ICT AND THE ARCHITECT'S WORK AND CONTRIBUTION IN THE DESIGN PROCESS

an exploration of use and implementation of IFC-based BIM in the AHUS project

project report "architectural design: theory and practice"
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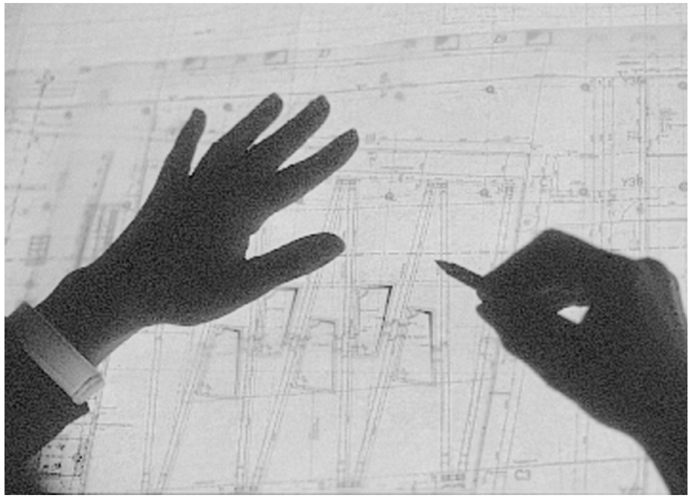

Figure 1. The work of the architect (www.siat.de)

FOREWORD

Design in general can be seen to pass through phases of relative certainty and doubt." (Lawson, 1997, p. 163)

This report is part of a subject called "Architectural design: theory and practice". The purpose of this subject is to gain knowledge about theory and practice within architectural design. How does the architect think and work in practice, and how does the architect interact with the other participants in the architectural design process? How does the use and implementation of ICT impact on these issues?

The subject is part of a PhD-study and doctoral scholarship financed by the Norwegian University of Science and Technology (NTNU). The main topic of the PhD-study is to explore the relation between ICT and the complex and iterative processes embedded in the development of architectural design, with special focus on the architect's work and interaction with other design process actors.

The main purpose of the report is to explore benefits and challenges regarding the implementation and use of an IFC-based 3D object model (BIM) in practice. The exploration is based on a case-study of a hospital development project in Norway and a review of key elements. in recent literature. A theoretical framework for exploring and analysing empirical and theoretical data is applied.

I would like to thank Tore Haugen, the main supervisor of the PhD-project, for his helpful comments and advice, and especially for his advice to explore this particular project. In addition, my sincere thank to Kjell Ivar Bakkmoen, Bård Rane, Astrid Seeberg and Steen Sunesen for their willingness to sacrifice time and effort for answering my many questions. C.F.Møller Architects is credited here for making their images available for this report.

Figure front page: Based on Theodor Kittelsen's "Soria Moria slott" (from: www.bergen.folkebibl.no)

Anita Moum, 5 December 2005

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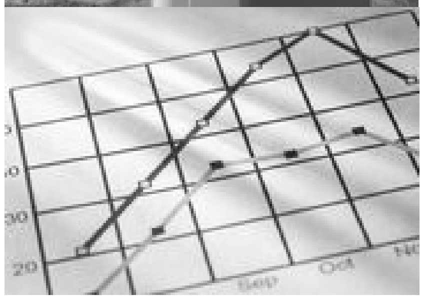

1 INTRODUCTION

1.1 Overview

A fundamental pillar of a successful building project is a good design process. The field of architectural design is complex, and the successful interplay between iterative and interdependent processes, roles and actions can be seen as a foundation of developing good architectural design solutions and building projects. Over the years, the development of ICT has led to several changes in the AEC industry. The network technologies, advanced visualization tools and CAD are some examples of ICT, which represent powerful potential of facilitating change and improvement. Much research of today focuses on the development of new and improved ICT (Information and Communication Technologies). However, the participants within the building design process face ICT related benefits and challenges on several levels. Both working processes and role definitions (Wikforss 2003) are affected. An understanding of how ICT impact the complex building design process (and the architect's work and contribution within it) can be crucial for ensuring good architectural design and management of building projects.

The new Akershus University Hospital (AHUS) is a major hospital development project in the suburbs of Oslo, Norway. The front building (one of five building parts) team uses an IFC-based 3D object model (BIM) to (almost) its full extent. Until now, there have not been collected much experiences regarding BIM-use in Norway, and an exploration of the AHUS project, for the moment regarded as a "front runner in Norway in the use of IFC-based BIM" (Khemlani, 2005), could give valuable insight in how such technology impacts the architectural design process and the architect's work and interaction with other participants.

1.2 Purpose and scope

The main purpose of the report is to explore the experiences made in the AHUS project regarding the implementation and use of an IFC-based 3D object model (BIM) in the architectural design process. Special attention is paid to the architect's work and interaction with other design process participants. Based on interviews with four architects involved in the front building project, the exploration attempts to give an insight in the motivations and aims behind the implementation, the experiences made from the use of the technology and the key respondents attitudes regarding future potential and challenges. For exploring and analysing the AHUS project and the interviews, a theoretical framework is applied. A brief explanation of the framework is given in the method section of the report, and the adaptability of the

FOCUS OF REPORT AND CASE-STUDY

WHAT: benefits and challenges regarding the use of IFC-based BIM in the AHUS project.

WHEN: architectural design process

WHO: the architect involved in management and design tasks

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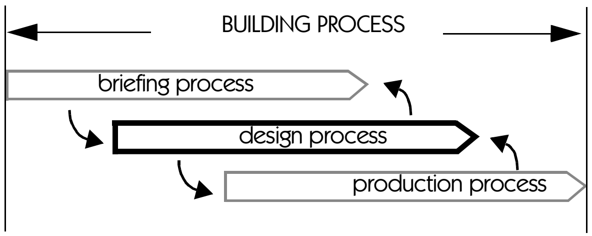


Figure 2. The building process and its main three phases (based on illustration in "Samspillet i Byggeprosessen" Haugen & Hansen 2000, p. 10).

framework is discussed in the conclusion part. The key BIM related benefits and challenges are summarized at the end of the report and some lessons learnt from the AHUS project are suggested. Finally, possible next steps and areas of further investigation are discussed.

1.3 Some central terms and how they are used in this report

The following section explains how central terms are used in this report.

The architect's work and contribution
The architect has traditionally a distinct and important role within the building design process (Gray & Hughes 2001). His skills makes him suitable for several tasks and roles, from being 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. This report focuses on architects involved in management as well as in design development.

The architectural design process
As a simplified explanation, one could say that the design process are situated between the statement of the brief and the start of the building site. One could perhaps also say, that the design process aims to translate the requirements and constraints defined in the brief into an architectural design idea, which through drawings/models/words again can be translated into physical form. The architectural design process can be sub-divided into different phases; for instance the outline design phase, the scheme design phase and the consultants' detailed design phase (Gray & Hughes, 2001). Different countries can have different definitions of the required performances of each of these phases. These definitions are often formal embedded in rules or guidances (Norway: AY, Germany: HOAI). However, in practice, a pure sequential process, where one phase follows the other, is a seldom phenomena. Because of several reasons, as for instance limited time recourses and poorly defined briefs, and the increased use of ICT, phases often overlap (Fig. 2). Therefor, it seems difficult to focus on the design process as an isolated phenomena, although the focus of the work is clearly placed in a project phase with a high density of design actions. The connections and joints to briefing and constructions will remain an issue, at least on an overall level. In the case-study introduced in this report, a "cut" through a late phase of the architectural design process is analysed and presented.

FOUR STRATEGIC CATEGORIES OF TECHNOLOGY

Wikforss (2003) describes four strategic categories of technology; database technology (server- or web-based database offering a pool of information as documents, drawings etc.), the network technologies (e-mail, Internet, World Wide Web), development of understandable user surfaces and the technology of computer graphic and new media (Virtual Reality, 3D object models/BIM, cyberspace etc.).

Architect. A master-builder. spec. A skilled professor of the art of building, whose business it is to prepare the plans of edifices, and exercise a general superintendence over the course of their erection. Oxford English Dictionary Online.

Benefit. Advantage, profit, good. (The ordinary sense.) For the benefit of: for the advantage of, on behalf of.To take benefit of (a thing): to take advantage of, avail oneself of. (Latin: benefactum good deed, kind action, lit. (a thing) well done, from bene facere to do well). Oxford English Dictionary Online.

Challenge. A calling into question or disputing; the state of being called in question. An invitation or summons to a trial or contest of any kind; a defiance. In weakened use: a difficult or demanding task, esp. one seen as a test of one's abilities or character (Latin: calumnia, trickery, artifice, misinterpretation, false accusation, malicious action at law: probably from calvi, calvere to devise tricks). Oxford English Dictionary Online.

ICT and BIM

The term Information and Communication Technologies comprises a broad range of devices and tools. This report and the PhD research generally focuses on computer supported technologies developed for the AEC industry. Communication technologies as e.g. cell phones are outside the scope. This report focuses especially on IFC based 3D object models, also called BIM (building information models). A more detailed explanation of IFC-based BIM will follow later in this report.

ICT related benefits and challenges

As an attempt to operationalize the very broad and diffuse word "impact", the terms benefit and challenge are used. Generally, the intention of this report is not to classify any of the explored ICT impacts on the architectural design process and the architect's work, as purely bad or good. Which seems to be a disadvantage in one situation or according to one person, could be perceived as an advantage in another situation, perhaps because the computer program is not used efficiently or the user is not skilled enough. To use the word challenge instead of weakness or disadvantage is a conscious choice. Challenge implies that something is questioned, without necessarily giving a judgement in the terms of good or bad.

2 METHOD AND FRAMEWORK

2.1 Methodological strategy

The case study method allows investigators to retain the holistic and meaningful characteristics of real-life events (Yin, 2003. p. 2).

The underlying aim of this report is to gain understanding of how ICT impact the architectural design process, with special focus on the architect's work and interaction with other key participants. A case-study strategy is chosen as main method for collecting data about the phenomena. A "learning from practice" can give valuable insight about processes and actors. An exploratory approach underpins the conducting of the case study. According to Robson (2002) an explorative strategy is appropriate when trying to find out what is happening in little understood situations, seeking new insight, asking questions, and generate ideas and questions for future research. The AHUS project was selected as the case study object, since this project is in a front position in Norway regarding the implementation and use of IFC-based BIM. The main part of the case study (the interviews) was carried out in May 2005.

A literature review of the field and the development of a theoretical framework establishes a "back drop" for conducting and analysing this explorative case study of the AHUS project.

As described in the introduction, the main objective of the case-study is to collect data about the key actors' (architects') experiences and attitudes regarding the use and implementation of IFC-based BIM in their daily work. Since a theoretical framework is used as a help to conduct the case study, another issue is to reflect on the ability of the developed framework to support the exploration of this real-life project. The scope of the case-study is consciously relatively open, since the aim of the exploration is to contribute with an overview of the complex relationships between processes and actors. However, in a next step, the exploration could become the fundament for narrowing the scope of further investigation in order to gain deeper insight within some of the problem areas.

