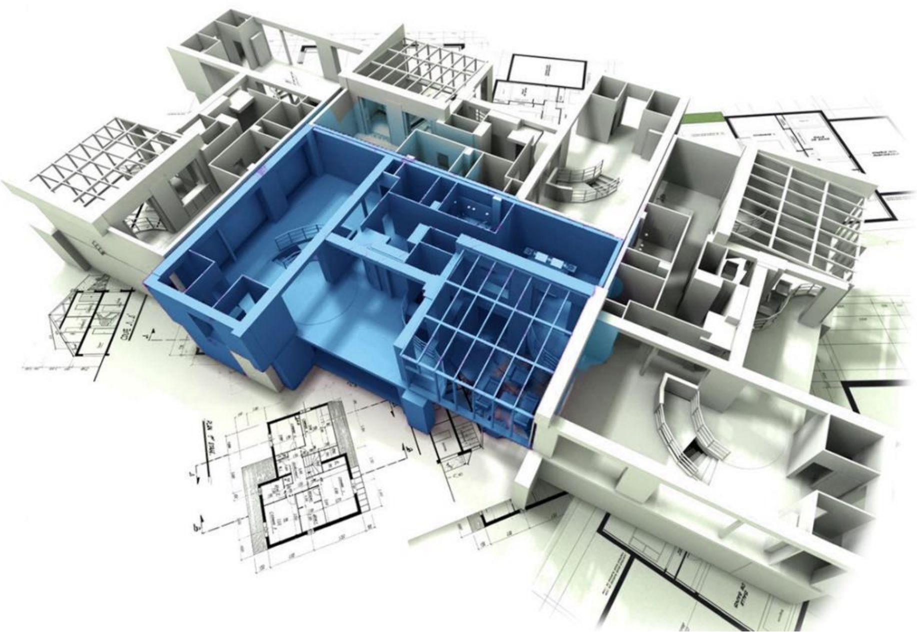

Improvement of the Design phase by BIM to transform into a model-based AEC industry

A review of the relation between architects, contractors, and clients

Master's thesis in Design and Construction Project Management

Maryam Kiani Hashemiesfahani
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DEPARTMENT OF DEPARTMENT OF ARCHITECTURE AND CIVIL ENGINEERING
CHALMERS UNIVERSITY OF TECHNOLOGY

Gothenburg, Sweden 2022
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MASTER’S THESIS ACEX30

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Institutionen för arkitektur och samhällsbyggnadsteknik
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Abstract

Technology has changed a lot over the years, and there have been many positive advancements in the digital sector. As the digital sector is increasingly used in the construction sector, it is necessary that the technology develops at the same pace and adapts to the user's needs. In the construction industry, Building Information Modeling, and despite the evolution of BIM technology, its adoption is limited. The Architectural, Engineering, and Construction (AEC) industry are still mainly using its traditional ways of working, which means using 2D drawings instead of 3D models. This thesis studies what limits the construction industry from transforming from the traditional ways of using 2D drawings towards becoming entirely model-based in the design and construction. In addition, the relationship between architects, contractors, and clients has been investigated since the collaboration with the parties involved is essential to achieving the full implementation of BIM in the AEC industry. To understand the relationship between the parties involved and why BIM is not used more widely on the construction site, information management through BIM and how the information is shared and presented between them has been analyzed.

The results of the thesis have been collected through eleven interviews with architects, engineers, and contractors. The results indicated that the most common way today is using and delivering a combination of 2D drawings and 3D models. It seems like producing 2D drawings, and 3D models require the same type of information, but despite this fact, architects put in a lot of effort and time to produce both. The results show many underlying factors to the limited transformation of becoming model-based. For instance, unclear demands from all involved parties, lack of knowledge, lack of frameworks and guidelines, unfriendly software, lack of trust in the BIM model, lack of supporting contracts, absence of open format, and the fact that the BIM model is not considered as a legal binding document.

Keywords: 2D drawings, 3D models, AEC industry, Architect, BIM implementation, BIM information, BIM model, Client, Contractor, Model-based production.

Förbättring av projekteringsfasen Med hjälp av BIm för att övergå till en modellbaserad AEC industri

Examensarbete inom masterprogrammet organisering och ledning i bygg- och fastighetssektorn

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Sammanfattning

Tekniken har förändrats mycket under åren, och det har skett många positiva framsteg inom den digitala sektorn. Eftersom den digitala sektorn i allt större utsträckning används inom byggsektorn är det nödvändigt att tekniken utvecklas i samma takt och anpassar sig efter användarens behov. Inom byggbranschen är Building Information Modeling (BIM) för närvarande den mest centrala tekniken inom digitalisering och trots utvecklingen av BIM-tekniken är användningen begränsad. Architectural, Engineering and Construction (AEC)-branschen använder fortfarande till stor del sina traditionella arbetssätt, vilket innebär att man använder 2D-ritningar istället för 3D-modeller. Detta examensarbete studerar vad som begränsar byggbranschen att transformera från de traditionella sätten att använda 2D-ritningar till att bli helt modellbaserad i design och konstruktion. Dessutom har relationen mellan arkitekter, entreprenörer och beställare undersökts, eftersom samarbetet med de inblandade parterna är väsentligt för att uppnå en fullständig implementering av BIM i AEC-branschen. För att få en djupare förståelse för relationen mellan de inblandade parterna och förstå varför BIM inte används mer ute på byggarbetsplatsen har informationshantering genom BIM och hur informationen delas och presenteras dem emellan analyserats.

Resultaten av examensarbetet har samlats in genom elva intervjuer med arkitekter, ingenjörer och entreprenörer. Resultaten visade att det vanligaste sättet idag är att använda och leverera en kombination av 2D-ritningar och 3D-modeller. Det verkar som att ta fram 2D-ritningar och 3D-modeller kräver samma typ av information, men trots detta lägger arkitekter ner mycket kraft och tid på att producera båda. Resultaten visar att det finns många bakomliggande faktorer till den begränsade transformationen av att bli modellbaserad. Till exempel oklara krav från alla inblandade parter, bristande kunskap, brist på ramverk och riktlinjer, ovänliga mjukvaror, bristande förtroende för BIM-modellen, bristfälliga kontrakt, frånvaro av öppet format och det faktum att BIM-modellen inte beaktas. som ett juridiskt bindande dokument.

Nyckelord: 2D-ritningar, 3D-modeller, AEC-industri, Arkitekt, BIM-implementering, BIM-information, BIM-modell, Beställare, Entreprenör, Modellbaserad produktion.

Table of Contents

Abstract..III
Sammanfattning..IV
Preface..X
1.Introduction and background..1
1.1 Aim 2
1.2 Research questions 2
1.3 Limitations 2
1.4 Structure of thesis 3
2. Method..3
2.1 Literature review 4
2.2 Empirical approach 4
2.3 Ethical considerations 6
2.4 Validity and reliability 7
3. Theoretical framework..7
3.1 Building Information Modeling 7
3.1.1 IFC 7
3.2 2D drawings vs 3D model 8
3.3 Benefits of BIM 9
3.4 Barriers of using and adapting BIM 9
3.3.1 BIM as legally binding document 9
3.3.2 Lack of knowledge and competence 10
3.3.3 Software 11
3.5 Levels of Development and Detail 11
3.6 Demands and influence of the involved parties 12
3.6.1 Contractor and architects 12
3.6.2 Client 13
3.7 The design process 14
3.7.1 Stages of Design 14
3.7.2 Throughout the stages of design 16
3.8 Contracts 17
3.8.1 AB 04 18
3.8.2 ABT 06 18
3.8.3 ABK 09 19

3.8.4 Partnership 19
3.9 Collaboration, communication and standardization 20
4. Findings...21
4.1 BIM 22
4.1.1 Interpretation of BIM 22
4.1.2 BIM Experience 22
4.1.3 Current use of BIM in the design phase 23
4.1.4 Current use of BIM in the production phase 24
4.2 Benefits and Drawbacks 24
4.2.1 Benefits of using BIM in the design phase 24
4.2.2 Benefits of using BIM in the production phase 25
4.2.3 Drawbacks of using BIM 26
4.3 Information 27
4.3.1 Needed information for producing 3D models 27
4.3.2 Decision makers regarding information 27
4.3.3 Contractor's demands regarding information 28
4.3.4 Sharing the information 29
4.3.4 Presenting the information 29
4.3.5 Necessary and unnecessary drawings 30
4.4 Contracts & Agreements 31
4.4.1 Types of contracts 31
4.4.2 Ways of payment 32
4.4.3 Contracts and relationships 32
4.4.4 Contracts and sharing and presenting information 33
4.4.5 LOD and stages of Design 33
4.5 Future 35
4.5.1 Sharing and presenting information in future 35
4.5.2 Limitations of becoming model based 35
4.5.3 Necessities for change 36
4.5.4 Expectations of the future 37
5. Discussion...37
5.1 BIM 37
5.1.1 Interpretation and current use of BIM 37
5.2 Benefits and drawbacks of using BIM 38
5.2.1 Benefits of using BIM 38
5.2.2 Drawbacks of using BIM 39

5.3 Information 41

5.3.1 Needs and demands regarding information 41

5.3.4 Sharing and presenting information 42

5.3.6 Necessary and unnecessary drawings 43

5.4 Contracts and agreements 44

5.4.1 Contracts effect on collaboration 44

5.4.3 Contracts effect of sharing and presenting information 45

5.4.4 LOD and stages of Design 46

5.5 Future 47

6. Conclusion and suggestions.......... 49

7. References.......... 53

Table of figures

Table 1. Information about the interviewees **5**
Figure 1: Relation of cost and effort with different stages of the design phase **17**

Preface

This master's thesis encompassed 30 higher education credits and was conducted in the spring of 2022 for the master's program "Design and Construction Project Management" at Chalmers University of Technology. The work has been carried out at the Architecture and Civil Engineering Department.

We are grateful to all the people who have participated, supported, and guided us during this research and made it possible to conduct the master thesis.

