Benefits and Barriers of BIM Implementation in Production Phase

A case study within a contractor company

Master's Thesis in the Master's Programme Design & Construction Project Management

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Abstract

Increasing efficiency, effectiveness, productivity, and project quality, as well as decreasing project cost and delivery time are the important aspects that construction industry today attempts to achieve. Building Information Modeling (BIM) has become a key approach in order to increase efficiency and effectiveness of construction projects through an improved collaboration among project participants. Therefore, the interest of this study is to investigate further about BIM benefits and barriers and to provide an effective recommendation of supportive actions that contribute to successful BIM implementation in contractor companies.

The main problem of implementing BIM is the lack of mutual BIM formats between architects and contractors. Some important factors that are required for computerized design databases and computer-based building models are human comprehension, manual data extraction, and construction planning and processing. Some of the other factors regarded as problems in the matter of BIM implementation are management tools and methodology, project participants skills, training of employees, technical upgrade requirements, standardization of processes, and procedures and systems.

Keywords: Construction industry, BIM definition, AEC, BIM adoption, Managerial task

Fördelar och Hinder för BIM Genomförandet i Produktionsfasen av Byggindustrin
En fallstudie inom ett entreprenadföretag
Masteruppsats i mastersprogram utveckling och byggprojektledning
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Sammanfattning

Ökande effektivitet, produktivitet och kvalitet, samt sänkande av kostnader och leveranstider är viktiga aspekter som byggindustrin försöker uppnå. Building Information Modeling (BIM) har genom att förbättra kollaborationen mellan de delaktiga blivit en huvudmetod för ökande effektivitet inom bygg projekt. Således är denna studies syfte att närmare undersöka fördelar och barriärer inom BIM och att bidra med en effektiv rekommendation gällande vidtagande av åtgärder som kan leda till en framgångsrik implementering av BIM inom byggföretag.

Huvudproblemet med implementering av BIM är bristen på gemensamma BIM format mellan arkitekter och byggföretag. Några viktiga faktorer som är nödvändiga för datoriserade design databaser och databaserade konstruktionsmodeller är mänsklig förståelse, manuell datautvinning samt bygg planering och ledning. Några andra faktorer som också anses vara problematiska gällande implementering av BIM är hanteringsverktyg och metodik, projekt deltagarnas färdigheter, utbildning av anställda, tekniska uppgradering krav, standardisering av processer samt förfaranden och system.

Nyckelord: Bygg industri, BIM definitioner, AEC, BIM införande, Chefs uppgift

Preface

The idea of this master thesis had come to our mind long before the spring semester of 2017 begun and it related to our interest to construction and new technologies. I would like to thank professor Petra Bocsh because of her generous supports and tutorials during the writing of this thesis. Her advices throughout the whole time of carrying out of this study means a lot for both of us. We hope that this piece of work could help students, academicians and companies regarding BIM implementation in production phase.

I would like to appreciate strong support of my husband, Ehsan who stood by me through all happiness and difficulties. I will be thankful to my daughter, Nikki forever for her patient as she has been with me from the first day of school.

June 2017, Gothenburg
/Bahareh Ghavamimoghaddam

Preface

This is my (Elmira Hemmati) final project in my master studies at the department of architecture and civil engineering at Chalmers University of technology. It has been carried out at Veidekke Construction in Gothenburg during the spring of 2017.

I would like to thank everyone who has been involved, for their much appreciated help throughout the project. Special thanks go to our Chalmers professor, Petra Bosch, for all your guidance and support. Also, all my love to the kindest husband who always encouraged and supported me to complete my studies. Last but not least I would like to thank all employees at Veidekke that I have been in contact with and interviewed, for their time and patience with my tenacious questioning.

Gothenburg, June 2017
/Elmira Hemmati

Contents

Chapter 1. Introduction

This chapter includes the background of the thesis topic and research area. It first describes the purpose of the thesis and a short description of the problem analysis. Further, it presents the research questions and brings the outline of the report.

1.1 Background and problem definition

Today's construction industry has a tendency to enhance efficiency, effectiveness, productivity, increase project quality, while it decreases project cost and delivery time (Azhar, 2011). As construction projects become more complex, it is required to have various expertise into different project areas and phases (Dossick & Neff, 2010). This diversity of expertise brings the issue of communication, collaboration, and coordination between specialized trades.

Building Information Modeling (BIM) as a virtual process has become a key approach in the construction industry in order to increases project efficiency and effectiveness through an improved collaboration (Dossick & Neff 2010) among project members such as owners, architects, engineers, contractors, subcontractors, and suppliers (Azhar, 2011).

The adoption of BIM within companies can significantly change the workflow and project delivery process (Hardin, 2009). BIM is often connected to an integrated project delivery approach, which integrates people, business and system structures through a collaborative process (Glick, et al., 2009). This delivery method not only reduces waste but also enhances efficiency during the whole project life cycle.

It is important to note that BIM is not only a software but also a process. Hardin (2009) states that BIM is more a cultural shift in the mindset of management teams where they collaborate rather than update software and the 90% of truly successful BIM is related to sociology while technology and software counts only as 10%. Thus, it is important to consider that the shift of members' attitudes and mindsets to more enabling behaviors is a key factor to the way construction is delivered. Generally, the three main factors that influence BIM adoption and implementation include process, technology and both organizational and personal behaviors, where the behavior is the most complex factor to be changed (Hardin, 2009).

According to Chen et al. (2013) the main problem of implementing BIM is the lack of mutual BIM formats among architects and contractors. Important factors are required to computerized design databases and developed computer-based building models include human comprehension, manual data extraction, and construction planning and processing. Besides, factors like management tools and methodology, project participants skills (Eastman et al., 2011), training of employees, technical upgrade requirements, standardization of processes, procedures and systems (Conway, 2010) are counted as other problems in the matter of BIM implementation. Common management issues regarding BIM adoption include changing mindset, making balance among various expertise and integrating project teams (Dossick & Neff, 2010).

In the date and time of when this study was conducted, the adoption and implementation of BIM in the design phase has achieved a relatively proper level according to numerous existed studies (Barlish and Sullivan, 2012). However, information regarding BIM adoption in the production phase of Architecture, Engineering and Construction (AEC) industry is barely found in scientific studies. Therefore, authors of this paper consider that further research is required in this field. In addition, behavior factors for people and organization are less studied compared to the technology aspect and process (Hardin, 2009). Thus, in this study the focus was more on this aspect which is one of the main challenges of BIM adoption and implementation.

1.2 Purpose

In today's construction industries, BIM has successfully been adopted into the design phase, while due to the lack of integration among the design phase and production phase as well as the client's lack of knowledge about BIM effectiveness and productivity, the BIM technology has been less implemented into the production phase. Therefore, the objective of this study is to investigate more about BIM benefits and barriers and to provide an effective recommendation of supportive actions that contribute to successful BIM implementation in contractor companies.

In this paper an attempt will be made to investigate existing scientific data as well as data from a case study at a construction and civil engineering company called Veidekke located in Gothenburg, Sweden.

1.3 Objective and Research Questions

The objective is to give a reliable description of the important factors that influence the adoption and implementation of BIM in contractor firms for the construction phase and to collect the data that contribute to answer the research questions defined in this chapter. The investigation should serve to make the appropriate information needs visible for future BIM development. The above-mentioned purpose leads to the following research question:

- ❑ What are the success factors and hindrances for adoption and implementation of BIM during the production phase in the construction industry?
- ❑ How well are the current managerial tasks developed in terms of BIM in the production phase within contractor companies?
- ❑ What actions by management on site contribute to a successful implementation of BIM in the production phase?

1.4 Delimitations

This master thesis is based on the functions at Veidekke as a construction company in the production phase. Veidekke is the fourth largest in Scandinavia construction and Civil Engineering Company. The BIM technology is utilized in many projects of the company, however the study is only investigated on a residential complex project located in Gothenburg, Sweden.

Furthermore, the study is limited into the production phase and the design phase is not included. The contained information within the analysis part is based upon the activities primarily performed by site managers and supervisors.

1.5 Disposition

***Theoretical Framework**:* This chapter has a key role to this thesis in order to evaluate primary data that are assembled during observation and interviews. It contains secondary data including books, academic papers, case studies and other academic thesis, which are related to the subject of this study that is BIM on production phase. In order to find these materials, the key words such as BIM, benefits of BIM, BIM on production in AEC industry, and BIM and management are searched in different database. Furthermore, it is required to achieve complete knowledge about aspects that are connected to research questions and will be discussed later on in the discussion section. The chapter begins with BIM, its definition and characteristics then it is followed by role of BIM on production phase of construction and finally influence of BIM on management tasks during production and vice versa.

Methodology: In this chapter the methodology of the study is explained, which involves research approach and data collection. In the part of research approach readers find out how the study is planned and carried out according to its objectives. In addition, different method of data collection, which is interview and observation are briefly discussed. The importance of this part is that it allows readers to perceive how the authors plan to conduct and follow the study.

Case Description: It is intended to focus on a single project produced by a contractor company in order to find appropriate answers for the research questions. Therefore, in this chapter a basic information regarding the project together with companies' characteristics is described to establish a certain scope for the study. On the other hand, the interviewees and their roles, all in management level, and the reason why they are chosen are described at the end of the chapter.