WORKING WITH LEVELS

Yin (2003) describes four different groups of theory; individual theories (e.g. cognitive behaviour, individual perception), group theories (e.g. work teams, interpersonal networks), organizational theories (e.g. interorganizational partnerships) and societal theories (e.g. marketplace functions, international behaviour). (Yin, 2003. p. 31).

Emmitt and Gorse (2003) refers to Kreps (1989), who divides human communication into four levels: 1) intrapersonal communication (thought process of one person), 2) interpersonal communication (communication between two), 3) small-group communication and 4) multi-group communication (enables different groups to coordinate efforts). (Emmitt & Gorse, 2003. p. 44)

The terms micro-, meso- and macro are used in different settings, among others within economics and communications.

2.2 The theoretical framework

To explore the ICT impact on the architectural design process is a huge undertaking. The need for an approach for organizing and analysing the multiple and complex amount of information collected from theory and practice, led to the development of a theoretical framework. The intention of the framework is to support the exploration of the topic, in order to help keeping overview and to contribute to a better understanding of relationships and events. This framework has already been introduced in papers presented on three international conferences (Moum a-c, 2005).

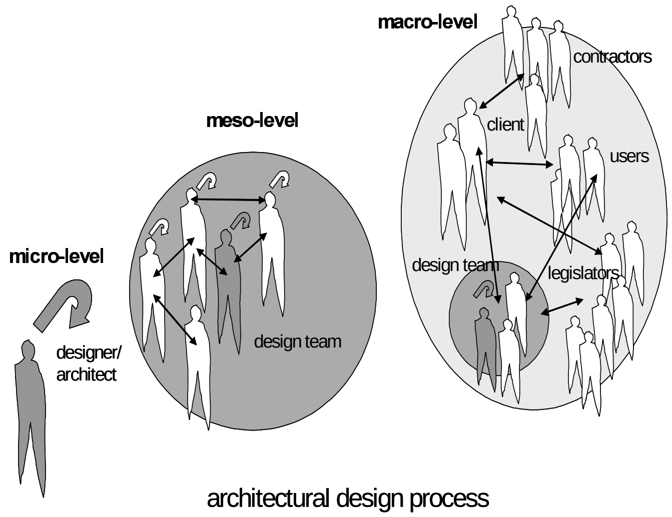


Figure 3: The three hierarchical levels

Figure 4. The ICT Impact Matrix

	micro-level	meso-level	macro-level
design generation			
communication			
design evaluation			
decision-making			

summarizing key points from ICT impact exploration

The framework is based on the suggestion of three levels of operations and actions within the architectural design process; called the micro-, meso- and macro-level (fig. 3). 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, as e.g. architectural- or project management (Moum, 2005a-c).

The framework focuses furthermore on four central aspects of the architectural design process; the generation of design solutions, communication, the evaluation of design solutions and decision-making. A primary idea emerges in a designer's head based on a complex iterative process between problem and solution. Taking into account different constraints set for the project, the primary idea "materializes" into something that can become the conceptual fundament of the building project (Lawson 1997). Making good decisions regarding which design solutions are worth being put to the paper or which proposed architectural design concept should become the foundation of further development, relies heavily on the designer's individual ability to generate, but also to communicate good design solutions. Communication is in much literature emphasized as a key to success and good decision-making on several levels in the architectural design process (Emmitt and Gorse 2003, Kalay 2004, Lawson 1997, Lundequist 1992c, Schön 1991). The communication and interaction between the building process actors, each representing different interests and experiences as basis for evaluation and interpretation of the proposed design solution, can essentially impact the decisions made and the further development of the architectural design solution.

As a part of the framework, an ICT impact matrix is suggested (fig. 4) as a tool for summarizing and giving overview of the key points of an exploration (Moum, 2005a). The lines between the different levels and design aspects in the illustration, should rather be understood as a "translucent" screen between interdependent elements than fixed borders between rigid categories. A puzzle could probably be an appropriate metaphor to describe the complexity embedded in the matrix (fig. 5).

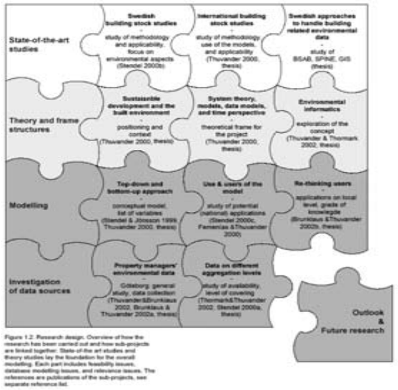


Figure 5. Puzzle (from: thesis Liane Thuvander 2002, p. 7)

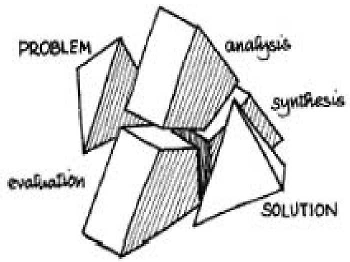
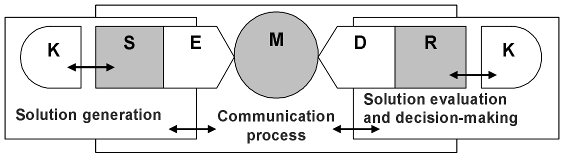


Figure 6: What is going on in the head of the designer? (from "How designers think - the design process demystified" Lawson, 1997, p.47)



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

Figure 7: Illustration of communication process.

THE FOUR DESIGN ASPECTS

The generation of design solutions. There has been a lot of effort to describe and explain the design process and the generation of design solutions since the early 1960s (Lundequist 1992b). The first generation design methodologists focus on the design process as something sequential and linear, was to be challenged. Lawson (1997) critically emphasizes that there is no clear distinction between problem and solution, analysis, syntheses or evaluation in the design process (Fig. 4). The design process is a simultaneous learning about the nature of the problem and the range of the possible solutions. The design problem is difficult to define and reveal, is multi-dimensional and interactive. The challenge for the designer is to understand what really constitutes the problem, to recognize hierarchical relationships, to combine and to integrate (Lawson 1997). The generation of design solutions is not reserved the individual. The importance of collaboration is growing. 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).

Communication. Schön's (1991) description of the design practice (e.g. sketching) as a conversation or reflective dialogue between the designer and the design situation or design issue, or what Kalay (2004) calls ideation or an intra-process role of communication represents one level. The dialogue between two individuals, the extra-process role of communication represents another. As illustrated in figure 7, 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). Generally, some of the knowledge playing a part within the design process is of tacit character. 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 1992a). Misunderstandings can occur when terms from one game are used within another. The language games are based on tacit rules embedded in the context, culture and way of life. A central part of the architect's competence is to understand the language games and to use terms in a meaningful way (Lundequist 1992a).

Evaluation of design solutions. The architectural design process is in addition to the measurable, quantitative and conscious based on the qualitative, intuitive and tacit (Kiviniemi 2004, Lawson 1997, Wikforss 2003). 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]. Lawson (1997) emphasizes that a crucial skill of the designer is to balance qualitative and quantitative aspects. Lawson (1997) relates the use of computer within the design process to several roles. The computer in a solution generation role actually designs for us. The computer in the solution evaluation role however, only responds to the design ideas of the designer, giving feedback on e.g. how it will work.

Decision-making. The generation and evaluation of design solutions, and the issue of communication, can be seen to establish the foundation of decision-making. The moments of decision-making on different levels are crucial for the development of design solutions and building projects, as they distinct impact on both process and product. A German PR slogan claims that "success is the sum of good decisions".

The application of the framework on the case-study, have similarity with the use of what Yin (2003) calls table shells (see quotation). The framework should support the defining of focus

Table shells. These are the outlines of a table, defining precisely the rows and columns of a data array - but in the absence of having the actual data. In this sense, the table shell indicates the data to be collected, and your job is to collect the data called forth by the table. Such table shells help in several ways. First, the table shells force you to identify exactly what data are being sought. Second, they ensure that parallel information will be collected at different sites where a multiple-case design is being used. Finally, the table shells aid in understanding what will be done with the data once they have been collected. (Yin, 2003, p. 75)

INTERVIEW TRANSCRIPTION AND EXPLORATION

Four interviews are carried out with architects involved in the hospital project. Originally, the intention was to transcript all four interviews. This was not possible within the time limits, thus the key points of two of the interviews can be found in handwritten notes. However, since the exploration focuses on the meaning and not on the use of words, these handwritten notes have been a sufficient basis for analysis, at least for the purpose of this report.

This report among others explores and presents the interview respondents "speculations" about the future. Such "speculations" can give an impression of the benefits and challenges users eventually can expect. At least, this reflecting regarding implications for the future, can be a good starting point for further discussions, although they probably cannot be counted as "scientific data".

The interview respondents are made anonymous in this report.

and the decision which persons to be interviewed, what questions to be asked, how to analyse and finally present the findings.

It could be tempting to order these four design process aspects sequential or chronological. At first the architect generates his idea, before he communicates it to e.g. a client, who after an evaluation of the design idea, makes his decision about further development of the design idea. However, such an approach would be a misleading simplification of the very complex field of design. The four aspects are highly interdependent and interconnected, and do in a dynamic and iterative interplay between all three levels, together form the process of design

2.3 Conducting the case-study

Yin (2003) recommends to use appropriate time on the preparation of a case study. For instance, a case study protocol should be established. Such a case study protocol as a guide for collecting the data has been made also for this case-study (appendix 2). Key elements of the protocol are for instance an overview of the project, field procedures and the case-study questions (both the research questions and the questions to be asked in the interviews).

To get an overview of the project and its context, information from different sources was studied. There is a huge amount of information about the AHUS project, since it is a public and one of the biggest projects built in Norway for the time being (2005). The main source for collecting "hard facts" about the project (size, time plans, strategies etc.) was the public website (www.nyeahus.no). In addition, records of different project presentations has been reviewed. Since the main focus of the case-study is to gain knowledge about the project processes, not about the product, other sources in addition to documents and records had to be consulted.

To collect information about some more "soft facts" (attitudes, experiences) about the project and especially regarding the impact of ICT, four key persons were interviewed. These persons are all architects, involved on different levels and with different tasks (presentation of respondents on page 15-16). Since the intention of this report is to give a rough and broad picture of how the use and implementation of IFC-based BIM impact on all levels of the architectural design process, rather than achieving converging lines of evidence, interview respondents were selected representing experiences perceived from different levels, views and positions within the front building project. The interview respondents' percipience of an event or situation can deviate from how something really happened. However, interviews could contribute with insight into not very visible and explicit processes and events.

"SOFT" DATA from interviews:

BIM motivation/aims
BIM experiences
BIM visions and future challenges

COMMENT TO LAYOUT

In comparison to papers for journals and conferences, where the layout is pre-defined, for this report it was an aim to use the possibility of the layout to support the "readability". The side column contains pictures, figures, references to theory, quotations, notes and comments, which are meant to supplement the main text.