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Gothenburg, June 2022

Maryam Kiani Hashemiesfahani & Madeleine Skogh

Notations

List of Abbreviations

2D – Two dimensional (length and width)

3D – Three dimensional (length, width and height)

4D – Fourth dimensional (time scheduling)

5D – Fifth dimensional (cost calculation)

AEC – Architecture, Engineering and Construction

AI – Artificial Intelligence

AIA – American Institute of Architects

BIM – Building Information Modelling

BSAB - Byggandets Samordning Aktiebolag

DB – Design-Build

DBB – Design-Bid-Build

IFC – Industry Foundation Classes

IPD – Integrated Project Delivery

LOD – Level of Development, Level of Detail

LODt – Level of Detail

LODv – Level of Development

PDF – Portable Document Format

RFI - Request for Information

English – Swedish Dictionary

As-built document	Relationhandling
Detailed Design & Construction Document	Bygghandlingsskede
Feasibility study & Investigation phase	Förstudie och utredningsskede
General Conditions of Contracts	Allmänna Bestämmelser
Pre-Design	Programskede
Program document	Programhandling
Project Planning Document	Systemhandling
Schematic Design	Systemskede
Traditional contract	Utförandeentreprenad
Turnkey contract	Totalentreprenad

1. Introduction and background

At present, every industry has been influenced by technological advancement, and the construction industry is not an exception. The construction industry is considered one of the largest and most fragmented industries (Lindblad, 2013; Nepal & Staub-French, 2016). In addition to the fragmentation, the construction industry has other disadvantages, such as low productivity and inefficiency, forcing the industry to change and use the technology more (Nepal & Staub-French, 2016). One of the most significant transformations regarding the use of technology in the Architecture, Engineering, and Construction (AEC) industry is Building Information Modeling (BIM), which is the foundation of digital transformation (Autodesk, 2022). The concept of BIM was introduced in the 1970s (Eastman et al., 2018; Sundquist et al., 2020), and its benefits and potential have been studied for several years (Sundquist et al., 2020). The construction industry is a collaborative environment, and cooperation is the key to achieving efficiency and success in a project. Therefore, using BIM, with its many facilities and features, provides good opportunities to create a beneficial collaboration and information exchange between all parties involved during a project (Gu & London, 2010; Azhar et al., 2008). Using BIM can reduce costs and increase efficiency and success (Bosch-Sijtsema, 2018; Azhar et al., 2008; Czmoch & Pekala, 2014).

BIM has not been successfully implemented because of the slow adaptation of the construction industry (Gu & London, 2010; Azhar et al., 2008). Some of the reasons for the slow adaptation may be lack of demands from the client, complexity of use, lack of knowledge of the people, unfriendly tools, and the fact that BIM is not considered a legally binding document (Tallgren, 2018; Bosch-Sijtsema, 2018; Sundquist et al., 2020). The lack of BIM as a legally binding document has been one of the main barriers to the implementation of BIM, which has resulted in a lack of support for BIM in the General Condition of Contracts (Azhar, 2011; Brewer et al., 2015). Therefore, there is currently an overall ambiguity regarding the management of information through BIM models and the issue of ownership of the information between the client, contractor, and designers (Alreshidi et al., 2017).

Most documentation in the construction industry is produced in a traditional way, which means that the information is delivered in the form of 2D drawings (Ramirez & Kreaker, 2019). 2D drawings contain a lot of information that is constantly changing due to changes in the design. Therefore, they must be updated and available to related people, which is a time-consuming and labor-intensive activity. However, the BIM model provides the same information in more facilitated processes such as 3D simulation, time-scheduling, and economic analysis. Despite this, the construction industry still uses 2D drawings as the main source of technical information (Bosch-Sijtsema, 2018). However, paper documentation has started to be challenged by digitalization innovation in recent years. Today, it is common for BIM models to be delivered as a complement to traditional 2D drawings (Sundquist et al., 2020; Disney et al., 2021).

In order to reach a fully model-based design and construction process, the AEC industry needs to change. The problems and barriers behind its slow implementation and their causes need to be investigated to achieve this change. Therefore, it is necessary to examine how the main parties involved in construction projects, i.e., architects, contractors, and clients influence each other and relate to each other. The design process needs to be studied, including their tasks and responsibilities and how the information is shared and presented between them. In addition, the agreements that define the relationship between the named parties and their responsibilities must be analyzed. In all these studies, the relationship and connection of these areas to BIM needs to be investigated to know the limitations of BIM implementation.

1.1 Aim

Previous research shows that BIM has many advantages, but despite this, the construction industry is still mainly using its traditional ways of working. Therefore, the focus of this report is to examine what limits the transition to a fully model-based design phase. Hence, this research aims to investigate the current use of BIM to produce and share information in the design phase and how the relationship between architects, contractors, and clients can support BIM implementation.

1.2 Research questions

To fulfill the purpose of this study, the following research questions were used and taken into consideration:

- RQ 1: What is lacking in the construction industry to transform towards being entirely model based?
- RQ 2: How should the relationship between architects, contractors, and clients be to achieve fully model-based design and construction?
- RQ 3: How should the information be produced, shared, and presented efficiently?

1.3 Limitations

In this study, the group of interviewees consists of architects and contractors with different backgrounds, degrees, and responsibilities. No interviews were conducted with clients, and the information about the client was gathered in the empirical part through the perspectives of architects and contractors. As the study investigates the Swedish AEC industry, its practices are mainly applicable in Sweden. In addition, this study is more focused on the building sector, and the findings do not apply to other industries such as infrastructure, roads, and railroads. Although some interviews were conducted with representatives of contractors, the process discussed with all interviewees was in terms of the design process. Still, it is unavoidable to refer to the construction stage.

One limitation of this study was different interpretations regarding the definition of BIM and LOD among the interviewees. Therefore, while asking questions, there was a range of different answers based on different interpretations, which were all correct but not necessarily for the exact purpose of the questions. Therefore, specific questions required a lengthy explanation, and some replies that the authors were looking for were eventually missing.

Another limitation was the Swedish word phrases that were unfamiliar to some interviewees in English and difficult to translate into English. It was difficult to compare the English and

Swedish phrases, as they refer to specific documents, stages, and conditions that are never referred to in English and are particular to the Swedish AEC industry. The literature study is conducted with worldwide sources, as it is a broader source of information that provides a broader perspective. In contrast, the empirical study is only conducted within the Swedish construction industry. It should be mentioned that this study will not analyze any software, and it will consider the general outcome of the BIM tools and how the data is produced, shared, and read. Furthermore, this thesis does not propose any strategy for implementing the solutions and changes. The study was carried out between February 1st and June 1st, 2022.

1.4 Structure of thesis

The thesis is developed according to the following structure:

- Chapter 2: The methodology, including explaining theoretical and empirical parts, was performed and conducted.
- Chapter 3: The theoretical part includes the information gathered from surveyed articles, books, and other scientific references.
- Chapter 4: The empirical part in which the essential information based on interviews is presented. This chapter consists of the most relevant information regarding the research questions gathered in the interviews to provide data for further discussion.
- Chapter 5: The discussion part compares the conducted literature and the empirical part. This chapter aims to find connections, such as similarities and differences, in order to find answers to the research questions to draw any conclusions.
- Chapter 6: The conclusion part in which the findings are presented in the form of clear answers to the research questions. Moreover, further research related to the topic of this research which is worth investigating is suggested.

2. Method

This section describes how the study was conducted and why the methods were chosen. This research method is based on a literature study and empirical study consisting of interviews conducted parallelly. The reason was to get a broader perspective on the issue and develop a better understanding of the topic (Bell et al., 2019). According to Creswell & Creswell (2017), there are three main approaches to apply in terms of choice of the method depending on the nature of data to reach the aim of the research. They are qualitative, quantitative, and a mixture of the two. In this study, the chosen research method is qualitative with semi-structured interviews. The qualitative approach is a more flexible alternative because the questions can be changed during the process and provide a better understanding of the topic (Magne Holme & Krohn Solvang, 1997; Eliasson, 2006). In contrast, the quantitative approach has a more structured nature in which the questions are not changed during the process (Magne Holme & Krohn Solvang, 1997).

2.1 Literature review

A literature study was conducted by selecting relevant literature and reviewing it to gain a fundamental and deep understanding of the topic and accordingly analyze and compare the collected information with the empirical data (Bell et al., 2019). The related literature consisted mainly of scientific articles, books, handbooks, and masters' thesis found through databases such as Google Scholar, Research Gate, Chalmers Library, and Scopus. To find relevant literature, the following keywords were used: *Advantages and disadvantages of BIM, AEC industry, architects and contractors' relationship, BIM codes and standardizations, BIM and legally binding, BIM guidelines, BIM implementation, BIM information, BIM instructions, collaboration and cooperation in the construction industry, construction contracts, construction documents, contractors' demands, design phase, design process, knowledge transfer between architects and constructors, level of detail, level of development, LOD, model-based production in the construction industry, slow adoption in the construction industry, transition towards 3D models, 2D drawings.*

2.2 Empirical approach

The most common way for gathering qualitative data is having interviews which can be conducted and performed in three different ways; structured, semi-structured, or unstructured. In structured interviews, strict questions are asked in a standardized order, while in an unstructured type, the interview is more like a natural conversation (Jamshed, 2014). A semi-structured interview is somewhere between the two in which predetermined open-ended questions are asked, and the participants can discuss the related issues through a conversation (Longhurst, 2003).

In this study, semi-structured interviews were chosen because it was considered the most appropriate method given the purpose of the study. Another reason for the choice was that semi-structured interviews allow the interviewee to elaborate and talk about the areas that the interviewee considers essential. While maintaining a specific structure in the interviews is to keep the participant within scope, which is a significant advantage that semi-structured interviews provide. The semi-structured interviews allow interviewees to share their perspectives in detail with flexibility. Since the respondents were allowed to add further questions in the interviews, there was a possibility to gather a deep understanding of the topic. Also, the interviewers vehemently tried to avoid feeding the answers to the interviewees.

In this research, eleven semi-structured interviews were performed based on questions focusing on the research questions of this study. The predetermined questions were chosen in an easy form to help the interviewee feel comfortable and open-minded in order to reach a detailed ending (Sociology Harvard, 2018). All interviews were performed online in English through Teams and Zoom between the 4th of march and the 25th of march. The length of the interviews varied from 20 minutes to 100 minutes, with an average length of about 40 minutes. The interview questions were structured according to primary and sub-questions, with all main questions being asked and sub-questions being asked when a more precise picture was needed or when the answer did not emerge from the main questions.

All interviews were recorded and transcribed to pay full attention and listen carefully to the interviewee to avoid misinterpretations, forget important information, be involved in a discussion, and ask follow-up questions. According to Bell et al. (2019), recording and transcribing interviews avoids misunderstandings by providing their exact words as a basis for further comprehensive analysis. The questions were not handed out prematurely to the respondents to create a less prepared answer. Respondents were only given a brief description of the topic to get a natural conversation with as honest answers as possible. Once all the interviews were completed, the information was categorized into different topics to compare the data in detail and finally extract the most important information and present it in the results section.

The selection of respondents has aimed to get a perception from the point of view of both architects and construction companies to get an overall picture of how the use of BIM looks in the ordinary working place. This was to check whether they have different perspectives on how BIM should be used in the current situation and how it should evolve in the future. However, to avoid becoming overly broad, the study focused on those with a strong relationship with BIM and who use it regularly. In addition, the interviewees were of different ages and had different lengths of experience in the industry to get a broader picture of whether this has any impact on how they perceive the situation. The eleven interviewees consisted of architects and engineers with different responsibilities related to BIM, such as managers, supervisors, and model responsible.

