Building Information Modeling (BIM) Adoption Barriers: An Architectural Perspective

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Abstract

Building Information Modeling (BIM) is the latest development in the Architecture, Engineering and Construction (AEC) Industry. This development can be used for planning, design, construction, operation and maintenance of any facility. The majority of the users of BIM technology are architects. Although its benefits had been highlighted and underlined especially in comparison with older developments such as Computer Aided Design (CAD) tools, its implementation is considered still in an early stage due to low adoption from architects.

Right now in Sweden and more specifically in the Stockholm area, the construction sector is booming due to the increased demand for housing. Thus, there is an increased demand for more houses in a shorter time.

BIM is a technology that can enhance the society in terms of design and construction with regard to the building environment. This can be achieved by avoiding human errors, decreasing project costs, increasing the productivity and quality, and reducing the project delivery time. Moreover, BIM can assist the management team in maintaining and operating different facilities.

The focus of this research is on the barriers to adopting BIM technology in architectural companies. Furthermore, the attempt will be to investigate the individual, organizational and technical aspects that affect BIM adoption. This study will implement a qualitative research method by in-depth interviewing four professionals in the area of architectural design.

This investigation will be driven by the main research question, which is: What are the barriers to adopting Building Information Modeling (BIM) in architectural companies?

Key Words: Building Information Modeling, BIM, CAD, AEC, Technology Adoption, Technology Acceptance, Architecture
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Abbreviations

AEC: Architecture, Engineering and Construction
BIM: Building Information Modeling
CAD: Computer Aided Design
IT: Information Technology
IFC: Industry Foundation Classes
MEP: Mechanical-Electrical-Plumbing
TAM: Technology Acceptance Model
2D: Two-dimensional
3D: Three-dimensional
BDS: Building Description System
“There is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in each success than to take the lead in the introduction of a new order of things. Because the innovator has for enemies all those who have done well under the old conditions, and lukewarm defenders in those who may do well under the new.”

-Niccolo Machiavelli, The Prince
1. Introduction

*In this part we will have a brief overview of the history of architectural technology and its tools that led to the Building Information Modeling (BIM) technology.*

1.1 Background

Traditionally, managing an architectural project has involved a laborious drawing of plans. Over time, these plans were giving rise to a whole set of documents, which included, among others, constructive details and specifications in which the way of building were described. The plans, sections and facades were drawn carefully, line by line, plane by plane. The traditional plans, both physical and digital, were composed of graphic elements, each line being part of a larger abstract entity that aims to express each of the project intentions in order to finally lead to the construction of a building.

When Filippo Brunelleschi drew the plans for the cathedral of Santa Maria del Fiore (see figure 1.1 below), during the Italian Renaissance, the plans reflected only an approximate idea of the final appearance of the building. They were simplified representations of the finished project that served to communicate their idea to the patrons. In those days, the architect and builder were the same person, so there was no danger of loss of information between the project phase and the execution phase of a building.

It was the time of the master builders, in which the architect and builder shared responsibilities and functions. In spite of everything, Brunelleschi still had to communicate his vision to the patrons and workers, and for that he not only drew some excellent plans but also elaborated careful models that allowed other people to visualize the project easily.

As more complexity was introduced into the buildings, the need arose to separate and specialize the design and construction processes, for which more elaborate methods of
information exchange had to be devised. There was no longer a single person in charge of the project and construction phases, and this forced the design architects to generate more information and more precise instructions to communicate their project decisions (Dzambazova et al., 2009).

By the 20th century, the use of steel had become widespread, allowing buildings to reach higher levels. The era of skyscrapers and modern construction was at its peak. The Power and Light Building was built in just 19 months in Kansas City, Missouri, as an Art Deco legacy to the audacity of those times. The construction of this building was carried out without the use of modern earthmoving equipment or any other type of heavy machinery. The plans of a building of these dimensions probably occupied about 35 pages in the 1930s. The building was more complex than its predecessors, but much simpler than today's large commercial projects (Dzambazova et al., 2009).

By the end of the 20th century, buildings reached a higher level of complexity. Design specifications require work of several disciplines and produce a large amount of drawings. Moreover, the number of people involved in the design and construction processes increases significantly. Integrated systems and networks in buildings are gaining complexity as technology advances in the sector. Nowadays, buildings have more requirements than ever in terms of electricity, data, telecommunications, security, ventilation, air conditioning and energy supplies. The quality and quantity of information that are part of the documentation of a project can no longer be measured in terms of abstract approximations; the cost of an error, of whatever kind, may be too high and, to avoid this, perfect coordination is required. Furthermore, the use of computer technology has replaced pencil and paper. Drawing and editing lines are now faster and more efficient, but in the background the drawings are still sets of hand-created elements (lines and texts).

The 1990s brought the Internet boom. A new way of understanding architectural documentation is about to be born, starting from a very simple premise: to create a model and give architects the power to visualize it, modify it and make notes about it, from any view, in any moment.

A change made in any of the views of the model supposes the automatic update of the rest (drawings and views). Plans cease to be a series of independent and uncoordinated lines and instead, become products automatically generated by a design program based on the creation of 3D (three-dimensional) building models. This was the moment where Building Information Modeling technology was born.

A definition of BIM technology could be:

“BIM (Building Information Modeling) is an intelligent 3D model-based process that gives architecture, engineering, and construction (AEC) professionals the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure.”

1 According to Autodesk Revit software definition [www.autodesk.com, accessed: 180408]. Autodesk is a multinational software corporation. Their software is primarily used by architects, engineers and structural designers to design, draft and model buildings and other structures. Autodesk is considered reliable source since it is has been involved in the creation and development of CAD and BIM since their early appearance.
1.2 Research question

Taking into account the definition of BIM in the previous paragraph, the research question is formulated as follows:

**What are the barriers to adopting building information modeling (BIM) technology in architectural companies?**

1.3 Research purpose & research objectives

The main purpose of this investigation was to set a research frame that would:

- Produce new knowledge for the researcher’s areas of interest, which are management, innovation and architecture,
- Underline the intersection of the above areas and how these areas can coexist.

This purpose is set in practice through the latest architectural technology tool called Building Information Modeling (BIM). BIM is a technology that intersects architecture, management and innovation throughout the building life cycle (figure 1.2).

According to Graham (2003), in the building life cycle, there is a phase of pre-design and development planning that involves project financing and feasibility study. Conceptual and detailed designs are the next steps of the process. Continuing, occurs the construction phase that implies analysis and documentation. The operation is the result of the use of the actual building. During the maintenance phase that follows, the building may undergo refurbishment including renovation. Finally, it may be possible for a building to become obsolete and therefore there is a need for demolition.

![Figure 1.2: Main phases of building life cycle](Dispenza, 2011)
However, although the interest in BIM is high, the advantages during the implementation process are not fully reached due to the low adoption from architects. Figure 1.2 below shows a comparison of BIM adoption between U.S. and Europe. In this graph 36% of AEC industry participants have adopted BIM. This percentage includes architects (47%), engineers (38%) and contractors (24%) (McGraw-Hill Construction, 2010). Thus, it is important to understand the barriers of adopting BIM technology in architectural companies and discuss its advantages and disadvantages.

![BIM Adoption—North America vs. Europe](image)

**Figure 1.3: BIM Adoption comparison between Europe and U.S. [McGraw Hill Construction, 2010]**

1.4 Delimitations

This section’s aim is to point the research choices and to define the set of boundaries for this study.

The author has a background in and experience with the architectural and construction industry in Sweden. Moreover, the author’s interest in management and innovation led to the investigation of possible combinations of these fields. All these areas are represented by Building Information Modeling (BIM) technology.

The focus of the research will be on the Scandinavian market and more specifically in the Swedish one, which right now is booming in the architectural design and construction sector. This market is on a transitional phase in BIM adoption and implementation in Europe, in comparison with countries such as UK, Germany and France that are leading the BIM implementation process (McGraw Hill Construction, 2014). All the collected information will reflect the Swedish market and its relation with BIM technology.

In this thesis only the architectural design industry will be studied by interviewing participants from two architectural companies operating in Stockholm. Other cities of Sweden will not be investigated. The construction industry will be mentioned but not investigated. The selected companies are involved in residential projects mainly in the area of Stockholm.

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2 Not available data regarding the Swedish market. Instead European data are provided in comparison with U.S.

