the planning. Cut-offs and the viewer technology make the access to the 3D object model easier. However, respondent D perceives the model being a black box to which the client has no directly access, unless he has special ICT competence. In this project, this drawback of ICT is compensated by the collocated situation, since the client can easily get information from informal face-to-face meetings with the architect.

An unexpected limitation of the implementation was the need for more powerful computer processors. The object model files are heavier than the traditional line-based 3D models. With this experience, another and improved file structures could be adapted to future projects. The emerging viewer technologies could support a better overview and help preventing information overload. In this project physical views make the 3D object model easier accessible.

AHUS: USE AND IMPLEMENTATION OF ICT ON MESO-LEVEL

Although every communication between the architects and the other consultants theoretically should include the client, informal communication within the design team is usual and to some degree also wanted. All respondents emphasized the advantages of the collocated situation, with the opportunity to build up a common understanding and culture, and to exchange information and make ad hoc decisions in an uncomplicated and fast way. Because of the collocated situation, there is only a limited use of ICT and the 3D object model within the meso-level design process.

Meso-level experiences from implementation and use of ICT- some examples
As only the architects work directly with the 3D object model, the other consultants use the once a week 2D cut-offs and dwg-files as their base of planning. The cut-offs and the dwg-files are accessible in the document database. The elements received from the consultants, for instance columns and slabs from the structural engineers, the architects partly must "transform" to fit into the model. Since the architects themselves generate model objects from other consultants' elements, they have according to respondent B, better control of the consistency between e.g. architectural and structural elements. As described, the everyday communication within the design team comprising architects and other consultants are mostly face-to-face, but also telephone and e-mail are important communication tools. Tentative and informal drawings are often exchanged using e-mail.

AHUS: USE AND IMPLEMENTATION OF ICT ON MICRO-LEVEL
Every architect working with the AHUS project shall be able to operate the ICT tools implemented in the different project parts. There are offered courses and manuals for learning and updating knowledge about continuously and rapidly developing software.

Micro-level experiences from implementation and use of ICT- some examples
The individual architect works within a 2D user environment, dragging and dropping 3D objects. According to respondent C, this way to "draw" should be easier as the traditional drawing with lines, and normally no special competence of the every day operator is necessary as long as pre-defined objects are accessible. However, till now, there are no pre-defined library of objects and building elements available. Every intelligent and IFC exportable object must be defined "from scratch". Both defining and changing these objects means time consuming processes within narrow time limits. There are not many architects within the project having the required competence for such tasks. This leads to bottlenecks in the planning and loss of valuable time. Respondent A indicates the danger that planners could be tempted to avoid improving changes in stressed project periods. Furthermore, she points out that the lacking time and recourses to learn and be up-to-date partly lead to an inefficient use of the rapidly developing ICT tools. The implementation of the model requires that the architects working with it continuously have to extend their competence concerning the use of the software, which till now is difficult to operate, not intuitive and parametric. The narrow time limits do not allow much time for absorbing information offered through courses and user-manuals.

Respondent B emphasizes the importance of knowing the limitations and problems due to the technology used, in order to realistically understand and manage the manpower and time needed to build up the front building 3D object model. More time than expected had to be invested in programming and modelling. In the front building team, one person is full time involved with programming and building the 3D model. Also the maintenance of the room database requires extra effort, since every change must be made in both the 3D object model and this database. However, the R&D project regarding the linking of the room database with the 3D object model is partly implemented. In close future every participant in the architectural team should be able to enjoy the benefits of this combined technologies. Generally, the working with the ICT tools implemented in this project requires much discipline, effort and resources.

Both respondent A and B only to a limited degree use the 3D object model in the individual generation and visualization of design solutions. According to respondent A, she first makes some rough sketches with pen and paper, before she transforms the idea into computer generated drawings, which with its accuracy offer an early "test" of the design idea's feasibility. However, her concern is that the middle stage between rough sketch and detailed precise drawing has disappeared, eventually leading to loss of creative freedom and overview of the totality. She tests her design ideas traditionally in 2D computer environment, using lines, not objects. Transforming the 2D lines into 3D objects is made later, which partly results in a 3D model not completely based on objects. In addition, both respondents see the lack of time recourses and the "heavy" operating of the model as the main barrier of using the 3D model directly for visualization and testing of design ideas. However, respondent A emphasized the possibilities of reusing details and solutions as a benefit of ICT and a support of generating design solutions.

