Building Information Modelling in the business of architecture

Case of Sweden

EWA MAJCHEREK

Degree project in Entrepreneurship and Innovation Management Second cycle Stockholm, Sweden 2013
Abstract
Architectural practice, although its first objective is providing a design value, is nevertheless a business branch. Creative work of architects needs formal managerial guidelines and principles in order to ensure financial profitability of the firm. One of the challenges of architectural management is carrying through innovative solutions. A prominent example of a recent innovation in architecture, engineering and construction industry (AEC) is Building Information Modelling (BIM). In Sweden BIM regulations supporting its further diffusion across the industry were first established in 2013. The research indicates managerial practices which are crucial for the successful implementation of BIM in Swedish architectural offices and consequently bring significant business benefits to its adopters.

KEY TERMS:
Architectural management, Architectural business, Innovation in architecture, Innovation implementation, BIM
## Table of Contents

1.0 Introduction .................................................................................................................. 5  
1.1 Background of the research .......................................................................................... 5  
1.2 Research question ......................................................................................................... 5  
1.3 Research purpose ......................................................................................................... 5  
1.4 Research scope and limitations ................................................................................... 6  
1.5 Structure of the document ........................................................................................... 6  
2.0 Literature review ........................................................................................................... 7  
2.1 Architectural management ............................................................................................ 7  
  2.1.1 Background ............................................................................................................. 7  
  2.1.2 Sense of architectural management ........................................................................ 7  
2.2 Innovation ...................................................................................................................... 8  
  2.2.1 Introduction ............................................................................................................. 8  
  2.2.2 Implementation of innovation ............................................................................... 9  
  2.2.3 Implementation of a system and radical innovation ............................................... 11  
2.3 Building Information Modelling .................................................................................. 12  
  2.3.1 An overview .......................................................................................................... 12  
  2.3.2 Understanding BIM .............................................................................................. 14  
  2.3.3 Implementation of BIM ........................................................................................ 16  
2.4 Summary ....................................................................................................................... 17  
3.0 Research methodology .................................................................................................. 19  
3.1 Identification of paradigm: .......................................................................................... 19  
3.2 Choice of methods ........................................................................................................ 19  
4.0 Findings ......................................................................................................................... 20  
4.1 Survey organization .................................................................................................... 20  
4.2 Survey participants ...................................................................................................... 20  
4.3 Survey results .............................................................................................................. 21  
4.4 Conclusions and suggestion for further research ....................................................... 22  
5.0 Summary ....................................................................................................................... 25  
Acknowledgements ............................................................................................................ 26  
References .......................................................................................................................... 27  
Appendix ............................................................................................................................ 29
**List of Figures**

Figure 1: "MacLeamy Curve" ........................................................................................................ 13
Figure 3: Interacting BIM Fields ................................................................................................... 14
Figure 4: BIM Stages and leading to them BIM Steps .................................................................. 15

**List of Tables**

Table 1: Participants’ structure .................................................................................................. 21
Table 2: Survey results ................................................................................................................. 23
1.0 Introduction

1.1 Background of the research
Architecture is a complex domain marked by creativity, collaboration and marriage between art and technology. The image of architecture has always been dominated by its artistic component and practitioners themselves have been reluctant to accept its commercial aspect, although, architecture simply does not exist without its clients and users. Even in the context of professional institutions, service of an architectural firm was long recognized only for its design value, leaving behind the business potential (Cuff, 1992).

During the last half of the 21st century however, architecture, engineering and construction sector (AEC) have gone through transition which brought a new perspective to the profitability of architectural business. First, attempts to apply traditional managerial practices to the context of architecture resulted in the emergence of Architectural Management (Emmitt, Prins, and Otter 2009). This distinctive domain of management provided methodology for both project work and functioning of the design office in order to deliver architectural value without compromising the commercial profit, or vice versa.

The second step towards the transition was an introduction of a computer-aided design (CAD) - a radical innovation, which became a dominant concept in the designer’s workspace (Murphy, Perera and Heaney, 2008). Progressive development of CAD and information technology techniques contributed to the invention of Building Information Modeling (BIM). This innovative system enables, briefly speaking, creating a digital building with its documentation through a concurrent work of architects, engineers, contractors and other involved actors, raising the competitive advantage of the firms by improving their working processes. (Tidd, Keith, Bessant, 2005). BIM’s positive influence on AEC sector within the last decade has been so significant that requirements and deliverables of BIM become a more and more often regulated issue, by organizations and governmental bodies in different countries (Succar, 2009).

Given the importance of BIM this study aims at understanding architectural management tools that enable successful implementation of BIM. The following research question is formulated:

1.2 Research question
How do managerial practices enable successful adoption of BIM in Swedish architectural firms and what are the business outcomes of this process?

1.3 Research purpose
The purpose of the research is twofold:

a) To describe the implementation of BIM in architectural firms with focus on managerial practices applied to the process
b) To discuss the benefits and challenges it brings to the adopter company. The issue will be researched using literature findings and survey outcomes from a group of Swedish architectural firms who are BIM users. The result of the research will illustrate: application of innovation theories to the context of architecture and BIM, and practical implication of this process on architectural business performance. The project could be a help to practitioners planning to adopt BIM in the future, or to adopters willing to assess the ongoing adoption.

1.4 Research scope and limitations
The scope of the study will not include all Swedish architectural offices using BIM, but only those who are members of an international organization OpenBIM, which supports the development of BIM. Due to limited time the research will focus on basic aspects which received most recognition in the literature, and no financial results will be studied. The aim is not to provide a common business model for BIM users, but rather suggest practices regarded as most successful.