3 Architecture Engineering and Construction
(city and suburbs). One of the companies is already established (since 1983) and has approximately 100 employees, and the other one is relatively new (since 2014), with 26 employees and has a management team with more than twenty years of previous leading experience. There is a difference in the size of these companies that most possibly will affect the internal organization and structure alongside with the BIM technology integration. Both companies are considered as medium size companies with regard to Stockholm architectural standards. Bigger architectural companies were avoided due to the existence of different and more complex organizational structures and additional departments such as construction, transportation, installations etc. that are not of interest for this study.

Considering the above, it is important to investigate the information related to BIM adoption from architects. The most related theories and theoretical frameworks for this investigation are Technology Acceptance Models (TAM). Regarding TAM and BIM theories, articles and books related to BIM adoption, BIM history, BIM benefits and barriers, BIM implementation, BIM acceptance model, Technology Acceptance Model and BIM challenges and risks will be reviewed. However, the focus for this study will mainly be in the BIM adoption barriers and decisions from architectural companies and the management team.
2. Literature review

This section’s main purpose is to address the research question (RQ) from two perspectives. The first perspective is to understand the current context and evolution of BIM technology. The second perspective is to understand the chosen related theoretical concepts in order to inform the findings in a later stage.

2.1 Building Information Modeling (BIM)

BIM is an acronym that stands for Building Information Modeling. With regards to BIM, everything begins with a 3D digital model of the building. This model is far more than just geometry. It consists of the digital equivalents of the real building parts and components used in the actual construction. These building elements, systems, parts and components have the exact attributes (physical and functional) of the real building (for example, walls, columns, stairs, windows, roofs, etc.). Consequently, BIM enables the complete virtual simulation of the entire, real building before the construction development begins. Furthermore, BIM covers the whole life cycle of a building, that is, the design, construction, operation and maintenance of a building.

The concept of BIM goes back in 1975. Building Description System (BDS) was the first system relatively close to modern BIM. It was described from the architectural expert Charles Eastman (1975). BDS’s goal was a “paperless” design documentation that could provide additional benefits such as simple design input of complicated building components, re-use of the existing elements, generated building views and renders and automated building elements such as schedules and surveys.

Next important step in the BIM evolution was the creation of “Virtual Building” on 1987 from Graphisoft Archicad (Luciani et al., 2012). In that release Archicad could produce 3D building models with automatically generated views. Moreover, the software could support advanced parametric 3D shapes.

The first paper with the term Building Information Modeling, as we are using it nowadays, was published on 1992 at the Technical University of Delft (Nederveen et al., 1992). In that paper it was underlined the importance and advantages of reference-model based workflow as long as the need for tight and organized link between the architectural and engineering “information” systems. However, the term BIM was not popular until 2002 when Autodesk purchased the company responsible for Revit^4 BIM Software and released a white paper^5 named “Building Information Modeling”. Alongside with Autodesk other BIM software companies such as Graphisoft, Bentley Systems and industry’s analysts such as Jerry Laiserin^6 helped on popularizing and standardizing the term BIM for the digital representation of the building process (Eastman et al., 2008).

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^4 Charles River Software Company in Cambridge, MA, had developed REVIT BIM software before Autodesk purchased the company. Revit is considered one of the main competitors of BIM technology in the global market.

^5 A white paper is an informational document, issued by a company or not-for-profit organization, to promote or highlight the features of a solution, product, or service. [investopedia.com, accessed 180609]

^6 Jerry Laiserin focuses on future technologies for the building enterprise and on collaborative technologies for project-based work. [www.laiserin.com, accessed: 180609]
A definition according to Ashcroft would be helpful to understand the BIM concept: A building Information Model, or BIM, utilizes cutting edge digital technology to establish a computable representation of all the physical and functional characteristics of a facility and its related project/life-cycle information, and is intended to be a repository of information for the facility owner/operator to use and maintain throughout the life-cycle of a facility (Ashcroft, 2008).

Concluding, BIM is changing the way architects, engineers, contractors, and other building professionals operate in the industry today. Eastman, in the BIM Handbook, describes Building Information Modeling as an innovative way to design, fabrication, pre and post construction and operations and management in comparison to the traditional way of drawing (Eastman et al., 2008).

2.2 CAD versus BIM functionality

The basic difference between the BIM technology and the design methodology Computer Aided Design (CAD) is that a classic CAD system uses many separate (usually 2D) drawings to describe a building. These documents are created separately, thus there is no correlation or "smart" connection between them. For example, a wall illustrated in a drawing is depicted in two parallel lines, without any information that these lines represent the same wall in another drawing. Therefore, the probability of uncoordinated data is high.

BIM, on the other hand, has the opposite approach. It concentrates all information in one database and associates all data with those objects (building and building components). The BIM model is therefore a centralized database model, where all data are correlated to each other in an intelligent way. Moreover, this centralized model is assisting in the collaboration between all involved disciplines (BIM interoperability). On the other side, traditional tools (such as CAD) require more traditional ways of communication between the various actors (See figure 2.1 below).

![Figure 2.1: 2D data exchange in comparison with BIM interoperability](http://biblus.accasoftware.com accessed: 180407)
In general, CAD (figure 2.2) is a 2D technology that exports a collection of drawing lines and texts on one page. Moreover, a CAD design has greater efficiency and many advantages over pen and paper, but in fact, it is just a digital simulation tool. Previously, designers were making drawing plans and then were developing the sections, facades and details by hand. However, during the development of a project, if there was a problem with some of the drawings, all the changes had to be done manually in every single drawing that was affected by those changes. For a long time, this meant architects had to use this tedious and time-consuming process. With BIM, that problem is avoided, since a change in one component will be applied automatically to all the affected drawings. Thus, the architect has to make the change only once.

The crucial difference with BIM technology is that it automatically implements all the changes. Unlike CAD, the intent of BIM technology is to rely on the computer to take more responsibility for interactions and calculations (something which computers are good at), giving its designers more time to design and evaluate their decisions. When a change is made to a component of the project, the system will propagate the change to all other affected parts and elements of the project. The modified drawing plans of the project automatically produce the new modified facades, new sections and various new design elements. When a change is made, the designer can decide whether to finalize it or not. The system will take care of the rest.

For example, with BIM software (figure 2.3), when modifying the window of a building, the
change will be implemented (syncs) throughout the model: sections, floor plans, tables, timetables, forecasting and forecasting tables. In a system based on CAD, it can easily be omitted in some of the drawings because the window has to be manually changed. This fact can lead to forgotten or misplaced position of the window. BIM is based on the interrelated real relationship of the data, reducing the likelihood of mistakes in the event of modifications.

Another aspect to consider when talking about CAD and BIM technology is their relation to effort/ cost/ effect in correlation with the time and different phases of every project. Patrick Macleamy, CEO of HOK⁷, introduced the Macleamy Curve in 2005. In the diagram below (figure 2.4) we can see the cost of decision mapping along the timeline of a typical construction period. From this diagram we can see clearly that decisions made early in the project (during the design phase) can decrease significantly the cost of the project while at the same time having great effectiveness. BIM workflow is number 4 in the diagram and as we can see its impact is early in the project. Drafting centric workflow can be considered as CAD technology (Number 3 in the diagram below). The main difference with CAD is that it moves the curve to the left. This means that by working with CAD we have less ability to impact cost and performance while maintaining high cost of design changes.

⁷ HOK are the initials of Hellmuth, Obata + Kassabaum. HOK is an American international design, architecture engineering and urban planning firm [www.hok.com, accessed: 180407]
2.3 The applications of BIM

There are different BIM applications over the development and the lifecycle of a building. These applications are related to various dimensions of the BIM technology and how it is implemented.

The ones that follow are only a portion of the uses of BIM that can be connected to each part of the development process through its design, planning and construction stages.

- Development Scheduling: The particular time schedules can be arranged well and impart precisely as intended to the contractual workers and other actors.

- Site Utilization Planning: Optimizing the construction site and allocating space for different temporary facilities such as materials storehouse, construction equipment etc. in order to avoid onsite conflicts during the construction phase. For example, when new materials, which are ordered for the construction, arrive into the site then they will occupy a certain space for a certain time until they will actually be used. Considering those factors the materials have to be located in a position within the construction site that will not disturb the workflow or the arrival of other building elements and materials.

- MEP (Mechanical-Electrical-Plumbing) BIM Coordination and conflicts detection: MEP frameworks are intricate alongside with different disciplines involved. It is of high importance to detect internal and external conflicts from the total coordination in
order to save great amount of effort and money. For example usually coordination between different disciplines such as architects and mechanical engineers is necessary in order to achieve the right results. Pipes in a building, for example, need this type of coordination. The architect has to locate those pipes (within BIM) and design accordingly the right covers and ceilings so that the pipes are not visible.