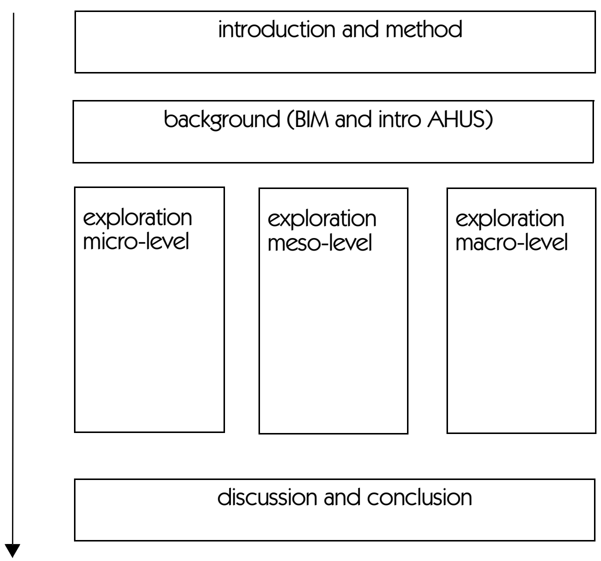


Figure 8: Structure of report

The case-study represents a "cut" of the running project (spring 2005). The respondents experiences, attitudes and expectations regarding what have been (past), what is (present) and what is going to be (future) are viewed from this "cut". Thus, the respondents were questioned about three issues regarding BIM use and implementation; motivation/aims, experiences and visions/future challenges. The framework was used as a guideline throughout the interview situations, which were open and not structured. Only some main points for defining questions were pre-defined. In a test-interview carried out before the case-study, it was made an attempt to use the ICT impact matrix as an interview guide. This did not work out well, since it was difficult to separate between the four design process aspects, especially regarding the partly unconscious cognitive processes on the micro-level. Therefore, in this case the framework was used to generate "orientation points" in a freer interview form.

2.4 Structure of report

The next section of this report will give an overview of recent research regarding 3D object models or BIM. What are the intentions and the challenges within resent research? Furthermore, the AHUS (the front building project) and the interview respondents will be briefly presented.

The main part of this report, the analysing and presenting of the case-study data, is divided into three parts, since the use and implementation of BIM in the AHUS project are explored due to each of the three hierarchical levels. As a "back drop" of the exploration of the empirical data within each level, some references to theory are included in the discussion. In the last part of the report (discussion and conclusions), an ICT impact matrix will summarize the key points of the exploration, and the adaptability of the framework on this case study will be discussed. Furthermore, some lessons learnt from the AHUS project, and the next steps and possible areas of further investigation regarding the relation between IFC-based BIM and the architect's work, and interaction with other participants in the architectural design process, will be discussed and suggested (Fig. 8).

3 BUILDING SMART WITH BIM?

3.1 IAI and the development of IFC

Parallel with the growth of several ICT vendors developing different software systems, incompatibility and system" lock ins" have become an increasing problem. There has not been possible to sufficient exchange files and information between different systems. Double work and the risk of losing information during the exchange of data are some of the unpleasant consequences. With the aim to ensure interoperability and efficient information exchange between different ICT systems, IAI (International Alliance of Interoperability) was founded in 1995. IAI is the key actor behind the development of IFC (Industry Foundation Classes), which shall ensure an "system-independent" exchange of information between all actors in the whole life cycle of the building (from briefing to maintenance of building).

Figure 9. The "IAI-logo" (from www.IAI-international.org).

IAI is an alliance of organizations within the construction and facilities management industries dedicated to improving processes within the industry through defining the use and sharing of information. Organizations within the alliance include architects, engineers, contractors, building owners, facility managers, manufacturers, software vendors, information providers, government agencies, research laboratories, universities and more (...) The International Alliance for Interoperability (IAI) was started by twelve companies that wanted to be able to work with each other's information without being concerned about the software that they or anyone else was using. They created a set of prototype software applications that were demonstrated at the A/E/C Systems '95 show in Atlanta, Georgia. These prototypes proved that interoperability was not just a dream; it could be made into reality. In September 1995, they opened up participation to AEC/FM companies worldwide and formed the IAI. (http://cig.bre.co.uk/iai_uk/new/index.jsp).

Improving communication, productivity, delivery time, cost, and quality throughout the whole building life cycle (...)Providing a universal basis for process improvement and information sharing in the construction and facilities management industries. (...) Building on the collective knowledge of the global construction and facilities management industries to define Industry Foundation Classes (www.iai-international.org).

The IAI specifies how the 'things' that could occur in a constructed facility (including real things such as doors, walls, fans, etc. and abstract concepts such as space, organization, process etc.) should be represented electronically. These specifications represent a data structure that can be shared between software applications (...) The classes defined by the IAI are termed 'Industry Foundation Classes' or IFCs. The reasons for this are: They are defined by the AEC/FM industry, They provide a foundation for shared information, They specify the classes of things in an agreed manner that enables the development of a common language for construction. (http://cig.bre.co.uk/iai_uk/new/index.jsp)

3.2 3D object models/BIM

With the development of IFC it will be possible for all building process actors to work with the same 3D object model. Today (end of 2005), the abbreviation BIM is more commonly used for this type of models. But what is BIM or 3D object models?

The following explanation attempts to give a general understanding and overview of the technologies. A specific technical description falls outside the scope of this report.

BIM is the abbreviation for Building Information Model, a computer model based on three-dimensional objects containing intelligent information about e.g. materials, qualities, prices etc. All building project information is gathered in this one model, and "traditional" drawings as plans, sections etc. can directly be generated from it. Thus, there are no parallel illustrations of building parts comprised on different drawings and documents. A change must be made only once; in the model. This can reduce one of the main sources of building site failures: inconsistency within the fragmented drawing and document material (Kiviniemi 2004, Wikforss 2003). When the defined BIM objects are based on IFC, this opens for powerful possibilities of interoperability. BIM data can be exchanged between all different systems, building process phases, actors and organisations. In a guest lecture on the Norwegian University of Science and Technology on the 28. october 2005, Bakkmoen (the chairman of the Norwegian IAI Chapter and involved in the development of the AHUS project) referred to several investigations of efficiency in the AEC industry, stating that between 15 - 30% of the total building costs can be related to failures, misunderstandings and bottlenecks in the build-

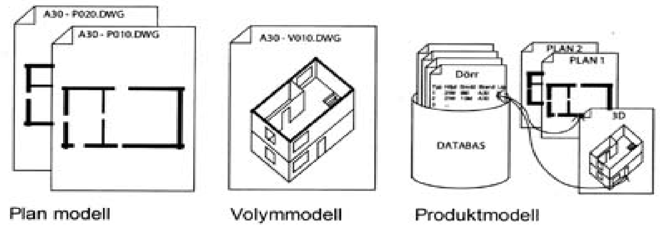


Figure 10. From 2D drawing to 3D object oriented modelling (from Wikforss, 2003, p.352)

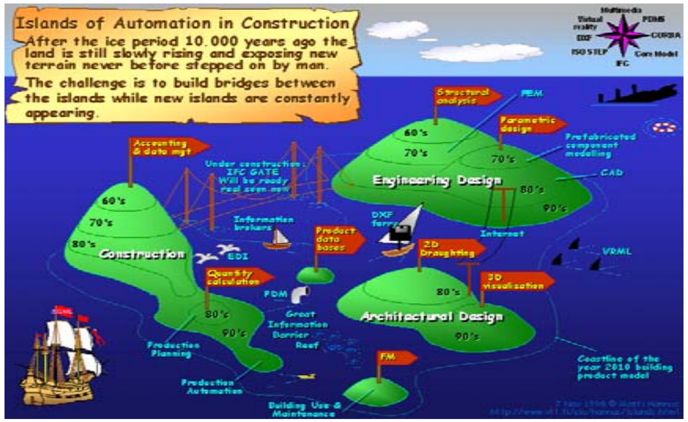


Figure 11. Islands of Automation in Construction (from http://cic.vvt.fi/hannus)

ing process. Same information must be drawn or described up to seven times, which makes it seven times more probably to make a failure. According to him, the use of IFC-based BIM could reduce the costs related to communication friction in a building project. The potential of BIM is illustrated in “Islands of Automatisation in Construction” (fig.11). A “landrising” can be achieved, where the fragmented situation (many small islands) develops, with the help of for instance BIM, to one big island.

Throughout the whole life-cycle of the building, and through the many actors contributing, with the time the BIM will contain a huge amount of information. Both the limited capacity of human ability to absorb information and the capacity of the computers, triggers some recent research.

For instance the development of different viewer technologies. A view shows a selected amount of information. Within the AHUS project, a view represents a physical limitation of the model, shown as a drawing (of e.g. one building floor). Another approach is to limit the information through a thematic focus (the architect’s view, the contractors view etc.). And a third approach and possibility is to use the viewer technology to make more efficient walk-throughs. The computer does in such a case know what it have to build up when the person “looks around the corner” (respondent C).

Finally, here another glance into some of the research going on in the moment (summer 2005) regarding BIM. On the CIB W78 conference on “Information Technology in Construction” (Dresden, Germany, July 2005), one of the workshops discusses the development of multiple product models (Kiviniemi & Haymaker, 2005, p.35). *”Although the IFC model specification covers a substantial part of the required information, AEC projects still have encountered many problems putting this model into practice. AEC professionals still find it difficult to have dynamic, lossless, truly effective data flow amongst the different participants and applications. It is obvious that file based data exchange alone is not a feasible solution; some other solution for integrating project information is necessary”* (Kiviniemi & Haymaker, 2005, p.35). Kiviniemi suggests to break the one big building information model into 4 main types of models (requirements models, design models, construction models, maintenance models) is suggested. This requires a standard way to link the objects in different models to each other, which could become one of the challenges in further research (of VVT/Finland and CIFE/Stanford).

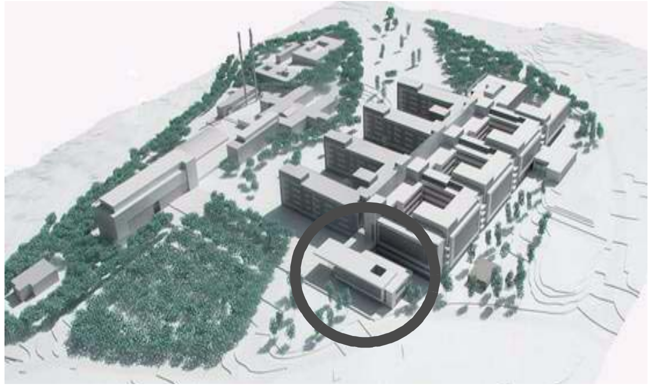


Figure 12: "Nye AHUS" (Courtesy: C.F. Møller Architects).

AHUS KEY DATES:

Total floor space whole project 116.000 m2 (new buildings)
Total floor space front building 2.500 m2
Architectural competition 2000
Final project outline completed 2003
Full operation autumn 2008

Figure 13: The front building (Courtesy: C.F. Møller Architects)

4 The AHUS project and R&D

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 (fig. 12). 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 (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. The case-study and this report focuses on this front building part (2.500m2), which contains the main entrance, an auditorium and a canteen (fig. 13). 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. The case-study represents a "cut" of the running project, made at the end of the design process, shortly before the front building project is going to be handed over to the contractors and the production of the building starts (fig. 14). The front building has its own building contractor. However, the technical contractors are the same for the whole AHUS complex.