1.5 Structure of the document
The next section presents literature findings about architectural management, theory on innovation, and Building Information Modelling. The literature review is then followed by results of a survey on managerial experiences and business considerations around BIM implementation. Theoretical and empirical findings are combined to provide an answer to the research question. The last section of the project paper includes a summary and a suggestion for further research.
2.0 Literature review

2.1 Architectural management

2.1.1 Background
Architectural Management was an unidentified research domain until 1962 when the term first appeared in reports by Royal Institute of British Architects. Their studies carried out in the following years revealed the need for better management of architectural practices (RIBA, 1962 cited in Emmitt, Prins and Otter, 2009, p.XVIII). In addition Dana Cuff (1992) in her research of American firms recognized the dominating role of design value and at the same time underestimation of practices, like project management or architectural consulting, expressed by professional community itself: “The AIA [The American Institute of Architects] as an institution only recognizes design – the only awards programs are for design, and mainly for the building exterior at that. There’s no recognition for good business in architecture. I think it’s about time we gave management a better rap. Let’s give out awards for good managers, and publish the project manager’s name next to the project architect’s in the glossies [the professional magazines]“.

Poor management knowledge among practitioners, and pressure for improved performance and delivery of better value expressed by clients led to organizing a conference on architectural management at the University of Nottingham in the UK in 1992. Afterwards a Commission for architectural management, CIBW096 was established. In the following two decades until today the subject has been developing in theory and practice, giving practitioners a powerful tool that can be applied to the benefit of their practices and to the building process in its totality (Emmit, 1999).

2.1.2 Sense of architectural management
Architectural firms are project-based organizations. Comparing with other types of industry, they provide quite a unique service. Each new project is like a prototype - conditions are hardly ever the same in two architectural projects. To deal with them, a close collaboration with numerous external actors is required, and these are architects who coordinate this collaboration, and in general, play the most important role in creating a new architectural object. The architectural firms tend to be small and tasks their employees deal with differ greatly throughout the project life-cycle. The staff themselves are in majority highly qualified and creative.

Thus, application of formal, industrial management guidelines and principles to the world of architecture is limited. Since management is equally important in creating a good architecture as design and technology (Emmit, 1999) emergence of a distinct domain is well justified. Definition of architectural management is unclear therefore I chose to describe its role instead. The essence of architectural management is “achieving synergy between the management of the design office and of individual projects (...) to ensure a profitable
business” (Brunton et al., 1964 cited in Emmitt, Prins and Otter, 2009, p.XIX). Clearly the management applies here to two areas: to the functioning of the office, and to the project work. The former aims at identifying effective and wasteful routines within the office to improve, respectively, eliminate them through proper administration systems. The methods must be designed in a bottom-up manner as creative workforce tends to feel hindered by bureaucracy. The latter area of architectural management defines such elements as quality assurance and risk management in relation to particular projects. Van Aken (2005 cited by Emmitt, Prins and Otter, 2009, p.211) claimed that “the main concern in architectural management should be the conceptual design phase, since decisions made in this phase largely determine what can and cannot be done in the future building design stages. The focus should be on creating conditions in which different design disciplines within a design team will have the opportunity to introduce their different design knowledge” and subsequently to integrate it into design concepts. This quotation carries important information about challenges of architectural management. I interpret the mentioned “conditions” as a result of coordination of collaboration and communication, both of which are crucial to the success of AEC projects.

2.2 Innovation

2.2.1 Introduction

“Innovation has become the industrial religion of the 21st century” (Westland, 2008). This vast concept has been the theme of both theoretical and empirical studies for decades, as many, beginning with Schumpeter, recognized its key role in the competitive advantage of companies (Slaughter, 2010) and consequently, its catalytic power in industrial change and economic growth (Dosi, 1988).

Invention and its commercialization remain as two core elements of innovation, while its precise definition and perception depend on the profession it relates to. In the context of this work I use a definition after Slaughter (1998): “Innovation is the actual use of a nontrivial change and improvement in a process, product, or system that is novel to the institution developing the change”.

Two systems of classification are particularly helpful in comprehending innovation in the context of architecture, engineering and construction:

1. Classification determined by the area innovation applies to:
   - Product innovation - new technologies, materials or solutions (Murphy et. al 2008)
   - Process innovation - which enables a greater output per unit of input (Tatum, 1989)
   - Organizational innovation - which involves changes to organizational structure, introduction of advanced management techniques, and implementation of new
corporate strategic orientations (Anderson and Manseau, 1999); (Blayse and Manley, 2004)

2. Classification determined by advancement of the state of knowledge, and its links to other components or systems (Slaughter, 1998):
   - Incremental innovation: brings a small change, based upon current knowledge and experience;
   - Modular innovation: entails a significant change in concept within a component, but leaves the links to other components and systems unchanged;
   - Architectural innovation: involves a small change within a component, but a major change in the links to other components and systems;
   - System innovation: integrates multiple independent innovations that must work together to perform new functions or improve the facility performance as a whole;
   - Radical innovation: brings a breakthrough in science or technology that often changes the character and nature of an industry.

In this paper I discuss a process innovation of a system and radical type. In other words: novel practices enhancing work on a new architectural project, which emerged from a combination on previous innovations and have a potential to render current working methods obsolete.

The benefits innovations bring to the industry and individual firms are both monetary and intangible. They have potential of winning the projects, improving financial results and raising competitiveness among others (Blayse and Manley, 2004; Slaughter, 2010); and respectively: raising the prestige of a firm or increasing personal satisfaction of practitioners and clients. Whether the company takes advantage of an innovative solution depends not only on this solution’s features themselves, or the company’s own capabilities, but also on governmental or institutional input, and economic incentives to the whole process (Nelson, 1986 cited by Dosi, 1988).