- Recognizing time-based conflicts: BIM represents how a specific activity is done, alongside its anticipated time and cost. BIM ensures that the arranged grouping of tasks and their time periods do not overlap or conflict. Accordingly every activity, for example, temporary constructions such as storehouse for materials etc., occurs without disturbance.
- Energy efficiency: The whole procedure of building development and building lifecycle optimizes the use of energy. Sustainability factors are taken into account for implementing the energy efficiency.
- Cost Estimation: BIM permits representation of development activities and the gathered expenses. Furthermore, cost estimation is more precise with BIM technology rather than with old methods.

2.4 Technology Acceptance Models (TAM 1-2-3 and BIM TAM)

Although it is believed that BIM has strong potential and advantages in design and construction, its adoption and possible uses are still a concern of research and practice. This section discusses the differences between the three Technology Acceptance Models in order to understand the role of BIM technology as an IT tool (software).

Moreover, the objective of this research is to discuss the BIM Technology Acceptance Model based on the previous acceptance behavior related theories such as TAM 1, 2 and 3. This part of the research is structured as follows: first we are going to discuss and analyze each of the main models-theories and their main differences. At the end of the analysis of these three models, a synopsis with a short statement will follow highlighting the main objectives of each model. Continuing, we are going to discuss about a modified model named BIM TAM which was introduced by Lee et al. (2014). This modified model includes aspects of the three previous theories (TAM 1, 2, 3) while at the same time is focusing on BIM technology.

The Technology Acceptance Model or TAM (Davis, 1989) was the first model to introduce psychological factors that influence technology acceptance and has helped to understand the Behavioral Intentions and usage of IT. The aim of TAM is to determine the factors involved in IT tools’ acceptance, and so, to explain user behavior. It was introduced by Davis in 1989, adapting the Theory of Reasoned Action (TRA) (Fishbein and Ajzen, 1975) and the Theory of Planned Behavior (TPB) (Ajzen, 1991), and relating them to user acceptance of information systems.

Perceived Usefulness and Perceived Ease of Use are the main factors affecting the acceptance behavior. TAM suggests also that external variables are obliquely influencing the Attitude
Towards Using, which leads to the IT system use by affecting Perceived Usefulness and Perceived Ease of Use. According to TAM, the individual’s Behavioral Intention to Use an IT system depends on Perceived Usefulness (the extent to which one believes that using the system will help with the job consummation) and Perceived Ease of Use (the extent to which one believes that using the system will be easy). The External Variables (training, system characteristics, effort etc.) influence the intention to use, being harmonized by Perceived usefulness and Perceived ease of use (as shown in figure 2.5 below). The weakness in this model is that it does not include social factors that are influencing user’s attitude (Yu et al., 2005). This was one of the reasons of TAM 1’s further development.

![Figure 2.5: TAM 1 Model diagram](www.researchgate.net, accessed: 180408)

In comparison with TAM 1, TAM 2 (Venkatesh and Davis, 2000), also called the extended TAM (theoretical extension of TAM 1), adds Subjective Norm, which reflects perceptions that other people desire the individual to perform in a particular way. Barki and Hartwick (2001) found relevant the Subjective Norm in case of the compulsory system use, working as another possible predictor of Intention to Use (figure 2.6, Venkatesh and Davis, 2000). Additional to Subjective Norm there are some other social influence processes such as Voluntariness and Image and some knowledge contributory processes (Output Quality, Result Demonstrability, Job Relevance etc.) that affect the user acceptance.

Considering the above information, TAM 2 is trying to explain Perceived Usage and User Intentions in terms of social influence and knowledge contributory processes and to clarify how these variables alternate by expanded use over time in a technological system (Kripanont 2007).

The purpose of TAM 2 according to Yanez-Luna et. al., (2012) is:

- To permit organizational interventions that can enhance user acceptance and usage of new technology,
- To help on understanding how the effects of these additional determinants (figure 2.6 below) can increase user experience over time,
- That Experience and Voluntariness can function as moderators to Intention to Use and Perceived Usefulness.
Deeper research of TAM 2 led to TAM 3 (figure 2.7, Venkatesh and Bala, 2008). This model is targeting mostly IT applications in comparison with TAM 1 and 2 that are open for implementation to different settings. Moreover, TAM 3 was developed to help the decision making in organizational level. In this extended model, TAM 2 determinants and determinants of Perceived Ease of Use are combined. Furthermore, are expressed in more detail the factors that affect the Perceived Ease of Use (the degree to which a person believes that using IT will be easy). These additional details are Computer self-efficacy (individual’s possibility of realizing a task through the computer), perception of external control (perceived system support with organizational and technical means), Computer Anxiety (individual’s attitude when using computers), Computer Playfulness (spontaneity through computer interactions), Perceived Enjoyment (individual’s perception of enjoying the use of the system independently from performance results), Objective Usability (system comparison of effort needed for specific tasks). The TAM 3 model was set in practice in real life conditions of IT applications (Venkatesh and Bala, 2008).
Each TAM model had a different focus and was developed for a certain purpose related to technology acceptance:

**TAM 1** is introducing psychological factors (Behavioral Intention) and external variables (Perceived Ease of Use and Perceived Usefulness). Social factors are not included in this model.

**TAM 2** is trying to explain Perceived Usage and User Intentions in terms of social influence and knowledge contributory processes. This model can assist organizational interventions for enhancing user acceptance and new technology usage. Moreover, user experience over time can be studied in relation to the different variables.

**TAM 3** is targeting mostly IT applications. It is expressing in more detail the factors that affect the Perceived Ease of Use. The purpose of this model is to help the decision making in organizational level.

It was important to describe and analyze each model in order to understand that there is not a universal model that applies to every case of technology adoption. The development of TAM models is an ongoing process that has the flexibility to adapt to certain circumstances. Regarding which model applies to a specific technology, this is related to the focus of the research. In our case with regard to BIM adoption, the focus of the research includes psychological factors such as Behavioral Intention (TAM 1), social and knowledge factors (TAM 2) and lastly the factors that apply to an IT application from a Perceived Ease of Use perspective (TAM 3). Therefore, TAM models can be considered as the core theoretical models.

As we already mentioned, TAM is applicable to BIM as IT software in the architectural sector.
In figure 2.8 below, Son et al. (2014) propose a modified technology acceptance model for BIM users. In this BIM TAM model the factors that influence the behavioral intention of architects towards BIM adoption are examined. More specifically, in the model we can see external variables such as Top Management and Technical Support, Computer Self-efficacy, Compatibility and Subjective norm. Moreover, elements such as Perceived Usefulness and Ease of Use and Intentional Behavior that are affected by external variables are taken into account too.

Behavioral Intention focuses mostly on the architect’s adoption of BIM rather than actual use. Moreover, Perceived Usefulness and Perceived Ease of Use are contributory for describing the user’s intention towards BIM.

In some cases the land developer and contractor can request the use of BIM. In these cases BIM use is required and architects have to use BIM technology. The reason for using only the Behavioral Intention in the BIM TAM model below (figure 2.8), and not the actual system use as seen previously, is because Behavioral Intention is more appropriate for technology adoption in mandated environments (Son et al., 2014).

When architects are using BIM and they consider that their performance is increased, then it is more likely to have a positive effect on Behavioral Intention. Furthermore, it is believed that BIM can escalate productivity (Burton et al., 2006).

Below we will describe briefly the characteristics of the external variables of the BIM TAM model according to Son et al., (2014) and also their impact on the other elements of the same model. (For description of Perceived Usefulness and Ease of Use please see TAM above):

- Top management support: Individuals’ perception of management’s willingness and support on IT functions within the architectural companies (Chung B. et al., 2008),
- Technical support: Knowledgeable people’s assistance for hardware or software products (Ralph, 1991, and Ngai et al., 2007) offered to architects.
- Computer self-efficacy: Individual’s belief that one can use a computer skillfully (Compeau et al. 1995),

![Figure 2.8: BIM TAM model [Son et al. (2014)]](image-url)
• Compatibility: Individual’s perception that technology aligns with the needs, values and work practices (Rogers, 1983),
• Subjective Norm: Individual’s belief that others think that the individual assumes people should or should not do specific actions (Sherrie et al., 2006)

BIM TAM Model’s elements impact (H1, H2..H9) according to Son et al., (2014):

• H1-H2: Perceived usefulness and perceived ease of use will have a positive impact on behavioral intentions accordingly,
• H3: Perceived ease of use will have a positive impact on perceived usefulness,
• H4: Top management support will have a positive impact on perceived usefulness,
• H5: Subjective norm will have a positive impact on perceived usefulness,
• H6: Compatibility will have a positive impact on perceived usefulness,
• H7: Compatibility will have a positive impact on perceived ease of use,
• H8: Technical support will have a positive impact on perceived ease of use,
• H9: Computer self-efficacy will have a positive impact on perceived ease of use.