Some "specialities" of this project should be mentioned for better understanding the processes and strategies. At first, all key participants of the total building project work collocated directly beside the building site. Secondly, this is a huge project, demanding years of planning and production. The size of the project and the time issue make it possible to establish long term strategies, for instance strategies regarding BIM. Thirdly, the future users play a very central and influential role in the design process. Fourth, the need for saving cost and space resulted in an extensive "re-design" of the whole project in 2003 within very limited time frames (1/2 year). And finally, in this project the client organization carries the juridical responsibility for the planning, also including the responsibility for project management.

4.1 The four ICT cornerstones and the R&D project

There are four ICT cornerstones in the front building project. Firstly, the 3D object model (AutoCad ADT 2004). This report focuses mainly on the implementation and use of this 3D

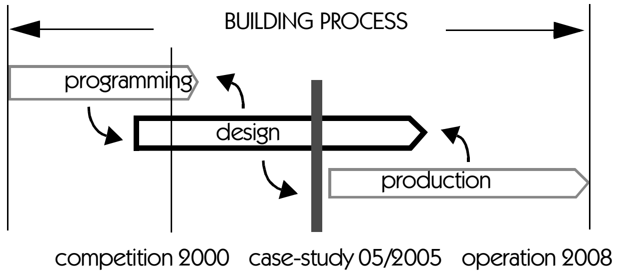


Figure 14. Case study "cut"

Given the huge size and complexity of the project (see Figure 6), 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. To date, over 3000 drawings have been derived from the model created in ADT. IFC was again a critical component of this project, enabling the model to be used for consistency checks, quantity takeoffs, clash detection, energy analysis, fire egress and environmental hazard studies, 4D visualization, and checking the design for the satisfaction of programming requirements. Needless to say, the Akershus University Hospital project is regarded as a front runner in Norway in the use of IFC-based BIM. (www.aecbytes.com/feature/norway_prefab.htm, 28.02.2005).

Figure 15. All the key participants in the AHUS project work collocated directly beside the building site (author's photo).

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. 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.

Three IFC R&D projects are going to be and partly are implemented and tested within the planning of the front building (fig. 16). 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. At the time of the case study, this project has partly been implemented. The last project is to transfer object information to Facilities Management (FM) systems (Bakkmoen, BuildingSMART conference in Oslo, 31.05.-01.06.2005). Against the original intention comprising both architects and consultants, only the architect work directly with the 3D object model (at the time the interviews were carried out). In close future every participant in the architectural team should be able to enjoy the benefits of this "merging" of different technologies. As a part of the R&D project, the next step is to test the potential of interoperability; all central actors in the building process (consultants and building contractors) shall start implementing and using the front building BIM during autumn 2005.

4.2 Introducing the interview respondents

All four persons interviewed are architects, involved with different 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).

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.

Figure 16. Three R&D projects (Courtesy: C.F. Møller Architects).

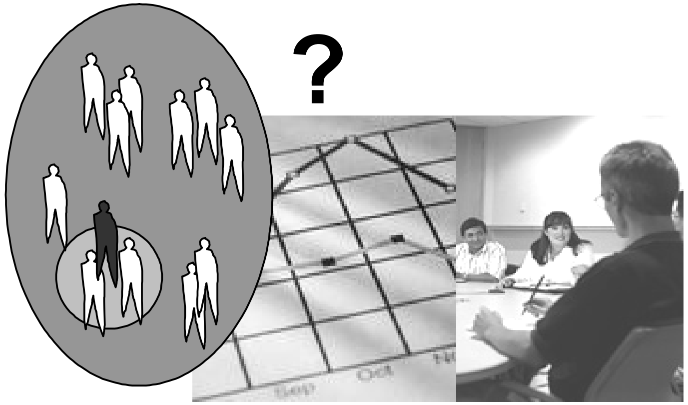


Figure 17. How do ICT impact the macro-level?

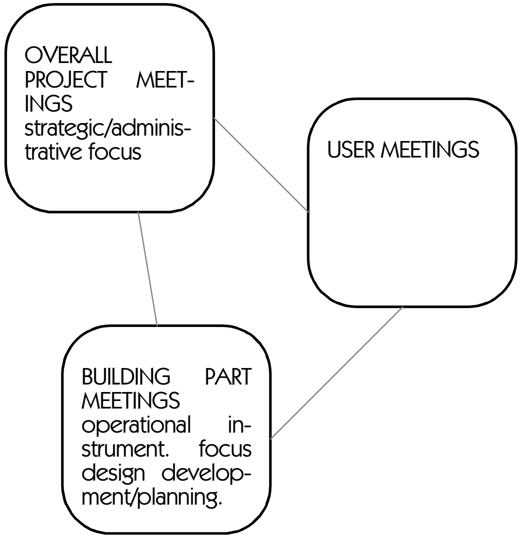


Figure 18. The three main fora for communication, evaluation and decision-making

5 AHUS: USE AND IMPLEMENTATION OF BIM ON MACRO-LEVEL

The macro-level comprises processes and actors on overall project level. At the time of the case-study, the client organization, the users and the design team are playing the main roles in the interview respondents' descriptions.

5.1 Processes and routines

On the macro-level in this project, most processes are formalized and shall involve the client organization. There are established three main fora for communication, evaluation and decision-making regarding design and development; the building part meetings, the user meetings and the total project meetings. These meetings find place regularly every 1-2 weeks (fig. 18).

The **building part meeting** is the operational instrument of each of the five main AHUS building parts. Every presentation, evaluation and 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. The **total project meetings** focus 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 during autumn 2004 (**user meetings**).

5.2 Strategies and motivations behind the BIM implementation and use

On overall level there are three main motivations behind the implementation of IFC-based BIM.

At first, the overall motivation is the learning effect; to collect experiences and build up competence around the implementation and use of this still quite new and untested technology within the AEC industry. Such knowledge could give the companies involved a front position on the AEC market. Both the client organization and the architectural company are convinced that IFC-based BIM within few years will become the major planning tool in building projects.

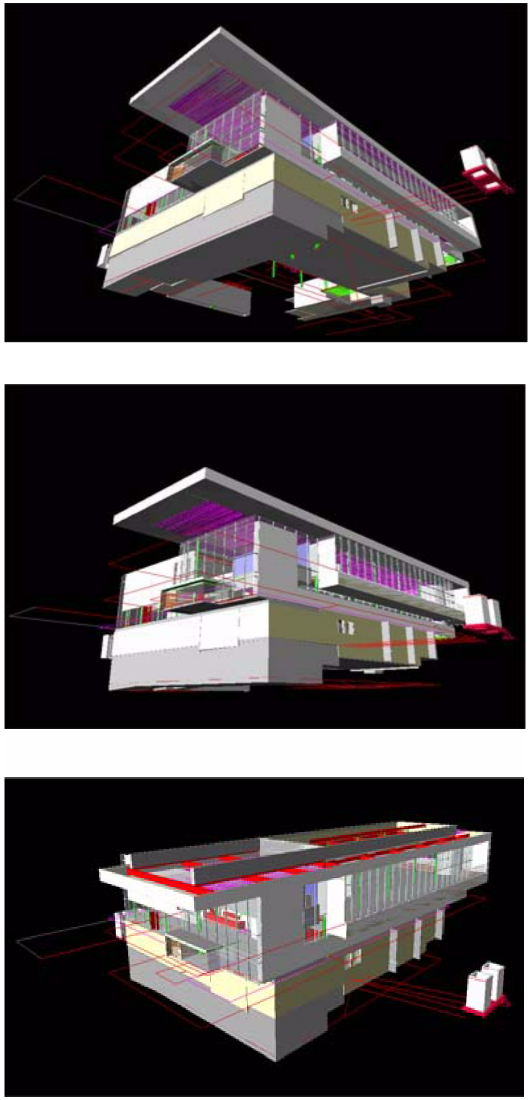


Figure 19. Three views of the front building (Courtesy: C.F. Møller Architects).

Secondly, the possibility of IFC-based BIM to support interoperability; an uncomplicated, transparent and efficient exchange of information between the different actors and systems involved in the AHUS project, is another essential motivation behind the implementation.

And thirdly, as Bakkmoen emphasized in a guest lecture at NTNU (28 of October 2005), the potential of BIM to control and ensure consistency and quality of project material, is viewed as a crucial benefit. All information shall be found on only one place (in the model), everybody shall have access to this information, and know that it is updated and correct. In this project, the development and testing of the quality assurance abilities of BIM, is more important than exploring and developing the possibilities of visualization.

Both the aspects of interoperability and quality assurance could reduce failures and misunderstandings in the whole building process, thus decreasing building time and costs.

5.3 Experiences from implementation and use of BIM - some examples

Generally, the 3D object model is to a limited degree used directly in the formal meetings. And to directly use BIM for real-time simulations, have until now not been an issue. The implemented IFC version does not support rendering of the objects. Thus, it is not possible to generate realistic visualization 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. Regarding this potential of easy simulation of technical aspects, respondent B warns against a biased focus in the decision-making process, and eventually a misbalance in the relationship between quantitative and qualitative aspects.

Since the model is heavy to use and change in this late stage of design, to work directly in the 3D environment in meeting situations demonstrating e.g. "live" simulations seems to remain being difficult. For being an effective support for real-time evaluation of alternatives and solutions, more rapid simulations or visualization of results are required (respondent B).

The size of the BIM files is huge, and computer capacity was an underestimated issue in the moment the decisions were made regarding file structures. It is partly very time-consuming for the computer to build up the model. With this experience, another and improved file structure could be adapted to future projects. Still, within this project the use of physical views or cut-offs make the 3D object model easier accessible. The BIM files are for the mo-

Figure 20. The physical model is still supporting the design process (author's photo).

"WORKING" VS. "PRESETING" MEETING FOCUS

Based on my own experience, in the formal meetings with the clients and the users, the architect often focuses on the issues of "selling" his design idea. The design idea must be visualized and presented in a convincing way, in order to impact on the client's decision. Much effort is therefore put in the production of perfect presentations in advance. The meetings with the consultants mostly have another setting. Here the focus are on coordination, and on the common effort to generate and develop design solutions. The setting is rather of a "working" than "presenting" character, perhaps encouraging more lively and freer discussions and dialogues.

ment maintained by the architect, and are part of the architects' own server. However, a common and shared future model should only be available from a common and "independent" server.

In the **overall project meetings**, every participant brings his own laptop, which can be connected to the whole project database. In addition, cut-offs from the model can be projected on the wall with a beamer.

Once a week cut-offs (2D drawings and views generated from the BIM) are made available through the document database (ProArc). Thus every relevant and up to date drawing or document is easy and fast accessible. Every participant in the project have access to updated project material, any time. As long as e.g. the client or the consultants regularly use this database to get the updated material, there is no risk to use obsolete project material as background for planning or decisions. This requires a certain discipline, since this means a change from the traditional "push" (passive receiving) to "pull" (active collecting) of information.