In the following section the process of adopting innovation with its most important components will be presented.

2.2.2 Implementation of innovation
Implementation of innovation by a company follows an “initiation” process, during which the potential adopter gathers necessary knowledge about a novel solution, forms attitude to it, and takes decision of its adoption or rejection. The process is enabled or motivated by prior conditions and through exchanging information using different communication channels within a specific time (Rogers, 2003). To the implementation itself, three steps apply: Redefining/ Restructuring – when both the organization and innovation become adjusted; Clarifying - when innovation is widespread to all members; and “Routinizing” - when innovation is incorporated.
Resources and incentives for successful adoption of innovation which fit in the above mentioned steps appear in literature on general innovation theory, as well as in the construction-related one. Concepts such as: rate of adoption, absorptive capacity, knowledge codification, champions, innovation brokers, and relationships with collaborating actors, are combined into an innovation strategy and have impact on a successful innovation performance at a firm level. “The final form of the strategy will be a function of the quantity and quality of organizational capabilities” (Walker and Hampson, 2003 cited by Blayse and Manley, 2004).

**Rate of adoption**

The speed with which an innovation is adopted by members of a social system is labelled a rate of adoption (Rogers, 2003). It is greatly affected by the characteristics of the innovation itself: the degree to which it is better from the idea it supersedes; whether it responds to existing values and needs; how difficult it is to understand and use it; whether it is possible to experiment with it; and if the results of the innovation are visible to others. Also the external factors, like the nature of a social system or its decision-making process influence the rate of adoption.

**Absorptive capacity and knowledge management**

On the other hand, the characteristics of organizations which raise their ability to adopt the innovation, or specifically to: recognize the value of new, external innovation; assimilate it; and apply it to commercial ends; is labelled absorptive capacity (Cohen and Levinthal, 1990). It is built mainly of prior internal knowledge and diversity of background within a company. The importance of the former comes from a concept that a unit which posses prior knowledge or skills is able to use the external knowledge or skills. This explains why some firms invest in general research, even despite spill-overs. The latter element - diversity of background - enables creating novel linkages and associations, and therefore, generation of new ideas (Utterback, 1971 cited by Cohen and Levinthal, 1990). Diversity relates not only to individuals, but also to groups and departments. Linkages between e.g.: R&D, manufacturing and marketing create so called “cross-function absorptive capacities”.

Acquiring knowledge by a company, especially a project-based one, does not automatically mean that this knowledge can be used to its full potential. To do so, the knowledge has to be constantly managed through its codification, articulation, and through accumulation of experience both among individuals and on organizational level (Prencipe and Tell, 2001).

**Innovation champion**

When it comes to the role of individuals in implementing innovation the most frequently mentioned character is an “innovation champion”, whether technical, business or an executive one (Roger, 2003; Blayese and Manley; 2004, Tatum, 1989). He or she possesses the ability of pushing the idea forward and motivating others to cooperate towards a common goal. Without an input from a champion change in an organization is likely to be slow and less successful.
Institutions (Innovation brokers)
The external context in which the development of innovation takes place is created by institutions. From the perspective of cultural evolution institutions refer to complex of socially learned and shared values, norms, beliefs, meanings, symbols, customs, and standards that delineate the range of expected and accepted behaviour in a particular context. Other perspectives allow interpretation of institutions as “the rules of the game” (North, 1990, cited by Nelson, 1995), or as structures and bodies of law, which define public order (Casella and Frey, 1992, Ibid.). Blayse and Manley (2004) saw the potential of institutions in orchestrating cooperation and knowledge growth to achieve innovation outcomes, and labelled them “Innovation brokers”. They act as: producers and/or repositories of knowledge; a ‘space’ for the evaluation of the merits of competing technologies; or information intermediaries between construction firms and others, helping firms become aware of technologies and competencies that may not otherwise come to their attention (Gann 2001; respectively Winch, 1998; respectively Manseau, 2003 cited by Blayse and Manley, 2004). Manseau noted especially the potential for innovation brokers to enhance the innovative capacity of small to medium enterprises.

2.2.3 Implementation of a system and radical innovation
As previously mentioned Slaughter distinguished 5 types of innovation applicable to AEC industry: Incremental, Modular, Architectural, System and Radical. Further, she identified activities and resources necessary to effectively implement innovation (Slaughter, 1998, 2010):

1. Commitment
2. Coordination within the project team
3. Resources
4. Active supervision

These considerations apply to all types of innovation, but their timing, degree, amount and level create a distinct implementation strategy for each type.

The first consideration – commitment – defines at which stage of the project progress the firm needs to assign resources to the implementation of the innovation, and often announce publicly the usage of innovation. System innovations, which often involve new functions or increased levels of performance, require early commitment, for instance, in a design phase. In case of radical innovations, the commitment is likely to be made even before the project is initiated, due to high risk and uncertainty of novel solutions. The process may involve the highest authorities from the involved organizations and will often be highly visible to the industry and the general public.

The second consideration regards the degree to which use of an innovation requires implicit and explicit coordination among the members of the project team, including the client, designers, contractors, and subcontractors. Implicit coordination can include informal
negotiation and collaboration of different purpose, while explicit one – formal documents. System innovation mobilizes all company members to explicit and implicit coordination, even those, who are not supposed to work with the innovation directly. Radical innovation may additionally require coordination from other organizations, or network of organizations, which can provide technical competence for credible trial of the innovation.