A critique to the above is that TAM theories (TAM 1, 2, 3 and BIM TAM) have limited application when applied beyond the working environment and that due to its fundamental elements that do not fully represent the varieties of the user tasks environments and limitations (Son et al, 2014).

Moreover, according to Salovaara et al., (2008), the simplistic understanding of “acceptance” does not always identify the potentiality of invention of new uses for technology in several circumstances. Lacking this recognition fact can lead to the assumption that users are passive absorbers of technological products, independently of context, tasks, or collaboration (social attitude) aspects. Considering the above, technology use and acceptance must actually be understood in a more diversified context as a process in which different users approach and use the product in varied ways.
3. Methodology

This section’s main purpose is to present the research approach, the chosen paradigm framework and the method for data extraction and analysis.

3.1 Research approach

This thesis employs qualitative research. It is believed that qualitative way of data collection is ideal for extracting and exploring the perceptions, empirical knowledge, decisions, visions, barriers and benefits of BIM technology. As stated by Taylor: “qualitative methodology refers in the broadest sense to research that produces descriptive data, such as people’s own written or spoken words and observable behavior” (Taylor et al., 2015, pp. 7).

In order to conduct the study a specific number of professionals from the business of architecture will be selected for interviewing. The profiles of the users that will be selected for the interviews are architects that are using BIM technology in their everyday working routines, tasks and projects. The data extraction will be applied through the form of in person interviews.

Moreover, a number of additional aspects will assist in the research approach. These aspects include:

- Author’s personal experience (working with BIM technology platform(s) in several projects the last 9 years).
- Review of books, articles and internet sources related to management, architecture, technology adoption and acceptance, BIM characteristics, BIM benefits and BIM obstacles.

3.2 Research paradigm

According to Chilisa (2011), we have four main groups of research paradigms. Those groups are positivism/ post-positivism paradigm, constructivist/ interpretative paradigm, transformative/ emancipatory paradigm and postcolonial/ indigenous research paradigm (Chilisa, 2011). In our case, the analysis will be conducted with the interpretivist research paradigm. According to Chilisa the characteristics of this type of research paradigm are:

- To understand people’s experiences,
- The nature of knowledge is considered as subjective,
- Truth is context dependent,
- Qualitative methodology can support the interpretivist research paradigm by interviews,
- Hermeneutics and phenomenology operates as philosophical underpinning,
- Assumptions of the multiplicity of realities also inform the research process.

Moreover, according to Collis & Hussey, in such a paradigm the reality has a subjective
understanding that is affected by our experiences (Collis & Hussey, 2009, p.45).

Considering the above, a small group (4) of architect professionals will be selected from a specified environment (architectural companies). A qualitative data approach will be applied for the extraction of the results. Participants will be expected to express their experiences through subjective opinions.

3.3 Choice of methods (data extraction and analysis)

Qualitative research will be applied using in-person interviews. The settings for these interviews are two Swedish architectural companies that operate in Stockholm. The reason for these settings is the author’s related experience with Stockholm architectural market.

What led to the selection of participants from these two specific companies is author’s network within them. This network could assist in the communication for the conduction of interviews. Moreover, the existence of an already established network within these companies could enhance the quality of the provided information.

Regarding the choice of the sampling method of the participants, a non-probability sampling method was selected and more specifically a purposeful sampling technique was applied. This method includes identifying and selecting the participants that can provide rich information for the most effective use of resources such as limited time (Cresswell et al., 2011). Another aspect that was considered important for this type of sampling method according to Bernard, (2002) and Spradley (1979) was the availability and willingness of participants for the interviews and moreover the ability to communicate experiences and opinions in an articulate, expressive and reflective manner.

Regarding the number of interviews, four interviews are considered enough for the investigation of this topic. Furthermore, there is a time constraint with regard to the thesis investigation timeframe that allows only a small number of in-depth interviews.

The interview questions will be designed and formulated by addressing these four participants. The focus of the questions will be dedicated on extracting the most of the empirical knowledge from each interviewee.

The questions will be structured and organized in two phases. First we will try to understand the profile of the person we are interviewing regarding BIM technology, employment, experience, workflows, etc.

During the second phase we will apply open ended questions. In that way we will try to understand:

- The CAD and BIM experience and challenges of the interviewees,
- The challenges regarding the teamwork,
- The challenges related to BIM adoption,
- The BIM Usage

and discuss its barriers and possible ways of future development.
The process of the interviews will be structured in three steps. First, we will contact all the interviewees in order to explain and describe the context of the questions and the time that would be needed. Secondly, the interview questions will be provided to the interviewees at least one week in advance in order to prepare the answers. In the third phase, a time will be booked to meet with the interviewees and conduct the interviews.

The language of the interviews will be English so that the author will understand and collect all the necessary information (answers). During the interview process, it will be asked from the interviewees the possibility of recording the interview. This will be done in order to analyze the answers in a later stage. In case the interviewees will not agree, then the material for analysis will be the author’s and interviewee’s notes.

This will be exploratory research designed to gain familiarity and insights with BIM technology, its barriers, and its benefits applied on an architectural office.

The techniques that will be used are reviewing the existing and available literature. Alongside with the formal in-depth interviews, a series of informal qualitative approaches will be conducted. The approach will include discussions with other employees such as architects and the management team within the two selected companies.

Another aspect to consider is the author’s employment in one of the two interviewing organizations. The author has access to documents and information that are related to the scope of this study. However, the author’s role will be limited as “participant-observer”. According to Becker and Geer (1957), participant observation and interviewing means that the observer participates in the daily life of people under study. In this type of interview, the interviewer examines many aspects of his interviewee’s concerns and treating subjects as they develop in discussion. The participant-observer role provides a rich empiric context which prompts him to become alerted of unconnected or unfamiliar facts, makes him receptive to possible assumptions and nexus with other observed details, and thus forces him consistently to correct and adjust his theoretical orientation towards greater significance to the under research facts. Consequently, this type of context and its employed benefits cannot be replicated in interviewing.

3.4 Ethics and sustainability

In this study, Harvard referencing system is implemented in order to avoid plagiarism.

In order to extract information from the interviewees without them being concerned about their answers, we will preserve their anonymity as well as their companies’ anonymity. This means that instead of their real identities, we will provide codified names such as Interviewee A, B, C, D and for their interview organizations, Company 1 and Company 2. Moreover, the notes and observations will remain anonymous due to the responsibility of not exposing the interviews and sensitive information in any way. Furthermore, all interviewees will be informed of their right to review the obtained notes. In case someone of the interviewees asks for removing any type of sensitive information, then this information will be removed and not mentioned in the final (thesis) document.
In the Appendix it will be possible to review the interview questions. However, these questions will function as the foundation for further questioning. The contact and communication with the participants will be done in a respectful and transparent way. During the structuring of the interview questions we were aware of the theoretical research and we will try to maintain the balance by avoiding any possible emotional pressure. The focus will be solely in the extraction of relevant information.

All the interviews will be carried out face to face in Stockholm. From this perspective we will minimize the sustainability implications that would occur otherwise if for example we had to travel to another city.

Yet, the author’s employment in one of the two interviewing organizations is possible to raise questions regarding the access to sensitive, proprietary and confidential information. Considering this perspective there is an ethical obligation to handle the perceived information (from the interviews and from author’s experience during his employment in the company) properly and responsibly. This will be done by not exposing any type of information that may cause the company to lose value (for example by exposing workflows, competitions strategies etc.).
4. Findings and discussion

This section will include the description of both interview organizations and interview participants. Next will follow the interview results and analysis based on the collected results from interviews, informal discussions and secondary research data.

4.1 Interview organizations

More specifically the findings will result from:

- 4 interviewees within two architectural companies (Company 1 and Company 2). The interviews will be between 20-30 minutes depending on the duration of the answers. In case some of the answers are not clear a deeper explanation will be requested.