From the client's view (respondent D) ICT and BIM offer good possibilities for better to could follow, control and evaluate the development of the planning. Cut-offs and the viewer technology make the access to the 3D object model easy. Still, 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 architects or consultants.

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 paralysed the meeting participants and made it difficult for them to suggest changes.

A huge benefit of BIM the AHUS team experienced in the negotiations with the users. 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 **user meetings**. All these drawings (sections, plans and elevations) were generated directly from the 3D model, thus saving lots of time. In the user meetings, the architects sometimes, on a laptop, made changes in the model simultaneously with the decisions made.

In the **building part meetings**, the evaluation and decision-making material are 2D paper drawings (scale 1:200), normally printed out in advance. Pen, sketch paper and a physical 3D model are the main tools applied to mediate discussions and generate solutions in the meeting situation.

5.4 Potential and challenges for the future

What are the interview respondents attitudes about future BIM implications and potential on the macro-level, based on their experiences from the AHUS-project?

Re-thinking processes: interoperability, shared responsibility and transparency
A vision behind the development of BIM is to achieve a "land-raising" in the AEC industry and to reduce the borders between planning phases and roles which lead to communication friction, delays and misunderstandings. IFC-based BIM supports interoperability; all participants can work with the same model throughout the whole life cycle of the project. Such a blurring of the traditional borders and definitions, inherits several benefits, but also challenges.

BLURRING OF BORDERS BETWEEN DESIGN PHASES AND ROLES

Through the use of ICT, processes can be accelerated and traditional stages can overlap. Already at a very early stage of the design process, traditionally later participants can get access to e.g. the 3D product model. Contractors, specialists and manufacturer can contribute with knowledge that helps to reduce uncertainty early in the design process. The "wheel of dominance" (Gray and Hughes 2001), illustrating which participants dominating the different planning stages of the design process, could change. But the overlap between earlier and later planning stages can perhaps contribute with constraints that increase the complexity of the solution and problem finding, making it more difficult to focus on the right aspects to the right time. The Figure "Island of Automation in Construction" (http://cic.vvt.fi/hannus) illustrates the current construction sector as many separate islands in a big construction sector ocean. The ICT, in this case the product model, leads to a "land raising", the many small islands transform to one big island. Thus, the traditional boarders between roles or planning stages blur and change. The separate bits of the planning process are melting and compressed to a conglomerate. The understanding of these different changes is central. ICT impacts on the definition of work processes, roles and responsibility. How can such changes be handled within contract and procurement models? What about the traditional role and contribution of the architect?

In discussions about the implementation of IFC-based BIM, the emerging challenges linked to the issues of responsibility and contracts are "hot" topics. However, these challenges can, according to some of the respondents also be turned into benefits.

When all actors in the building process contributes to the same 3D object model, it could become easier to formulate and work toward common goals. A shared feeling of ownership can be built up, since all participants would carry their part of the responsibility for a well-working 3D object model. It can become easier for participants to share information. More efficient information delivery, transparency and less mistrust could be positive side effects. To integrate contractors early in the design process increases the contact area between the planners and the producers (between the design team and the contractors and craftsmen on the building site). This issue can lead to a better understanding of each others problems and intentions, thus some of the misunderstandings and conflicts often seen in the transition between design and production can be reduced (in the information meeting regarding BIM and tendering in the AHUS project, 30 contractors participated, which indicates a distinct interest in the contractor community).

Today, the negotiation of contracts and fees are experience based, and the contracts are not always optimal suited to the actual needs in a specific project. The blurring of borders be-

Figure 21. Live demonstration of interoperability on the international Building Smart Conference in Oslo June 2005 (from www.IAI.no).

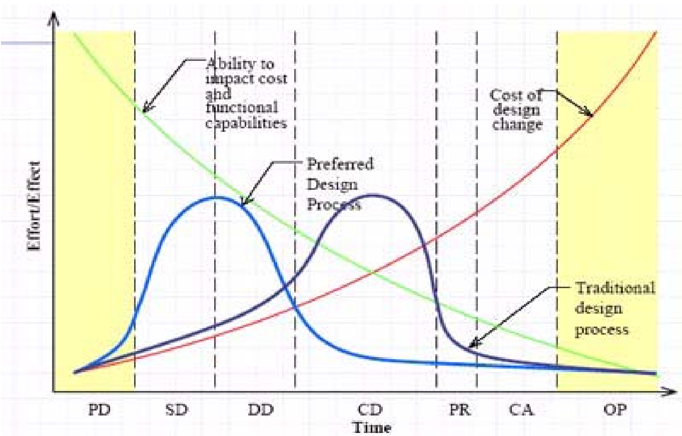


Figure 22. Preferred design process or "front-loaded" process. Presented on the international Building Smart Conference in Oslo June 2005, of Norbert Young, FAIA.

tween actors and project phases requires eventually a better understanding of the processes and the relationships between the actors. And an increasing consciousness could make it easier to deviate from classical contract making and lead to contracts and project organizations better suited to meet the special needs of a building project. Generally, as a consequence and potential of IFC-based BIM implementation, new types of contracts and partnerships can emerge (respondent C).

Professional clients, who develop and produce buildings for rent or sale, would probably appreciate a "merged" design process, eventually even a "merged" building process (parallel phases). However, a strong user participation makes it difficult to reduce the planning time and to eliminate borders between traditional design phases. The user participation can eventually be seen as a major reason for keeping, maintaining and documenting the traditional phases (respondent C).

Respondent C emphasizes the potential of the object based planning seen from a life-cycle point of view. According to him, generic objects from pre-defined object libraries could be the "building stones" of the design in the architectural design process. In the moment the project gets handed over to the contractor, he would replace the generic objects with his specific objects. In course of the building process also FM oriented information could be embedded in the intelligent objects. The use of genius pre-defined objects could reduce the planning time normally needed for detailing, and support the idea of a front-loaded building process (fig. 22). The pre-defined objects can support the capturing of (explicit) knowledge, since they inherit "reusable" information collected through the whole life-cycle of one or more buildings. However, libraries of pre-defined objects still do not exist, but the transaction of object information between the actors shall be tested out in the front building project.

To use IFC makes it possible to easy connect several programmes for achieving efficient fusions of different technologies. The four R&D projects are based on this thought (e.g. the connecting the a room database with the BIM). Since IFC allows a communication between systems independent of provider and vendor, the growth of more "specialized" systems better suited to the many needs in the building process can be encouraged. Also the previous investment risk for a company regarding product lock-ins and incompatibility between different systems and versions can be limited (respondent C).

The power of simulation and visualization

The potential of visualization Bakkmoen in his lecture on NTNU 28.10.2005 described as a "nice side-effect" of the tool. Although the visualization of design ideas was no important

THE CHALLENGE OF MAKING DECISIONS

Seemingly, it is easier to make a decision if every uncertainty is eliminated. ICT offers the possibility of storing and capturing previous project experiences, as well as reusing and modifying these experiences from previous building projects within new ones. This is an often-used method to reduce the high degree of uncertainty in the early design phases, and to better support the estimate of cost and time factors before the concept has reached the required level of precision. Lundequist (Wikforss 2003) sees a possible conflict between the established experience and the will to innovation. The knowledge reservoir is based on tested experiences, repertoires and routines. The inherent capabilities of ICT when it comes to knowledge storage and reuse could lead to a misbalance between previous knowledge and innovation in the creative process. ICT offers the possibility to simulate and visualize the building in a nearly realistic way, to make information available whenever wanted and to make processes transparent and "reusable". However, the nature of the design process is also qualitative, subjective and highly uncertain. As "the feeling of" is a part of the design process, intuition and the acceptance of risks are also part of the decision process. According to Griffith (2003) ICT supports the declarative nature of explicit knowledge. Possibly the analytic, quantitative and explicit nature of the computer could disturb the balance between the qualitative and quantitative, tacit and explicit, intuitive and conscious. This could potentially lead to a bias within evaluation and decision-making, having negative effects on the total building quality.

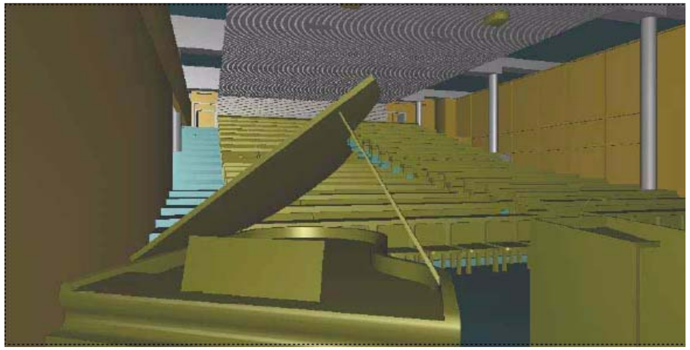


Figure 23. Rough visualization of auditorium directly from walk-through in IFC file by using Solibri (Courtesy: C.F. Møller Architects)

issue of the BIM implementation and use in the AHUS project, BIM still represents a huge potential also on this field (respondent B). A very immature version of the 3D model was in some cases used to visualize a problem not easy to understand for the client or user by only looking at the plan or the section. The visualization of the problem helped verifying the advice of the architect, and could thus perhaps help building up trust. For the case the IFC-based BIM applied to this project had been more complete, intuitive, parametric and easier to handle, the model could have supported the architect in the "selling" and verifying of his ideas better than the traditional drawings did. The visualization potential of BIM can help making the aesthetic and qualitative issues more visible, thus increasing the understanding of the more subjective and less measurable intentions of the architect. The intentions and aims of the architect are often not easy to measure and quantify. The fact that a building can fall down or that the ventilation does not sufficiently supply fresh air, are very cogent arguments compared to the fact that a building could get "ugly". Respondent B regards this issue as very problematic in decision-making processes regarding e.g. cost saving matters.

According to respondent C, in the AHUS project, they are only a very small step from utilizing the power of visualization and simulation. The next IFC version will be able to support rendering, and when the objects get surface information as a part of their definition, complete 3D visualization can easily be generated from the 3D object model. and "we can walk with the users into the (virtual) rooms". With pre-defined objects offered from suppliers containing correct information about properties and surfaces, the e.g. mechanical consultant could have made his quantity take-off directly based on the 3D model. Simulation of fire and escape scenarios, daylight simulations etc. could easily have been carried out. Today for instance materials are tested in a physical "sample room". In the case complete objects are available and applied, a virtual sample room could be established, for evaluating ceiling types, flooring materials etc. Some of these visions shall be tested out in the further planning of the front building. Dependent on the further development of the model server technology, the visions could become reality within 2006 (respondent C). Today, other programmes are used to generate walk-throughs etc. (e.g. Solibri, fig. 23).

It would be nice to put the virtual glove and glasses on, take the client by the hand and walk together with him through the building and decide which chairs shall be chosen for the virtual canteen, and how the acoustic should be handled in a specific room (...) they hear an echo, and through changing the material in real-time, they together can evaluate the acoustic effect in the virtual room. That would be ok. Then we get a more experience-based understanding of the factors of success and the fundament of decision-making (respondent B, authors's free translation to english).