Results and Analysis: During this chapter, interviews are analyzed and the results are classified in the shape of different points. In every points, one or more quotes from interviews are brought in order to justify how the authors come to that point. Furthermore, a completing description is added to each point to clarify the way that is thought to analyze and conclude. It is worth to know that these points are drawn out of the contents of interviews during a long and discreet discussion by the two authors. This chapter represents details of how the case study project has been conducted regarding BIM related issues together with methods and routines of the company in production phase of construction. Thus, it is considered that this data are fairly reliable to analyze and consider for further assessment in discussion part.

Discussion: the whole chapter is a comparison between theoretical and analytical part t in order to find how compatible the case study practices are with the assembled theory. Furthermore, some parts of theory are analyzed in order to investigate how they can be exercised in a real construction project. It can be said that the main outcomes of this study can be revealed in this part. The reason that discussion is placed in this study is to investigate case study compared to theory and here is where these two part together are discussed.

Conclusions and Recommendations: In the final chapter the authors gives a couple of recommendations for improvement for the company that authors have come up with for the company. On the other hand, some initiatives taken by the company are brought up, which can be used by others in the industry in order to enhance the effectiveness and efficiency of the process.

Chapter 2. Theoretical framework

In this part of the study, results of a conducted literature review in regard to the research questions, is presented. It is started with a short description of construction projects with a focus on production phase. Furthermore, the main subjects of BIM definition, its benefits in the AEC industry, barriers of adoption and implementation of it, and managerial activities in contractor companies are presented. Findings in this chapter will be used to assess the case study later on in the discussion and result chapter.

2.1 Construction projects

The different phases of the construction project include design, construction and occupancy (Brandon et al., 1998). In construction projects, issues such as organizational, legal and economical have hindered the design and production phases to get the levels of integration to be enable to successfully implement Information Technology (IT). Besides, the differences between each construction project, has provided the difficulties of production control and the effective use of IT.

One of the challenges of the organizational fragmentation in construction projects is getting right information to the right place (Davies and Harty, 2013). Therefore, the benefits of for instance reduction of transaction costs and minimizing of errors can be achieved by adopting and implementing new technologies such as BIM into the construction projects (CabinetOffice, 2011).

Construction projects are surrounded with problems and implementing BIM can contribute to the evolution of the construction industry through modernizing construction, increasing productivity, and adding value across many stakeholder groups (Rogers et al., 2015). The construction aspects that are required to achieve the significant benefits from information and digital technology include the huge amounts of information to be managed, the emphasis on production, and the dispersal of participants (Davies and Harty, 2013).

2.2 BIM Definition

The definition of BIM is changing constantly due to the rapid development of AEC industry (Migilinskas et al., 2013). This development has caused BIM to be described as various things at different times and thus, there is still no common accepted definition of it (Lee et al., 2013). In the beginning of 2000s BIM was rather defined as a structured model, which represents building elements and the usage of it expanded from pre-construction phase to post-construction phases.

In the late 2000s, BIM was used as a technology which not only changed organizational processes and tasks in the AEC industry but also improved communication, collaboration as well as efficiency and effectiveness by improving management of documentation in AEC projects. Until now, BIM has developed as a technology which affects the whole industry and helps to manage the process of planning, design, production and operation of facility more efficiently (Latiffi et al., 2014).

One of the definition of BIM is using rational 3D virtual models for product delivery in different dimensions such as project inception, design, evaluation, construction, operation and demolition (Migilinskas et al., 2013). In other words, BIM means a digital integrated data representing all information of building in all phases through a project lifecycle (Gu and London, 2010). Lattifi et al. (2014) define “BIM as a new methodology to manage and increase the AEC performance in completing and managing the project.” However, the current definition of BIM is more focused on looking at BIM as a process that as a paradigm shift for the industry affects all aspects of a project throughout the whole lifecycle of design-construction (Luth et al., 2014).

The concept of BIM began in the early 1980s. Further, it had started using CAD software, when researchers started to describe it conceptually and implemented in working software in CAD program (Migilinskas et al., 2013), but until middle of 1990 its usage was not extensive due to technological limitation (Abbasnejad and Izadi, 2013). In recent years, BIM has shifted from traditional three-dimension to fourth, fifth, and sixth dimension into its base Product Lifecycle Management (PLM), which has provided the opportunity of developing information capacity stored in 3D building models (Migilinskas et al., 2013).

2.3 Benefits of BIM

Using BIM within the construction industry assists to maintain the graphical elements and provides a data management environment (Lee et al., 2013). The BIM is related to both quantity and quality elements. For instance, the quantity aspects which BIM has influenced include cost, schedule, and material inventory that contribute to a quick decision making, while the quality aspects include analysing data concerning the specific structure and environment. Assisting to projects with benefits such as reduction of transaction costs and minimizing of errors, all contracts awarded by the UK government from 2014 onward require the involvement of fully collaborative 3D BIM into the construction projects (CabinetOffice, 2011). Application of BIM can be beneficial in project management as it reduces time consumption for documentation as well as improving collaboration between stakeholders (Bryde et al., 2013).

One of the important reasons of increasing popularity of BIM technology within companies is the ability of BIM to facilitate the information sharing and contribute to reuse this information through a project life cycle (Lee et al., 2013). Building information modeling will contribute to achieve greater efficiency in the construction industry by enhancing different project participant’s collaboration, reducing conflicts, and repeated work on correction and adaptation (Migilinskas et al., 2013). Although using BIM has great advantages for large scale projects such as the London 2012 Olympic Stadium, it can also be applied for individual components of a smaller scale project (Bryde et al., 2013). Moreover, big and medium sized companies can adapt and use digital construction (DC) tools, which emerged due to the increased use of BIM in order to solve different tasks (Migilinskas et al., 2013).

According to Allison (2010) there are some potential benefits for project managers in using BIM in managers’ practices such as organizing schedule and budget, working with design team and subcontractors, optimizing owner satisfaction, which all are related to this integrated and visual tool. An investigation of 35 real case studies of construction projects using BIM shows that most positive influences of BIM are on cost and time, communication, coordination improvement and quality is placed in the next level (Bryde et al., 2013).

BIM generally contributes to improved strategies and procedures of building project design, construction, and facility management by creating computer modelling and the object simulation technologies while developing processes (Migilinskas et al., 2013). This improvement brings the opportunity to secure the incorporated management of the graphical and information data progress including the process description, by implementing the integrated software environment. BIM development also contributes to integrate individual executors into teams and integrate individual's assignments into processes through the distribution of tools. It further leads to perform life-cycle operations of a construction in a more efficient and expedited way resulting in lower costs.

2.4 Barriers for Adoption of BIM

Problems that harden effective and successful adoption of BIM can be considered as hindrances. Most of these problems are related to knowledge, technology and processes required for BIM adoption (Jan and Damian, 2008). Barriers for BIM adoption are in different levels and some of them are easier to remove (Enshassi et al., 2016). Some obstacles, which have influenced the slow implementation of BIM within the construction industry. These obstacles are as follows (Lee et al., 2013):

- ❑ Unclear BIM advantages regarding growing practices.
- ❑ Unclear tasks and accountabilities regarding using data into a model and sustaining the model.
- ❑ Lack of knowledge regarding BIM adoption.
- ❑ Lack of knowledge and practices regarding use of BIM.
- ❑ Lack of resources both software and hardware regarding use of BIM tools.
- ❑ Lack of integration among project stakeholders in order to using model in project different phases.
- ❑ Lack of appropriate legal framework and tools regarding owners' view incorporation into design and construction.

According to Johnson and Laepple (2003) major barriers for BIM adoption that are identified through plenty of research are mostly:

- ❑ Unwillingness of industry for shifting from current practice and learning new technologies.
- ❑ Absence of clarity about roles, responsibilities and benefit delivery.

Furthermore, fragmented characteristics of the AEC industry, which is a project based industry, as well as difference in readiness of different countries' markets affect BIM to have a general slow rate of adoption (Johnson and Laepple, 2003). The common factors that hinder BIM adoption include higher additional project cost, the need of comprehensive training, and a majority of the designers who resist to use BIM in their design service (Takim, et al., 2013), which also influences the production phase.

During a study by Yan and Damian (2008), numbers of academics and practitioners in the AEC industry are asked to find out the rate of applying BIM and also reasons for using or not using this tool by companies. The results show that cost of human resources and time consuming processes for training are main barriers for applying it.

Furthermore, expectation of BIM is different (Johnson and Laepple, 2003) among different disciplines in industry. For instance, while design considers BIM as an extension for 2D CAD, managers and contractors expect to have more intelligent Document Management System (DMS) that provides CAD data directly to analyze, simulation and risk planning system. Thus, in terms of product, expectation of BIM differs largely by disciplines and it may prevent adoption of BIM in the industry.

In terms of process, new practices are required, where multiple participants work on a shared collaborative goal to develop a shared model. Therefore, more communication and collaboration is needed to interfere the old models that each discipline works on (Johnson and Laepple, 2003).

Finally, new roles and responsibilities that are defined through working in BIM have caused a change in traditional participation and working environment (Johnson and Laepple, 2003). Using BIM by people requires awareness, which includes recognition, interest and motive and all three must be obtained to apply the tool (Ahn and Kim, 2016). Therefore, more information exchange and training are required to work in new environment. Moreover, some roles as BIM manager are also created for a large scale project (Johnson and Laepple, 2003).

Management of change that should occur during shifting to BIM implementation (Bryde et al., 2013) is a great challenge, which is related to employees who need better training and engagement of stakeholders to new activities in order to help all actors to get used to this new process. Furthermore, Aranda-Mena et al. (2009) claim the role of project manager and their day to day activities as well as outcome of these activities after adopting BIM on construction projects is still unclear. In addition, it is discussing whether BIM can be a solution (Linder and Wald, 2011) to the problem that is followed by the fragmented nature of the construction industry which means that knowledge obtained by the team of a project through the whole project life cycle cannot be transferred to one another.