The third consideration states the types and sources of special resources needed in the adoption process. For system innovation special resources are distributed across several trades or areas of expertise, particularly in aspects of the system performance. This is similar to the radical innovation, however, resources in this case will probably not be sufficient without support from collaborating organizations.

The last consideration relates to the nature of the supervision activities, including the organizational level at which the supervision is required, the type of supervisory activities, and the specific competencies of the supervisors. In case of a system innovation an innovation champion will need to be able to promote the innovation across the project team and direct the evaluation through the implementation process, with respect to the overall performance objectives. The champion of a radical innovation must have credibility across multiple organizations and high technical competence to effectively present the arguments for the implementation activities.

2.3 Building Information Modelling

2.3.1 An overview

The most recent example of innovation in architecture, engineering and construction is Building Information Modelling – BIM.

3D CAD has been in use for some time in construction as a visualization tool to produce representations of designs and communicate ideas to clients and other collaborators on a project. Incorporating layers of information from architects, designers and engineers into the 3D model resulted in creating a 4D or nD, as possible added dimensions are claimed to be countless (Aouad et al., 2006 cited in Bryde, Broquetas and Volm, 2013). BIM is an example of such a multi-dimensional formation.

Various definitions of BIM have been proposed, but all of them recognize its fundamental part: it is a digital representation of a building (Aranda-Mena et al., 2009). Design process in BIM is object-oriented – it is composed of digital, predefined components which have relevant attributes attached to them, e.g.: materials or producers; and are defined with parametrical intelligence, which means that they can be altered by means of proportion, size or position with a simple change of parametrical values. Architects, engineers and contractors generate a model of a new structure in a virtual, 3D world, which stores the model with all its attributes, as: building geometry; spatial relationships; number of building components; and geographic information. This information is easily accessible to different project members, what in consequence enables quick identification of design and
construction issues and resolving them in a virtual environment well before the real construction phase (Jensen and Johanesson, 2013).

BIM as innovation falls into two previously mentioned categories: a process innovation, because it is aimed at enhancing working processes; and a system innovation, as it integrates multiple independent innovations which working together perform new functions. However, I think that BIM has a potential, or is meant to become a radical innovation. In order to this taking place, BIM will have to find application at all intended levels and be adopted on such scale, that the current ways of working will turn obsolete. Whether or not BIM becomes a radical innovation can only be resolved with a benefit of hindsight.

Nevertheless, the significance of BIM is acknowledged and best illustrated by an opinion among practitioners and researchers that firms cannot afford not to invest in BIM anymore (Ibid.) In a growing number of countries, not only organizations, but also governments engage actively in actions facilitating further adoption of BIM.

So called, “MacLeamy curve” has been central to propagating the intended benefits and effects of BIM in the building industry:

![MacLeamy Curve](image)

---

1 Green and red curves demonstrate distribution of design effort during a project lifecycle. The horizontal axis is divided into stages of a project lifecycle, while the vertical one indicates the amount of effort and achieved effect at a certain stage. The red curve illustrates a traditional building process, where the amount of work peaks between the stages of preparing construction documentation, and procurement. The green curve illustrates a process enabled by BIM (an Integrated Project
The diagram suggests that usage of BIM shifts the traditional work pace, so that the most effective work is done already in the design phase, where decisions and changes are easiest and least costly. This may be a solution to the worst drawbacks of AEC industry, which despite accounting with related industries, for about 15% of national product of most nations (Marceau et al., 1999 cited by Blayse and Manley, 2004), brings significant financial and environmental losses.

2.3.2 Understanding BIM

BIM is much more than a 3D-software. It is a “methodology to manage the essential building design and project data in digital format throughout the building's life-cycle” (Penttilä, 2006 cited by Succar, 2008). In the following sections the crucial components of this methodology will be explained.

BIM Fields

Building Information Modelling is spread on three, interlocking fields: Technology, Process and Policy (Succar, 2008). Each domain has a set of “players” and their “deliverables”, for instance: The Technology Field clusters organizations which create software; The Process Field clusters architects who design new structures or facility owners who maintain them; and The Policy Field clusters regulatory bodies which minimize conflicts among AEC actors. The fields interact between each other through exchange of information and cooperation among the actors. The dynamics determine this way the generation of the whole methodology.

![Fig. 2: BIM fields](image)

Delivery (IPD) resulting from a concurrent work of actors) in which most of the project work is done during the design stages. The black curves indicate consequences associated with the project work progresses: ability to impact costs and functional abilities of the project decreases with time, while costs of making changes in the project increase with time.

2 BIM Interactions are push–pull knowledge transactions occurring within or between fields. Push mechanisms transfer knowledge to another field while pull mechanisms transfer knowledge to satisfy a request by another field. Sample transactions include data transfers, team dynamics and contractual relationships between fields.
**BIM Steps**

The progress of BIM is enabled by fulfilling certain changes and milestones within each field, which are referred to as BIM Steps. Technology Steps embrace: software, hardware and network; Process Steps deal with: leadership, infrastructure, human resources, and product & services; and Policy Steps are divided into contractual, regulatory and preparatory. BIM steps are prerequisite for reaching a BIM stage, but they can also be a maturity level within a stage (Figure 3).

**BIM maturity stages**

As BIM is an extremely complex structure implementing it into an organization and an industry happens gradually, through consecutive stages. Each of the stages represents a radical change in working processes of an organization or network of organizations. There are two main factors which determine which stage has been achieved. The first one is a phase (or number of phases) of a project lifecycle in which BIM participates: Design, Construction, or Operations. The second factor is data flow – the type of shared information and the way it is shared, e.g.: synchronous vs. asynchronous communication (two-way information exchange through dialogs during meetings; respectively one-way file sharing).