THREATS AND OPPORTUNITIES

Gray and Hughes (2001) describes in their book “Building Design Management” (p. 2) the development from the yesterdays “Architects hold the dominant position of authority in the design process” to the today’s “Architects are losing position and authority within the design team to managers specialist designers, services and other engineers”.

On the international IAI (International Alliance of Interoperability) conference “BuildingSMART” in Oslo June 2005, one of the key-themes was the ICT (especially IFC-based BIM) related paradigm shift within the AEC industry and which threats and opportunities this shift could inherit for the architect.

EXAMPLES POSSIBLE AREAS OF FURTHER INVESTIGATION:

- contract and responsibilities
- do the use of BIM lead to more efficiency (drawing production)?
- do the use of BIM lead to a more conscious attitude to roles and processes - hence to indirectly improve processes?
- BIM potential for the architect regarding work and/or position in project
- re-use of knowledge vs. innovation
- front-loaded (“merged”) design process vs. the need for time for “maturation” and the challenge of info overload

BIM and the future contribution of the architect

A frequent attitude and opinion among architects, and an issue also described in some literature (Gray & Hughes 2001, Emmitt 1999), is the diminishing standing and influence of the architect in the AEC industry. According to Emmitt (1999), the traditional leadership role of the architect within management partly has passed to other management oriented professions. An interesting question is to which extent ICT and IFC-based BIM can support the “strengthening” of the architects position in building projects.

Respondent B and C both emphasizes the importance for the architect to be a in a front position in the development of IFC and BIM. Architects could be suitable for taking the powerful position of the “information distributer” in a BIM-based building project and the architect should be the one claiming his ownership to the model. In the AHUS project it seems that the architects have a central and influential position. Some reasons for this can be the architects’ key role in the testing and development of IFC-based BIM, and the client organization’s interest and enthusiasm regarding the R&D project.

Especially the architectural companies can play an important part in this development, as they can offer services based on a broad range of expertise, object libraries etc. In the AHUS project, the quantity-surveyor played a crucial part in the development of the hospital plans (even more crucial role as the architect). This competence, however, was a part of the service of the architectural team (respondent C).

A last issue to be mentioned here, is the architects challenge to utilize the potential of ICT without generating too big expectations of the other actors. A negative spin-off effect of more powerful tools could be the client’s increasing expectations and requirements to the design services, regarding the time needed, the level of precision and certainty etc. (respondent B).

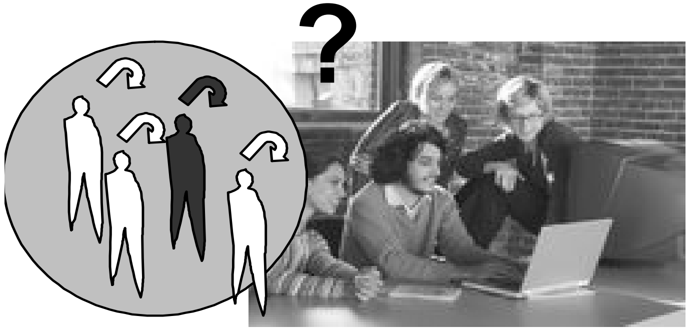


Figure 24. How do ICT impact the meso-level?

THE CHALLENGE OF COLLABORATION

The importance of collaboration is growing, as globalisation and increasingly complex technique and products require more teamwork, and the complexity of the problem becomes unmanageable for one individual. The focus changes from the individual to the collaborative design process, and introduces a new dimension in the idea finding process: the interaction between the individual and the group (Lawson 1997). Participants with different backgrounds, preferences and experiences try to achieve a common goal. Barrow (2000) introduces the term Cybernetic Architecture: "... cybernetic architecture is a return to the pre-Renaissance comprehensive integrative vision of architecture as design and building (...) the emerging architecture process is a 'collective' body of knowledge and speciality skills found in many individuals" (Barrow 2000, pp 272-273). 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 and Weisband 2003). Within the design team, this is mostly not the case. Failed communication can cause conflicts and misunderstandings, negatively influencing the building project if not recognized and solved at an early stage. The issue of communication is a challenging aspect in the design process, since the building process actors come from different companies and organizations, have different experiences and frames of reference, they have often never worked together before and will perhaps never work together again.

6 AHUS: USE AND IMPLEMENTATION OF BIM ON MESO-LEVEL

On the meso-level, the case study focuses on the interaction between the architects and the other consultants in the architectural design process.

6.1 Processes and routines on meso-level

Although every communication between the architects and the other consultants in the AHUS project formally must 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 a direct, uncomplicated and rapid way. If important issues and problems are recognized, the decisions regarding further development have to be made on a formal (macro-)level including the client and the users (respondent B).

6.2 Strategies and motivations behind the BIM implementation and use

One of the IAI-aims behind the development of IFC is to frontier interoperability. The front building architectural team have built up a BIM based on IFC, enabling interoperability. As a next step (part of the R&D program), all actors of the design team are supposed to work with this one model (during autumn/winter 2005).

6.3 Experiences from implementation and use of BIM - some examples

However, at the time this case-study was carried out, only the architects worked directly with the 3D object model. The other consultants used the 2D cut-offs and dwg-files as their base of planning. The architects formally made these cut-offs and the dwg-files accessible once a week in the document database (ProArc). Informally, as a short-cut to this procedure, participants exchanged project material, for instance tentative and informal drawings, by using e-mail (respondent A). Because of the collocated situation and the fact that only the architects worked directly with the IFC-based BIM, this model only to a very limited degree was used on the meso-level.

The building elements received from the consultants, for instance columns and slabs from the structural engineers, the architect at this time "transformed" to fit into the 3D object

"The designer has a prescriptive rather than descriptive job. Unlike scientists who describe how the world is, designers suggests how it might be (…)This is obviously a rather hazardous business, and carries with it at least two ways of being unpopular. First, the new often seems strange and therefore to some people at least unsettling and threatening. Second, of course, the designer can turn out to be wrong about the future. It is very easy with that wonderful benefit of hindsight to see building failures" (Lawson, 1997, p. 113).

DIFFERENT WORKING CULTURES?

Regarding the different traditions of design development, I would like to give an example from another project (own experience). In this project, architects and consultants were employees in the same company, and worked in a collocated situation based on frequent face to face contact. A challenge in the collaboration between the architect and the consultants was the exchange of mutual necessary informations. Following situation can illustrate this difficulty. The client requires a conceptual solution of clima/energy aspects of the building. The architect, which is the responsible design manager in the project, asks one of his consultants whether the capacity of the floor heating maintains the requirements to room temperatures in a huge meeting hall. The consultant must then estimate the capacity of this system, and he involves a supplier of a specific floor heating system. This supplier needs detailed information to make his estimate, a time consuming service based on his goodwill to deliver this information for free (thus, the consultant attempts to avoid a situation, where he must ask the supplier to carry out this estimate more than once). The consultant contacts the architect, and requires more detailed and final defined information about e.g. the placing of floor joints and the properties of the flooring material. The architect have obvious problems of giving the consultant this information. The client still has not given green light for the architect's suggestion of applying natural stone flooring material. To decide the sizes and format of the stones as basis for deciding the positions of floor joints, would be the next step. The architect does not understand why there is not possible to make a rapid and rough estimate based on sketches, the consultant does not understand why the architect cannot give information, which will not change again within short time. This situation develops to become a bottleneck in the design development and decision-making process.

model. Since the architects themselves generate the model objects from other consultants' elements, they have, according to respondent B, better control of the consistency between e.g. architectural and structural elements.

The everyday informal communication within the design team is mostly based on a face-to-face situation. In the informal meetings between the architect and the consultants, they use the "traditional" tools of design, as pen and sketch paper, and physical models, to generate and evaluate design solutions. According to respondent A, she sees no immediate need for using computer generated 3D visualization in such meetings, since all participants involved in the front building design team are well experienced and used to "think in 3D". Although, for the case the discussion partner does not have this experience and understanding, or alternative solutions should be tested directly in the meeting situation, a more intuitive and "easy-to-handle" version of BIM could become a valuable support (respondent A)

6.4 Potential and challenges for the future

Challenge of different "working cultures"
The vision of interoperability inherit several challenges regarding the "merging" of architects' and consultants' efforts and contributions to one shared 3D object model. How to define the borderlines between responsibilities and services in contracts and in the daily work is an often discussed and questioned issue also on this level. To decide how to handle and divide the model requires coordination and an agreement about processes and systems (respondent B).

Respondent C points on another, more indefinable, challenge behind the vision of interoperability; the issue of different working cultures. The consultants' way to develop and produce project material seems to be based on other traditions and working methods than the architect's way to develop design solutions. The architect produce drawings/models very early in the process. The architect's models and drawings change frequently throughout the design process, as the design solution develops and step-by-step gets more precise. The consultants seem to work toward the attitude that drawings etc. (ideally) should be produced only once. For them, to change project material frequently, leads to seemingly unacceptable cost- and time consuming processes.

The architect as the only master of design?
Respondent B describes following scenario which could be enabled by the development of advanced simulation systems within BIM. Computer programmes which simulate for instance structural loads or ventilation issues, could eventually make the traditional services of

the consultants redundant (also an issue in the lecture of Bakkmoen, NTNU 28.10.2005). Respondent B portrays a situation where the architect, supported by powerful simulation tools, can be able to take over all building design services, included the services of the consultants. The role of e.g. a structural engineer could in such a scenario change from being a consultant to become a "verifier", employed by the architect.

THE ONLY MASTER OF DESIGN

However, such a scenario implies and requires an architect role based on a very broad base of knowledge base. Although the technical consultants could face such a situation in the future, a critical question would be whether the client automatically and necessarily sees the architect as the right person for the described key position. Thus, the future of the architect position in a building project will further depend on the profession's and the architectural firm's ability to convince the client about the importance of the architect's contribution in a building process. ICT could play an essential role in the "battle fight" about leading positions in the AEC industry

EXAMPLES POSSIBLE AREAS OF FURTHER INVESTIGATION:

- different working cultures
- responsibilities and contract
- do the use of BIM lead to more efficiency on the meso-level?
- BIM potential for the architect regarding work and/or position in project?

7 AHUS: USE AND IMPLEMENTATION OF BIM ON MICRO-LEVEL

The micro-level comprises cognitive and individual processes, and is here illustrated by the architect's experiences and attitudes from the BIM user's point of view, regarding both design development and production of project material (drawings, models, descriptions etc.).

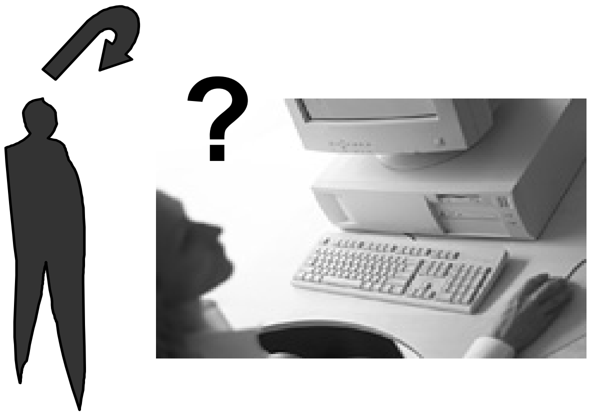


Figure 25. How do ICT impact on micro-level?