SUMMARY

The ICT impact matrix (Table1), which is based on the three hierarchical levels and the selected four design process aspects, summarizes some of the experiences made due to the use and implementation of ICT in the AHUS project. The focus of the 3D object model in this project lies more on the implementation of an object-oriented way to work than the possibilities due to 3D visualization (Bakkmoen, BuildingSMART conference in Oslo, 31.05.-01.06.2005). According to the interview respondents, the key advantages and possibilities of the ICT are better project material quality and consistency, and a more uncomplicated project transition from planning to construction. However, much time, competence and effort are invested in modelling and programming, partly caused by the lack of pre-defined objects. The model is "heavy" and difficult to use regarding the normal design process day. But all respondents, also the every-day users of the 3D object model, are aware of what they perceive as the overall benefits of using the ICT tools in this project, such as better control of rooms and equipment, the generation of building descriptions, the quantity take-off etc. Especially when it comes to the construction of the building, the key persons behind the ICT implementation hopes to "reap the fruits" of the many participants' effort and commitment.

CONCLUSIONS

This paper has illustrated how the introduced three-level-approach can be used to explore the ICT impact on a hospital development project in Norway. The tentative impressions of the approach' adaptability on practice, is the potential for supporting and guiding the collecting, analyzing and presenting of the empirical data. Regarding the project presented in this paper, the approach helped keeping overview of actors and processes, and their experiences due to use and implementation of ICT. 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. 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 within architectural design and management in special. This paper only presents the first impressions of the approach's adaptability on practice. For extending the empirical basis, further case studies and interviews should be carried out. Also more participants of the AHUS project could be interviewed, not only architects. The applying of the approach to more real-life projects could on the one hand contribute to further improvement and development of the approach, and on the other hand contribute to a better understanding of how ICT impact on the design process and the architect's role and work.

Table 1: the ICT impact matrix, outline summary of experiences from implementation and use of the 3D object model

	Micro-level	**Meso-level**	**Macro-level**
Generation of the design solution	**Use and experiences:** • 3D object model not used directly for design generation, rough hand sketches and 2D line-based drawings the facilitators of design generation – after finding an appropriate solution, it is "transformed" into object-based modelling. • 3D object model heavy to operate and change – it is not intuitive and parametric. • Individual architect is working within a 2D environment, dragging and dropping 3D objects. • No pre-defined objects available, every object and element must be defined from scratch – time consuming. • Few people have competence to change objects – bottlenecks and delays by changing - danger of avoiding improving changes. • Possibility of reusing solutions and details benefit.	**Use and experiences:** • Ad hoc solutions mostly developed using traditional tools as pen and paper, physical models etc. in a face-to-face environment.	**Use and experiences:** • Rigidity of ICT generated finished looking drawings and illustrations presented in the meetings paralyzed the participants and made it difficult for them to suggest changes. In this case, the ICT tools did not support dynamic, open and flexible discussions.
Communication within the design process	**Use and experiences:** • 3D object model not used directly for design generation, rough hand sketches and 2D line-based drawings are the basis for the "designers conversation with the design situation" (Schön 1991)	**Use and experiences:** • On this level there is mostly informal face-2-face communication. • Only architect work with 3D object model. • Once a week cut-offs from model (dwg) is made accessible on document data base. • Exchange of tentative data by using e-mail.	**Use and experiences:** • All participants have access to document and room database – always up to date material. • Use of beamer makes the project material easy accessible to all participants in meeting situations. • 3D model itself a "black-box" for client, unless special competence. A limitation of directly following the design development. In this project collocated situation compensate the limitation.
Evaluation of the design solution	**Use and experiences:** • Much information to be overviewed and maintained in the model, development of viewer technologies could help focusing attention for evaluation. • Use of hand-drawn perspectives, sketches and 2D computer line-based drawings rather than directly using 3D model for evaluation– which is to "heavy", unless special competence.	**Use and experiences:** • Today, the 3D object model is only to a limited or no degree used in design idea evaluation. • However, the model shall in close future support simulations of e.g. indoor climate etc. • The architect partly "transforms" slabs and columns from structural engineer to 3D model objects – gives opportunity to directly control consistency between architecture and structure.	**Use and experiences:** • 2D views and cut-offs of the 3D object model regularly accessible to the client and the other participants. • The 3D object model not directly used for "live" simulations and vizualisations in meeting situations – model to "heavy" and the IFC version implemented does not support rendering of the objects.
Decision-making within the design process	**Use and experiences:** • Use of hand-drawn perspectives, sketches and 2D computer line-based drawings rather than directly using 3D model for decision-making. • The model-checker enables clash-and doubles detection of 3D object model –higher quality and consistency of drawings before passing drawing to next level.	**Use and experiences:** • On this level there is mostly informal, ad-hoc and face-2-face decision-making. Formal decisions on macro-level. • Ad hoc decisions based on f2f discussions and the use of pen, sketch paper and physical drawings.	**Use and experiences:** • Decisions made only in formal meetings. • In the project meetings participants have own laptops – always directly access to data base and up to date material. • High quality and consistency of project material. • Generation of drawings from 3D object model benefit when decision material regarding 1000 unique room must be made.

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