Below is a presentation of the eleven interviewees, including their current professional roles, abbreviations of their professional positions used in the text, work experience in the industry, and a brief description of their working tasks. Information about the interviewees is shown below in Table 1.

Table 1. Information about the interviewees

Interviewee	Current Professional Role	Abbreviations	Years of experience in AEC industry
Interviewee 1	Structural engineer & Construction Supervisor	Const. Eng. 1	10
Interviewee 2	Engineer & Model Responsible	Arc. BIM 1	9
Interviewee 3	Project Manager	Const. PM	13
Interviewee 4	BIM Manager	Arc. BIM 2	26
Interviewee 5	Architectural Engineer & BIM Manager	Arc. BIM 3	7
Interviewee 6	Development Engineer & BIM Coordinator	Const. BIM	20
Interviewee 7	Building Engineer & Architect	Arc. BIM 4	8
Interviewee 8	Architect	Arc. BIM 5	18
Interviewee 9	Project Engineer	Const. Eng. 2	8
Interviewee 10	Building Engineer & BIM Manager	Arc. BIM 6	17
Interviewee 11	BIM Department Manager	Eng. BIM	30

- **Interviewee 1** (Structural engineer & Construction Supervisor): *Const. Eng. 1* has worked in the AEC industry for almost ten years in construction companies and architectural and engineering consultancy companies. Const. Eng. 1 has mainly worked with building construction issues such as climate shells like roofs and walls and drawing drawings and models.
- **Interviewee 2** (Engineer & Model Responsible): *Arc. BIM 1* has almost nine years of working experience in the AEC industry. During the last six years, Arc. BIM 1 has

been working in an architectural office where being responsible for the models and the engineering part.

- **Interviewee 3** (Project manager): *Const. PM* has been working in the AEC industry for almost 13 years and, in the last five years, has been working with system documents for the production with the collaboration between architects, constructors, and installations.
- **Interviewee 4** (BIM Manager): *Arc. BIM 2* has been working in the AEC industry for 26 years. In the last six years, Arc. BIM 2 worked as a specialist in BIM management and business development and worked regarding business benefits and incentives when transforming from 2D CAD to 3D/BIM.
- **Interviewee 5** (Architectural Engineer & BIM Manager): *Arc. BIM 3* has worked for seven years in the AEC industry.
- **Interviewee 6** (Development Engineer & BIM Coordinator): *Const. BIM* has almost 20 years of working experience in the AEC industry. In the latest decade Const. BIM has worked with digital tools that are being used in design and production, as well as the implementation of new solutions in project development.
- **Interviewee 7** (Building Engineer & Architect): *Arc. BIM 4* has worked for eight years in the AEC industry.
- **Interviewee 8** (Architect): *Arc. BIM 5* has 18 years of work experience and the last six years Arc. BIM 5 has worked as managing architect.
- **Interviewee 9** (Project Engineer): *Const. Eng. 2* has been in the AEC industry for almost eight years and has worked with the project management group for the last three years. Const. Eng. 2 has been involved throughout the project, like a red thread, from the early stage to the end. Working in the development group regarding production tools and development of BIM has been one of Const. Eng. 2's tasks.
- **Interviewee 10** (Building Engineer & BIM Manager): *Arc. BIM 6* has been working in the AEC industry for almost 17 years.
- **Interviewee 11** (BIM Department Manager): *Eng. BIM* has been working in the AEC industry for almost 30 years. In the last 16 years, Eng. BIM has worked with implementing BIM in projects and developing BIM strategies, routines, and manuals for other companies.

2.3 Ethical considerations

According to Bell et al. (2019), four main factors in research need to be considered regarding ethical issues while conducting empirical studies: harm to participants, lack of informed consent, invasion of privacy, and deception. In addition, the interviewees' rights regarding anonymity, discretion, and confidentiality must be preserved to secure their information which increases the honesty and credibility of their answers (Magne Holme & Krohn Solvang, 1997; Bell et al., 2019). Therefore, in this research, all the interviews were performed with participants' complete willingness, and their identities were kept anonymous not to put them in vulnerable positions. Hence, their names are replaced with abbreviations of their current professional roles, as described in Table 1. Moreover, the recording of the sessions was done with the interviewees' permission, and they had the chance to avoid answering any questions they wished. Before every interview, the respondent was well informed by the purpose of the topic and reason for the research, and the fact that this study was done by authors from the Chalmers University of Technology

2.4 Validity and reliability

To provide transparency in this research, the questions of interviews were the same for everyone, which are provided in the appendix. In addition, the methodological approaches were clearly described to increase the validity of analysis, criticism, and discussion (Bell et al., 2019; Ahrne & Svensson, 2011). Also, most articles used in the literature study were chosen from trustworthy scientific sources that experts have reviewed in the fields to increase the credibility of the literature part (Luleås Tekniska Universitet, 2016).

3. Theoretical framework

This section presents a comprehensive review of the theories and concepts used in the discussion. Based on the literature review, the studies around the definition of Building Information Modeling, following its use and its current situation in the AEC industry, are explained. To study this situation deeper, the comparison between the 2D drawings and 3D models and the consequent influence of using those two on the AEC industry is studied. This comparison opens further topics related to the involved participants in the construction projects, which might influence the use of 2D drawings and 3D models. As a result, the relationship between them, their responsibilities and influences, and the aspect that affect their collaborations are studied.

3.1 Building Information Modeling

The concept of Building Information Modeling, BIM, has no universal definition, and different individuals, organizations, and institutions describe it differently. A common description of BIM is that it is an information management method that consists of various activities in object-oriented three-dimensional models to collect information about the products and processes (Jongeling, 2008; Borrmann et al., 2015). BIM is a platform in which the information is communicated through constant collaboration among participants in the project (Ashcraft, 2008). Moreover, BIM is not just the digital 3D model which one can orbit around, but it is a working environment in which the information of the building is modeled, and the design and construction process of the building is shared through an interactive approach between designers, contractors and other participants (Doan et al., 2019). A BIM model is used to gather and organize all information during the process of a construction project and can be seen as a virtual model of reality. In today's Architecture, Engineering, and Construction (AEC) industry, a key function of BIM models, aside from sharing information across relevant actors, is optimizing construction procedures and making them more efficient (Jongeling, 2008).

3.1.1 IFC

In the BIM environment, the data is accumulated in a 3D model in which every individual can use them in a file-based approach according to their needs. These data are stored in a shared location, and depending on how the data are collected and shared, this environment can be named Open BIM or Closed BIM (Bucher & Hall, 2020). The project's information is gathered in a separate repository in the Closed BIM and is processed within a specific BIM-software platform. The use of Closed BIM lets every participant in various disciplines access the data in a particular way. The environment in Closed BIM is limited to the format of software and phase of the project (Bucher & Hall, 2020; Köhler, 2019). In other words, there is a need to exchange data between participants while moving to different stages of a project which can hinder the collaboration between actors. Therefore, due to the need for full integration of data among other disciplines, Open BIM appears by which the exchange of information occurs continuously through every stage of the project (Bucher & Hall, 2020). Open BIM is an "interoperable open standard exchange" which is practicable through an open standard exchange format called "Industry Foundation Classes" (IFC), by which every information can be shared. In other words, Open BIM works with "neutral, non-proprietary file formats," which can be used among various disciplines regardless of the type of BIM software (Juan & Zheng, 2014; Köhler, 2019).

3.2 2D drawings vs 3D model

In BIM, the information is in one place and compared with the traditional style in which the 2D drawings are the only source of information it is easier to access the information. In other words, both BIM models and 2D traditional drawings contain similar information, according to Jongeling (2008), but the way of accessibility and reading them is entirely different. Using BIM and 2D drawings individually have its pros and cons. People find it easier to use 2D drawings since they are used to it and know where to find the information. But on the contrary, the information gets outdated quickly, and information can get lost during the project (Luo & Xu, 2014). Moreover, it is challenging to understand drawings when there is a lot of information accumulated in one drawing, which causes faults that result in changes and reworks.

According to Van Berlo & Natrop (2014), some projects were performed in which the 3D model was the only source of information, but the number of these projects is relatively low. One example of a project almost exclusively based on 3D models is the Celsius project. Celsius is a 10,000-square-meter building with offices and labs in Uppsala Science Park (Vasakronan, 2021). The Celsius project is the most mentioned in Sweden, and in 2020 the project was appointed the world's top BIM project at the "buildingSMART Virtual Summit" (White Arkitekter Sverige, 2020). To a large extent, the BIM model has been the only source of information for the construction of the Celsius project in terms of planning, design, and execution. The initial idea was that the project would only be based on 3D models and be completely drawing-free. Still, in the end, a few drawings (electrical and plumbing) were produced as supporting documents to the BIM model in the form of Portable Document Format (PDF) files (Byggstyrning, 2020). According to Disney et al. (2021), the details are difficult to describe in the 3D model, and therefore combining 2D-PDF with the 3D model could be beneficial. The Celsius project was successful due to its ability to carry out a project under the budget and planned schedule. This construction project demonstrates significant evidence that today it is possible to execute large construction projects based on 3D models and minimize the use of 2D drawings. The Celsius project can be seen as a role model for future projects in the construction industry and the first step toward an entire model-based industry. However, according to Lindström (2013), it is not possible to exclude the 2D drawings from the project because the knowledge of the project might get lost. Hence, there is a need for a new method of using technology, BIM, and traditional style, 2D drawings, to be combined with reading and using the information with the most benefits.

3.3 Benefits of BIM

When using BIM, various tools are utilized resulting from technological advancements in Computer-Aided Design (CAD) (Ramirez & Kreaker, 2019). BIM is beneficial for an efficient and collaborative process in the project. In the BIM environment, all the information is accessible through interdisciplinary collaboration. Each discipline uses different software, but the information is combined in a single model accessible to all disciplines (Ramirez & Kreaker, 2019; Czmoch & Pękala, 2014).

Through BIM, the information is updated and shared between different participants contributing to a more efficient work process regarding time and effort (Alassadi & Khallouf, 2020). BIM is based on 3D models which support the design in a multidimensional way. 3D models give opportunities to be used for visualization and detailing. Moreover, a 3D environment is used for navigating the model instead of looking into several drawings. Clash detection and information take-off are the common use of 3D model in BIM (Czmoch & Pękala, 2014; Sebastian, 2011; Merschbrock & Nordahl-Rolfsen, 2016). Further dimensions that the BIM model can support are the analysis called 4D and 5D simulations. 4D and 5D are indicated for scheduling, and economic analysis is time estimation and cost calculation, respectively (Jongeling, 2008; Sebastian, 2011). According to Azhar (2011), in BIM, the costs could be estimated more accurately and in less time. The new dimensions enhance the presentation of the project's development and improve communication between the participants. This possibility facilitates testing and analysis of the design and could help the project avoid errors and further modifications. Therefore, it enhances the construction project's quality, accuracy, and efficiency (Lee et al., 2020; Sebastian, 2011; Crotty, 2013). As a result, stakeholders can understand the project better through facilitated visualization and communication, specifically in complex projects (Jensen, 2012).