7.1 Processes and routines on micro-level

As the interviews were carried out, the design of the main concept behind the front building was completed and all major decisions about the design were made. Thus, the main design task at the time of the case study was to "translate" the overall design concept into buildable and specific solutions and details, considering several requirements regarding legislation, environment etc. As a consequence, the collaboration with consultants, users and client, and the coordination of efforts, were crucial tasks of the architects. Before taking part in formal or informal meetings, the architects had to use time and effort to develop and prepare solutions as basis for evaluation and decision-making. In addition, the production of the building project material was crucial at the time of the interviews, since the "handing over" deadline regarding contracting and the involvement of the building contractors was close (summer 2005).

Figure 26. The work space environment of the AHUS architect (author's photo)

7.2 Visions and motivations behind the BIM implementation and use

The potential of BIM regarding the (visual) control and assurance of consistency and quality of project material, was described as a major motivation behind the implementation on macro-level. This is of course also an important issue for the individual user of the tools, as the other macro-level visions are. Both respondent B and C emphasized the importance of communicating the overall benefits of using BIM to the everyday users, since the use of BIM in several cases leads to more work for the individual. The visions and expected benefits defined on the macro-level, are not necessarily perceived as such for the every day user of BIM.

Every architect working with the AHUS project shall be able to operate the ICT tools implemented in the different project parts, a division between architectural- and "technical drawer" tasks is not wanted. There are offered courses and manuals for learning and updating knowledge about continuously and rapidly developing software.

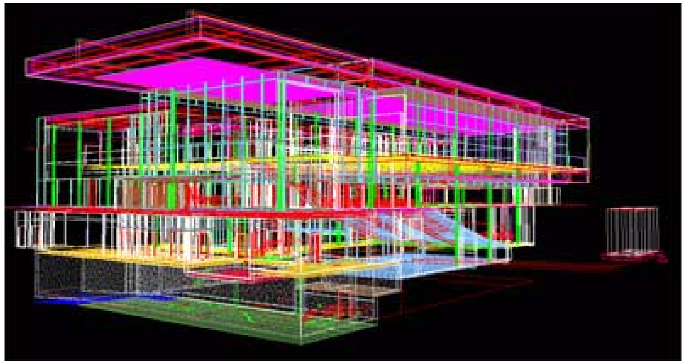


Figure 27. The aim is to build up a well-working and IFC based BIM of the front building (Courtesy: C.F. Møller Architects).

CAD = COMPUTER AIDED DRAFTING?

The generation of design solutions is still perhaps the area, in which the ICT has gained less foothold (Lawson 2005, Lawson 1997). The CAD (Computer Aided Design) systems used within the design process, supports drafting and modelling rather than special design attributes and analytical capabilities and have not changed the task of drafting or modelling (Kalay 2004). Designer skills such as intuition and the "feeling-of" are difficult to describe and map, and until now the computer has been unable to copy these parts of the human intelligence. In addition, the design process is still not fully understood; the human brain will for the next time probably remain the main media of the creative process.

JUGGLING WITH SEVERAL BALLS

An important skill of the designer is to juggle with several ideas at the same time, without forcing a premature precision or decision (Lawson 1997). Does the use of ICT force too early decisions and generate artificial constraints? Is there a limit of time compression within the architectural design process and decision-making? Also Wikforss (2003) emphasizes the importance of enough time for maturing in the planning- and decision process, and that there is enough time to reflect and understand the consequences of different solutions and decisions. He emphasizes that ICT tools, e.g. the 3D product model, must allow a step-by-step precision.

The front building team aims to establish a 3D object model that can become a sufficient and well-working basis for achieving the aims on macro-level. According to respondent C, another vision on this level, is not only to implement a new tool, but to implement a new way of working and thinking. The architect shall not only model, but also think, object-oriented.

7.3 Experiences from implementation and use of BIM- some examples

BIM and design generation

The "traditional" design tools as pen, paper and physical models are still of major importance for the individual architect in the front building team. According to respondent A, she first makes some rough sketches with pen and paper, before she transforms the idea into computer generated line-based 2D drawings. The computer offers, with its accuracy, an early "test" of the design idea's feasibility, which she perceives as a distinct benefit of the tool. The transformation of the 2D lines into 3D objects is made later, which partly results in a 3D model not completely based on objects.

Respondent A expresses the concern 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. In the traditional "2D process", the designer generates several sets of drawings with increasing precision and scale. She further questions whether this traditional step-by-step process is an important element for the "maturation" of design ideas.

Also respondent B only to a limited degree uses the 3D object model when he generates and visualizes design solutions. However, as a support to achieve a visual control of very complex situations, he in some cases models directly in the BIM (e.g. visualization of glass roof construction of main traffic area). But this is rather an exception, since such requires too much effort and time resources to be used frequently. Both respondent A and B see the lack of time resources and the "heavy" operating of the 3D object model as the main barrier of using the model directly for visualization in this specific project.

Object-oriented working

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 than 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, since AHUS is the first major project where the architectural company has implemented an IFC-based BIM, and BIM generally is a new CAD technology in the norwegian AEC industry, there are no pre-defined li-

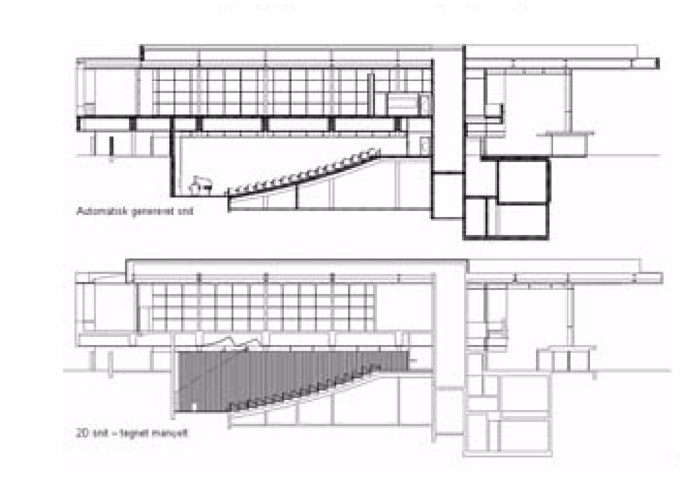


Figure 28. 2D sections generated from the IFC-based BIM.

> THE DANGER OF INFORMATION OVERLOAD
>
> The network technologies make an easy and fast access to and distribution of information possible. This has been a huge benefit within the building project and has, according to Schwagerl (Schwagerl 2004), contributed more to accelerate the design processes than the CAD tools. The use of data bases, network technologies etc. supports the distribution speed of information required to keep the project continuously running. However, much of the information could be considered more of a distraction than actually useful, given a specific situation. We do not know much about how the human being handles and edits information (Wikforss 2003). The ability to absorb information is limited, and when confronted with too much information, the receiver can lose the overview, or worse, completely ignore the message communicated; thus leading to crucial information being lost and unrecognized. An information overload could possibly result in a loss of focus on the important aspects within evaluation and decision-making. Valuable time must sometimes be spent filtering relevant from unimportant information. The attention of the receiver is becoming an important resource (Davenport and Beck 2002).

brary of objects and building elements available. Every intelligent and IFC exportable object in the project must be defined "from scratch". Both defining and changing these objects means time consuming processes within narrow time limits. The persons responsible for maintenance of the object library and the structures, must have much expertise. There are not many architects within the AHUS 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.

Required user effort

It has been more time consuming than expected to build up and work with BIM, especially to define and change the objects. When a wall must be changed, the user cannot only move two lines as in a traditional 2D line-based drawing. In the 3D object model, such changes have to be made on a completely another level, ensuring that the intelligent objects contains the right information which again shall be exportable to IFC. In the front building project, one person is more than full time involved with building up the BIM. There is still very much to do and improve on the programming and system development side of implementing and using BIM (respondent B).

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 nor parametric. There are handbooks and updated information about the programme available. However, according to respondent A, the narrow time limits do not allow much time for absorbing information offered through courses and user-manuals. Which again could lead to an inefficient use of the rapidly developing ICT tools.

Thus, the implementation and use of BIM requires much effort of the everyday user, but also of the person managing the team. Respondent B emphasizes the importance of knowing the benefits and challenges 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.

Rapid production of consistent project material

BIM is perceived as a crucial support for the drawing production since 2D drawings from interior situations (plan, section) can be automatically generated from the model (fig. 28). Changes thus have to be made only once, in the model, which help to ensure the production of consistent and correct drawings.

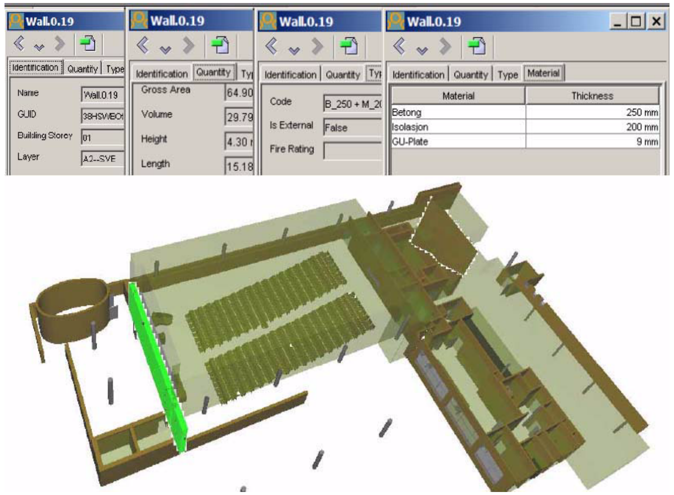


Figure 29. A glance into the front building IFC file with Solibri Model Checker (Courtesy: C.F. Møller Architects).

In addition, respondent A emphasizes the benefit of reusing details and solutions as support of generating design solutions and producing project material.

These benefits made several users (originally not only positive to the BIM implementation) realize that the everyday effort and struggle actually can bring some benefits. However, respondent B still emphasizes that it is not easy to fulfil all the aims and visions behind the implementation. A very high degree of discipline and effort of each of the involved is required.

7.4 Potential and challenges for the future

The object-oriented way of thinking: re-enforcing the standing of the architect?
The future architect shall have access to libraries of pre-defined objects. This is one of respondent C's visions. Independent research institutions such as e.g. "Byggforsk" could be responsible for pre-defining the objects, based on many years research and experiences. It can be questioned whether the use of pre-defined objects can obstruct innovation in the architectural design process. Respondent C does not regard this issue as a problem. He emphasizes that the architect can change or re-define the pre-defined objects. However, this requires a knowledge about the program and about the objects itself. If the user wants to use a wall type not available in the pre-defined wall-library, he must define a new type, which requires knowledge about how this particular wall should be built up. To build up knowledge required for developing a new wall type, respondent C regards as a more difficult task than to handle a computer programme. Furthermore, the implementation of IFC-based BIM can force the designer to become more conscious about the elements of his design earlier in the process (respondent C). To define a wall type, is normally made much later in the design process (building description).