The main differences of the organizations are:

- The size (approx. 26 employees at Company 1 and approx. 100 employees at Company 2).
- The degree of implementation of BIM technology (Company 2 has fully implemented BIM technology while Company 1 is working both with CAD and BIM technology).
- Company 2 is using ArchiCAD BIM software while Company 1 is using REVIT BIM software.

The main similarities of the organizations are:

- Operating in the Swedish market.
- Involved mainly with the housing sector.

4.2 Interview results and analysis

The interview questions are structured and organized in two phases. First it is attempted to understand the profile of the person interviewed regarding background, employment, and role.

During the second phase it is attempted to understand:

- The CAD - BIM experience and challenges,
- The collaboration challenges,
- The adoption and outcome difficulties and
- The BIM Usage

The interview questions were grouped according to these four aspects above that were defined and driven by:

- the reviewing of the literature
- the author’s experience
- the informal discussions with the employees of the two organizations
Four tables are created for each of the aforementioned categories (CAD-BIM Experience-Challenges, Collaboration, Adoption-Outcome and BIM Usage). Every relevant answer from all interviewees will be placed next to each other for comparison purposes. The answers will be placed in original version.

### 4.2.1 CAD-BIM Experience and challenges

According to the table in the next page (figure 4.1) the interviewees are using BIM- ArchiCAD, BIM-Revit and AutoCAD Software. The tasks vary from 3D model development to 2D drawings. Regarding the software challenges these are: producing a good 3D model, using the right tools in order to save time since the development of a good 3D model implies a large amount of time. Yet, another challenge also is that BIM software is not intuitive and when it comes to complex geometry becomes frustrating.

Regarding the question about if BIM is a successful replacement of CAD tool there are different responses. 2 out of 4 are tending to yes and the other 2 are in doubt regarding the full replacement. Moreover, the switching from CAD technology to BIM technology it was complicated for all the interviewees. The reason for the switching difficulties are the mindset difference (2D versus 3D mindset), the long learning process (since it is less intuitive than CAD), and lastly the lack of artistic freedom capabilities (such as sketch tools) for the creative professionals (architects).

Considering the realization time of a project, all agree that BIM technology shortens the delivery time. Moreover, another aspect that is added to this question has to do with the size of the project, where smaller projects are not affected by the use of BIM. Furthermore, from an administrative outlook the preparation time is considered much less. This aspect makes BIM technology far more efficient than CAD.

“The biggest challenge was to be forced to always think in 3D terms in BIM. In CAD all the drawings were made in 2D.”

-Interviewee A
<table>
<thead>
<tr>
<th>Question 1</th>
<th>Interviewees A</th>
<th>Interviewees B</th>
<th>Interviewees C</th>
<th>Interviewees D</th>
</tr>
</thead>
<tbody>
<tr>
<td>What software do you use to carry out your tasks/projects?</td>
<td>AutoCAD</td>
<td>Revit, Autocad</td>
<td>Revit</td>
<td>Mostly BIM software (Archicad). Also AutoCad, but in a lower level (2D drawings such as construction details which we receive in dwg format).</td>
</tr>
<tr>
<td>The most frequent tasks are to build up the 3D-model in BIM for the project I am working with.</td>
<td>The main challenges are to find the most optimal way to build up the 3D-model so I can save time by using the right tools. It is also about building the 3D-model so I can get the most out of it. For instance, building a good model will make the tool ‘Schedules’ easier to use.</td>
<td>Working with complex geometry is a complicated task within BIM softwares. Although possible, this is still something that can be heavily improved. BIM softwares allow great efficiency in reasonable projects but need to see great improvements and allow a more creative design process.</td>
<td>I do not have important problems when working with BIM, since I got to feel comfortable with this software. But for example, producing a good 3D model, that is the source of the visualization of the project, is a process that implies a large amount of time.</td>
<td></td>
</tr>
<tr>
<td>Question 3</td>
<td>What are the main challenges with the software you use when carrying out daily tasks?</td>
<td>Question 4</td>
<td>How many years of experience do you have with BIM and BIM technology?</td>
<td>17 years, Revit</td>
</tr>
<tr>
<td>CAD: 17 years, Revit: 4 years</td>
<td>CAD: 17 years, Revit: 4 years</td>
<td>11 years of CAD experience and 1 year of BIM experience.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Question 5</td>
<td>Do you think BIM is a successful CAD replacement technology and why?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>I think it is. Doing a project with BIM will always take less time and do it with CAD. Thanks to having a BIM model, you can have all your views (2D, 3D, plans and sections) taken out of the model so you can change something in the project you only need to do it once and it will automatically show in all your views. This doesn’t happen in CAD.</td>
<td>I don’t think so. It changes drastically the way you design and limit the possibility to test different options and sketch a intuitive, fast way.</td>
<td>In many ways yes – it allows more efficient and precise collaboration between different fields. Architects, engineers, contractors and subcontractors can simultaneously work on one file. BIM allows an expanded interaction which previously didn’t exist. It has closed the gap which used to exist between architects, engineers and other consultants and the multiple softwares which is available in each of the individual fields. Having to export and convert files so other software are able to read them is something that now seems to belong to the past.</td>
<td>I am not sure if BIM can replace completely CAD technology (BIM also enables the work in 2D). CAD is closer to the “free-hand” idea, that is of high importance in architecture. BIM is successful when it comes to collaborative work, as several people can work with one file at the same time, and with a more real approach, since it works with construction objects that include qualitative and quantitative characteristics. Maybe BIM is a good tool for very early stages of a project. And of course for the learning of architecture in general.</td>
</tr>
<tr>
<td>Question 6</td>
<td>What were the challenges from switching from CAD technology to BIM technology?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>The biggest challenge was to be forced to always think in 3D terms in BIM. In CAD all the drawings were made in 2D.</td>
<td>Long learning process while my efficiency was lower than average.</td>
<td>BIM softwares are extremely bad for “sketching” on projects. CAD softwares allows a more creative environment. This creative aspect of software seems to have been somewhat lost with the existing BIM softwares.</td>
<td>The learning of BIM takes time, it is a change of the mindset, since it works with real objects not lines. There is a big amount of information that needs to be defined, which does not happen in CAD. In the learning process, BIM is less intuitive than CAD.</td>
</tr>
<tr>
<td>Question 7</td>
<td>How do you think BIM technology affects the completion time of a project?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>BIM technology speeds up the completion time of a project.</td>
<td>It shortens the completion time when dealing with large repetitive projects (from 10 000vern) whereas it doesn’t affect completion time when dealing with smaller, more free projects.</td>
<td>BIM has reduced much of the administrative work which revolves around drawings and the documentation of projects. Such administrative work can take up to works with CAD softwares – however, BIM softwares have been designed to synchronize this kind of work throughout the drawing stage, reducing the time which is required to finalize and present the drawings together with its necessary numbers. Along with the feasibility of working on one model together with different actions in the field, I believe the reduction of pre-production work with BIM softwares have made the technology a much more time-efficient methodology of working. Used correctly, I believe BIM technology can save both clients and software users up to months of work.</td>
<td>BIM technology affects in a positive way the completion time of a project reducing it. From early stages there is a control of the project, spotting errors and avoiding extra costs and time, the collaboration between the actors involved in the construction process is more effective.</td>
</tr>
</tbody>
</table>

Figure 4.1: CAD-BIM Experience table (information extracted from interviews)
4.2.2 Collaboration

Regarding the table below (figure 4.2) all the interviewees seem to agree that BIM is a collaborative tool within the architectural company. More specifically, it allows the efficient collaboration between different co-workers. When it comes to BIM collaboration with different external actors, BIM can be incompatible with different software and that can provoke problems between these actors. However, in a general perspective seems that BIM can support the collaboration between the same platforms but it may possibly appear compatibility problems with actors that are using different software. However, as stated from one of the interviewees the IFC (Industry Foundation Classes) is an independent system with purpose of eliminating the compatibility issues between different software.

Regarding the communication between the architect and the client, BIM is a great tool for building visualization and in that sense the communication improves, although usually it takes time to produce an appropriate 3D model.

“From my experience, the collaboration between team members with BIM is very good.”

