EARLY ARCHITECTURAL DESIGN AND BIM

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Abstract. This paper examines the meaning of information and communication technology (ICT) for architectural design in early design project phases, with a particular interest in building information modelling (BIM). Contemporary digital design environment, research context and objectives are first clarified, followed by the presentation and analysis of a few BIM-related projects. A key finding is that the architectural working environment, the design methods and the designer's roles have changed in the contemporary project context. Furthermore, other methods and tools are needed in addition to BIM in the early project phases, because it can not solve all required design aspects. [The presentation is part of the author's post-graduate studies in architectural BIM].

1. Background

1.1. CHANGES IN THE DIGITAL DESIGN ENVIRONMENT

It has recently been noticed that several changes within the domain of architectural design have been strongly affected by information and communication technologies (ICT).

The working environment of building designers as well as most of the core activities in the AEC-sector became digitalized during the 1990s (Samuelson 2002). In the Scandinavian construction sector, roughly 70-80% of drawings are currently produced digitally. A Nordic IT-barometer scanning the ICT-status was first published in 1998, then again in 2002 and a third survey is currently in progress, and is due to publish follow-up information in spring 2007.

Despite the tools and technology, the widening spectrum of requirements posed by our society has accelerated these changes in the professional environment. All these prevailing changes together are currently re-forming the contemporary profile of the architectural profession. New professional roles have also emerged within the architectural practice, in particular the ICT leaders, coordinators and managers (Penttilä 2006).

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A positive sign is that the central designers' professional organizations (Bucher 2003; Eastman 2006) as well as other bodies in the construction field have noticed and reacted to these changes in the working environment, which are likely to expand with an accelerating pace in the future.

1.2. THE ADVENT OF BIM

It has been claimed that Building Information Modelling (BIM) has become one of the major trends in contemporary AEC-field information technology (Froese 2003) and will continue to do so in the near future. BIM is an integrated digital framework that forms the information management basis for all building project collaboration over the lifespan of the building in the design-construction-maintenance -chain. Recently, BIM-based methods have started to expand to design and construction practice. Active efforts towards BIM have been recognized at least in USA, Finland, Norway, Japan, Denmark, Germany, Australia and Singapore.

BIM has so far been mainly tested and piloted in component-based detailed design phases, where one selected design proposal is selected to be developed further. Beyond design, active fields for BIM-piloting have also been construction planning and actual construction phases. Even if the addressed and proposed advantages of using BIM derive from the earliest project phases, model-based design methods have not yet been used so much in the early project phases nor in early architectural design. Although the benefits of BIM in the management requirements of the early project phases have been addressed (Kiviniemi 2005), there are still no proper software tools to manage project objectives or requirements in the model-oriented design environment.

The major recent technical cross-platform data exchange standard in BIM applications is IFC (Industrial Foundation Classes). But despite IFC's ever-widening distribution, there have also been some drawbacks in the pilot projects in recent years. The criticisms have not been targeted so much towards the standard itself nor its structure but rather the IFC's actual promotion and the insufficient development activities (Kiviniemi 2006). Nevertheless, it seems that IFC will quite obviously be developed and used in the near future as the independent data exchange tool together with other software specific formats such as DWG and ArchiCAD’s PLN.

Criticism has also recently been raised towards BIM from a theoretical aspect. It has been questioned whether top-down-oriented and “centrally controlled” data management approaches, which follow a single modelling method – such as BIM – really can be a proper platform for comprehensive architectural design data management (Kalay 2006). The nature and essence of the architectural information environment is heterogeneous, and hence

rich and complex information structures should also be taken into account (Tuncer et al. 2001).

2. The Research Effort

2.1. THE RESEARCH CONTEXT AND LINKS TO RELATED RESEARCH

There is certainly a long research tradition in the design theory and design methods community within architecture (Groat 2002). The wide topic of *architectural design* can be seen as a design context issue as well as a qualitative issue. Design can also be seen as a more pragmatic design practice issue, dealing with the design activities, work and processing (Cuff 1992). The latter praxis-approach is closer to the research scope of the present on-going study.