BIM maturity stages (Figure 3):

- **A starting stage is a PRE-BIM**, which represents an organization which uses traditional working methods, e.g.: 2D software, or 3D only as a visualization tool.
- **Stage 1 is an object-based modelling.** At this stage a company has implemented the software, but designing remains through single-disciplinary 3D models without parametric attributes. BIM is used only in design lifecycle phase and communication and collaboration are traditional.
- **Stage 2 is a model-based collaboration.** BIM is used in both design and construction phase and collaboration between different disciplines is improved through BIM tools.
- **Stage 3 is a network-based integration.** Capacities of BIM are fully used, so exchange of information and ease of communication enable concurrent work on the project by different actors, throughout the whole project lifecycle. This processed is referred to as Integrated Project Delivery (IPD).
- **Further stages depend on future advancement of technology and lead to improved IPD.**
2.3.3 Implementation of BIM

Implementation of BIM is a matter of an overall process of transformation affecting not only an individual company, but a network of companies in the industry. It is associated with a “paradigm shift” (Jensen and Johannesson, 2013) and management of change (Bryde, Broquetas and Volm, 2012), mobilizing and affecting technical, operational and business capability of a firm (Aranda-Mena et al., 2009). In preparing a business case analysis for BIM implementation following groups of facts should be taken into consideration (Ibid.):

- Initiatives - The business, process, people, technology, and organizational actions/projects undertaken to achieve the outcomes; also, the contributions of each initiative to individual outcomes; and specific action items associated with the BIM implementation.
- Alignment issues between BIM implementation program and existing systems and procedures (regulations, policies, and business strategies)
- Efficiency - Improvements to the efficiency of designing and managing building projects.
- Design functionality - Issues that lead to better building designs.
- Collaboration - Improved support for collaboration among project participants.
- Resources/expenses - The resource requirements for BIM, and the corresponding costs.
- Risks - Critical risks facing a program, including risk quantification and mitigation.
- Assumptions, constraints and conditions for BIM implementations.

Successful implementation of BIM brings certain outcomes which result in enhanced technical, operational and business capabilities of the adopters. The first two areas reflect in general what was previously described as prerequisites to achieving a BIM stage: Technical and Operational Capabilities improve when the adopters, thanks to BIM tools, are able to prepare and exchange technical documentation in 3D, and communicate effectively throughout the process. Enhanced Business Capabilities are observed in these firms which can:

- Complete larger design projects with greater efficiency than before (particularly important for the smaller practice).
- Reduce risks associated with information-related errors (associated with information consistency in drawings, errors introduced during information exchanges, etc.)
- Improve design outcomes through better understanding of design alternatives by clients and designers (measured by client satisfaction levels and designers qualitative opinions of design).
**Issues and difficulties**

BIM technology brings a number of benefits, but its implementation and use in the current state of the art inflicts problems. Jensen and Johannesson (2013) in a study of the Nordic countries of Europe, indicated that the main challenge of BIM implementation on the organizational level lies in getting the employees to learn, accept and get used to new working procedures. Understanding the system and gaining necessary skills to use it require an appropriate training, which is usually limited to software manual. Thus, BIM has been criticized for excessive focus on technical infrastructure, with loss for design culture (Holzer, 2011). Moreover there is a discrepancy between clients’ demands for a project produced in BIM and their actual ability to process the deliverables. Also the distribution of effort, time, and costs differs in reality from those propagated by MacLeamy curve. In consequence risk management can become weakened, and managerial decisions uncertain.

On the network level, issues with BIM result from the fact, that different users understand the methodology in a different way: architects tend to see BIM as an extension of CAD, while contractors as a project management tool. The technical infrastructure is sometimes not mature enough for either purpose (Gu and London, 2010).

BIM challenges are also related to the modelling, specifically the lack of modelling standards. Practitioners have individual drawing styles and this creates conflicts when the projects reach detailing phase and virtual communication between disciplines accelerates. When models are exported to formats enabling collision control, number of mistakes increases drastically only owing to the different modelling style. The lack of common guidelines for all project actors depreciates the core innovative assets of BIM.

**2.4 Summary**

The literature review of this project paper presented findings on three interrelated fields: Architecture as a part of AEC industry; Innovation; and Building Information Modelling. First a world of architectural practice was introduced. Due to its unique characteristics comparing with other units of industry, architecture received a separate management domain. One of the managerial challenges, regardless of the type of business, is generating or adopting innovation in the company. Architecture is a highly innovative industry, first as a purpose of its existence is creation and design; second, as together with closely related industries, it adopts or uses a great number of innovative solutions for processes and products.

Innovation, which is generally defined as a commercialized invention, is a driving force of technological transformation. Studies on the domain gathered mechanisms beyond the development of innovation, and identified guidelines and principles for the successful implementation of innovative solutions, which can be applied also to the architectural context.

A recent, prominent example of such solutions is Building Information Modelling. BIM is a methodology to manage the essential building design and project data in digital format throughout the building’s life-cycle. This system, and potentially radical, innovation is being
gradually spread across the AEC industries and revolutionizes the working methods of architectural firms.

The above concepts were used as a background and framework to the empirical research on the implementation of BIM in architectural firms in Sweden. The purpose was to identify which managerial practices are applied to the process and what benefits it brings to the adopter company. The report of the research is presented in the next chapter.
3.0 Research methodology

To study the managerial practices associated with introduction of BIM and following benefits I have conducted a survey among a number of Swedish companies using BIM.