One could say that the architect "thinks" both in terms of space and objects. But, according to respondent C, many architects of today are not skilled in the object-oriented way of thinking. He perceives this as a huge problem and one of the reasons for the architect's loss of position in the building process. The architect must build up his competence about how actually a building works. Not only draw lines without knowing what these lines implies. The use of IFC-based BIM can make the architect (again) expand his competence beyond the borders of "only doing design".

On the question whether the use of pre-defined objects rather could lead to a loss of competence about how to build and detail., than the other way round, respondent C gives following answer. Compared to the situation of unskilled detailing, he would from his point of view

EXAMPLES POSSIBLE AREAS OF FURTHER INVESTIGATION:

- use of pre-defined objects: standardization vs. innovation
- do the use of BIM encourage competence building?
- do the use of BIM lead to more efficiency on the micro-level?
- BIM potential for the architect regarding work and/or position in project

prefer to know that the objects chosen actually do work and respond to legislation etc. The use of pre-defined objects could thus itself ensure quality. And furthermore lead to a reduction of the time traditionally needed for production of details, which again could release more time for other central aspects in the design process.

ICT can support the capturing of (explicit) knowledge, for instance can the information embedded in the intelligent 3D model objects be seen as capturing of knowledge, which thus can be reused in other projects. An evaluation of the experiences made in the AHUS project could also help capturing the knowledge and the competence built up. By interviewing key participants also individual knowledge can be made available for the company. The findings of such an evaluation could be a sufficient starting point for new projects (vision of respondent B).

Challenges for the users

A frequent motivation regarding ICT use, is the expectation of increased efficiency through faster project material production. According to respondent A, there are several "spin-off" effects from ICT implementation and use that counteracts efficiency (in terms of drawing production). She questions whether the possibilities of faster production leads to increasing client requirements and expectations regarding work speed and the possibility to reduce planning and building time. According to her experience, with the implementation of ICT systems, the users of the technology face an increasing and time-consuming bureaucracy, built on the need for pre-defined procedures and systems.

For utilizing the benefits and potential of ICT, it is crucial that the architect knows how to use the tools (at least until the moment where the computer develops from being stupid" tool to becoming an intelligent partner. Respondent B).

The development of more advanced computer programmes requires more hardware capacity. However, according to respondent B, the challenge is not to develop computers able to handle larger amounts of information. The challenge lies rather in the human ability to absorb and overview information. The development of viewers and multiple models are attempts to solve this problem.

table 1. The ICT impact matrix and key points of exploration

	micro-level	meso-level	macro-level
design generation	**benefits:** - reuse of solutions - pre-defined objects **challenges:** - not intuitive and parametric - much competence required - time-consuming - object-oriented working method and pre-definition of objects	**challenges:** - not intuitive and parametric, heavy - BIM not used directly for design generation	**challenges:** - not intuitive and parametric - rigid presentation not allowing dynamic design generation with e.g. clients
communication	**benefits:** - better access to consistent and updated information - potential of generating ideas in virtual reality - rapid production of consistent project material **challenges:** - not intuitive and parametric - rough handsketches the basis for the ideation	**benefits:** - better access to consistent and updated information - potential of increased shared understanding **challenges:** - different working cultures - responsibility - from push to pull - redefinition of communication processes and culture	**benefits:** - better access to consistent and updated information - - visualisation support communication of esthethic issues **challenges:** - BIM a black-box if not special competence - redefinition of communication processes and culture
design evaluation	**benefits:** - precision - "visual" control of complex estethic issues **challenges:** - too time-consuming	**benefits:** - potential of real-time simulations - potential better control of interfaces between participants **challenges:** - too time-consuming	**benefits:** - BIM a testable prototype of real building - visualisation of difficult understandable issues **challenges:** - increased expectation to precision - time-consuming
decision-making	**benefits:** - consistency and precision of decision material - reduction of uncertainty **challenges:** - presentation taking focus from content of design	**benefits:** - consistency and precision of decision material - reduction of uncertainty **challenges:** - bias in relation qualitative and quantitative aspects	**benefits:** - consistency and precision of decision material - reduction of uncertainty **challenges:** - bias in relation qualitative and quantitative aspects - presentation taking focus from content of design

8 DISCUSSION AND CONCLUSION

This report has explored the use and implementation of IFC-based BIM in the AHUS project. The exploration was limited to the architect's work and interaction with other participants in the architectural design process.A theoretical framework and references to theory have been used to discuss and summarize the key points in the interview material. The motivation behind the implementation, the experiences from use and the implications and visions for the future was explored on three hierarchical levels in the design process.

8.1 Summary of the explored key points

The ICT impact matrix (table 1) summarizes some of the explored BIM related benefits and challenges in the AHUS project.

The focus of the 3D object model in this project lies rather 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 IFC-based BIM are better project material quality and consistency, and a more uncomplicated project transition from planning to construction. Regarding the generation of design ideas, the 3D object model was not used directly either by the design generation nor by real-time evaluation or decision-making. Instead, the traditional tools as pen, paper and physical models "mediated" the creative processes and e.g. the direct testing of alternative solutions in an meeting situation. BIM partly supported evaluation of design solutions and decision-making through the possibility to (before a meeting situation) visualize complex, not understandable and recognizable issues in 2D. 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.

However, all respondents, also the every-day users of the 3D object model, seems to be 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.

6 LESSONS LEARNT

1. visions and motivation should be visible on all levels

2. not underestimate time and personnel recourses required for learning new technology

3. competence and expertise required both from BIM user and manager of the design development

4. still much work to do regarding further development of technology

5. discipline required by modelling

6. establish strategies for implementation and use

8.2 Lessons learnt from the AHUS-project

What can we learn from the experiences made in this project regarding use and implementation of IFC-based BIM? Derived from the exploration of the project, at least six key "lessons" can be suggested. These six key points do of course not cover all the interesting aspects in the exploration. The intention is to supplement the ICT impact matrix (summarizing benefits and challenges) and the suggestion of future interesting fields of research, with some practice oriented "findings". The suggested lessons could be interesting for the participants in leading positions on both meso- and macro-level.

Firstly an important issue in the AHUS project was to make the visions made om macro-level visible for actors also on the meso- and micro-level. Especially since the implementation of this quite untested technology led to much extra work and effort for the every day users of the technology. This was essential in respect of motivating the users to use the technology in an efficient way.

Secondly, implementation seems to require much time resources for training and updating. At least as long as the technology is new for the project participants. Although the key persons behind the implementation seem to invest much effort in arranging courses, making user manual available etc., the general time pressure in the project made it difficult for the users (according to respondent A) to actually update themselves as often as they should, in order to optimal enjoy the benefits of the tools. This could indicate that the time plans for building projects should allow enough "free" time for learning and practising.

Thirdly, as a continuation of "lesson" two, the use of IFC-based BIM requires special competence of the user, and also of the persons managing the planning (for estimating the real needs for time- and personnelin the AHUS project resources). In the AHUS-project, not every user had the expertise to define objects from the basic, which, according to user A, sometimes led to bottlenecks in the planning and production, especially in cases with many changes. A more optimal situation would perhaps be if every user had such expertise. However, at least in such a big project, it would be a huge undertaking to bring everybody up to this level of special competence. This problem will probably be reduced in the case all object are pre-defined and available from libraries. Thus, theoretically, it will be no need to change objects.

Fourth, since to use IFC-based BIM is a quite untested and new situation (at least in Norway), there is still much work to do with improving the software and with building up and defining the objects. In the AHUS project, this was part of the R&D project, however, as indicated in lesson two, this requires time and effort which must be considered in addition to the resources needed in for purely carrying out the planning of the project.

Fifth, although IFC-based BIM reduce the need for drawing same information in e.g. plan, sections and descriptions, to use the system still requires much discipline and precision of the users. They must strictly follow the definitions and guidelines set for the modelling. For instance, in the case the user draw an object with lines instead of using or defining an intelligent 3D object, programmes made for quantity take-offs, clash controls etc. will not recognize these, and the informations generated of such systems will not be correct.

An finally, sixth and based on the first five points, to have a clear strategy and vision before the implementation would be of advantage. For instance, questions could be asked in which phases of design the model should be implemented, what are the expected benefits, which resources are required etc. For instance, in the AHUS project, it was from the beginning clear that BIM in this project should primarily support control and assurance of project material quality and consistency, rather than supporting the architect in his creative tasks.

At the time the case-study was carried out, only the architect was using the model directly in their planning day. The next step in the project is to include the other consultants and the contractors (autumn 2005), and thus also experiences regarding the potential of interoperability can be collected. What are the benefits and challenges for the architect in his work and in his interaction with the other participants on mese- and macro-level. Which lessons can further be learnt?

8.3 Adaptability of the framework

The tentative impressions of the frameworks adaptability on practice, is the potential for supporting and guiding the collecting, analysing and presenting of the empirical data. Regarding the project presented in this report, the framework helped keeping overview of actors and processes, and their experiences due to use and implementation of BIM. 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 organizing of actions and actors due to the three hierarchical levels functioned well. More challenging it was to "place" the benefits and challenges in the right design aspect "box" in the matrix. In the further development of the framework it could be considered whether there are other ways to "draw the lines" between the four design aspects. Should it

A BROAD APPROACH

It could be questioned whether the framework is based on a too broad and ambitious approach. Each of the "boxes" in the matrix theirselves represent complex fields of research. This report does not give deeper insight into each of the many aspects. However, this is also not the intention in this phase of the investigation.To understand the mechanisms in the architectural design process and the architect's work and interaction with other participants seems to require an process-oriented thinking and the "aspiration" for an overview. At least in the first steps of the exploration. Next steps could be to, based on this broad exploration, to chose one or more of the suggested possible areas for further investigation.

Figure 30. Theodor Kittelsen's "Soria Moria slott" (from: www.bergen.folkebibl.no)

be made differences in the matrix between expected benefits and challenges and the experienced ones?

8.4 Next steps

As basis for further exploration of the topic, and further improvement of the framework applied, the empirical basis should be extended by carrying out more case-studies of relevant projects (multiple case-studies). The framework could have potential for supporting a comparison of empirical data from multiple case-studies (pattern matching).The focus of this report has been on the architect and the architect's interaction to other key-participants in the architectural design process. It could be discussed whether the focus should be extended to e.g. all actors in the design team.

The intention of this report and the case-study of the AHUS project, was to be as open as possible within the chosen scope. The exploration aims to give a insight in many facets and levels of the project, and to contribute with an overview of a complex area. Thus, eventually and hopefully this report can contribute to a better understanding of the use and implementation of IFC-based BIM in the AHUS (front building) project. To gain deeper insight in some of the many interesting themes explored in this report, another next step would be to narrow the scope of further investigation. This report and the exploration of the AHUS project could become a good fundament for doing so.

"So little done, so much to do." Cecil Rhodes, last words

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