3.4 Barriers of using and adapting BIM

Despite several benefits of BIM, some obstacles hinder the AEC industry from implementing BIM in a better way. In the past few years, this industry has been moving from 2D drawings to 3D models, and currently, there is a mixture of the two. However, 2D drawings are still considered the most valid construction document (Alassadi & Khallouf, 2020; Sundquist et al., 2020; Jongeling, 2008). In construction projects, the BIM model is mainly developed and used in the design phase of the project, and it is not often implemented in the construction stage (Olsson and Arvidsson, 2012).

3.3.1 BIM as legally binding document

Today, due to the unclear legal status of BIM in Sweden, 3D models are not considered legal documents, and only 2D drawings can be used as legally binding documents. Therefore, BIM models are often used to complement traditional 2D drawings (Disney et al., 2021).

According to Azhar (2011), legal or technical issues are the most common barriers to implementing BIM. Disney et al. (2021) and Bosch-Sijtsema (2018) argue that BIM is currently far from becoming a standard. Partly because today in Sweden, it is not obligatory to deliver BIM documents as legally binding documents. The regulations, rules, and contracts only require 2D drawings as legal documents preventing BIM implementation in the AEC industry. This can be considered an issue in the construction industry since an essential prerequisite for successfully implementing BIM projects is precisely the legally binding agreement. The agreement could be on, for example, model quality and content when handing over the BIM model to the owner (Borrmann et al., 2018). Although Celsius is a project in Sweden in which BIM documents were used as the only information carrier from early design to construction, BIM was used as the legally binding construction document at the site (Disney et al., 2022). Since paper drawings were not produced during the project, all subcontractors were forced to use digital tools to carry out their work. For the success of the Celsius project, it was essential that BIM was developed in detail and that the subcontractors were provided with the proper support and knowledge of how to use BIM.

3.3.2 Lack of knowledge and competence

According to Eastman et al. (2011) and Czmoch & Pękala (2014), because of the complexity of using BIM, the knowledge and skill of the team can play an important role. As Leśniak et al. (2021) believe, one of the barriers to implementing BIM is related to the habits of people. In other words, today's people working in the AEC industry for years in a traditional way are reluctant to learn BIM. These people might be employed at some levels of organization that would not be aware of the benefits of BIM. They could have relatively limited knowledge of it and are afraid to learn and use BIM. Therefore, there is a lack of willingness to gain new competence in using BIM. Russell et al. (2014) also believe people's lack of skill and poor information management would result in resistance to change. As Eastman et al. (2011) and Czmoch & Pękala (2014) state, in case of lacking experts and skillful workers, the working hours would increase, and the model would not function fully.

Jongeling (2008) and Eastman et al. (2011) believe that the user interface of BIM software is not user-friendly. Often professionals with better knowledge and skill can work with them more efficiently. This fact limits the number of users in the project, and it can be challenging to ensure that all the project's participants have the competence and willingness to use BIM, which affects the quality of both design and model (Eastman et al., 2011). Furthermore, in the study of Norberg & Brantitsa (2018), there is a lack of information regarding parts and components in the BIM model, and it is often difficult to find trustworthy and accurate information by which the designers can develop detailed drawings. Also, interoperability of information is an essential factor that Sundquist et al. (2020) and Norberg & Brantitsa (2018) believe is an issue in software and standardization level.

There are a number of disciplines and participants involved in the construction projects which probably lack BIM knowledge. They have resistance to moving toward BIM and escape from learning and using BIM (Zakaria et al. 2014). However, according to Alassadi & Khallouf (2020), there is a willingness to use BIM, but it is low. The reason is the constant updating of related software or the fact that new versions or types of software are introduced frequently. Therefore, if they choose to learn one program, it is soon outdated, and constant upgrade of their knowledge is required, and they are not interested in this at all. Moreover, the lack of information is not limited to the project team, and the client's lack of information could also be problematic. For instance, limited knowledge about BIM capacities and lack of understanding about project scale could mislead the client, and the requirements they place would not be compatible with the use of BIM (Arvidsson et al., 2014).

3.3.3 Software

According to Lindbland (2013), the use of BIM software is not only complex but also is not successfully fulfilling the user's needs. Previous research shows that BIM is perceived as complicated and not user-friendly among involved actors when related to tasks, such as performing measurements, quantity calculations, planning, or finding information regarding materials (Norberg & Brantitsa, 2018). Sundquist et al. (2020) mention that one reason for being unfriendly is that there is still a lack of suitable filtering information for BIM objects. According to Sundquist et al. (2020), BIM needs to be adapted to the specific needs of an organization and the people involved since the advanced technology itself will not be able to solve the barriers associated with a BIM implementation. This adaptation depends mainly on the purpose of the use of this technology. The advantage of BIM use compared to 2D drawings is in coordination and increase of understanding between the different involved disciplines. However, one of the solutions for adapting BIM is the Property Set or information mapping, which is a feature performed in IFC models (Jeon & Lee, 2019). The property set is provided as a template in the IFC model, which contains different values that need to be determined. According to Autodesk (n.d.), property sets are developed in BIM software to determine and access properties customized for a specific object. Property sets help define and filter particular characteristics of a category of properties related to a specific object. These properties could be a layer, color, line type, etc. According to Jeon & Lee (2019), there is no standardized method to define Property sets in BIM tools, and defining them is done with different approaches depending on organizational preferences.

3.5 Levels of Development and Detail

LOD is associated both with *Level of Development* and *Level of Detail*. Level of Development (LODv) is a classification system usually used as a framework introduced to BIM. This framework allows the participants in different disciplines in the AEC industry to specify and articulate the 3D model very clearly. LODv ranges from 100 to 500 and helps to understand the model's progress from conceptual idea to detailed description (Germano, 2022).

On the other hand, implementing BIM in a construction project can be done at different levels depending on how accurate and comprehensive the information imported into the model is. Level of Detail (LODt) represents the number of details of information provided in the 3D model element. Latiffi et al. (2015) describe that LODt is a degree by which the geometrical information of model elements is described. Furthermore, LODt is created and used to identify specific content requirements for different elements and minimize the problem of insufficient information in a project.

According to Latiffi et al. (2015), both LODv and LODt help the team to rely on the model and its information because it is easy to misinterpret the elements of the model, and it would lead to not being sure about the accuracy of information. Therefore, by LODv and LODt, everyone would be sure about the precision of information they need to take from the model. In this study, the focus is on the Level of Development, and from now on, this will be called LOD. The Level of Development contains six levels that represent different specific content requirements. LODs are described and defined below (Beetz et al., 2018):

- **LOD 100:** "The model element is represented graphically by a symbol or a generic representation. Information specific to the element such as costs per square meter can be derived from other model elements."
- **LOD 200:** "The model element is represented graphically in the model by a generic element with approximate dimensions, position, and orientation."
- **LOD 300:** "The model element is represented graphically by a specific object that defines its size, dimension, form, position, and orientation."
- **LOD 350:** "The model element is represented graphically by a specific object that defines its size, dimension, form, position, and orientation as well as its interfaces to other building systems."
- **LOD 400:** "The model element is represented graphically by a specific object that defines its size, dimension, form, position, and orientation along with information regarding its production, assembly, and installation."
- **LOD 500:** "The model element has been validated on the construction site including its size, dimension, form, position, and orientation."

3.6 Demands and influence of the involved parties

3.6.1 Contractor and architects

According to Monteiro & Diezel (2018), in Sweden, the role of architects in the AEC industry was weak, and the contractors had more acceptance during the stages of the design and construction of the project. Some of the reasons were low degree of power, leadership, and certainty in the project stages. Also, architects and engineers play the consultant role more than leading and managing positions. However, the gap between the architects and constructors was filled by adding the engineering studies of "building" to the curriculum of the architectural branch as a separate field. Finally, with emerging BIM in the AEC industry and the appearance of new roles such as BIM coordinator, the interaction between architects and constructors increased, and architects could take more prominent roles in the AEC industry. By changing the tractional way of construction by BIM, the traditional role of architects, mainly covering the aesthetical aspects of design, will change as well.

Eastman et al. (2011) explain that in working with 2D drawings and 3D models, coordination and estimations are based on the same information, regardless of whether the architect is working with 2D or 3D-CAD systems in the design process. However, according to Lindström (2013) by using 2D drawings, the contractor needs to perform quantity takeoffs by hand to make a correct schedule and estimation for the project, which is usually very expensive, slow, and error-prone process. Quantity takeoff is one of the important tasks that the contractor does to know the exact amount of material that is going to be used. This task helps with the cost estimations and affects the calculation of both material and workloads.

Today, contractors are beginning to see the value of BIM and how it can create more effective collaboration between construction management and project teams. Nowadays, BIM has been used to help the task of quantity takeoff to make it easier to extract the information faster and more accurately. Since the accuracy of information such as area and volume are high in BIM, the cost estimation would be with minor error (Monteiro & Poças Martins, 2013).

Furthermore, Eastman et al. (2011) highlight the importance of the contractor's need to be involved early in the design process. The use of BIM technology in the design process increases the opportunity for the architect to deliver models at an early stage in the procurement process. With this, contractors can use the models created by architects and make better planning and estimates. According to Eastman et al. (2011), a building model such as BIM must be delivered with sufficient detailed information to provide the contractor with a BIM model that is useful for them and facilitates their work. Eastman et al. (2011) therefore emphasize the minimum requirements for the type of information that should be included in a building model, which is described below:

- ***Detailed building information*** where it is possible to see a graphic view and extract specific detailed information from all the different components with various building characteristics.
- ***Temporary components*** that are essential to a project's planning, logistics, and equipment.
- ***Specification information*** is needed by the contractor for the execution of procurement, operation, and installation. The information needs to include details of all specific building components with textual reference to each component purchased or built within the project.
- ***Analysis data*** contain information on procurement, detailing of construction, fixed installations, and manufacturing, linked to project requirements and performance levels. This may include data on, for example, heating and cooling requirements, structural loads, or connection reactions.
- ***Design and construction status*** of all components related to procurement, design, and installation to validate and evaluate the progress of the components during the project.