3.1 Identification of paradigm:
The analysis was carried out in the interpretivist framework:

- A small sample group represented users of an analysed work system in a specified environment;
- The results were derived from a qualitative data – descriptive, explanatory and contextual information about applied methods and their results; a subjective opinion of the participant was allowed and expected;
- The findings can find use in another, similar context.

3.2 Choice of methods

This is a descriptive research which purpose is to provide an illustration of the state of managerial practices applied to innovation in architectural firms under specific conditions (Sweden, BIM users). The primary data was collected from a survey, and the secondary data - from literature comprising both theoretical and empirical findings.
4.0 Findings

4.1 Survey organization
The survey contained 14 questions divided into 3 sections.

The first section starts with general questions about the participating firms. The aim of this part was to learn about the differences and similarities between the firms’ size and age, to find out whether those factors have influence on the survey answers. The section comprises additionally common statements which appear frequently in the literature on BIM in order to learn how Swedish architects evaluate the system in general.

The second section includes questions about the management of BIM adoption. The specific practices were derived from the literature on innovation implementation. The aim of this section was to indicate which of the theoretical findings find confirmation in case of Swedish architectural offices, and how important they are.

The last section regards business capabilities which were indicated in the literature as the business benefits of BIM.

4.2 Survey participants
In Sweden state initiatives on use of BIM in construction were first issued in 2013 (www.OpenBIM.se), a few years later than in neighbor Nordic countries. Certain number of firms in Swedish AEC sector adopted 3D modeling as a design method long before that. In this research I concentrate on firms providing architectural services and being members of OpenBIM. OpenBIM is a universal approach to the collaborative design, realization and operation of buildings based on open standards and workflows. It is an initiative of buildingSMART International (bSI) and several leading software vendors using the open buildingSMART Data Model. BuildingSMART International is a neutral, international and unique non for profit organisation supporting open BIM through the life cycle.

The survey was sent to 15 Swedish firms and the answers were submitted by 8 of them:

1. Fojab Arkitekter AB
2. Liljewall Arkitekter AB
3. Tengbomgruppen AB
4. Tyréns AB
5. Scheiwiller Svensson Arkitektkontor AB
6. Sweco AB
7. White AB
8. Zuez AB

The structure of the respondents looks as follows: firms consist of ca. 20 to 1200 employees, are 12 to 111 years old, and have been using BIM for 3 to 25 years:
<table>
<thead>
<tr>
<th>Company name</th>
<th>Firm size</th>
<th>Firm start-up</th>
<th>BIM start-up</th>
<th>BIM stage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td># employes</td>
<td>date #years</td>
<td>date #years</td>
<td></td>
</tr>
<tr>
<td>Sweco AB</td>
<td>500</td>
<td>1902 111</td>
<td>1988 25</td>
<td>1,2,3</td>
</tr>
<tr>
<td>Schweinwiller Svensson arkk. AB</td>
<td>42</td>
<td>1995 18</td>
<td>1995 18</td>
<td>2</td>
</tr>
<tr>
<td>Liljewall arkitekter AB</td>
<td>110</td>
<td>1980 33</td>
<td>2002 11</td>
<td>2</td>
</tr>
<tr>
<td>Zuez arkitekter AB</td>
<td>+207</td>
<td>2001 12</td>
<td>2004 9</td>
<td>1,2</td>
</tr>
<tr>
<td>Tyrens AB</td>
<td>1200</td>
<td>1977 36</td>
<td>2008 5</td>
<td>2</td>
</tr>
<tr>
<td>FOJAB arkitekter AB</td>
<td>100</td>
<td>1972 41</td>
<td>2009 4</td>
<td>1,2</td>
</tr>
<tr>
<td>White arkitekter AB</td>
<td>680</td>
<td>1951 62</td>
<td>2009 4</td>
<td>2</td>
</tr>
<tr>
<td>Tengbomgruppen AB</td>
<td>+500</td>
<td>1906 107</td>
<td>2010 3</td>
<td>1,2</td>
</tr>
</tbody>
</table>

Table 1: Participants’ structure

The remaining 7 firms which didn’t submit responses consist of 25 to 118 employees, are 18 to 40 years old, and have been using BIM for 1 to 13 years (data from the firms’ websites).

4.3 Survey results

Architectural firms are often small and rarely turn into corporations. As the sizes of the researched firms, and even the remaining ones, indicate, OpenBIM members belong to a group of relatively big firms. There are no start-ups among them, with majority existing for over 30 years, respectively over 20 years in case of members who didn’t submit the answers. Structure of the respondents and typical for architectural practice diversity of background, specialization and experience among employees may indicate that the absorptive capacity of the researched firms is high. They have financial and knowledge capacities the implementation of innovation requires, and therefore appear among the early BIM adopters.

All of the companies declared that they reached a second stage of BIM maturity and only one firm, which has the longest BIM experience, reached the third stage. The same respondent was the only one who disagreed with a statement that “firms cannot afford not to invest in BIM anymore”. Other common statements about BIM: that it requires an overall transformation of the firm, and that it is generally profitable; were agreed on by all participants, regardless of their size, age or experience.

There was no specific correlation between the chosen answers and structure of the answering firms concerning the second section of the survey – managerial practices. Half of the firms considered their in-house skills sufficient, while half used help of consultants or institutions in the implementation process. All firms but one stated that an innovation champion aided the process, but the type of the champion – technical, business or executive – differed among the firms. Similarly the areas of major changes – environment, structure and staff were of different importance in different firms. Among the specific managerial practices the highest priority received most often: “Coordinating the change of software”, “Distributing time and effort” – although equal number of offices assessed it as a task of average importance; and “Finding the right pilot project “– although one company claimed not to deal with this task at all. The most frequently pointed task of a lowest urgency was “Getting support from an institution/consultant”.