2.5 IT Adoption and Implementation in the AEC Industry

Implementing advanced technology is counted as a major factor in improving competitive position of firms and industries and contributes to enhance national economic growth and standards of living (Mitropoulos and Tatum, 1999). However, construction industry is slowly adopting and utilizing new technologies and is still resisting to implement productivity and innovation.

According to Rogers et al. (2015), the major amount of involvement and investigation of all project participants is required to fully achieve the adoption of BIM. Cultural issues and people's resistance to change are the primary reasons to not successfully achieve organizational changes and are counted as major barriers to IT implementation in the AEC industry (Davis and Songer, 2008). In addition, undetermined consistency to resistance provide difficulty for technology change implementation.

Generally, Information and communication technology (ICT) is continuously changing, and this change influences every aspects of our daily life (Azhar & Ahmad, 2014). The role of ICT is to use all forms of computing technologies in order to create, store, exchange, and utilize information in various forms. A new technology can only contribute to economic growth when it is widely adopted and used and important factors that influence the achievement of an adoption is directly related to individual decisions to begin using the new technologies (Takim, et al., 2013). These decisions are often associated with comparison between the uncertain benefits of the new invention and the uncertain costs of adopting it.

Technology today is a key factor to facilitate the integration of information in the AEC industry, however it counts as 20% of achieving successful integrated projects, and the rest of 80% is changing the work processes (Azhar & Ahmad, 2014). The AEC industry attempts to be able to adopt the technologies that enhance the quality and productivity of the industry (Takim, et al., 2013). Thus, it is essential that the AEC industry contributes to reshape its own culture and systems in order to adopt and implement the ICT revolution.

The AEC industry has encompassed many ICT techniques and tools in the area of visualization, data analysis, communications and collaboration, information sharing and management, and information modeling (Azhar & Ahmad, 2014). Much attention in the AEC industry today is focusing on BIM as an emerging technology to cooperate in different project phases such as design, construction and operation (Takim, et al., 2013). Benefits of using BIM include improving customer satisfaction to time, cost, safety, quality and functionality of construction projects. Using BIM contributes to encourage the integration among various stakeholders' roles within a project, which provides a greater efficiency and harmony between project participants (Azhar 2011).

2.5.1 BIM Acceptance in AEC industry

Organizational transformation is a crucial factor to consider in order to get successful adoption and implementation of BIM (Ahn and Kim, 2016). BIM technology is a process and thus, it influences the whole organization's activities and affects roles and relations. Therefore, an organizational transformation occurs when BIM is fully implemented within the organization. As a contradiction, lack of awareness is the most important barrier to accelerate BIM adoption and thus developing BIM knowledge and raising the awareness of it can contribute to a better BIM acceptance. Johnson and Laepple (2003) claim that the lack of appropriative incentives and trust among participants may be counted as one important aspect that causes collaborative design tools to not achieve objectives. Besides, effective training, motivation and development of employees at all levels and different practices within organizations are the essential factors that enhance the quality of companies' project performance (Tabassi et al., 2012).

Regarding motivation, it is worth knowing that there are different reasons or objectives that make people do a certain task (Ryan and Deci, 2000). The most important distinctions are intrinsic and extrinsic motivation. Perceiving enjoyment or finding an interest in something is result of intrinsic motivation while, a pleasant outcome or reward is reason of performing a task by extrinsic motivation.

In addition, the Awareness of BIM illustrates a range of members' perceptions including recognition, interest, and prejudice, toward BIM (Ahn and Kim, 2016). Participants' awareness of BIM even influences the attitude of the group, which affects both the BIM utilization and the effectiveness of its use. Another factor that may increase the difficulties for organizations to make rational decisions for BIM adoption is the relatively high uncertainty of BIM benefits and efficiencies (Cao et al., 2004). Lee et al. (2013) investigate that a significant amount of annual wastes in facilities construction industries are related to interoperability inefficiencies. Re-entering and using new information and data as well as duplicating business operations are the factors that provide these inefficiencies.

BIM adoption differs in different projects and even in different project levels such as design phase, production phase, delivering phase, and so on. To achieve BIM acceptance in an organization, the company's individuals should not desire to utilize BIM tools for their own tasks, but the organization should also cooperate to utilize BIM and to encourage coworkers or other organizations in a cooperative relationship to use BIM (Lee et al., 2013). Furthermore, BIM implementation requires stakeholders' interests, relations and priorities to be absolutely taken into consideration (He et al., 2015).

When BIM is adopted within a project or a company, it is followed by significant changes in project management processes. This change in the processes encloses spreading of innovation and transmission of policy and culture (He et al., 2015). Thus, the acceptance from both the individual usage of BIM and by the group sharing information and decision-making are the important aspects to completely accept and implement BIM technology within companies (Lee et al., 2013). In addition to the mentioned change, the adoption process requires some new managerial products, create new roles, affect relationships in team involvement in a project and finally collaboration in working environment is a necessity of this adoption (He et al., 2015).

Generally, selecting a proper processes according to project objectives is the first step to accomplish a successful project. Then, it is required to define an approach to be adapted in order to meet the requirements (PMI, 2013). Those who are involved in association of BIM practices are becoming stakeholders (He et al., 2015). The involvement of stakeholders within a project and having sufficient communication with them are the important factors that contribute to meet their expectations. Through the whole project, balancing scope, budget, quality and resources is a great challenge (PMI, 2013). Continuous development of technical aspect of BIM is followed by giving life to new roles and relationships for stakeholders as well as affecting types of contracts and project delivery systems (He et al., 2015).

2.5.2 BIM Standardization within production in Sweden

The construction industry is one of the industries that has long been criticized for being hesitant to adopt new and innovative technologies (Cao et al., 2004). Typically, new technologies are almost imperfect at the beginning of adaptation and implementation (Tyre and Orlikowski, 1994). This issue may reveal problems and contingencies that were not determined before implementing and using, which can cause uncertainty and affect organizations to resist adoption and implementation of new technologies. Moreover, the standards are applied into the production industry aim to increase the safety and quality and decrease the rate of failure (Hooper, 2015). These standards contribute to a collective and common perception and expectation in order to provide a good communication and involvement among the project's stakeholders.

Over the past decades, BIM has become popular for researchers and professionals as a new way to create, share, and utilize project life-cycle data (Cao et al., 2004). According to proposed advantages of standards in Sweden, some effort is made to standardize the use and application of BIM as a technology that can add great value to the construction industry (Hooper, 2015). Using BIM appropriately can contribute to facilitate the integration of design and operation process and achieve a variety of project benefits (Cao et al., 2004). These benefits include both the efficiency enhancements and effectiveness improvements such as model-based quantity takeoff and off-site fabrication, fewer design coordination errors, more energy-efficient design solutions, and lower construction costs (Cao et al., 2004). However, in order to achieve these benefits, management of standardization and process of adoption is needed. Furthermore, achieving these benefits contributes in getting a successful implementation of BIM and its awareness (Hooper, 2015).

However, adoption and implementation of BIM is still developing slowly worldwide and many companies still proceed in the opposite direction of adopting BIM (traditional way) especially in the production phase (Cao et al., 2004). Further research by Tyre and Orlikowski (1994) shows that there are some physical aspects of the technology that influence IT adoption such as users' procedures, assumptions, knowledge, or relationships.

A key factor that impacts BIM adoption is the client/owner support, which has a varied mediating role in this impact (Cao et al., 2004). Typically, the next phase after operation within construction projects is delivering to the client, therefore, clients/owner can significantly affect project design and construction activities, including innovation adoptions. The three important factors the client must support to facilitate BIM adoption include paying for BIM costs, championing BIM utilization, and supporting process and organizational change.

Other necessities that must be considered, according to Hooper (2015), in order to adopt BIM standardization into the company include finding a common language to communicate through, having a common concept and the classification of that concept, exchanging information by neutral formats of data models, and using the same process through the whole phases. Moreover, Cao et al. (2004), claim that there are three types of institutional isomorphic pressures that influence BIM adoption within construction projects. These three types include coercive, mimetic, and normative pressures, which can impact the amount of BIM adoption into different project levels. Coercive means the formal and informal pressure that the organization can receive from other dependent organization (Cao et al., 2004). Mimetic pressures lead the organization to imitate and use other successful organizations' methodology and structure. Normative pressure are related to the organization's professionals who can form shared norms and collective expectations in accordance with technology development and environment change.

2.6 BIM Management

It should be considered that BIM is not a new technology to be adopted but it is rather a process. It emerged as the industry required an improved technology as well as advanced collaborative methods (Hardin et al., 2015). The construction industry has now passed the challenge of adoption of BIM to some extent but it is struggling to realize the benefits of BIM better. Moreover, it is crucial to know the secondary requirements, which appear after adoption of BIM such as method of sharing information and coordination. Through applying BIM in construction processes, many advantages not only in design but also in digital documentation, administration work, minimizing construction errors and improvement in speed and quality can be derived (Ahn et al., 2016).

2.6.1 BIM Management in Production

The construction phase is based on communication dependent tasks and obviously, the use of BIM on construction sites is limited to managers who are acting in this aspect as advisors as well as informers for others (Mäki & Kerosuo, 2015). According to Bråthen and Moum (2016), BIM is still not extensively used on construction sites. However, the possibilities of visualization allow workers to perceive the planned building much better. In addition, access to the BIM model provide workers to the updated version of planned work, continuously.