-Interviewee D

<table>
<thead>
<tr>
<th>Collaboration</th>
<th>Interviewee A</th>
<th>Interviewee B</th>
<th>Interviewee C</th>
<th>Interviewee D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question 6: What are the main challenges you face when collaborating with other team members within the company (internally)?</td>
<td>I think collaboration between team members within the company works good with BIM. Archicad has a very well developed teamwork function that enables several people to work at the same time in the same project.</td>
<td>I don’t find any special challenges.</td>
<td>There seems to be different ways for individuals within the company to approach technical challenges within the software. This can be both good and bad. Sometimes this can allow someone to solve an issue which you don’t have solution for. Whilst other times, “shopy workarounds” can give you a headache.</td>
<td>From my perspective, the collaboration between team members with BIM is very good.</td>
</tr>
<tr>
<td>Question 9: What are the main challenges you face when collaborating with other actors for the various projects (externally)?</td>
<td>The main challenges can be when other actors use different software for example, Revit and it is an IFC-file what we use to ‘communicate’ with each other. Sometimes there are problems when exporting an IFC-file from Archicad because it can be incompatible when importing it in Revit and vice versa.</td>
<td>I don’t find any special challenges.</td>
<td>I have not faced any such challenges that I can think of. Collaborating with other actors have thus far been much easier than within CAD environments.</td>
<td>Most of the information from the consultants is received in 2D that needs to be added also in 2D, that implies a non-global 3D view.</td>
</tr>
<tr>
<td>Question 50: In your opinion, what are the main challenges with direct communication between you and the client?</td>
<td>Most of the times the clients need our 3D-model to do their own calculations and they ask us to build it in a way that works with their software.</td>
<td>BIM is a great tool to visualize any part of the project for client immediately, but making model visually attractive takes too much time. Also preparing and presenting different options in Revit is not intuitive, time consuming.</td>
<td>Once again - thus far, BIM software has allowed an easier communication process with clients. First of all, communicating in 3D is simply much easier. Furthermore, the BIM software drawing and presentation material has a more communicative friendly language.</td>
<td>I don’t answer to this question, since for the moment I have not been in direct touch with the client.</td>
</tr>
</tbody>
</table>

Figure 4.2: Collaboration table (information extracted from interviews)
4.2.3 Adoption - Outcome

Considering the table that follow (figure 4.3 – A and B) there were some difficulties that the interviewees had when adopting BIM technology. The time for adoption was long since it implied a change of the mindset as we said before and moreover, it was hard to get instant familiarity with the software. That, decreased the efficiency in early stages.

Regarding adoption, the interviewees, except from one, agree that BIM is a helpful tool that can address some of their important challenges. According to interviewees, BIM appears to be a more successful tool comparing to CAD.

Both companies seem to have implemented BIM technology in their workflows. More specifically regarding the workflow and time needed for the development of a building, all interviewees agree that it affects in a positive way since all the actors involved are allowed to follow simultaneously and directly the project at any phase. This characteristic assists in the control of the project and in reducing the time for decision-making.

Considering quality and outcome of a building, all the interviewees agree that BIM technology affects positively both quality and outcome since it allows great precision and less space for errors. However, a restriction in BIM creative capabilities is present but there is a hope that this restriction will change over time.

Regarding BIM recommendation to the professional network, most of the interviewees (3/4) are willing to recommend BIM technology. One of the interviewees stated that it would depend on the type and size of the project since BIM technology is efficient mostly with large, repetitive and standardized projects.

According to the interviewees BIM technology is lacking some aspects. These aspects are divided in three areas: the technical area, the knowledge support area and the product area. Regarding the technical area:

- There is a lack of sketching capability tool,
- There is a lack of an efficient visualization tool for interior spaces,
- There is a lack of BIM support for very big architectural projects,

Regarding the knowledge dimensions:

- There is a slow training process until becoming a BIM expert,

Regarding the product area:

- There is a high cost of purchasing software licenses,
- There are continuous software updates into new versions that require continuous investments in new software versions purchases.
Considering the full advantage of BIM technology, 3 out of 4 interviewees state that are not taking full advantage. The main reason for that is the continuous development of the software in comparison with not equivalent training.

<table>
<thead>
<tr>
<th>Adoption-Outcome</th>
<th>Interviewee A</th>
<th>Interviewee B</th>
<th>Interviewee C</th>
<th>Interviewee D</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Question 11</strong></td>
<td>The main difficulties were to think in a 3D way and use AutoCAD where everything is drawn in 2D.</td>
<td>It took too much time to draw simple things in the beginning.</td>
<td>To be restricted when it comes to sketching out ideas fast. CAD softwares are designed to more efficiently test and sketch things. BIM has thus far limited this creativity.</td>
<td>Apart from the time spent on learning and the change of mindset that I mentioned before, one other difficulty was the work focus on the 3D model. It is necessary to get a good 3D model, since it will contain the information of the project. There is a big amount of time spent on producing an accurate 3D model.</td>
</tr>
<tr>
<td><strong>Question 12</strong></td>
<td>I think it will help me because it is easier to see the project in a 3D model and what it can have as development possibilities. Sketching in paper is definitely still needed in early stages of the project.</td>
<td>No</td>
<td>It will address some of the important challenges which today exist within the CAD environments. The process of laying out pages as well as assisting other objects. BIM does this in a very effective and rigorous manner in ways that CAD softwares don’t.</td>
<td>Yes, BIM is a helpful tool, very positive for architectural processes (costs, collaboration, control of the building etc.). Yet it is limited, for example when it comes to the inner insight of the building, an aspect that I think it lacks. BIM has many good possibilities, but in order to achieve a full control of the program is necessary to spend time in training.</td>
</tr>
<tr>
<td><strong>Question 13</strong></td>
<td>It affects the workflow and time needed for the development of a building and how it affects the quality.</td>
<td>Office uses both Revit and AutoCad.</td>
<td>It is hard to say because some tasks become less consuming whereas others take more time to finish in comparison to CAD.</td>
<td>The office works mostly with BIM (Autodesk). The projects are developed around the 3D-model created with BIM, but other tools are used, such as Sketchup and AutoCad. In order to share the information for presentations, Adobe software is used.</td>
</tr>
<tr>
<td><strong>Question 14</strong></td>
<td>Yes, BIM technology affects the workflow and time needed for the development of a building and how it affects the quality.</td>
<td>The practice uses other tools as well.</td>
<td>Yes, I believe BIM allows a great reduction of the time required for the development of a building. Various actors are allowed to interact with one model and tackle project complications simultaneously and directly. Furthermore, the finalization and preparation of drawings which previously could take months have been heavily improved through technology and can now be produced and calculated with a few clicks.</td>
<td>Yes, I think BIM affects the workflow. It is a tool, but also an innovative way of working, where all the people involved in a project can work and follow the other’s work in real time. It is not an individual tool, but a collaborative one. The sharing of information is faster and more efficient. BIM affects also the time needed for the development of a building, since there is a big amount of information that is shared. This fact makes possible for example the calculation of costs and materials from early stages, that means saving time in the decision-making.</td>
</tr>
<tr>
<td><strong>Question 15</strong></td>
<td>Yes, it affects the quality in the sense that what you draw in BIM or in the 3D-model is closer to the final built project. It is easier to collaborate between different branches and check collisions. BIM also allows the project to be more efficient - the design oriented actors suffer from some extent from this technology. At the stage in which BIM exists today, it reduces and limits the creative work of architects to a great extent. I am however sure this will change over time.</td>
<td>It is easier to collaborate between different branches and check collisions. It’s also easier to check quantities and areas. In general these increases are shrinking when using BIM.</td>
<td>Yes, BIM allows a greater precision in 3D which previously was not as well developed within the CAD systems. However, as previously mentioned - the quality of producing something from the creative perspective has been limited. Although BIM in many ways have allowed the more technical actors among its users to be more efficient, the design oriented actors suffer from some extent from its technology. At the stage in which BIM exists today, it reduces and limits the creative work of architects to a great extent. I am however sure this will change over time.</td>
<td>Yes, BIM affects the quality and outcome of a building. In terms of quality, it provides faithful information (qualitative and quantitative) of environment that takes place in the project from early stages of design, as well as it includes simulations, scans for construction etc. I think the quality of the building is guaranteed.</td>
</tr>
<tr>
<td><strong>Question 16</strong></td>
<td>Yes, it saves time and it makes collaboration easier between all the actors involved in the project. It depends on type and scale of the project. BIM is very efficient with repetitive, large, standardized projects.</td>
<td>Yes, it saves a hell of a lot of unnecessary work and time.</td>
<td>Absolutely yes. BIM helps throughout the construction process (collaboration, control of the project, economy of time and cost etc.). It helps to create responsible architecture.</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4.3: Adoption-Outcome table A (information extracted from interviews)
4.2.4 BIM Usage

Considering the table below (figure 4.4) and the usefulness of BIM technology through time, there is a variety of answers. For one of the interviewees, the usefulness has changed, for two of them not so much and the fourth one has not enough experience in order to comment.