21
In the section of business capabilities, only the biggest firm denied improved efficiency of work after BIM has been introduced. According to the same company design outcomes have not improved, while most of the firms stated otherwise. The last question concerned risk mitigation. Five firms agreed that error-related risks reduced, while two firms, both of which have been using BIM for relatively short time, responded negatively.

Table 2 (p.23) presents detailed results of the survey, where the literature findings are confronted with the empirical findings.

4.4 Conclusions and suggestion for further research

The results of our analysis help to understand how the managerial practices enable successful adoption of BIM in Swedish architectural firms, and what the business outcomes of this process are.

Adoption of BIM is a demanding process. Most of that what composes a company, in a tangible and intangible way, will undergo a change. First of all, an environment of an organization needs adjustment. It involves changes in culture, mission, and internal policies, all of which create a framework for working processes. On the other hand, it may also mean protection of the above from potential negative outcomes of BIM, as for instance, excessive focus on technology while neglecting design values. A firm’s culture is related to how the employers behave and interact with each other, and whether there is a common sense of identity and purpose among them. The management role is to provide an appropriate training to help employers learn the software (where CAD experience is hardly useful) and comprehend the capabilities of the whole system. Otherwise insufficient knowledge and skills will cause confusion and frustration among the staff, and consequently will bring a detrimental effect on the work flow. It is also important to generate modelling standards early in the implementation, and share the routines with external actors, because it will profit in the further stages of BIM maturity. Due to extended information exchange connected with this process, internal policies must include new control methods.

Structure of the company defines organizational working units, how they are run and what their responsibilities are. It is an individual characteristic of each company and there is no common model for BIM users. Regardless of the structure a company already has, its shift is unavoidable: new positions, for instance a BIM manager, need to be established, while other might turn out redundant.

A right pilot project often facilitates the carrying out the whole adoption. Commissioning an external consultant is also a frequent practice, although some companies deal equally well with in-house capabilities only. In any case, a process is likely to be slow if it is not driven by an individual who is engaged and powerful enough to mobilize the work of others. So called “innovation champion” is most visible in managing technical infrastructure. The executive champion acts as a sponsor of the process, while a business champion provides a business framework for the adoption process.
Table 2: Survey results

<table>
<thead>
<tr>
<th>Facts from the literature:</th>
<th>Facts indicated by architectural firms:</th>
<th>Conclusion:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acknowledged benefits of BIM:</td>
<td>All of the researched firms confirmed that BIM is financially profitable and gives advantage over the competitors. However opinions about the affordability of BIM were divided. One respondent implied that BIM is especially important for developers and contractors, while the implementation by architectural companies often results from the demands of clients.</td>
<td>BIM can bring significant benefits to the architectural firms in Sweden however, its implementation is not yet obligatory to carry on with the business. At the moment the process is often initiated in order to meet clients’ expectations.</td>
</tr>
<tr>
<td>“Firms cannot afford not to invest in BIM anymore”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BIM raises competitive advantage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BIM brings financial benefits</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crucial managerial practices:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Implementation of system or radical innovation requires cooperation with institutions and external organizations</td>
<td>There are no doubts about the scope of change BIM brings to the adopter firm. Respondents confirmed the structural, environmental and staff changes, including new roles, like a BIM manager.</td>
<td>Swedish firms have in many cases sufficient in-house capacity considering knowledge and skills necessary to adopt BIM. Technical champions play a leading role in the process, while the role of institutions does not get special recognition, despite the fact that all the firms are members of an OpenBIM institution.</td>
</tr>
<tr>
<td>Implementation of system or radical innovation induces an overall reconstruction of a firm</td>
<td>However, external support from consultants or institutions was accepted in less than half of the firms. Among some of the offices, both large and small, in-house skills were deemed sufficient to run an adoption process.</td>
<td></td>
</tr>
<tr>
<td>An “innovation champion” is a critical</td>
<td>The role of an innovation champion was generally recognized, in an order of importance: Technical, Executive, and Business Champion.</td>
<td></td>
</tr>
<tr>
<td>The main managerial challenges relate to human resources, technical infrastructure, and time and effort distribution</td>
<td>Assessment of the managerial tasks:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Highest priority:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coordinating the change of software</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Distributing time and effort</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Finding the right pilot project – although one company claimed not to deal with this task at all</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower priority:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Training the staff</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Convincing the staff to new working methods</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gathering necessary knowledge and skills</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Finding/ allocating resources</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Risk management</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Getting support from an institution/ consultant</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>The lowest priority:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Finding competent staff</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coordinating collaboration with associated companies</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Responding to legal issues and regulations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Distributing time and effort</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Getting support from an institution/ consultant</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BIM enhances business capabilities through:</th>
<th>Almost every respondent confirmed that BIM makes it possible to complete larger projects with greater efficiency than before</th>
<th>Swedish architectural firms experience business improvement thanks to various aspects, out of which greater efficiency of work is the most important one.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved design outcomes,</td>
<td>Design outcomes were improved and errors reduced in 80% of cases. One respondent stressed that when reporting and delivering information changes, a change in control methods is inevitable (risk management)</td>
<td></td>
</tr>
<tr>
<td>More efficient work,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mitigation of risks</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Swedish architectural firms experience business improvement thanks to various aspects, out of which greater efficiency of work is the most important one.
Successful management of BIM implementation is meant to assure consistent formation of the environment and structure of the office. These two elements give basis for developing a business model and business strategy of the firm. They describe how architectural value is created and delivered to the customer for a financial return (Teece, 2010), and respectively how all resources of the company are developed and employed to guarantee the company’s most profitable and long-term survival (Knittel-Ammerschuber, 2006). BIM enhances business capabilities of architectural firms in different ways. It enables completing larger projects with greater efficiency than while using traditional methods. Moreover, most companies experience that design values improve as communicating ideas to clients becomes easier and architects are able to grasp more design alternatives. What turns out profitable as well is reduced number of documentation errors.