A central role which connects design to production is vital in construction and site managers play an important role in this (Mäki & Kerosuo, 2015). A recurring problem in the construction industry is that design documents are insufficient or there are errors in them and it is the site manager who corrects or interprets these errors during the production phase, which costs both time and money.

By adoption of BIM on site management activities, the tools of site managers would be changed. Moreover, it can affect the object of work and it will possibly be included more and more in design management activities. This change demands a wider perspective on the whole process of construction, improving perception of design work. In addition, it requires more collaboration with other disciplines such as design part or material suppliers. It is important o consider that by only replacing drawings by BIM model full advantages of BIM cannot be gained (Eastman et al., 2011; Mäki & Kerosuo, 2015).

On the other hand, in this phase, contractors should work with close coordination to all subcontractors, which allow subcontractors to follow the BIM model. In addition, several profits including money, time and accuracy through sharing model information can be gained by for example offsite prefabrication (Eastman, 2011).

2.6.2 Scheduling and Planning with BIM

A very time consuming task for managers in the construction process is scheduling and planning, which has recently been facilitated by BIM. This can help to reduce the time as well as increase the productivity of this assignment. Currently, BIM does not support this task completely and it can only link building elements with the respective construction process, which is known as 4D BIM. In addition, this linking process between construction process and sequences of dependencies is carried out manually. However, in recent years some research has shown the alternative ways for automation of this task. It is found that a predefined template that is generated according to a 4D model can be applied for similar projects after some change and adoption. Interestingly, it would minimize the time and cost that require for scheduling although it needs expertise and knowledge of planners (Sigalo and König, 2016).

It should be mentioned that many managers use visualization ability of BIM as a help but they do not use the BIM model directly as a base for generating the schedule. There are some issues such as construction approval, funding or even weather conditions that must be taken into account in order to plan for construction. Above mentioned factors are not included in a standard 3D BIM model, which is based on the Industry Foundation Classes (IFC). Considering these elements on the model helps the manager/planner to complete and correct the schedule to be more precise and reliable. It demands a predefined template, which can be reused by an adoption and saves much time by skipping a time consuming process. Definitely, this adaption is required as construction projects are unique (Hartmann, et al., 2012).

It is worth knowing that difficulty of interaction between scheduling software and BIM can create many advantages of this technology to be undermined. The key is to enhance ability of using information stored in a BIM model for scheduling, in order to reduce time of this process significantly compared to the traditional manual method. There is relatively less research in academia conducted in order to investigate the possibility of automated schedule generation directly by the information stored in a BIM model. An international data standard schema called ifcXML can be used in a data exchanging system to create a BIM based schedule. Assembled data provided through ifcXML can help to create construction tasks, calculating durations or applying sequencing rules. However, using this methodology has few limitations related to ifcXML such as scalability and complexity. Although such a model has been tested in the proposed process, it was a relatively simple BIM, containing limited details. One should consider that increasing complexity in models affect the time required to generate scheduling, noticeably (Kim, et al., 2013).

2.7 Summary of Theoretical Framework

Due to need of AEC industry to increase productivity and adding value to stakeholders groups (Rogers et al., 2015) applying new technologies such as BIM has become popular. BIM minimizes errors as well as reduces information transactions costs (CabinetOffice, 2011). Currently, BIM refers to a process, which affects all aspects of a project from design to construction (Luth et al., 2014).

By applying BIM in AEC projects much benefits can be gained including reducing time consumption for documentation and improving collaboration between stakeholders (Bryde et al., 2013). Moreover, some benefits of BIM is facilitating of information sharing and ability for reuse of these information throughout whole lifecycle of a project (Lee et al., 2013).

However, some obstacles influence the adoption of BIM in the industry such as lack of knowledge about BIM benefits and lack of software and hardware resources (Lee et al., 2013). In addition, the industry shows resistance to such a vast change as well as tasks and responsibilities followed by BIM is unclear for them (Johnson and Laepple, 2003).

A major barrier to IT implementation and achieving full advantages of BIM in the industry is cultural issues and resistance of people within the industry (Davis and Songer, 2008). New technologies can contribute to economic growth only when they are widely adopted and implemented and this is directly related to individual decision for using this technology (Takim, et al., 2013). ICT techniques including BIM has brought many opportunities to industries such as visualization, data analysis, communication, information sharing and many others (Azhar & Ahmad, 2014). Regarding construction industry, lack of awareness is the most important factor that hinder adoption and implementation of BIM. Thus, raising knowledge about BIM can contribute to acceptance of BIM in the industry (Ahn and Kim, 2016). Furthermore, new roles and relationships, different contract types and project delivery systems are brought to the industry by continuous development of technical aspects of BIM (He et al., 2015).

Hopper (2015) proposes that finding a common language to communicate through, having a common concept and following a same process throughout of the whole phases are some factors required for standardization of BIM in the industry.

After the adoption of BIM some secondary requirements such as management of documentation, administration and improvement in speed and quality become of importance (Ahn et al., 2016). Since the construction phase is dependent on communication based tasks the role of site managers will be a key role as advisor and informer (Mäki & Kerosuo, 2015). Management in construction phase should work through close collaboration with design phase as well as subcontractors. It means that the model should be shared by all participants in order to enhance benefits such as offsite prefabrication (Eastman, 2011).

On the other hand, BIM can help management in construction phase for some time consuming and demanding task such as time scheduling and planning however it requires knowledge and expertise of planners (Sigalo and König, 2016). Although, today managers use visualization ability of BIM for facilitating time scheduling, the direct and automated scheduling by standard BIM model is not widespread yet. Interestingly, there is opportunity to create a template that can be reused for another project with some minor changes (Hartmann, et al., 2012). This opportunity can reduce the time of this process as well as such a schedule will be more precise and reliable (Hartmann, et al., 2012).

Chapter 3. Methodology

In this part the authors aimed to describe how this study was conducted and then the choices that were made for carrying out the thesis work will be justified. Through reading this part readers can illustrate how the study was begun and proceeded during a period of 4 months.

3.1 Research Approach

The research strategy that was chosen for this study is a qualitative method due to its compatibility with the situation and characteristics with the conducted study. As Taylor et al. (2015) describes, qualitative methodology “refers in the broadest sense to research that produces descriptive data, people own written or spoken words and observable behavior” (Taylor et al., 2015, pp. 7). To conduct this study, a number of managers in different levels are interviewed in order to answer the research questions. Therefore, this methodology is the proper one to be applied, considering the nature of this study.

Furthermore, our qualitative research is inductive as it moves on to new advanced concepts, understandings and visions instead of assessing predefined models, hypotheses or theories (Taylor et al., 2015). The study also includes a real case study of Veidekke AB, for which more information about the company can be found further in the case description in chapter 4. The investigation is mainly from production phase in the case study. It is intended to apply data from a real case study into the academic research in order to improve quality of work as well as compare gathered data collection with what it is experienced during a real project. The process of the case study is completed with the design phase and is at the beginning of the production phase. This aspect is the main reason that encourages the authors to work with this particular case study. Another reason to choose this case is that all parts except the foundation is prefabricated, which called Veidekke Max. This is the first project in the company that has combined BIM with this characteristic and thus, it is interesting to the authors to work with it.

3.2 Data Collection

Research questions shape the conducted study, and everything created, gathered and all data collected, is in direct response to the given research questions. Furthermore, the origin of this research project and the chosen study method are required to be matched. Thus, interviews and direct observations are defined in order to approach the objective. All kind of data collection and the structure of it is also based on the objective of this study and it is formed and developed through time.

3.2.1 Interviews

In this study, a total of 8 qualitative interviews were conducted, in order to emphasize the experiences and perception of reality working and to investigate which main factors influence more BIM implementation in real life construction projects. The interviews helped us to collect the opinions and experiences from people working with the information and functions that the study comprehend, which contributed to a deeply investigation of the research questions presented in the introduction. Kathryn Roulston (2010) claims that: “Methodological texts on qualitative interviewing frequently provide guidelines for effective interviewing–signifying the importance of the procedures by which data are generated for the assessment of quality” (Roulston, 2010, pp. 201). According to Peter J.M. Tutton

(1994), qualitative interviews are categorized in four quality fields of motivation, appropriateness of cognitive style, appropriateness of interpersonal style, and verbal communication skill.

The researchers used semi-structured interviews in this study in order to use a form consisting of equivalent questions to all persons being interviewed. The quality of the interviews can be increased and secured through designing and verifying questions against each target group and therefore questions of the interviews was pre designed and pre formalized. This structure helps interviewees to have the possibility to choose direction of the answer. Semi-structured interview also consist of an element less predetermined, which provides the opportunity to use exploring questions when it is needed. In addition the amount of questions were approximately the same and each interview lasted approximately the same amount of time.

The interviews were held both in Swedish and English and a full review of the interview question material can be found in Appendix A. All interviews in this study were recorded and transcribed in order to not lose the concentration during interviewing and not to miss any valuable information. It is also useful to provide an easier opportunity to use relative citation for each part was discussed further in the analysis part. Generally, it is common that qualitative interviews are being recorded and transcribed, since it help the researcher to concentrate on what is being said and how it is being said.