The main research contexts of this work are *architectural ICT*, computer-aided design (CAD) as well as computer-aided architectural design (CAAD). This work is also related conceptually to several other design-related research domains. The most obvious context, *BIM-related research*, can be regarded as another major research trend.

Building information modelling has been under research within construction and design fields since the 1980s (Eastman 1999), but information modelling research in other industry areas such as product design, ship building, automotive & aviation engineering are still valid fields to include within the overall context. Model-based information management has much more extensive use in automotive design and naval architecture than in construction, and hence knowledge gained from these will definitely have an influence on some future trends, bringing forward solutions to architecture as well. Model-related issues and so-called simulation-based design (SBD) have been an active research area within naval architecture (Baum et al. 1997; Chang et al. 1998).

CAD and BIM have a strong research connection with software engineering. Within the building design context, one object-oriented software platform to test BIM in educational and research environment was the Building Design Advisor (BDA) during the late 1990s (Papamichael 1999). Despite the object-oriented approach, such topics as CAD-automation, design content analysis, design collaboration and agent-based design (Beetz et al. 2004) have been essential in design data integration. Currently active BIM-related research topics include, for instance, multiple model environments and BIM-model servers, which will possibly offer some solutions also for early design dilemmas.

Since the 1990s economy-oriented leadership and business management have affected the expansion of the design management research domain. Changes in business processes as well as the status of the architectural

profession within construction have come to mean that architectural design is a sector which has to be managed, and hence the field requires also leadership actions (Otter and Prins 2002). Within the context of leadership, economic and organizational changes, an enthusiastic research domain in the management of change appeared the mid-1990s (Kotter 1996).

General design theory within civil and mechanical engineering and systems science has tackled the essential question of collaborative design and it has also been discussed within architecture (Haymaker 2000). Design requirements management, which has been a domain in systematic engineering and product-oriented design, has just recently emerged as a question in building projects information processes (Kiviniemi 2005).

To summarize the present research context, architectural design and construction field related ICT and BIM is a multi-disciplinary research area, where several adjoining and loosely related research domains form the actual research context, and where also non-traditionally architecture related domains have to be studied as well.

2.2. AIMS AND OBJECTIVES

The aim of my research (in the doctoral thesis) is to analyze and validate the possibilities of the widespread use of ICT in early architectural design, in project planning, in design proposals and their evaluation. Since the concept of BIM has recently raised hopes and aspirations, the changing effects of ICT- and BIM-based methods will be at the centre of the scope of the research.

Most important architectural design ideas and project principles are created in the earliest phases of architectural design. Fundamental design decisions are also made in the early project phases. Despite the designers' reputation and known references, another critical aspect in early design and even earlier designer approval, is the ability to generate and present design ideas and project proposals. Nevertheless, currently developing model-based design methods, such as BIM, seem to require very detailed component-based building modelling, methods, which usually are used only in the later design phases.

2.3. DESCRIPTION OF THE RESEARCH METHOD

A study of the literature dealing with contemporary architectural ICT and BIM has been made, as well as a few empirical case-studies. The next planned major research step is to undertake interviews to collect early design-related material from the Finnish AEC-field.

From the collected material (literature, case-studies and interviews) a comprehensive description of ICT and BIM within early architectural design

will be presented in the form of a hypothetical framework or “model”. Finally, the created framework and findings will be evaluated and validated.

Research categories for this work are applied research and information transfer from research to design and the construction field practice.

2.4. EXPECTATIONS OF THE FINAL RESULTS OF THE RESEARCH

The research will clarify the content and management of early architectural design related issues, in order to fit early design activities better within the contemporary digital design and construction chain.

Rather new topics, such as requirements management and modelling (Kiviniemi 2005), design management and client-related communication are regarded as essential and important for early architectural design; hence the role of ICT should be discussed in this context.

This work will also help in analyzing the dualism between architectural design and ICT, between "computer-aided" and “design”. The dualism is characteristic of architectural ICT: on the one hand, the semantics of the most essential design content – the most traditional architectural virtue – and, on the other hand, the more pragmatic syntax of ICT-tools and methods in representing and managing the design content.