Lastly, all of the interviewees were requested to start using BIM either because of the company they are working for, or either because of their clients. This is considered positive since according to the research 55% of non-users in Europe signify as main reason for not implementing BIM the lack of client demand (McGraw-Hill Construction, 2010).

<table>
<thead>
<tr>
<th>BIM Usage</th>
<th>Interviewee A</th>
<th>Interviewee B</th>
<th>Interviewee C</th>
<th>Interviewee D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question 19</td>
<td>I don’t think so. I have been using Archicad for 5 years and the program has not changed so much during this time.</td>
<td>Not that much.</td>
<td>I have not worked with BIM long enough to judge this.</td>
<td>Yes, I started using BIM software because of professional reasons (it was required to work at my current office) and I was not aware of the possibilities of this software. Now that I see that the building process is more effective and easier, I would like to continue getting deeper in the software.</td>
</tr>
<tr>
<td>Question 20</td>
<td>The company I work for uses BIM-Archicad.</td>
<td>Company and client forced me to use it.</td>
<td>Pressure from architectural offices as well as clients. Pressure from the industry basically.</td>
<td>I started using BIM at the company I am working currently, as knowledge on BIM (Archicad) was required. A training course was provided by the office.</td>
</tr>
</tbody>
</table>
4.3 BIM TAM External Variables

In this section the External Variables of BIM TAM model (section 2.4) that are affecting the Perceived Ease of Use, Perceived Usefulness and by extension the Behavioral Intention towards BIM technology, are going to be discussed in relation with the answers from the conducted interviews. The aim is to review and discuss the model’s External Variables from an empirical perspective.

Top Management was not mentioned from the interviewees in a direct involvement related to BIM. However all interviewees mentioned that one of the reasons they were using BIM software was because the company was using it. Furthermore, it is highlighted that Top Management support is vital for the technology adoption within the company (Chung et al., 2008). Moreover, Top Management authorizes priorities, contributes in funding and instrument protocols related to technology adoption (Sultan et al. 2000). According to Son et al. (2014) Top Management should have a comprehension of the intention of the technology users within the company and how this technology can profit these users alongside with the expenses that are linked with BIM technology. Furthermore, when Top Management supports the technology it can assist in providing direction and assistance to employees who are not content with the technology or are hesitant to change (Fishbein et al., 1975).

In this research, Subjective Norm can be considered as architect’s perception that BIM is beneficial. According to the interviewees all agree that BIM is beneficial since it saves them a lot of time, it enhances the collaboration (internally and externally), it has great precision, it provides an administrative assistance and moreover it improves the overall quality and outcome of the project they are working on. The above beliefs can have a great impact on the Subjective Norm and Intentional Behavior. Consequently, Subjective Norm has a greater impact in early stages of technology adoption where there is a limited experience. This happens because employees have not yet shaped behaviors towards this new technology (Won et al., 2013).

Compatibility is one of the external variables that has a great impact on the technology adoption. Employees will adopt BIM technology when they consider it is suitable and capable for their work purposes, since it allows effective data management related to their architectural projects. This data can be retrieved anytime from the architects and can be visualized in order to transmit the information to other co-workers or clients (Goedert et al., 2008). Regarding the interviews, there are indeed many important aspects in BIM technology that make it both suitable and capable for their everyday tasks. These aspects are related to the collaboration both internally (with co-workers) and externally (with clients). The collaboration and communication with other actors is much more effective in BIM (because of the 3D capability) and much more user friendly than in CAD systems. Furthermore, one of the interviewees stated that BIM provides an effective and rigorous communication with many actors (Interviewee C, 2018).

Technical Support is one of the most prominent elements that impact the technology adoption through the Behavioral Intention (Staples et al., 2004). In cases that technology adoption is mandated then Technical Support will provide assertive interest on the individual IT practice (Sun et al., 2011). Technical support also implies training for the BIM software in
practice. As it is observed in the interviews, all participants struggled in becoming familiar with BIM. That was because there is a fundamental difference in the mindset from switching from a CAD platform (2D technology) into a BIM platform (3D technology). Furthermore, it was noticed that most of the interviewees still have not achieved full advantage of BIM benefits.

**Computer Self-Efficacy** describes the attitude of architects and their confidence when facing new technology systems such as BIM. Computer Self-Efficacy is linked with both abilities and perception about abilities of the use of BIM technology. Considering the above, a person that has high Computer-Efficacy is more likely to be faster learner with less support. On the contrast a user with low Computer-Efficacy will struggle more in getting familiarity and proficiency with BIM technology (Wangpipatwong et al., 2008). Regarding the interviewees, it was not noticed any lack of confidence. BIM technology was accepted quite smoothly. However as we already pointed, the change of mindset was crucial for adoption. Therefore, this fact has a positive perspective for the individual: it implies the self-development (knowledge and training) in a new IT system such as BIM.

As a conclusion to the above comparison of External Variables with the conducted interviews it is important to highlight that these External Variables represent a broad spectrum of different subject areas. These include the individual (Computer Self-Efficacy), the social (Subjective Norm), the organizational (Top Management Support and Technical Support) and the technical subject area (Compatibility) (son et al. 2014). In our example we have two types of adoption that are included in the BIM TAM model: the individual and organizational.

A related study is conducted from Frambach et al., (2001) with regard to intra-organizational acceptance. This study is important to understand the individual innovation adoption in organizational context. Although both of our organizations have invested in BIM technology this is of little value if this technology is not used or not integrated successfully with the processes of the organization. Moreover, the target groups (employees-architects) in order to accept the BIM innovation have to understand and realize the benefits. Therefore, by studying the BIM Acceptance of architects it is possible to reveal if the desired results can be achieved.
5. Conclusions

This section includes a summary of the findings and answers to the research question. Moreover, limitations and suggestions for further research are introduced.

5.1 Conclusions

As we already mentioned Building Information Modeling (BIM) is the ultimate development in the Architecture, Engineering and Construction (AEC) Industry. Many researchers and academics from areas such as architecture, engineering and management are outlining the BIM influential factors and technology aspects of the advancement methods. Additionally, international companies (such as Autodesk and Graphisoft) had been involved in researching the implementation aspects of BIM technology. However, there are not adequate studies addressing the correlation between BIM influential factors and BIM implementation.

The majority of BIM users are architects. Moreover, the benefits of BIM technology had been extensively highlighted but still there is a low adoption rate. It is believed that BIM enhances the quality and outcome of a building project. More specifically, during this thesis was investigated and discussed the perspective of the adoption from architects. Considering the above, this thesis was driven by the following research question: What are the barriers to adopting Building Information Modeling (BIM) in architectural companies?

Taking into account both literature review and findings we concluded that adoption barriers are broken down in two main categories:

The first category is based in the literature review and is related to BIM Technology Acceptance characteristics. During the literature review, it was given an extensive emphasis in Technology Acceptance Models since they can best represent and assist in approaching the research question. TAM theories were analyzed and compared and moreover a BIM Technology Acceptance Model was discussed in detail. During that part, the importance and contribution of different variables were underlined. These variables included the role of Top Management Support, Subjective Norm, Compatibility, Technical Support and Computer Self-Efficacy. These variables have a vital role in the adoption of BIM from architects.

In the second category, informal discussions with professionals in the field took place (architects). Moreover, the review of the related literature and the author’s experience with BIM technology, defined four different subcategories for approaching the research question. These subcategories included the CAD- BIM Experience and Challenges aspect, the Collaboration aspect, the Adoption-Outcome aspect and the BIM Usage aspect. All the aforementioned subcategories were investigated through in-depth interviews.

After the completion and analysis of the interviews, a comparison between the answers was implemented. Additionally, these answers were compared with the BIM TAM External Variables as we already mentioned.
The conclusions of comparison between Interviews are:

- Architects are getting advantage firstly of the 3D-modeling capability and secondly of the data management that accompanies BIM-technology.
- The software could be more intuitive and could make possible the design of more complex geometries.
- Collaboration capabilities are highly appreciated within the companies and within consultants that use the same BIM platforms, however, software conflicts are inevitable with different BIM platforms.
- At the current phase it seems that BIM has the capacity of replacing fully CAD systems but due to transitional period and low adoption from architects and other consultants it is necessary to coexist with CAD systems.
- Basic training can accelerate BIM adoption by providing knowledge and self-confidence to users. Advanced learning is recommended for surpassing difficult and frustrated tasks.
- BIM is reducing significantly the manual administrative work especially with large projects.
- Control is linked with BIM since early stages making it easier to spot errors and fixing them reducing in that way the cost errors.
- BIM is a great communication tool between co-workers and clients.