3.2.2 Observations

The main purpose of direct observation in this research project is to present information obtained by interviews. In other words, due to limitations and insufficiency that sometimes happen with prepared interviews or surveys, information gathered through observation can help authors to create a more reliable work

Meetings with VDC expert (education): during the time that this study was conducted, the authors had an opportunity to join one of regular meetings that are held with BIM educational purposes for personnel. This meeting started with a presentation by a VDC expert from Malmö office of Veidekke regarding new technologies that have been applied in recent projects done by the company. Then participants from different department brought their VDC related issues into discussion in order to receive updated solutions and answers. The nature of the meeting were considered merely educational by the authors as observant.

Advanced technology: This study is conducted when the case study was in the foundation process and there was opportunity to observe some stages of foundation work. It can be said that the technology used in this phase was progressive and machines and construction related apparatuses were extensively applied. Computer desks, laptops, screenplay, iPad, GPS, Total station, full extravasation machines, which work according to the BIM model, were some examples of technology tools applied in this project.

Coordination: During the time that authors had access to the site of construction for the case study, an effective coordination by the management level can be perceived. This coordination was realized due to daily meetings between managers as well as meetings with coordinators of different aspects of the project. It seemed like this type of meeting intended to not only keep every side of the work updated but also boost self-worth of workers on site as they feel part of real group work. Moreover, it can also contribute to more efficiency and less errors as this coordination allows management to have better control on the entireness of work.

ICE Meetings: The possibility of being an observant on one of the ICE meetings provided the following information. A regular weekly meeting known as ICE meeting are held during the design phase in order to gather different participants such as architects, planners, constructors and many others to work together. Each single participant provides parts of information and plans required in order to create a comprehensive BIM model. Generally, the leader of these meetings is a design manager, who leads these people to work together toward in the same manners. As information is gathered gradually, there is a possibility to identify clashes and errors, which must be corrected by the responsible participant before the next meeting. The purpose of such a meeting is to keep people working through the same process as well as joining these meetings provides participants an easy access to the shared information during the meetings.

Planning: Observation revealed that planning by site manager was done manually and it even was confirmed by the site manager. Available schedules on the office of inside the site were pull- back plans and Gantt charts, which had not been completed in the time of this study. The site manager said that he did planning with help of provided visualization.

3.3 Results and Analysis

This section describes the findings of analysis and interviews performed in accordance with the description of the methodology in the earlier section of the thesis. The findings were organized in a way following the research process. In the beginning, a brief summary of the case study, and the company and its policy of BIM and Virtual Design and Construction (VDC) are explained. Later on the interview analysis and the important factors that influence BIM implementation in the real case study are described. Finally, the discussion and comparison from the case study and theory are presented.

3.3.1 Data Analysis Codes

After analyzing of interviews the authors found out some important points that have been addressed by interviewees several times or interviewees put special emphasis on them. These codes are interpretation of the authors out of interview materials. These points will be described separately in finding section together with related quotes.

- ❏ Different role level
- ❏ Generation shift
- ❏ Size of the project
- ❏ Motivation
- ❏ Trust on IT, model

- ❑ Benefits of using BIM
- ❑ Common challenges and problems for BIM implementation
- ❑ Prerequisites for BIM implementation
- ❑ Technology problem
- ❑ Communication and coordination
- ❑ Awareness / usefulness
- ❑ Management role

3.4 Ethics

The process of the conducted interviews included two steps. Firstly, we contacted the interviewees to describe the context of interview and the time it might take to answer. Secondly a time was booked to meet for the interviews. The language was Swedish as it might be easier for interviewees to express themselves in that language. The voice of interviewees were recorded by their permissions because it could be more precise to investigate it later on. The data we gathered through interviews and observations were kept anonymously due to our responsibility not to harming interviewees and the company with that private information. Furthermore, all of interviewees were informed about their right to look at the manuscript of the interviews that translated in English however, no one asked for the control of translated manuscript.

Chapter 4. The Case Study

The following chapter describes a specific case at a contractor company. It starts with an introduction of the company and is followed by the company's internal learning platform and its evaluations. The way the company works with BIM and the level of their BIM maturity has influenced the results of this study. Findings reported in this section are based on the interview with the management team within the selected housing project and also direct observations made by the authors.

4.1 Veidekke

Veidekke was founded in Norway in 1936 and is the fourth largest in Scandinavia construction and Civil Engineering Company. The company is represented in most areas of the building sector such as construction market (building, housing development, infrastructure and facilities), and asphalt operations, production of crushed stone and gravel.

The Veidekke group currently has about 7400 employees spread over five regions of northern, western, eastern-mid Sweden, Skåne, and Stockholm region. The turnover of the company reported on 2016 was about 30,1 billion Norwegian kroner.

The case project is the construction of 70 flats divided in 4 different structures. At the time the case study was conducted the project was in the foundation phase and the work mostly consists of excavation by machines and it did not start with the concrete process yet.

4.2 Virtual Design and Construction (VDC) development

The Swedish construction industry is currently facing a major technical shift to using the tools and methodologies such as BIM/ VDC on a large scale (Tjärnberg, 2010). This technical change and adoption makes companies achieve different benefits that will affect the entire construction process, from design to management. Veidekke is one of the first companies in Sweden that attempted an implementation of VDC in their production (Persson and Johansson, 2013) and is expanding the venture on large scale after achieving successful project objectives by implementing it within the organization (Tjärnberg, 2010). The three main parts of VDC include product, organization, and process (Persson and Johansson, 2013). The product is often illustrated as a BIM-model, the organization is more related to the intention of putting right person and team to different tasks, and the process is more in the relation of effective ways to operate.

4.3 The Residential Complex Project

As can be understood by the research questions, this study is mostly focused on implementation of BIM and its influence on managerial tasks. The case project chosen is a housing project located in Gothenburg, Sweden, and the purpose is to investigate and find proper answers to the research questions.

As we mentioned before in chapter 3, the special characteristics of this project is called Veidekke MAX, which means that all parts except the foundation is prefabricated. The different technology devices used both in the establishment and on the site include computer desks, laptops, screenplay, iPad, GPS, Total station. Moreover, the level of BIM in this project is in 3D level which, concrete, quantity and volume are included in the model. The use of technology is relatively high in this project. For instance, the machines are equipped with visualization technology such as screen, which facilitate working with the model.

4.3.1 Different roles have been interviewed

Different roles in the management level have been interviewed in this project and later on will be analyzed in order to find out the different aspects influencing BIM adoption in the production phase. The managerial roles that are interviewed in this project include the project manager, design manager, VDC-engineer, site manager, foundation manager, measurement management, and supervisors, whose roles will further be described as well as their engagement with BIM.

The site manager is the one who plans the work with economy and setup and is involved with the project design meetings. Above all he leads the daily work on site and works with BIM in his daily tasks in this project.

The project manager is responsible for one of four groups on the construction in the west the west region construction. He is responsible for the economy, hiring people, and projects' bid and contracts, and does not use BIM in his work. He only uses the model to understand and have insight of the whole project but he manufactures and acts by 2D-drawings.

The foundation manager is the one who works on the foundation part and doesn't use BIM in his daily tasks, but only when he wants to check the heights and in his other tasks such as reinforcement he uses 2D-drawings.

The design manager is leading the design process and is the one who gathers different participants together in order to work on the design process. These participants are designers, architects, electrical design engineer, planners, structural engineers, hvac engineers, etc. that participate on weekly meetings to work in order to create a comprehensive 3D model. Then, when information is assembled and 3D model is achieved by VDC engineer in the same software, the design manager is responsible to deliver information to the production. During the whole construction phase the design manager is involved as changes may occur, which gives design managers the chance to resume the process again however, he/she has no responsibility to participate in the production itself.

The VDC-engineer is the one who is responsible to bring the information from the design phase to the production and is involved through the whole process. She is also responsible for creating the BIM model when it comes to technology and working with Solibri (3D-software). The process of delivering the design, updates and changes is based both on weekly meetings and also by updating the mutual homepage called Sharepoint. The information they receive is concluded of drawings, requirements, 3D models etc. It is the whole model of electricity, pipes, plans, walls, volume and so on.

Measurement technician is the one who only works in the foundation part and sets everything into the right place (e.g. determining the points where columns will be set). He is the one who has contact with constructor and uses BIM in his daily tasks. Moreover, it is his responsibility to put all necessary models and information into the different machines on site that workers use.

The supervisor is the one who is responsible for much of the practical work with the management team. Therefore, it is important that the supervisor is aware of possible risks employees may be exposed to and attempts to provide a safe workplace where can make workers aware of risks. One of the supervisors interviewed in this thesis was mainly part of basement related activities and concrete processes and the other one mainly focused on the calculation of related tasks.

The project manager, design manager and foundation manager in this project are relatively more experienced, while the site manager, supervisors, VDC engineers and measurement technician are younger with less than 10 years experience.

Chapter 5. Finding Section

In this part**,** the focus is on analyzing assembled information during interviews and observations, which helped us to lift up the points that can be considered important regarding the subject of the study.

Different role level: In this project, all participants received the whole model and information, however, they all used it differently depending on their role. This variation in use may influence to what extent someone can use the BIM model to their advantage.

The usefulness of BIM differs depending on the tasks. For instance, in this project the site manager and the supervisors are those who use BIM in their daily tasks. The site manager believed that BIM is one of the best tools that contributes to facilitate his daily tasks even in the managing and leading part. Therefore, the management team on site attempted to help all workers to use the model in their daily tasks. He claimed that: "*all workers here should learn how to use the model. Therefore, there are some intensive courses for those who cannot read it*". Moreover he said: "*We have different meeting for different groups of employees such as coordination meetings, weekly meetings, etc. in order to inform them about the changes and plans.*" On the other hand, the project manager and the foundation manager do not use the BIM model, though they join meetings held to discuss the BIM model and any changes. It can be realized that a mutual usage of BIM by all participants is its possibility for visualization.