3. The Early Architectural Design Framework

Contemporary architects have to be, in accordance with their professional tradition, skilful designers who concentrate on design content, form-giving and overall design quality issues. But beyond the design work, architects today also have to be communicative leaders and project managers, who can coordinate and guide pragmatic design work. In the current ICT-dominated working environments, architects have also to master a wide variety of technical skills; i.e. to be ICT-specialists.

3.1. CLASSIFICATIONS

Since building projects vary a lot in regard to their organizational and owner structures, the project volumes and objectives as well as their design content, they have to be classified by their ICT-structure and information content. A usable classification basis has been put forward, for instance, in Anders Ekholm’s paper “A conceptual framework for classification of construction works” (Ekholm 1996) and in ISO's classification of information in the construction industry (ISO 1994). But beyond the classification on the conceptual level, a more pragmatic classification has to be performed (i.e. project-owner based, size based, housing, building renovation, etc.) in order to properly fit the ICT-methods to the actual project context.

3.2. NEEDS AND OBJECTIVES FOR INFORMATION MODELLING

An important task before launching any building project is to define the project's information management objectives and aims, and to answer the question of *why* ICT or even BIM will be used in the project. Together with the defined objectives, also the pragmatic information management methods and tools have to be defined precisely.

3.3. INFORMATION EXCHANGE NEEDS

Derived from project objectives, all considerable data exchange needs in all project phases should be estimated before the project commences. Typical early project data exchange requirements are, for instance:

- information delivery to clients and project management
- the public sector's and authorities' information requirements and needs
- coordinated data exchange to later detailed design phases
- integrated information delivery within the design team (collaboration)

Especially in BIM-projects, proper information structuring, starting from the earliest project phases, has been crucially important to avoid later data format or structural modifications which will always cause unnecessary losses in information content.

A very pragmatic solution for the project’s data exchange needs and definitions can be a list of agreed file formats and versions (DOC, DWG, IFC, etc.) as well as methods to be used (email, project web, etc.).

3.4. EARLY DESIGN MODEL CONTENT REQUIREMENTS

Since early design always has to be based on poorly structured, vague and fuzzy information, assumptions, best possible guesses or even illusions, the early architectural design information management context has to be as versatile and flexible as possible.

The ICT tools and methods for early architectural design have some general but important requirements. Characteristic of ICT in the early design phases is that all methods and tools have to be "supportive" for the design work as well as for decision making. Since early design data is by nature cumulative, the methods have to be easily modifiable. Because of the extensive variety of possible source information, the tools have to be very "responsive" to receive in the beginning almost whatever information.

4. Motivating Case Examples – An Empirical Approach

Three BIM-related case studies are presented briefly in order to describe the nature of early architectural design and its relation with ICT, CAD and BIM.

All presented cases are still on-going projects where the author has had a noticeable contribution.

4.1. BIM GUIDELINES AND STRUCTURAL LIBRARIES

The National Finnish Pro IT -guidelines for BIM were first written in 2004 and they were updated in 2005-2006. Two of them have already been published and the rest are currently in the process of being published by the Finnish Building Information Group. (The publications are being published in Finnish only, but there are plans to translate also a report in English in the near future).

TABLE 1. Finnish Pro IT building information modelling publications.

	published	*publishing plan*
General BIM guidelines	2006	
Architectural design BIM-guidelines	2006	
Structural design BIM-guidelines		2007
Technical design BIM guidelines (HVAC, etc.)		2007
Project guidelines for a BIM-project		2007

Together with these reports, a set of structural building components have also been developed to form a proposed future platform for integrated design and production. The main idea has been to collect, approve and publish around 200 typical layered structural type structures, such as slab-, wall- and roof-types in digital form, which then could be used in BIM-based applications. The structural libraries will be published:

- as part of Building Information's so-called RT-building files (paper & CD)
- in CAD-systems' starting templates (Revit and ArchiCAD)

Figure 1. Finnish Pro IT structural type library, 2005.

Pro IT has been accomplished as a committee work, with several active participants. The author, together with his company, has contributed as an editor in four of the above-mentioned reports as well as the structural type library.