3.6.2 Client

According to Adam & Lindahl (2017) and Dakhil et al. (2019), the client has the all-embracing power to control and manage the projects in the AEC industry due to their position of procuring. Regarding the use of BIM in the construction project, there might be a need for a change to increase the use of BIM, and in that regard, initiatives would play an important role. However, these initiatives are not easily achieved in the AEC industry (Bresnen et al., 2005), and the clients are not primarily positive about implementing changes (Ivory, 2005). The result is that the client’s lack of support could become a barrier to the change. A lack of clients’ demand for using BIM is a common barrier in the AEC industry (Chan 2014 & Hartmann et al., 2008). Dakhil et al. (2019) believe that the client should be knowledgeable and experienced and understand their role in BIM implementation to request the correct information. Moreover, a supportive client needs to have enough competencies in BIM. As Newcombe (2003) and Sexton et al. (2008) discuss, professional clients who carry out many projects could have better capabilities in implementing innovative changes than occasional clients. Having a higher level of technical experience and competence helps them understand the requirements better and develop innovative solutions (Hartmann et al., 2008).

On the other hand, Bosch-Sijtsema et al. (2017) insist that the individual's attitude regarding BIM plays a more significant role than the client and internal perception of BIM is stronger than external pressure from the client. As Mäki and Kerosuo (2015) agree, implementing BIM depends highly on project managers, and their willingness to use it is very influential on the project's direction.

3.7 The design process

In the construction project process, the design phase could be considered one of the most significant phases since its early stage has a decisive impact on the outcome of a project. The design phase consists of several activities, such as the planning and modelling of a project, as well as the calculation of costs and resources (Maylor, 2003). The first step in the design phase consists of an assigned design team that has the task of collecting the customer's thoughts and ideas, which later develop into documents in the form of drawings, models, and specifications (Freire & Alarcón, 2002).

The construction process in the Swedish construction industry usually consists of the same steps, regardless of whether it concerns infrastructure projects or building projects (Berner et al., 2016). From a house building perspective, the design process is a part of the construction process (Roos, 2021). The design process is an essential process in which many decisions are made and form the basis for designing technical solutions, drawings, and models. The design process consists of different stages which have various features. Meanwhile, according to Eastman et al. (2011), BIM has different impacts on the procedure of the project, and by enhancing the correlation among the works and disciplines in the project, it could come to help architects, engineers, and contractors in the development and improve the quality and reduce the errors.

3.7.1 Stages of Design

Feasibility study and investigation phase

The first step in the design process is usually the feasibility study or the investigation phase. During this phase, the scope of a project is investigated, the objectives are defined, and wishes and requirements are analyzed and identified (Roos, 2021). According to Eastman et al. (2011), in this step, the initial estimation of the project takes place, namely, non-spatial quantitative specification of the project, cash flow details, function and income generation, related areas, and needed equipment, initial costs estimation are evaluated. This should result in creating a preliminary plan and an overall description. In addition, issues related to costs and time aspects can be discussed (Boverket, 2019b). This step might overlap with the next stage, which is the pre-design phase, and get repeated during the production stage and economic planning (Eastman et al., 2011)

Pre-Design

Pre-Design, also referred to as Conceptual Design, is an early stage in the design process that starts with gathering fundamental information from the client. In this phase, descriptions called *programhandling* are prepared called Program documents in English. This document summarizes the conditions for a project and is used as a basis for the future decisions taken in the design (Berner et al., 2016). The Program documents for a project should include decisions on technical standards, building size, as well as design. According to BCA (2013), the contractor reflects on the constructability of the building and estimates the initial cost. Therefore, the architect ought to deliver the design model with massing concepts with site considerations that contain representative data such as dimensions, area, volume, location, and orientation.

In the pre-design phase, the main parties involved are the client and the architects, but the contractor is also selected at this stage by the client and is partly involved in the process (De Cos Castillo, 1997). According to Deli (2017), the client must decide the contract form during the pre-design phase, whether it is a traditional or a turnkey contract. According to Ramirez & Kreaker (2019), the use of BIM at this stage can be seen as a visualization tool that primarily facilitates communication between the client, architect, and contractor. The classification system of this phase is usually LOD 100 (Mohanta & Das, 2016).

Schematic Design

The next stage is the Schematic Design, called *Systemskede* in Swedish, in which the concept of the project is designed to give an overall picture of the design of the planned building (Berner et al., 2016 and Haines, 2012). For this purpose, both architects and engineers collaborate to carry out time and budget estimation and scope definition. To meet the requirements of a project, the materials and technical systems that provide the best solutions are investigated in the system phase (Berner et al., 2016). Furthermore, Eastman et al. (2011) add that the primary design specifications such as plans, building's shape, alternative materials, and system types are determined in this stage that their LOD is 200 (Mohanta & Das, 2016). According to BCA (2013), the primary design, which is based on the redefined model from the previous stage, may not have any geometric properties, but it has the generalized building component with approximate dimensions, shape, location, orientation, and quantity. The system documents should clearly summarize the technical choices and technical systems, identifying the advantages and disadvantages to avoid complications later in the design of the construction documents (Roos, 2021).

If these outcomes contain more detailed information, a more precise scope would be defined, and the need for future changes would be decreased. Therefore, the budget would be saved by avoiding later costly changes in further stages (Broberg, 2018; De Cos Castillo, 1997). The advantage of using BIM is the 4th and 5th dimensions (4D and 5D), time schedule, and cost estimation (Jongeling, 2008 & Sebastian, 2011). By using BIM, the accuracy of these two important activities would be increased.

Detailed Design & Construction Document

According to Eastman et al. (2011), the next stage consists of two steps, Detailed Design and Construction Document, but according to Berner et al. (2016), this stage is a unique step called *Bygghandlingsske*d. During this phase, the architect and engineer work extensively and are in direct contact to refine and enhance the project's details and inform the changes (Haines, 2012). In this stage, production begins in which the construction documents are created, later forming the basis for procurement and production (Roos, 2021). At this stage, details are developed in all areas of the construction project, including everything from different types of materials for walls and floors to security systems, electricity, foundations, and floor plans (Eastman et al., 2011). According to BCA (2013), non-geometric properties should be provided. The detailed design and construction models are created with exact dimensions in which the components, shape, location, and quantities are with high accuracy, with LOD between 300 and 400 (Mohanta & Das, 2016).

At this stage, all relevant information and requirements regarding the project must be clearly stated and described, including everything regarding design requirements, accessibility, and layout (Projektledning, 2018). Clash Detection is a task performed in BIM, and by that, the collision of components of a modeled building is controlled (Blom et al., 2013). When the interference of parts is identified, several parties could be involved, and interdisciplinary communication would be required (Motiejunas, 2016). Refining the design and construction models continues until the design model is finalized and the final cost estimation and construction scheduling are provided (BCA, 2013).

In both the Detailed Design and the Construction Document stages, the collaboration between the design team and contractors is crucial. Since BIM is a vital tool in providing cooperation between actors, productive communication would happen, the information could be shared better, the quality of the production based on design would increase, and the conflicts would be subsided (Eastman et al., 2011).

3.7.2 Throughout the stages of design

Figure 1 by Eastman et al. (2011) shows the relation between effort/effect and stages of the project and the designers' ability to make changes during the project's lifetime. In the earliest stages of the project, since the design is conceptual and without details, changing the design is easier. It takes less time and effort, and this is how a great deal of budget would be saved by making accurate decisions at the beginning of the project. However, according to Muñoz-La Rivera et al. (2019), the budget is estimated at the beginning of the project in the construction industry. There is a limited amount of information available at this stage, and it is troublesome for the project in terms of further changes. The most significant effort is made in the Construction Documentation step in the traditional design process. By using BIM as a preferred design process, this effort would be shifted to somewhere between Schematic Design and Detailed Design. The advantage of using BIM in this regard is that the maximum effort is needed when there is more ability to impact cost and functional capabilities and the cost of design changes is still low. In contrast, in the traditional design process, the maximum effort is when the cost of design changes surges and the ability to influence expenses decreases.

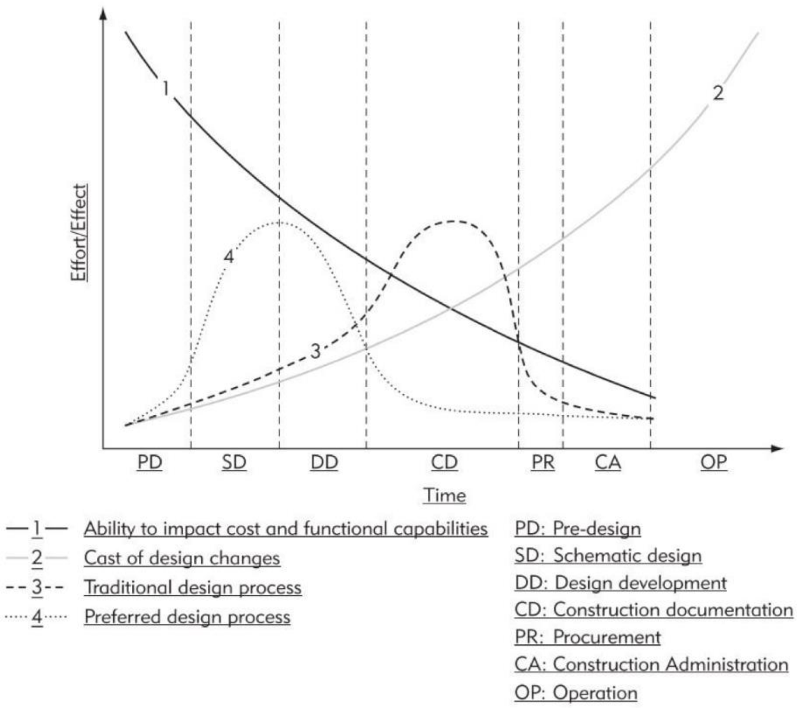

Figure 1: Relation of cost and effort with different stages of the design phase (Estman et al., 2011)

3.8 Contracts

To legalize the relationship between the parties involved in a building project, an agreement needs to be conducted in which different terms and conditions among them are described. Depending on their type and form, these agreements could influence the relationship between architects and contractors and decide who is responsible for what. The agreement can be conducted in different types. The most common contract forms are Design-Build-Build-Bid (DBB), Design-Build (DB), and Partnership. Through every format of contract, the party responsible for the early design process is the architect, and this process is carried out in the same way, regardless of the type of contract, according to Ramirez & Kreaker (2019) and Bragança et al. (2014), but the involvement of parties depends on the type of contract.

As the use of BIM has been increasing in the AEC industry, the stakeholder's awareness regarding the risks and their responsibilities has been triggered. As a result, the need for having an overwhelming contract in which the shared risk and rewards are mentioned to minimize the legal risks (Azhar, Khalfan & Maqsood, 2012). The standard contracts have several benefits for the parties involved, but regarding adopting BIM, there are still some barriers in those contracts which need to be solved (Alwash, Love & Olatunji, 2017). According to Brewer et al. (2015), many documents, conditions, and specifications belong to the current contracts, but none of them support BIM. However, they can be easily replaced by the information extracted from the BIM model.