The conclusions of comparison between Interviews and BIM TAM External Variables are:

- BIM TAM model as described in chapter 2.4 and chapter 4.3 is a valid tool for understanding the intentional behavior of the employees/BIM users towards BIM adoption.
- Top Management, Technical Support, Compatibility, Computer Self-Efficacy and Subjective Norm can greatly affect the BIM adoption in architectural companies.
- In case of mandatory use due to client/contractor the use of Technical Support is highly advisable and recommended.
- Continuous training is very important for both company and employees. This ensures confidence, knowledge and readiness for undertaking even the most difficult tasks.

Concluding, BIM is an advanced technology that is changing how the AEC professionals are working and collaborating. However, there is still room for development and architects can be part of this development intentionally. Top Management usually is promoting BIM technology and clients have the right in some cases to require the use of BIM. Consequently, it is important to understand the above adoption barriers. As a result BIM integration can be smoothed and accelerated. Moreover, BIM commitment among users can be increased in order to reach the full potential of this technology’s benefits.

“BIM is fantastic and is definitely a technical development towards the right direction. I do believe it will be heavily improved within years to come and adapt to the creative needs of the industry.”

-Interviewee C
5.2 Limitations

At this stage of the research, it was of high importance to remark the existence of a group of aspects that limited and, at the same time, drove the way in which this thesis was conducted. This critical exercise was done by reviewing the quality of the findings and to what extent the research question was answered.

There were some aspects that limited the research from early stages, as for instance, the duration of the master thesis. This led the study, especially in terms of methodology, that was selected according to this constraint. Therefore, a non-probability sampling method was selected and more specifically a purposeful sampling (Palinkas et al., 2013) technique was chosen. This method was considered optimum with regard to efficient use of resources (time) and gathering of rich information.

However, although, this type of sampling method was considered as the most appropriate option for an exploratory research which was the aim of this study, it is difficult to measure participants’ knowledge, experience and ability to communicate experiences and opinions in a reflective manner. This could possibly affect the extracted results and analysis of the interviews.

The non-probability sampling was performed by a limited number (4) of interviews and consequently, to a limited number of profiles, that meant that the findings could not be generalized to a larger amount of people. However, the data collected, of qualitative nature (perceptions, opinions, feelings etc.), was enough to understand that, effectively, there are some barriers for architects to BIM adoption.

Due to the restricted number of architectural companies (2) asked, the results did not represent the majority of the companies in Stockholm area, but for sure it provided an idea of how they approach BIM and how the employees face the daily workflow.

It is important to underline the lack of BIM statistics and data that are primarily related to the Swedish market. This fact directed the research to use secondary data from Europe as a whole (for example with regard to BIM adoption). A further investigation is necessary considering this topic.

In this study, software prices and switching costs were not taken into account. However, the price is also another limitation especially when talking about technology switching costs (software, hardware, training etc.). Although in the literature 41% of the non-users in Europe are pointing that the software is expensive (McGraw-Hill Construction, 2010) only one of the interviewees mentioned the software high cost. However, the author’s limited authority and access to sensitive data (such as exact costs, software packages prices, number of licenses etc.) was not available during the conduction of this study.

Another important limitation considering the available studies on the field is the limited available research in both the academia and companies regarding the correlation of BIM adoption influential factors and BIM implementation. This fact limited but not restricted this research since it was understood early in the process. As a result BIM influential factors were
studied independently from BIM implementation methods. Afterwards the correlation of these two aspects was applied.

Moreover, some researcher’s biases may have presence during this work, such as cognitive bias (“curse of knowledge”) that makes reference to when an individual, when communicating with others, assumes their background in order to understand; and confirmation bias, that refers to the tendency to redirect the information in order to corroborate previous hypothesis.

5.3 Suggestions for further research

The focal point of this study was investigating and discussing the BIM adoption barriers to architectural companies. The main interest was given in both the background and evolution of BIM technology and also in the Technology Acceptance Models. Moreover, extensive focus was provided in the interviews since it is considered a valuable tool for gaining direct technology insights. However, this study could imply both extensive literature review and further investigation from a bigger range of companies. Consequently, it is advisable for researchers interested in BIM technology and its barriers to use the methodology and findings of this thesis as base for further research.

An important fact to consider for future studies, as we already mentioned in the limitations part, is the adequate research that includes correlation of BIM influential factors and BIM implementation. Recognizing this gap in the research field, both academics and companies could minimize the adoption barriers by investigating these aspects.

There are a number of topics that can be used for further research and which were mentioned directly and indirectly in this thesis. These include the research methodology and approach that can be possibly applied to different regions of Sweden, Scandinavia, Europe, U.S. and elsewhere, for the purpose of more extensive BIM adoption barriers or for use in related BIM investigations.

As already mentioned in the limitations, investigation and research on pricing and relevant switching costs from older technologies, could be of high importance for architectural companies in order to compare and evaluate both in short and long term perspective the BIM technology investment and its return.

Moreover, additional research could focus on the transitional period from CAD to BIM technology. It could include a guideline or manual that would facilitate the technology switch in a smooth and efficient way. This research could solve the great issue that demands huge effort and time from both companies and users.

Furthermore, another area of future development includes unified research related to collaboration principles and characteristics that describe BIM as an advanced technology. More specifically, in the interviews it was mentioned the IFC (Industry Foundation Classes) as a tool for reducing the interoperability conflicts presented from the use of different systems. It would be really valuable if big BIM corporations such as Autodesk (Revit) and Graphisoft (ArchiCAD) could develop themselves solving the compatibility issues rather than requiring the
use of a third IT system (IFC).

Hopefully, researchers and academics can employ this investigation for further development of the areas of architecture, management and innovation.
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7. Appendix

Interview questions:

The questions will be structured and organized in two phases. First we will try to understand the profile of the person we are interviewing regarding BIM technology, employment, experience, workflows, etc. During the second phase we will try to understand the difficulties of BIM adoption and discuss its barriers and possible ways of future development.

First phase:

- Practical matters:

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<td>Start-End time of interview session:</td>
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- Understanding the profile of the interviewee.

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<td>Employed at (Name of Company):</td>
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<tr>
<td>Number of employees (Current Company):</td>
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<tr>
<td>Qualifications (Specialization e.g. Architect, Civil engineer, Interior designer, etc.):</td>
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Second phase (open-ended questions):

CAD-BIM EXPERIENCE AND CHALLENGES

1. What software do you use to carry out your tasks/projects?
2. What are the most frequent tasks you face in a daily level at your company that are related to BIM?
3. What are the main challenges with the software you use when carrying out daily tasks?
4. How many years of experience do you have with CAD and BIM technology?
5. Do you think BIM is a successful CAD replacement technology and why?
6. What were the challenges from switching from CAD technology to BIM technology?
7. How do you think BIM technology affects the completion time of a project?
COLLABORATION

8. What are the main challenges you face when collaborating with other team members within the company (internally)?
9. What are the main challenges you face when collaborating with other actors for the various projects (externally)?
10. In your opinion, what are the main challenges with direct communication between you and the client?

ADOPTION-OUTCOME

11. What are the difficulties that you faced when you had to adopt BIM technology?
12. Do you think (full) adoption of BIM technology will help address some of your important challenges? Explain...
13. Is your architectural office fully operational with BIM technology or does it use other tools?
14. Does BIM technology affect the workflow and time needed for the development of a building and how?
15. Does BIM technology affect the quality and outcome of the building and how? Provide one example...
16. Would you recommend BIM technology to your professional network? (Y/N and why?)
17. What do you think BIM technology is lacking nowadays that would enhance its spread towards the whole architectural industry?
18. Do you consider that you are getting full advantage of BIM technology? Explain...

BIM USAGE

19. According to your experience: has the usefulness of BIM changed through time? Explain...
20. Why did you start using BIM? Explain... (For example pressure on using BIM from client, government, professional network, company, colleagues, etc.)

21. Is there anything else you would like to add that may be important?
22. Can you refer to others who might be open to an interview?