The BIM-related research work and the recent pragmatic application and piloting phase together have formed a common understanding about a "desired BIM future" in Finland, where the whole process chain from building design through to production and maintenance could be managed and run in a well-structured and software-independent project environment.

The BIM-related activities are currently instructed with software-related and technical guidelines, but also some company level strategic and integrated instructions are available. The general objective for guidelines has changed from application-oriented guidance towards more operative steering procedures.

One important area, which needs further effort, is the juridical aspect of design and construction. Contracts and agreements between project participants concerning processes, operations and activities are currently based on [design] documents, even if they are done with CAD. The slow but indispensable evolution from document-oriented design towards model-oriented design still requires much rethinking and adjustments in regard to most parts of the building project chain. Recently most major project organizations and key players in the national AEC-field have produced their own objectives and strategies for modelling, which means that also the written and economic agreements will in the near future fit better to the BIM-context.

4.2. BIM IN RENOVATION DESIGN

Senate Properties, the largest real estate owner of state facilities in Finland, announced in December 2006 that after 1.10.2007 they will require design content to be delivered in IFC-format (Senate Properties 2006).

So far BIM activities have concentrated mainly on new buildings, and hence, Senate Properties launched a project to study BIM in the context of renovation of culturally-valuable facilities. Currently 55% of the total volume of construction in Finland is concerned with renovation projects. This research study was carried out by ArkIT, HUT's digital architecture team, and the work is due to be documented during spring 2007.

The main focus of this effort has been the different aspects of model-based renovation as it concerns the facility owners, project managers and renovation designers. In renovation design, especially in culturally-valuable facilities, all existing project inventory and status information should be easily accessible, usable and also digitally referable in order to support design decisions in all project phases.

In addition to presenting the various available information management, 3D-modelling and measuring methods such as 3D-laser scanning, the concept of an inventory model has been elaborated. Scattered inventory information has to be collectable and storable in well-structured formats through the whole renovation process.

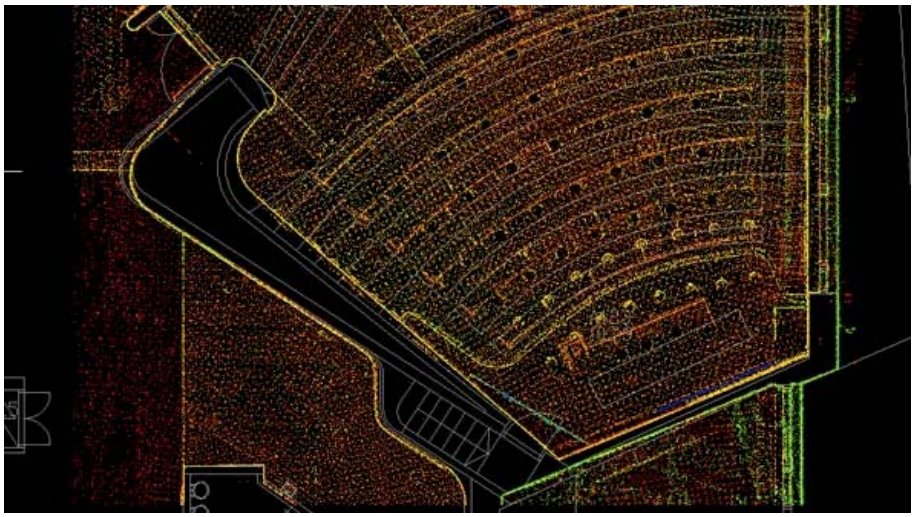

Figure 2. Example of inventory data from HUT's Department of Architecture building. Integrating the architect's original drawings (Alvar Aalto, 1961), digital inventory drawings (1994) and contemporary 3D-laser scanning data (2006).

One key finding has been the confirmed observation that renovation-related early design has to tolerate, accept and manage versatile material, which could hardly not be integrated into a single 3D or BIM-environment. Typical examples of existing content are photographs (paper and digital), written specifications, old drawings (paper and scanned) but also phone calls, agreements, approvals and decisions of various kinds. This may be the major difference, which deposes renovation design from considering designing new buildings.