Regarding various contractual documents in the AEC industry, General Conditions of Contracts (Allmänna Bestämmelser in Swedish) is one of the most common (Deli, 2017). The General Conditions of Contracts encompass various standard contracts published in several editions. Three frequently used contract types are AB04, ABT06 and ABK09. These three types of contracts balance obligations and rights and are designed to provide a financially optimal distribution of risk between the parties involved (Byggandets kontraktskommitté, 2007).

3.8.1 AB 04

"*General Conditions of Contract for Building and Civil Engineering Works and Building Services*" (Byggandets kontraktskommitté, 2004). According to Willborg (2020), AB04 is used for Design-Bid-Build contracts. This form of agreement is applied to the procurement of building and civil engineering works and building services, in other words, a traditional contract (utförandeentreprenad in Swedish). The agreement is first between the client and architect for developing the design process, and then it is between the client and the contractor to construct the building. The client and architect are involved from conceptual design until tender documentation. Then after a bidding process, the contract between client and contractor is conducted (Eastman et al., 2011). In a traditional contract, the employer is responsible for completing the design. This includes, among other things, handling the construction documents, for example, delivering the correct drawings and description of the technical execution in detail. At the same time, the contractor is responsible for the execution of the whole project, according to the details presented in the construction documents. The client is also responsible for ensuring that the product meets the design, function, and quality requirements. According to Hooper & Widén (2015), this type of contract is the traditional contract in Sweden and has been used for almost ten years. However, BIM, which requires a high level of collaboration, is not supported by this contract if the client does not put the requirement of BIM.

Using this type of contract can cause some limitations for using BIM (Su-Ling et al., 2018). For example, the responsibility of the stakeholders is clearly defined, and therefore their motivation to be active further than their defined role and collaborate with other disciplines could be less. Another limitation could be that since contractors' participation starts after the termination of the design process, the collaboration that is expected to be provided by BIM will be restricted. As Ramirez & Kreaker (2019) state, the efforts between the design and construction phases would be doubled.

3.8.2 ABT 06

"*General Conditions of Contract for Design and Construct Contracts for Building, Civil Engineering and installation works*" (Byggandets kontraktskommitté, 2007). According to Boverket (2022), ABT06 is used for Design-Build contracts. ABT 06 is referred to turnkey contract (Totalentreprenad in Swedish), which is applied to the procurement of building and civil engineering works and building services. In this contract, the employer describes the intended functions and characteristics, but the contractor has total responsibility for both the design and execution towards the employer (Beard et al., 2001; Ramirez & Kreaker, 2019). Furthermore, the contractor is responsible for ensuring that the project is carried out correctly and fulfills the specific functions that have been agreed upon. In this type of contract, the architect and contractor are in one team, and they have a more suitable type of relationship, which is opposite to the DBB type (Johansson & Johansson, 2016). According to Hooper & Widén (2015), this contract is suitable for partnering agreements and is very good for starting construction when the design is not finished yet. As Hooper & Widén (2015) add, this type of contract supports the collaboration between different parties, but due to the lack of standards of BIM in Sweden, the use of BIM faces barriers. As Eastman et al. (2011) indicate, the DB contract was a solution to combine design and construction responsibilities and give it to one single party. Hence, DB or ABT06 contracts would be useful in putting BIM's collaborative potential into practice. The errors and changes in the design and the construction would be widely avoided, the design and construction phase would be overlapped, and the time delivery would be reduced. In addition, the project delivery costs would be reduced due to the constructability of the design (Beard et al., 2001; Ramirez & Kreaker, 2019).

It should be mentioned that in a traditional contract (AB04), the construction documents are produced by the client. In contrast, in a turnkey contract (ABT06), the construction documents are produced by the contractor (Berner et al., 2016).

3.8.3 ABK 09

"*General Conditions of Contract of contract for Consulting Agreements for Architectural and Engineering Assignments*" (Byggandets kontraktskommitté, 2010). In all technology fields, it is possible to use ABK 09, from the earliest stages of the conceptual design to the final detailed design. Furthermore, the General Conditions of Contract are applicable to other consultancy assignments such as surveys, investigations, construction management, and project management (Byggandets kontraktskommitté, 2010). One of the intentions of ABK 09 is that it should provide conditions for higher quality in the assignment result. The consultant and the client must have a similar view of the assignment's scope, purpose, and quality level to achieve this. According to Hooper & Widén (2015), the latest version of this contract has not been developed to support BIM and meet its requirements because it does not only support 2D drawings but also does not support a strategy for collaboration. For instance, in the ABK09 contract, the owner and responsible participant of the digital information is unclear.

3.8.4 Partnership

Another type of contract is the Partnership, in which all the parties are widely collaborating, and their relationship is based on trust and mutual understanding (Hardin & McCool, 2015; Hartmann & Bresnen, 2011). This type of contract in Sweden is called Partnership, while in the US, it is named as Integrated Project Delivery or IPD, which is proposed by the American Institute of Architects (AIA) (Johansson & Johansson, 2016). The goal of offering this contract was to minimize the negative relationship between stakeholders in other contracts (Marco and Karzouna, 2018). In this type of contract, the risks, costs, and benefits are shared among all the parties by setting a shared goal to guarantee collaboration among all the involved actors. As Eastman et al. (2011) state, the IPD contract is the most suitable for BIM projects which stretch from the beginning to the handing over. In addition, in IPD, the contractors infer the design sooner, and the architects also focus on the construction and not only on the design. Regarding the use of BIM, the high level of collaboration in this type of contract is aligned with the collaboration provided by BIM through the design and construction process.

3.9 Collaboration, communication and standardization

Transferring knowledge among projects is highly related to collaboration and communication. According to Josefsson & Lindhe (2020), if the “same parameters and language” are used in the construction industry to transfer knowledge, communication between different disciplines would be eased. In other words, using standards in the model and its parameters classifications would lessen the need for beforehand preparations, and the information would be communicated between disciplines better.

As an attempt to facilitate the collaboration and communication and make the AEC industry speak the same language, a system called, “Byggandets Samordning Aktiebolag” (BSAB) was launched by Svensk byggtjänst, 1979 (Svensk byggtjänst, n.d). BSAB is a system that represents a common structure for handling information, consisting of codes for the different components of a project (Josefsson & Lindhe, 2020). The BSAB system has evolved into a classification system called CoClass, which was established to adapt more quickly to the industry's digitization developments (Eckerberg, 2017). Furthermore, Eckerberg (2017) explains that using standards when classifying a model minimizes the administrative workload and improves information sharing during the design phase.

As standardization and having the same language helps people communicate easier and better, the communication methods and the amount of that play essential roles in having effective collaboration, specifically for avoiding conflicts (Luo & Xu, 2014). BIM can help minimize the number of conflicts since communication is more accessible since all parties involved can work in the same BIM model and see what changes are taking place during the project (Alassadi & Khallouf, 2020). According to Wileman (1993), visual communications have the potential to provide clarity and understanding and work better than audio, email, etc. Also, the level of information transferred among people in a project is of great importance, and poor communication could result in problems regarding schedule and cost (Blomberg, 2019).

There have been some efforts to develop guidelines, strategies, and requirements for using BIM. For instance, the association of BIM Alliance (2020) in Sweden specified the requirements for creating and handling the information in the BIM projects and set development strategies. Finally, guidelines as a tool for developing the work process are developed by this association to facilitate the exchange of information and increase the quality of using BIM (BIM Alliance, 2020).

One of the latest efforts to standardize BIM usage is the BEAst BIM. BEAst or ”Byggbranschens Elektroniska Affärsstandard” means Electronic Business Standard for the Construction Industry is an “agreed industry-driven information standard” that facilitates reading the information for increasing the efficiency of communication of information. This system of standards focuses on how the information is reported. BEAst provides standards for many parts of the construction industry, and BIM is one of them. BEAst BIM helps structure information management by providing instructions, guides, and templates in BIM applicable in the whole industry. According to BEAst BIM, there are three requirements for modeling, aiming decision-makers, the client’s project manager, and the designer to give them a common goal of modeling. The instructions can be used in other projects such as Level of Detail (LOD) of the delivery, relevant software, etc. (BEAst BIM, n.d.). As Blomberg (2019) states, the classification of LOD in the 3D models helps the responsible managers expect specific information details at different levels of design. Through that, the reliability of the model is increased. Otherwise, the expected information details would be missing without LOD, and trust in the BIM model would not exist. Regarding the BEAst BIM's instructions for designers, the usefulness of digitalization is in direct relation to model-based information and how it is structured and standardized in the early stage. The model's requirements contain the following content: prerequisites, model structure, object information, delivery, and components. Also, by BEAst BIM, the project managers would ensure the level of consultants' knowledge delivery, plus the compatible software for the team. According to BEAst BIM, the software must be able to export IFC format (BEAst BIM, n.d.).

Granroth (2011) explains that designing traditionally in the design phase can lead to unnecessary conflicts due to the many different actors involved in the communication and information exchange process. However, Granroth (2011) believes that BIM can be a solution to avoid this issue. Jongeling (2008) also argues that BIM contributes to improved communication between different disciplines and actors involved in a project, such as people working on planning, calculation, etc. Jongeling (2008) believes that this is partly because all the information in the project is available in a BIM model, allowing everyone to see the whole project. Therefore, the use of BIM in the project can reduce the number of requests for information (RFI). For instance, requesting information and producing drawings are part of common communications in construction projects. Through BIM, there is the possibility that the drawings are produced without the necessity of a request from an architect to do so (Chelson, 2010). Therefore, the drawings would be accessible just in time by extracting directly from models, and the communication between disciplines and managers would allocate their time and effort to other stuff rather than providing drawings and information. Although reaching a fluent flow of this method demands time and effort at the planning and management level (Van Berlo & Natrop, 2014; Malmkvist, 2013).

While the BIM is very effective in providing collaboration between participants in the project, concerns about generated data also arise. According to Alreshidi et al. (2017), copyright, the ownership of the data, and Intellectual Property Rights (IPR) are the issues that are related to the legal and policy aspects of the BIM model. In a way, their weakness can result in loss or low liability for data. Fan (2014) states that the issue of ownership can be when the owners of the data want to use the information in the following projects, while the IPR of the model or data belongs to its creator. This issue can result in violations of the law. Therefore, the intellectual right of the data ought to be clearly defined in the early stage of the project's development which is handled by BIM (Chon et al., 2017). These issues are not only the matter of who is the owner of the data, but also it is of who is responsible for the information and its reliability. Because if there is no clarification of the responsibilities of the data and a problem arises due to the misuse of information or any other error in the building, then claiming can be very difficult (Jiang et al., 2015).

4. Findings

In this chapter, the results of the eleven interviews are presented, which were divided into six categories of themes. The structure of this chapter is divided into five themes with subheadings. The themes are as follows: BIM, benefits and drawbacks, information, contracts and agreements, and future. The information below is presented using the abbreviations described in Table 1 in the methodology section.