The differentiation of using BIM in different roles is related to the benefits that can be exploited in that specific role. Some roles are not defined to use BIM such as project manager whose role is more focused on recruitment, economy, contract and so on. The foundation manager said "*There are not many benefits of using BIM through the foundation part, because the main requirement in this part is height, therefore it is necessary to have a model in order to operate this part (by automatic excavating machines). It is almost same in all projects. It is only in the bottom plate that we use the model, the rest doesn't need to have the model*". Thus, the role is a key factor which influences who uses BIM and who does not. Consequently, BIM in its current state is a helpful tool for some managerial roles however, there is still managers whose role is not affected by BIM technology so much and they only use the model for visualization.

Generation shift: According to the interviewees, there is a common idea in the construction environment that some senior employees have a difficulty to use computers in their daily routine and tasks. This issue might be due to very different reasons such as being conservative in mind, having difficulty to learn new things and so on.

Undoubtedly, those who had studied and worked before computers emerged are not familiar with the advantages of computers. Thus, it can be perceived that the generation you are belonging to can be a crucial factor for using BIM. For instance, the foundation manager said that "*I am a bit old and use paper instead (of the 3D model). For example for me with 30 years experience in this field is better to have 2D-drawing because I can see it 3D in my mind and it is easier for me to understand the drawing, while I don't get the same feeling when I see it on the screen. The young generation on the other hand should use 3D-model I think, because they are born with computers. However, it is obvious that I use the model when we have changes and challenges but me by myself I don't use the model*."

It seems like a dilemma as industries are going to be more and more digitalized, where you cannot be successful unless you apply new ideas and technologies. On the other hand, industries such as construction require experienced people, which is one of the issues that has contributed that the construction industry become conservative. However, it can be counted as a matter of time and the older generation is slowly replace their place to the new generation all grew up with technology. Consequently, the construction industry is on its way to shift to more innovative approach by employing young generation. One of the supervisor's point out that: "*Sometimes it (technology) is needed. I think one will learn the program that sits actively, otherwise it is not possible. I am young and capable to use a computer and I can learn the program but in our industry there often work older people, and they work with old school methods and haven't used computers that much. It is a generation shift now. The young will for sure use more aid however the experienced ones have other abilities and can do other things*."

According to the above description, sometimes age can be counted as a hindrance factor for receiving advantages of BIM. On the other hand, the shift from a conservative approach to an innovative one can be considered as a success factor for the industry. Besides, hiring younger employees with the knowledge of using BIM can also contribute to a better BIM implementation in production phase.

Motivation: According to interviewees the importance of motivation regarding the use BIM has been revealed. In the past generation, it is somehow concluded that generation is a determinative factor for using BIM in daily tasks. However, there is evidence that shows the final decision is made not by age of user but by the will of using BIM, which encourages people to try and learn new technologies.

Regarding a question to a VDC engineer about how older people are used to working with BIM she answered: "*The willingness to learn is the most important thing. If one is interested in something, they will learn it. I have seen both older people who work with IT and those who do not work with new technologies. They will use it when they understand the point of using it*". Consequently, as there are some older people who use BIM and other new technologies emerging in industry, it can be understood that there is something more than age that determines the abilities of a person and that is will or motivation.

Trust in IT, 3D-model: Despite receiving a comprehensive 3D model including all required information, the employees are still using 2D drawings at first. The reason of this prioritization according to personnel is that the model can contain errors or parts that are missing. Thus, the 2D drawings are counted as a reliable reference and the model is considered as a helping or aiding tool. Drawings are a range of approved documents, which are inspected and finalized regarding any error or failures.

For example one of supervisors on site described how they prioritize 2D drawings to the 3D model and she said: *"Drawings always come first. They are our work material and then one can look at the model because the model is not reliable as the certified drawings are. So the model is often used as a visualization help for the drawings".* 0709522359

Moreover, the model is not so precise when it comes to planning and time scheduling. According to the project manager the model can only find the errors that are drawn into the model and is not able to recognize the errors that are missing, which can even make the problem worse for those who believe that the model can find all errors and makes them blind to trust it 100%.

The above mentioned quote was not the only one that we have heard during the interviews about not trusting the model. Therefore, even though they state so many times that BIM facilitates their tasks and minimizes the errors, they still prefer to use 2D drawings as the main reference. Evidently, there is no complete trust on IT including BIM which causes the industry to resist shifting from traditional methods. However, BIM has brought much progress into the industry. Thus, it should be considered that a major hindrance for obtaining the whole advantages of BIM is lack of trust in technology in the construction industry. Furthermore, through education regarding possibilities that BIM provide, one can enhance awareness of people in order to apply and adopt new technologies.

Benefits of using BIM: The site manager said in an interview that "*BIM helps me a lot. I use BIM to manage the tasks as planning, discussing about different roles, volumes, etc. almost every day. It is the world's best tool, and it helps me to facilitate and even manage workforces*."

There is no language problem when you use 3D-model, thus, it can even solve the problem of language barriers." The measurement technician says "*Working with Solibri and using the model helps me to better understand the drawing and have general insight of it.*"

The project manager claimed that "*the advantage of using a BIM model is visual and check every elements specialists draw are fitted into the building or not and it helps us to detect the clashes.*" Although, the project manager does not use BIM in his daily tasks, it helps him to visualize and understand the form and details of the building better. Moreover, in his opinion BIM can develop a better and easier planning in the way that make a better understanding of how the product will look like and in which order the product should assembled.

According to the statements above the benefits of BIM that facilitate current managerial tasks in the production phase are as follows:

- ❑ Facilitating managing tasks such as planning and operating
- ❑ Solving problems such as language barriers
- ❑ Better understanding of the drawing
- ❑ Giving an insight about what should be operated
- ❑ Detecting the clashes
- ❑ Prioritizing tasks through visualization
- ❑ Better understanding about the form and the details of the project
- ❑ Having a more proper planning

Common challenges and problems for BIM implementation: BIM is mostly affected in the design phase, but in the production phase there is still the lack of using BIM. However, according to the project manager, "*BIM is continuously developing and soon BIM will be adopted into other phases such as production phase, clients and bid phase*."

One common problem of implementing BIM into the production phase according to the site manager is "*to sync all information and changes into the different construction parts (e.g. pipe and electricity). Besides, it sometimes takes time the planner to update changes, which can cause repetition of work because sometimes some part has been constructed based on an incorrect model.*" This issue can be considered as a barrier of implementing BIM successfully into the production phase.

Another problem as reported by the project manager is about employees' skills and experiences. He stated that: "*those who are expert in seeing what is missing (senior generation) are mostly not capable to manage the model and those who are capable to manage the model (junior generation) don't have 30 years of experience to be able to see the errors that are not visual*." Hiring those who are experts both on BIM technology and management is related to the management team who can influence BIM implementation.

The project manager also asserted that "*there is still a lack of knowledge to know how much information should be put into the model and where the limitation is. During the years we use BIM, we have realized the limitation of putting information into the model through trial and error, and it costs time and money for us*." Gaining and improving this knowledge can contribute to better implementation of BIM and can be counted as a success factor in it.

Moreover, one common challenge is related to the changes and updates of the model. It can influence the time schedule and thus, the site manager together with supervisors must redraw the time schedule in order to manage the time they lose. As the site manager stated "*redrawing the time schedule can be counted as a challenge in these kind of projects (housing projects) due to a clear final deadline, which results in extra work and/or working in weekends in order to accomplish tasks before deadline*." Therefore, it can result in BIM not supporting management for tasks such as scheduling in practice.

Prerequisites for BIM implementation: One main requirement in production phase is still more education and IT knowledge for those who work in this phase. There is still lack of knowledge of using technology for some employees who are not born with this technology. The foundation manager asserted that: "*we as older generation who haven't grown up with computers, therefore it can be more difficult for us to use it. While, the younger generation who are for example 15 years younger than us and have grown up with computers, are better at using this technology*."

One solution to this problem, is different intensive courses for improving employees' IT-knowledge. In addition, there are different kind of meetings (daily, weekly, and monthly) with different group of employees where the management team informs all employees about changes and updates. As the foundation manager stated in an interview, there are also some persons in the management team who directly contact the workforces and try to help them with different problems. The foundation manager explained that: "*If workers have problems with the model, for example have problem in reading the model or something is drawn incorrectly, then they contact the measurement technician*".

Besides, the model should be more accurate, because it is not so precise when it comes to planning and time scheduling. It is also needed to develop the technology, so that it becomes more accurate and possible to measure from the model. The measurement technician stated that: "*One important factor* *that should be improved in order to better use BIM technology is to make the measurement more precise where we can use all measures from the model, for instance the heights. Generally the model must be developed into a level that we can fully trust*."

Another prerequisite is attempting to create a mutual software tool for all project participants such as architects, constructors, engineers, and so on in order to use BIM more efficient. It is also efficient if the technology can develop into the level that is eligible to determine the price of different material and estimate cost.

All statements above have mentioned possible problems and barriers that influence BIM implementation in production phase and attempting to solve these issues can be considered a success factor of the implementation.