4.3. A PRELIMINARY DESIGN MODEL STUDY IN COST ESTIMATION

The final case-study to be presented is the most technical, and it describes how a BIM-model can be connected to an existing CAD-tool.

Klara.biz is a PC-based single user cost-estimation software product for small- and medium-sized user organizations. The author has been responsible for the software platform and programming with relational database tools. Klara has been published in Finnish since 2001.

In the cost-estimation process, the most essential core information of design quantities is first transferred to Klara, either in a structured quantity

file or, more traditionally, by hand. Data exchange from CAD-systems is done in a simple file format, but the possibility of also including an IFC-module within Klara, has been studied. The first part of the actual cost estimation is to link the quantity data to Klara's product library which should be harmonized with the CAD-systems equivalent libraries.

In the cost estimation process it is first essential to discover the cost components, which are not included in the CAD-based quantities. Typical examples are builder-related general costs, site-related costs and such technical systems which have not yet been designed. The cost manager continues, then, to adjust, fine tune and specify the cost components and finally confirms that all needed and relevant cost-related items have been included and are based on realistic foundations within the project.

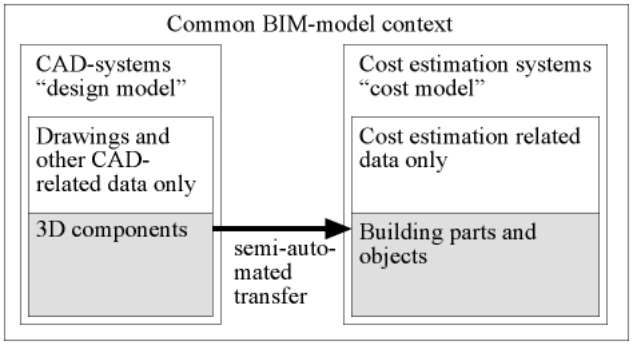

Figure 3. Diagram of CAD and cost-estimation data contents in relation to BIM.

If the design proposal is represented in 2D CAD-drawings, the cost components are created in Klara-software by hand, but if the design proposal is modelled with 3D-components, some 50-60% of the total costs can be related to the building geometry, and hence that data can be transferred automatically to Klara.

Accurate cost estimation requires special building economics expertise, but more general understanding of building costs can be grasped with less experience. Hence, rough design-related building costs could be included even in architects' common knowledge, though economics is not the designer's core area of competence. Evaluative cost estimations – e.g. what is expensive and what may be cheaper? – can be semi-automatically calculated with contemporary software tools.

Cost-based content analysis in early design phases can offer valuable information for clients and managers, if the cost simulations are easy and quick to produce. Combined with other simulations and analysis – such as visual, functional, or thermal aspects – the project leaders can acquire a

better and more comprehensive understanding of the project in a more extensive context already in the early and schematic phases of the project.

5. Conclusion

The work in the case-studies has been a question of re-defining and fine-tuning the BIM concept in terms of the way it has been of help in distributing the wider understanding of the model-based concepts and their meaning in design and construction practice.

The larger a building project is, the more potential it has to be a BIM project. For instance, well-structured and well-defined housing projects by one major developer have been effective for such modelling. The most successful BIM projects have had clear project objectives and a single major client/developer.

The need to coordinate interactively the complicated design contents of various disciplines, even with regard to long-term objectives in terms of lifecycle, has also been one feature (often a desired one) in the categorization of BIM projects. There is usually no urgent need to integrate information in small projects, but small projects may still well be valuable for learning and piloting building model-based activities.

The BIM concept is currently seen as one possible and promising working and data exchange method which enables wide cross-platform interaction and a possibility for life-long project data management. Nevertheless, BIM should not be seen as the one and only design method for an architectural designer in the early phases of a project. BIM is rather a method to be used, if and when interactive data exchange is required in later project phases.

BIM has been developed and so far also piloted mainly in detailed design and technical construction phases. For the early design context BIM is still a recommended entry point but one which needs further investigation, especially when further knowledge in the building project information chain is the desired objective in the information logistics of the construction field.

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