4.1 BIM

4.1.1 Interpretation of BIM

Based on the eleven interviews conducted, there is no single unique definition of BIM. Instead, it varies from person to person. However, according to almost all the interviewees, BIM is a model for gathering and managing information that can be used for different purposes. Arc. BIM 5 mentions that BIM is more than just a way to collect information. It is a visual database by which one can understand the process of the building in a better way and can connect all the data like dimensions, positions, objects, etc. In addition, Arc. BIM 1 and Const. PM adds that through BIM, a general picture of the project can be provided for everyone in different disciplines, which facilitates collaboration. Also, BIM can reduce collisions between work of different disciplines by keeping the team members up to date. Moreover, Arc. BIM 2 describes BIM as a digital tool for producing, communicating, and analyzing information. According to Const. BIM, BIM facilitates the flow of the right information in the project quickly. Arc. BIM 6 and Const. Eng. 1 highlights the importance of scheduling, calculating, filtering, and coding the objects which are possible in working with BIM.

4.1.2 BIM Experience

All except Arc. BIM 5, 6, and Eng. BIM stated that they had not been involved in any project that was “only” based on 3D models. But in almost all their projects, they have used 3D models in which there was a combination with 2D drawings. Moreover, Const. PM highlights the importance of the 2D drawings as significant support for the project.

From another point of view, both Arc. BIM 5 and Const. PM insists on the role of the client in employing BIM in projects. While Arc. BIM 5 mentioned that the willingness and capability of the client in understanding the BIM tools have helped them have a fully model-based project, whereas Const. PM stated that clients’ lack of knowledge in BIM has been problematic for utilizing BIM in their projects. Const. Eng. 2 mentions that their company has put the use of BIM as a requirement from the client, which has helped them employ BIM in their project to a greater extent.

Eng. BIM, Arc. BIM 5 and 6 were the three interviewees who were involved in the projects with high implementation of BIM, almost to a full extent. Arc. BIM 6 has worked on two projects in which they had produced drawings, but only for the purpose of informing the process of the client. However, the production stage was managed only by using BIM. Since Eng. BIM is working as a Head of the BIM Department, the projects that Eng. BIM was involved in was highly based on BIM. Also, Arc. BIM 5 was involved in the most well-known project in Sweden, called Celsius, which had the initial goal to do the project only based on BIM and not on paper drawings. As Arc. BIM 5 states that using BIM as the only source of information was a requirement from the client and the project management, and this approach was a huge challenge for the whole team. However, as Arc. BIM 5 describes that this approach gave the builders the power to understand designers' intentions just on the construction site, which is not the case in other projects

Regarding the legal aspect, at the Celsius project, they were not delivering regular documents according to standards and recommendations for developing construction documents in Sweden (bygghanldlingar 90), instead, they called them *handlingar,* which means documents in English. The reason was that there was no proper formulation of a technical document. As Arc. BIM 5 describes this approach as a new way of communicating between disciplines by which they were sending a sheet as a visual report. The result was a change in the mindset of people involved in the project, higher general satisfaction among workers, and more coordination and understanding of the project.

4.1.3 Current use of BIM in the design phase

Among all the interviewees, there were quite similar and different approaches in terms of ways of using BIM due to their roles in their projects. The primary responsibility of Const. Eng 1 was adding information such as heights, lengths, weights, and coordinates to get tables of contents by which the structural calculations proceed. Arc. BIM 1 uses BIM to deliver and exchange information among different disciplines. Const. PM also has a similar use of BIM, communicating among disciplines and seeing the whole picture of the project. Both Arc. BIM 2 and Const. PM uses the BIM model for clash detection and collision control, and Arc. BIM 2 uses the CAD tools of BIM to produce drawings, images, etc. In addition, quantity takeoff is one of the most common uses of BIM for Arc. BIM 2, 5, and Const. BIM.

During the interview with Arc. BIM 3,5 and Const. BIM expressed that one of their main uses of BIM is the calculation and estimation of costs. However, Const. BIM uses the BIM model throughout the process, from the early stages of the bidding phase to the end. The parts in which they use the 3D model are as follows: learning the project, calculating energy performance, making site plans in 3D, simulating or visualizing the progress of the project to make 4D simulations, and linking tasks in the time schedule with the objects in the 3D model, quality checks of the model, exporting and producing 2D drawings. Some of the named parts are usually done more than once to check if the project is on the right track and performed correctly. In similar with Const. BIM, Const. Eng. 2 is using BIM from the early stage to the end. Const. Eng. 2 uses it to make sketches of drawings, visualize the building, develop the design, and store information in the model. Const. Eng. 2 highlights that the more information is stored in the model, the more the model can be used in the production phase. They use a program called Dalux, is a BIM software for construction management by which they connect the control and delivery of the plans into the models to particular objects.

Arc. BIM 4 also uses a specific program called dRofus for leading, planning, and data management by which they generate the description of every room in the project. Arc. BIM 5 works a bit differently in terms of BIM tools, in a way that they create a hub in order to connect several databases for collecting and distributing information. However, Arc. BIM 6 also employs a coding system in the BIM model by which everybody can differentiate which discipline owns objects. For example, they know which object belongs to the architecture discipline or construction group. Eng. BIM works in a superior level of BIM management and makes BIM strategies, routines, manuals, and validations for other companies like property owners, building material companies, and contractors.

4.1.4 Current use of BIM in the production phase

Half of the architects, Const. Eng. 2 and Const. PM state that the rate of using the BIM model on the construction site is increasing; however, they are using the BIM model in both design and production. Const. BIM mentions that they are using 3D models in the production phase a lot, and Const. PM believes that using 3D models on the construction site helps workers to see the real-life picture of a project. However, the use of the BIM model in the production phase highly depends on the scale of the project. In other words, in smaller projects, it is relatively rare that the 3D model is used in production due to its high costs.

On the other hand, Eng. BIM believes that using a 3D model in the design phase is more common than in the production phase. Arc. BIM 3 also states that they are not involved in the production phase and mainly focus on the design phase. Eng. BIM takes advantage of 3D models for learning purposes and getting everyone on the same page, for instance, by planning and preparing different tasks which are going to happen in the production phase.

Const. BIM argues that 3D models are an essential communication tool to link information and take quantities. Const. Eng. 1 also shares the same perspective and insists on the importance of using BIM on the construction site and expresses that there is tight collaboration and communication between the workers at the construction site and the structural engineers. Also, the team of Const. Eng. 1 takes the quantity takeoff of the reinforcement and pipes instead of using the drawings and calculating by themselves. Also, Arc. BIM 5 insists on the importance of the direct collaboration between architects and constructors and that the architects need to support the construction site. Arc. BIM 5 believes that designers and builders ought to work together and be present on the construction site to update the information and answer questions. Also, Arc. BIM 5 and Const. Eng. 2 believes that the technological facilities of the construction site from the very first day of the project are of great value so that everyone can get the correct information very quickly and easily. Therefore, the model must be updated regularly for every worker on the site. Arc. BIM 5 also emphasizes the value of the 3D model for having a good flow of information and communication. By accessing the 3D model on-site, workers can inform the problems to the right responsible person with a direct message.

4.2 Benefits and Drawbacks

4.2.1 Benefits of using BIM in the design phase

According to Const. Eng. 1, one of the advantages of 3D models compared to 2D drawings is that the 3D environment facilitates collaboration among designers in the design stage and helps them understand the design better. In addition, Const. Eng. 1 and Eng. BIM mentions that one can get accurate numbers directly from the model instead of having to measure and calculate objects on a PDF document. Const. Eng. 1 as well as Arc. BIM 3 shares the same thought that 3D models estimate costs and time more accurately and decrease extra material use. According to Arc. BIM 6, this opportunity lets designers compare the cost and alternatives of material choices very quickly. This opportunity to assess the costs and materials quickly can help designers change the design at the very early stages.

In addition, Const. Eng. 1 highlights that using 3D models has benefits both in costs and carbon footprint. Arc. BIM 1 also states that in 3D models, one can find a great deal of information about every object just with one click, increasing time efficiency. Moreover, Arc. BIM 5, 6, Const. PM, Eng. BIM mention that the main advantage of the 3D model is that one can have an overall understanding of the building and see how every object is connected. For instance, as Arc. BIM 5 mentions that clash detection is one of the most common advantages of using BIM models. BIM 4 also states that technological advancements such as VR can enhance the benefits of the BIM model.

According to Arc. BIM 2 3D models can save time since designers can produce 2D drawings from 3D models in a short time, and they have better control over the model and drawings. This time saving allows designers to spend more time designing than producing documents that benefit the project. As Arc. BIM 5 mentions that using 2D drawings can lead to missing a lot of elements such as the height of objects and other possibilities. However, Arc. BIM 2 insisted that the model's efficiency depends on the persons who have designed the model from the early design stages to the later design stages, such as structural design. In other words, Arc. BIM 2 and 4 share the same view that the model would be more ready for the structural designer if the initial designers had a structural perspective toward the design. It saves time by not having so many changes later. Arc. BIM 2 also believes that the software itself matters, it means that if the software is good enough to cover all the stages of design from early design to production, they can use only one software as one package of all the features.

"*... one important thing in when you're designing a building is that you're designing on your experience and that experience is a total experience, you experience the others in the room, they experience the temperature in the room, they experience the light of the room, the textures of the room, the dimensions, the proportion of your body in the room, how do you feel and stuff. Doing that in 2D, of course, it's just sketching a paper...*"

BIM 5 .Arc

Const. BIM believes that 3D models can ease communication in the project through visualization and it helps different disciplines to understand which part of the project is being referred to. Also, it helps everyone track progress and control the quality of it. Const. BIM and Arc. BIM 5 believe that it allows the managers to coordinate everyone easier in the project. Having better prediction through the 3D model can facilitate a better flow in the project. Arc. BIM 6 adds that coding can ease this action.

4.2.2 Benefits of using BIM in the production phase

Regarding the benefits of 3D models in the production phase, both Arc. BIM 1 and Const. Eng. 1 believes that they are getting better at using 3D models and exporting drawings from them in the construction stage. However, Const. Eng. 1, 2 Eng. BIM believe that a combination of the 3D model and 2D drawings is beneficial and can help them understand the architecture and structure better, increasing the accuracy of the interpretation from the model. As Const. Eng. 2 insists that the 3D models are a comprehensive tool to ensure that they are building correctly. As Arc. BIM 1, 5, Const. Eng. 2, Const. PM and Eng. BIM state using 3D models helps the people on the construction site see the real picture of what will be built and know what they are supposed to do. However, Const. PM insists that using the 3D model on the construction site is highly dependent on the size of the project and if they can afford to use this technology.