Technology problem: Even though there are still some difficulties to use BIM in the design phase, it can be said that technology problems are relatively more experienced during the production phase. BIM is a computer based tool, which means that some electronical devices are needed in order to use it. In addition, tablets or other moveable devices can be used by workers on site, and there is lack of proper software in the shape of apps that open the whole model in such a device. A VDC engineer relates: "*speaking about production, a big problem is that sometimes there is no app that is able to read Solibri files. We try to provide tablets on site that enable us to stand on site and have the model in front of us and go around it on the site, but it is not possible today. You can download an app that reads only IFC files and it can read only one file at the moment and it is kind of mess of drawing so it is only lines. It does not help, so it is better to go back (to the office on site) to computers and take a screenshot and look at it. There is a need for developing and technology is not there yet*."

It demonstrates that experts on site require an advanced technology that allows them to get more advantages of using BIM. The supervisors also claimed that: "*files are very big and we cannot have them on our iPad. We can just have a single drawing in our iPad, while we need to have all of them simultaneously, otherwise a single drawing is like something hovering in midair*!"

Consequently, the investigation above demonstrates that despite advancement in technology, it must be attempted to solve the technological problems, in order to achieve a better result. Thus, technology problems today can be considered as a hinder that influence BIM implementation to be uncompleted. On the other hand, attempting to find proper solution(s) for this issue may contribute to a successful achievement.

Dependent on size of the project: a crucial factor to apply BIM on a project is the size of it. It means that for example it should be justified in order to work on production according to the BIM model. In other words, even leading companies carry out some project in the traditional method as the client wants to. One of the supervisors mentioned that this is the first project she works with a BIM model and then explained: "*On the smaller projects we do not use BIM model as it costs so much. This project is very big and is the first one that I worked with BIM*."

Therefore, it should be noticed that there is also economical issue to consider for using BIM. Basically, compared to traditional projects, using BIM requires skilled people, more advanced technology and following a certain process which, lack of each can affect the implementation of it negatively. Thus, in such a project as smaller group of people work the possibility to implement BIM will be minimized. On the other hand, as it is mentioned before using advanced technology requires more budget, which sometimes is in contrast with clients demand. According to the project manager: "*The important factor that should be considered is that making 3D model costs time and money and it requires clients' desire to pay that cost. Using BIM costs money, therefore it is necessary for organization to be able to recognize in which level (3D, 4D, 5D...) different projects should use BIM.*" Finally, needless to say, BIM is a process which needs a sequent of works in order to be implemented and it cannot be successful unless this process is followed. Thus, even if management level is capable to adopt and implement BIM, there is still other factors that may affect this process.

Communication and coordination: To perceive the process of working according to the model on production the design manager described:" *in Design process, we draw and create something, which will be sent to the production somehow (it is also described in the text) and in production things happen that cause some changes and then the information regarding changes in production comes back to the design manager. Next step is to call all planners involved to create the model to reconsider their work and then we send it back to the production. This is the ordinary process we follow every time. Another way is to send the changing information from production directly to the related planner and they also send it back directly to the production. However, although it seems easier and faster, there is a risk that taking the issue with only one planner, other parts become affected (as each aspect is related to others). So, it should be followed in the right path*."

According to the abovementioned description, it can easily be seen how important communication and coordination is, in order to work in such a process. Obviously, for following this path the responsible person, who is design manager in this phase should be able to get all involved people together to work in the right process.

Awareness or/and usefulness: It is worth knowing that the first step for applying a new technology or even an idea is to be aware of its benefits. In other words, one might not try new things unless they realize something interesting. The issue of awareness can also be applied when it comes to use BIM on production phase. During this phase of construction there are different types of tasks including; administration, construction, logistics and coordination, which some are not directly accomplished by using BIM. For instance, as the project manager claimed time scheduling is not carried out by using BIM. He said: "*there is still lack of knowledge to know how to use the model for making time schedule, which it also requires those who are expert on both time scheduling and BIM.*"

On the other hand, sometimes there is no justification to learn and use a newly emerged technology for a specific work. Therefore, in order to adopt new methods to do a task one needs awareness about it or seeing advantages to use it. For example, the foundation manager states that "*I don't use the model much. There are not many benefits of using BIM through the foundation part and BIM-model is only used when it comes to measuring heights, otherwise for detail reinforcement I use 2D-plans*." So, it means that he is not using BIM because he does not feel the necessity to use it. It should be mentioned that not using BIM may be related either to unawareness of the potential benefits or not to find it useful.

Management role: In the case study it is tried to find out more about role of management as well as their activities. According to the interviewees main activities done by management in the production and design process are bringing in people to work together through a same process. This collaboration requires an open wide communication and coordination, which is the most challenging work of management. Frequent meetings held both in design phase and production for informing and updating employees are activities that are done management toward this approach. Moreover, planning and time scheduling is a task for managers and it needs to be changed and updated continuously. On the other hand, managers are in contact with suppliers through the whole process of construction. This include all orders, information sharing and updates. Inconsistency and misunderstanding that occur during this relationship are usual in production phase and this is also a challenge for management to solve these types of conflicts.

Chapter 6. Discussion

This chapter firstly consists of a discussion regarding the information gained from interview analysis and a comparison of the theory and the real case study. Further, the study brings an effective recommendation of supportive actions that contribute to successful BIM implementation for the company. Finally, the chapter ends with suggestions for future research.

The purpose of this study was to investigate the factors that contribute or hinder the BIM implementation within the contractor company and to illustrate how management role can influence it. In order to answer these issues, a single case study at a construction company was investigated.

6.1 Success factors and hindrances in BIM implementation

Discussing success factors for adoption and implementation of BIM brings important factors to consider. Firstly it should not be neglected that success can be defined and described differently in different contexts. It is also important to consider that even in a same context like production phase in construction industry, the success cannot be measured easily. The fragmented nature of the AEC industry and simultaneously the fact that each project is uniquely realized, makes it difficult to define whether this is successful or not.

However, according to much research conducted in this area, there are some factors that can be considered as success factors in general. These factors include changing the mindset of management toward adoption of BIM, integrating project teams, having a balance among various expertise and continuous education and training of human resource (Lee et al., 2013).

Moreover, the ability for spreading the information across the team, involvement of client from the early stages, which can bring clients support during the construction process can be named as other success factors for adoption of BIM (Cao et al., 2004). Clients/owners have a major impact on project design and construction activities, including innovation adoptions, and therefore it is needed that they support the facilitating of BIM adoption by paying the costs of it, championing its utilization, and supporting process and organizational change (Cao et al., 2004).

Based on interviews and observations some of the above mentioned success factors are seen after investigation of case study. These factors are as follows however we cannot claim that whether this project will be done successfully or not. Integration of project team, early involvement of client as the contract is design-build, appropriate system of information sharing are some of these factors.

As it is considered that the employee behavior is the most complex factor to change, the shift of members' attitudes and mindsets to more enabling behaviors is a crucial factor to the way construction is delivered (Davis and Songer, 2008). This issue is also evident in the empirical findings. For instance, as it is mentioned in the previous chapter, some employees resist to change and use new technology, especially those who are not born with the technology. Thus, the BIM implementation can be developed by collaborating and making a cultural shift in the mindset of management teams. Measuring the level of this cultural shift in the case study is not possible for the authors due to some limitations such as time.

Besides, from the empirical findings we found that a common language was relevant and this is also confirmed in the literature. It is essential to have a common language to communicate through, and a common concept with the classification of that concept in order to implement BIM (Hooper, 2015). Exchanging information by neutral formats of data models and using the same process through the whole phases are counted as other important factors.

On the other hand, some identified hindrances for BIM adoption and implementation in production phase derived from the interviews include the conservative nature of construction industry, cost of human resource, resistance to accepting new technology, unawareness about BIM benefits, technical upgrade requirements, standardization of processes, procedures and systems and lack of trust on IT.

Another issue that may increase the difficulties to make rational decisions for BIM adoption is the relatively uncertainty of BIM benefits and efficiencies and the differences of BIM adoption in different projects and even in different project levels. The three institutional isomorphic pressures (such as coercive, mimetic, and normative) are also the critical factors that both can contribute to a better adoption or to hinder it (Cao et al., 2004).

Surprisingly, all mentioned hindrances derived from literature can be found back in the interviews, which proves that these obstacles are serious ones and hinder the path of BIM adoption. Furthermore, in order to have BIM fully adopted, it is required to focus not only on success factors but also to solve and clear up all obstacles.

An inconsistency that can be seen between theory and the real case study is that theory claims that using BIM not only has great advantages for large scale projects, but it can also be applied for individual components of a smaller scale project (Bryde et al., 2013; Migilinskas et al., 2013). While, in the real case study, it is believed that adopting and implementing BIM in very complex and/or very small projects is not economically efficient, when the adoption requires higher additional project cost and the need of comprehensive training.

Theory illustrates that BIM can be applied for the purposes of visualization, fabrication and/or shop drawing, code reviews, cost estimating, construction sequencing, conflict, interference collision detection, forensic analysis, and facilities management (Cao et al., 2004; Lee et al., 2013). Although in the real case study some benefits such as visualization, interference collision detection, construction sequencing, code reviews and fabrication have gained through the BIM implementation, the purposes such as cost estimation in the production phase is not completely adopted and the use of technology is not developed to be eligible to determine the price of different construction material.