Although BIM adoption requires major investment and special resources, Swedish architectural companies declare that the process is generally profitable. They see positive impact of the methodology on the firms’ competitive advantage; however, a statement that “firms cannot afford not to invest in BIM anymore” proves to be exaggerated. BIM without a doubt brings benefits, but its implementation is not yet obligatory to sustain the business profit, and a reason for which BIM is implemented at the moment is often a client demand.

Further, more detailed survey would give a chance for more critical results and an extension beyond the literature findings. More precise information would also be obtained through a case study and by use of a quantitative data on actual financial results of the firms. The research should be continued as BIM develops and more companies gain access to it. Moreover, in order to acquire more comparative results, findings from the research group should be confronted with findings on firms which use traditional working systems.
5.0 Summary

In this paper architecture is studied from the perspective of its business value. Profitability of an architectural office is assured through the synergy between administering the design office and leading individual projects, in which principles and guidelines of architectural management find its application. Architecture, engineering and construction (AEC) is an innovative domain and innovative solutions frequently contribute to the development of the industry. Innovation is the actual use of a nontrivial change and improvement in a process, product, or system that is novel to the institution developing the change. The most advanced types of AEC innovations are a system and radical innovations, which applied to the industry, enforce major transition or even turn previous solutions obsolete. Their recent example is a Building Information Modelling (BIM) - a methodology to manage the essential building design and project data in digital format throughout the building’s life-cycle. In Sweden some forms of BIM have been in use for over 20 years, but only in case of a few individual firms. It was a few years ago when the methodology began to spread on a wider scale. Practices of architectural management enable successful implementation of BIM in the design offices and thus enhance capabilities of the architectural business.

As BIM is a constantly evolving domain, further research is needed to track changes in the architectural offices, when BIM reaches new maturity stages and becomes a dominating work methodology.
Acknowledgements

Special thanks to: Zara Daghbashyan for supervising the project work; Nina Borgström, Kristen Broberg, Mårten Fridberg, Maria Grunditz, Pär Hagberg, Johan Svahn, Michael Thydell, and Pelle Öhlin, for participating in the survey; and Anders Feldbæk Kristensen for kind advice.
References

Appendix

Survey questions

General questions:

1. Please state below: your name, name of the company, year it was started, and a number of employees it has at the moment (counting in earlier companies if the firm was merged)

2. When did the BIM implementation process in your company start?

3. What stage of implementation has been reached?

   [Stage 1: object-based modeling (only design phase of a project life cycle; implementing software, designing through single-disciplinary 3D models without parametric attributes; communication is still asynchronous and collaboration is still traditional)
   Stage 2: model-based collaboration (design or design and construction phases of project life cycle; collaboration between different disciplines improves through BIM tools)
   Stage 3: network-based integration (all project life cycle: design, construction and operation phases; full usage of BIM capacities: synchronous communication and interchange of information; concurrent construction model)]

4. Do you agree with a statement that “firms cannot afford not to invest in BIM anymore”?

5. Do you agree with the statement that implementation of BIM is associated with a management of change; mobilizing and affecting technical, operational and business capability of a firm?

6. Do you find investment in BIM generally profitable?

7. Has BIM benefited the competitive advantage of the firm? Has BIM benefited competitive advantage of your firm (brought attributes which make the firm better than the competitors)?

Questions concerning the implementation process:

8. Was the process aided by consultants or institutions?

9. Was the process aided by an “innovation champion”

   [Innovation champions have been described in literature as powerful individuals in an organization, or lower-level individuals who possess the ability to coordinate the actions of others and have a critical role in implementing an innovative solution; 3 types of champions have been identified: technical, business, executive.]
10. Did implementation of BIM require changes in the company’s:
   - Structure (units constituting the firm, linkages and coordination between them)?
   - Environment (policies, objectives, mission, culture)?
   - Staff (number and type of employees)?

11. Assess how important were these management tasks in adopting BIM:

   1= this task was crucial and most urgent
   2= this task was more important than the other ones
   3= this task was of average importance, was not especially urgent
   4= this task was irrelevant to the implementation process
   5= I didn’t deal with this task at all

   - Finding competent staff
   - Training the staff
   - Convincing the staff to new working methods
   - Gathering necessary knowledge and skills
   - Finding the right pilot project
   - Getting support from an institution/consultant
   - Coordinating collaboration with associated companies
   - Finding/ allocating resources
   - Distributing time and effort
   - Coordinating technical infrastructure change/ adopting new software
   - Risk management
   - Responding to legal issues and regulations

Other crucial managerial practices:
Questions concerning business capabilities achieved by BIM:

12. Having adopted BIM, are you able to complete larger design projects with greater efficiency than before?

13. Having adopted BIM, are the design outcomes improved through better understanding of design alternatives by: a) designers, b) clients?

14. Having adopted BIM, are the risks associated with information-related errors reduced?