6.2 Management role in BIM implementation

A frequent matter of discussion is that whether BIM contributes to improved performance of management in the production phase or not. Looking from a production point of view, management has a key role during the production phase in order to manage the process as well as getting production work to be done (Hardin et al., 2015). It demands a huge collaborative effort, which a site manager as a person in charge, together with supervisors and coordinators of skill workers have to do. This collaboration includes an effective system of information sharing not only across the internal participants but also between the production and suppliers/subcontractors (Eastman, 2011). Evidently, BIM is a software tool that not only changes management tools but also affects the whole process of working. This change includes the relationships, the way of information sharing, and improve collaboration (Mäki & Kerosuo, 2015). According to the interviews, some managers state that BIM help them considerably in better understanding of the construction sequencing and minimizing misunderstandings and self-interpretation. Site manager and supervisors also relate that not not only planning is done better by ability of visualization of BIM, having a shared model cause to share information easier and more effective. However, some of the managers believe that BIM cannot add something useful to their work namely; foundation manager and project manager.

Moreover, some new roles are created during working with BIM, which are more focused on coordination and training (He et al., 2015; Johnson and Laepple, 2003). Examples of effective coordination and collaboration between the production and the design part that can be seen through working with BIM in the case (observations and interviews), are frequent meetings and strengthening of relationships, not only between participants but also between two phases of design and production. During the production phase some measures are taken to improve the method of information sharing and exchange of data. For instance, access for all participants to the model, weekly meetings for discussing updates and changes, and dividing managerial tasks that allow more focused work on different parts and so on. Interestingly, the contractor company of case study consider a role as VDC engineer, who follow the process of construction from the day that design begins to the end of production phase. This is a great help for production phase to have someone that have gone through the whole process as a reliable reference for design material.

On the other hand, through applying BIM into the production, the major problem - which is misunderstanding of drawings by people who were not involved in design process - is solved by the BIM ability of visualization. This is a great help for management as it minimizes the need of extra description about design material. It is also verified during interviews by management that BIM reduces workers' errors compared to the traditional way. However, it should not be neglected that theory suggests a continuous training for workers (Conway, 2010) in order to get familiar with new technology and more involvement of site manager (Mäki & Kerosuo, 2015) in the design phase in order to find out the rationalities and justifications of the design material. Back to the case study, it is seen that site manager joined educational course held in the main office regarding BIM technology.

Another important task that is traditionally done by management on production is scheduling and planning, which include both time scheduling and sequence of construction process (Sigalo and König, 2016). According to the theory, BIM technology can contribute to have a more effective action in relation with time consuming tasks or even define a template that can be reused in other projects (Hartmann, et al., 2012). However, empirical findings show that it is not implemented in this project and BIM was unable to support this action. Thus, it would be suggested to keep contact with academics by the company in order to receive new updates for enhancing use of BIM and other new technologies.

Educational support can be considered as a crucial factor in order to train employees working toward a new approach, which is a collaborative approach brought by BIM. Employees who are supposed to work in a new environment need to be educated and develop their knowledge of BIM not only as a tool but also as a method (PMI, 2013). This issue demands more communication and cooperation. It is also important to take into account that new methods of working that are adopted into the work environment need to be justified by management. In the case study, one of the management task is to facilitate the process above in the way that motivates the employees to work toward new approaches. Besides, new activities that are brought by new technologies are introduced and identified by managers. In other words, this change in the approach of work should be managed properly to motivate employees' learning and practicing (Conway, 2010). According to the site manager of the project case, for the educational purposes they have the policy for running periodic educational courses as well as providing an effective cooperation between expertise and juniors.

Communication is undoubtedly the most important tool for managers that help people to accept this new technology, which adds value to the activities. Simultaneously, it can improve capability of workers toward learning a useful tool. Besides, regarding motivation, it should not be neglected that there are two types of motivation; intrinsic and extrinsic (Ryan and Deci, 2000). When it comes to extrinsic motivation, it must be some incentives from management to encourage people to do a certain task. According to empirical findings, it is understood that between managers there is some who think that the most important thing is will while, some other believe that promotion in work and working in the group help employees to learn and practice new technologies.

Moreover, a recommendation for the company in order to better implement BIM, is that the company attempts to create the culture of accepting new technology.

Chapter 7. Conclusion

As it is mentioned at the beginning of the study, today's construction industry has tended to increase efficiency, effectiveness, productivity, and project quality, while it decreases project cost and delivery time. Besides, the complexity of construction projects today requires various expertise into different project areas and phases and this diversity of expertise brings the issues of effective communication and collaboration. However, in the production phase this effectiveness must be increased and it is important to consider that the relationship with subcontractors and suppliers is as important as relationship with the design phase. A crucial factor in order to enhance the productivity of workers is the manager's ability to communicate. Building Information Modeling as a virtual process has become a key approach in the construction industry in order to achieve these issues. As BIM technology is a process, it influences the whole organization's activities and affects roles and relations. Therefore, an organizational transformation occurs when BIM is fully implemented within the organization.

As BIM is well accepted in the design phase but not in the production, it is important to investigate the factors that contribute to a better BIM adoption and implementation in the production phase. Thus the purpose of the study was to investigate more about BIM benefits and barriers and to provide an effective recommendation of supportive actions that contribute to successful BIM implementation in contractor companies. The objective of the study was to collect the data that contribute to answer the research questions through an abductive and a qualitative method. The above-mentioned purpose leads to the following research question, which an attempt is made to be answered in the following text.

- ❑ What are the success factors and hindrances for adoption and implementation of BIM during the production phase in the construction industry?
- ❑ How well are the current managerial tasks developed in terms of BIM in the production phase within contractor companies?
- ❑ What actions by management on site contribute to a successful implementation of BIM in the production phase?

Answering the first question, some main problems and barriers based on both the theory and the empirical study include educational requirements, unclear tasks and accountabilities, lack of integration among project stakeholders, and people's unwillingness to change. On the other hand, some important benefits we found from the finding section that are relevant to the theory include facilitating managing tasks such as planning and operating, solving problems such as language barriers, better understanding of the drawings details and the form of the building, giving an insight about what should be operated, detecting the clashes and errors, prioritizing tasks through visualization, and having a more proper planning.

According to the findings, learning new technology is more difficult for older generations than for younger generations and it can be taken as a hindrance. However, it should be considered that it maybe is not the whole truth and another important factor is the nature of humankind that resist to change. A good news for BIM adoption in the construction industry is the gradual replacing of senior employees by younger employees, who are used to work with new technology. Moreover, according to the theory the cost of human resource, and the lack of awareness about BIM benefits and usefulness are other important barriers to accelerate BIM adoption. Thus, developing employees' knowledge of BIM and making them aware of its benefit can help project participants to easier accept changes and contribute to a cultural shift within an organization.

Regarding the second question, a key factor that contributes to the successful adoption of BIM is the major amount of all project participants' involvement. Findings demonstrate that gathering people to work together in the same process can be considered as a great challenge, which demands an active collaboration between different participants. It is a demanding task for the managers to create a collaborative approach in order to motivate people for working toward this method. While, some benefits and advantages of BIM have been perceived by contractor companies, a continuous education is required to raise awareness of industry actors about new supports provided by this tool.

Looking at the third question, studying recent published literature regarding BIM and task of scheduling show that some methods have been tested successfully that enable an automated scheduling based on the BIM model. Using this method can helps managers and planners to accomplish a very demanding assignment with the help of BIM much easier in shorter time. The tools of site managers would be changed by BIM adoption. The advantages applying BIM provides for management in the production phase include minimizing construction errors, and improving project quality. 3D models contribute to a better understanding of building plan through visualization. However, for better implementation, it needs coordination and communication among project participants and requires more collaboration with other disciplines such as designers and suppliers.

7.1 Suggestions for further research

Due to limitation of time and the focus of this study some areas for research are left for further studies. One of the major areas is how to enhance collaboration in the production phase. Regarding BIM adoption it is in interesting to know how the culture of the industry can be changed in order to accept such a paradigm shift. Last but not least it is worth to search and find new methods that can be adopted to automate time scheduling according to the BIM model.

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Division of work

We, authors of the master thesis believe that the work was fairly divided and we both were involved in writing of all sections.

Best regards
/Bahareh Ghavamimoghaddam
/Elmira Hemmati

Appendix

Interview Questions

1. Could you tell us what your position is and your role?
    a. Do you work with BIM in your daily tasks?
2. Who is responsible to deliver design information to the production? How is this process done?
    a. What kind of information do you receive in production (e.g., drawings, requirements, 3D models etc.)?
    b. Does receiving information differ from person to person?(according to their roles and disciplines)
3. How do you work with BIM (in production and whole team)? How the information is shared by BIM (the way you share information)?
4. If the model changes during production phase how do you handle it?
    a. How do you inform people about these changes?
    b. To what level do you use BIM in production? (4D, 5D or 6D)
5. How BIM can help managers to support their daily tasks? How do you/does management support (encourage) their staff to deliver their particular tasks?
6. How do workers on site receive information? (If they have language problem)
    a. If you work with BIM, how do you /managers inform about the 3D models
    b. What is the next phase of production in this project? How information on the model is delivered to the next phase?
7. Which device do you (all) use to read the model? Is there any screen on site that allows worker to access the model?
8. Which problem(s) do you face mostly when you are using BIM in the production? (Can be multiple problems and you can ask specifically for BIM use related problems)
9. What do you feel is needed in order to implement /work with BIM in production? (Which requirements compared to before introducing BIM to the production) give examples to them!
10. Do you feel that BIM facilitates planning? In what way? If yes how it may affect the production phase?
11. Who is responsible for the planning to this project!
12. Did they get full model from prefab?