In addition, Const. BIM and Eng. BIM believe that using the 3D model in the production phase is similar to the design phase in terms of using it as a communication tool that can help them understand and learn the project. Also, it is a valuable tool to solve problems just on the construction site through the information linked to the 3D model. According to Arc. BIM 5 also, through 3D model, one can have better coordination which saves time and enhances the quality of the building and the final product. Because as Arc. BIM 6 believes using 3D models allows people to check and correct their work in a short time.

4.2.3 Drawbacks of using BIM

Regarding the drawbacks of the 3D models' use, Const. Eng. 1 has faced people such as public clients and governments who are afraid of using 3D models in their projects because it demands a lot of time and money. In addition, Arc. BIM 3 says there are uncertainties if the BIM model can work perfectly or not. Although, Const. Eng. 1 disagrees and believes that by using the 3D model, one should not necessarily produce lots of drawings, and it saves time and money. Arc. BIM 1 also focuses on the relation between the client and the use of the 3D model and states that it highly depends on the client's level of knowledge. In other words, if the client doesn't have enough knowledge or doesn't have the software program, it would be problematic for their team to use it. Const. Eng. 1 also reflects on the software use and believes that it is another drawback of using the 3D model. Because the team is limited to using the same software and if they use IFC export, some information, such as geometrical aspects and information, gets lost in the transferring the files. Arc. BIM 1 also mentions that they are not completely free to use any software that they prefer depending on the type of the project. For example, some projects have strict regulations regarding confidentiality aspects. According to Arc. BIM 1, another common drawback of using the 3D model, could be the lack of clarity of what part of the model is still during design and which part of the model is ready to be produced at the construction site. However, Arc. BIM 5 believes that to increase the general awareness of the project and its progress during the constant updating of the model, the communication tool in the BIM model must get enhanced to avoid confusion among everyone.

As Arc. BIM 1 and 2 stated that in using 2D drawings, it is officially ready for production by stamping the drawings, but there is no such an affirmation in the 3D model. Moreover, Arc. BIM 2 and Const. Eng. 1 mention that the legally binding issue regarding 3D models is the most common drawback that still exists that causes other problems such as stopping many people from employing 3D models in their project. According to Arc. BIM 2, the 3D model today, is good enough for communication, taking quantities from and building based on it without producing 2D drawings, and there is no drawback with the BIM model itself.

Also, Const. BIM believes that one of the main drawbacks is that it is not possible yet to only use 3D models due to the type of project, lack of competence, right people, and proper tools. The reason might be that they have never been obliged to use the 3D model in their project, and therefore they are not ready for this change. For example, Eng. BIM mentions that in the 3D model finding information such as measurement could be hard to find for everyone. Arc. BIM 4 also shares the same view that lack of competence among the users of 3D models is one of the main drawbacks of using it. However, Arc. BIM 5 believes that the people working with the model need to have a lot of information and knowledge about the project stages because they need to make decisions. Const. Eng. 2 also believes that it is not possible yet for only the 3D models to be used, and they should be combined with 2D drawings to be more effective and avoid missing the details.

4.3 Information

4.3.1 Needed information for producing 3D models

Const. BIM, Const. Eng. 1, Eng. BIM, and almost all the architects believe that basically the same information is needed to produce 3D models and 2D drawings. But according to Arc. BIM 2,5 and Const. Eng. 1, when working with the 3D model, one must be more accurate regarding every parameter, and the numbers, dimensions, and layers must be exact. Also, Const. PM, Arc. BIM 5 and 4 believe that producing a 3D model demands more information in comparison to 2D drawings. In fact, it is necessary to define why they are making a model and what information they are taking out from it because there is a great deal of information that could be extracted from the 3D model, but they are not necessarily required. Defining the basis of the model and information depends on the type and size of the project, as well as the budget. Therefore, it is essential to plan in the first place, and everyone needs to have correct input values to know how advanced the model will be. Arc. BIM 5 also insists on the importance of having proper information management at the beginning of the project to coordinate the project better and map the information that the client needs.

Const. Eng. 2 also believes it is necessary to know what information the 3D model should contain. However, for that, there is no framework available, hence the required information could be different from project to project. But Arc. BIM 6 believes that the information that is needed to be known before the project depends on its stage of it. There is not much required in the early stage, but in the Pre-design stage, one needs to know more specific information, such as geometrical and structural information.

4.3.2 Decision makers regarding information

Regarding whom decides about the information in the design stage, there are different opinions. Both Const. Eng. 1 and 2, and most the architects believe that this is the people who order the work and provide the financial investment that decides what information is required to be produced. For example, Arc. BIM 1, 3, and Const. Eng. 1 believe that the client has a significant role but that the contractor, the builder, and the property owners can also influence the produced information. However, Arc. BIM 5, 6, Const. BIM and Const. Eng. 2 mention that a combination of the client, designers, and contractors contributes to the overall result. But Arc. BIM 1 believes that the workers also can affect the decisions. While the older generation refuses to deal with 3D models, the youth are open and more comfortable using them.

However, Const. PM insists that this is the Project Manager who mainly decides about the information and the decision of the project management depends on the scale and the budget of the project. Because the information being produced is expensive, the financial manager also could have an influence. Likewise, Arc. BIM 4 insists on a budget for the project and the fact that this is the most critical parameter in decision making. Also, Eng. BIM argues that the BIM manager is the one who decides on the clash detection and the quantity take off depending on the benefits that they are looking for. Also, the BIM manager is responsible for classifying the information, which plays a vital role in information management.

Arc. BIM 2 also looks at this decision-making for information from another angle and mentions that the type of contract can influence the person who decides on the information that are going to be produced. In the Design-Build agreement, it varies, and it could be either the client, the constructor, or an external company that decides on the information. Const. Eng. 2 shared the same perspective and believes that in the partnering type of contract, according to the agreement between both contractors and client, the information is determined for production. Furthermore, Const. BIM and Eng. BIM argue that rules and regulations impact the decision-making regarding the project's information. For instance, as Arc. BIM 1 explains, there are some descriptions that explain how the expectations of customers regarding 3D models should be and what information should be presented. These descriptions are delivered by both customer and building entrepreneurs, which explain what they want. This document is reviewed and discussed at the beginning of the project to reach a final agreement.

4.3.3 Contractor's demands regarding information

Regarding the contractor's demands from architects, Const. BIM believes that information is the primary demand that contracts are looking for. This information is related to all the objects that are needed for the production of the building. Arc. BIM 5 explains that as the project moves forward from the early stages, the requirements of the contractor increase. For instance, at the beginning of the project, they mostly request basic dimensions, but later they ask for more details such as material specifications and, in the end, they expect the complete documentation.

Arc. BIM 1 and 4 state that requesting information from a contractor depends on the scale of the contractor. The smaller contractors request 2D drawings, while the bigger ones are usually more in contact with architects and require more 3D models. Arc. BIM 2 and 3 share the same perspective and state that information request depends on the company's size. Arc. BIM 2 explains that while the big companies have different requirements, the smaller ones have the central document of requirements. In contrast, Arc. BIM 3 states that large contractors put high demands regarding information and documents, while smaller ones basically don't have any special demand. Moreover, Const. Eng. 2 and Const. PM believe that the contractor's demands depend on the type of project. Const. PM mentions renovating projects requires fewer demands, while in new production, demands are higher because there are various types and different numbers of materials. Const. Eng. 2 also mentions that the requirement is less for regular buildings, such as residential buildings. Still, in complex projects, such as hospitals, they expect more detailed components, which contractors have different demands regarding them.

Arc. BIM 6 argues that depending on the level of knowledge of the contractor, the number of requirements increases, and the more aware the contractor is, the more requirements they have. Similarly, Eng. BIM insists on the level of the contractor's knowledge and explains that if the model that architects and structural designers produce is not optimized for production, they need to reproduce the model for the production stage. Therefore, the amount of information that the contractors expect from designers can be very high.

4.3.4 Sharing the information

Regarding the sharing of the information, Const. Eng. 1 believes that the information is shared through the model exports, which contain a great deal of information about parts of the building. However, Arc. BIM 5 and Const. BIM state that the information is shared through 2D drawings and 3D models containing all the information about a project. According to Const. Eng. 1 and majority of architects, the most common form of export from the 3D model is IFC and Arc. BIM 1 and 2 mention that PDF is the most common form of 2D drawings export. According to half of the architects', sharing information is different from project to project. They usually share the information through a project portal, project database, or CDE solution such as Dropbox. These environments are updated regularly, and one can upload and download files related to each project. Regarding sharing information and collaborative management, one of the architects says:

"*...but now we have a cloud based collaborative issue management, so every single cloud is an object with an owner so if you do something I can see it in the cloud and you can assign problems to the correct discipline, so suddenly it's so much easier to work together so much clearer...*".

BIM 2 .Arc

4.3.4 Presenting the information

Regarding the presentation of the information, Arc. BIM 3 explains that in any type of IFC viewer, there are property sets where the specifications of the objects are presented. Arc. BIM 1,6 and Const. PM believe that the information is handled and presented in a good way. Arc. BIM 1 explains that because of the early agreement at the beginning of a project, everybody knows what information should be delivered in the IFC files through portals. Moreover, Eng. BIM argues that presenting information is efficient for houses and buildings but not necessarily for roads and railroads.

In contrast, Arc. BIM 3 and Const. Eng. 1 believe that the information is not always presented and handled efficiently in BIM. The reason, according to Const. Eng. 1 is that all necessary information is not added to the model until late in the project, and it is essential to have more information in the early stage of the process. Also, Arc. BIM 4 states that they are not using the model's full capacity and not using the model 100%. However, they think the way architects are using the model is efficient, but not contractors due to lack of skills. Arc. BIM 2 believes that collecting and presenting information is not handled as efficiently as it could be today. The model can be viewed and used pretty well when looking for properties of one object but organizing them and taking the quantities is complicated. Const. BIM also is mostly not satisfied with how the information is presented through the property sets. Because it is not easy to find the correct information among the huge amount of data in the IFC model, and it is not easy to be sure whether the information has been quality checked. In other words, it is mainly hard to trust the 3D model. Although Arc. BIM 5 explains that it is necessary to define the property sets from the beginning of the project to map parameters. Since several subcontractors work in the same model, it is crucial to coordinate where the information is placed. In that regard, creating several property sets can be helpful. Therefore, it is important to have a proper conversation with them to inform them where the information is located and how they can access it. Arc. BIM 5 describes workers' need to have the possibility to filter the information in the model and put tags on them to extract the quantities. Arc. BIM 6 states that the possibility of filtering information related to every object in the BIM model is beneficial for making rules and extracting information.

Const. Eng. 2 store the information of the project on different platforms where everyone has access and use a BIM viewer software called Dalux, by which they share information.

"*... today the smartest way of communicating and showing information is from systems like Dalux or streamBIM, where we have drawings and the 3D model, so we can get the best of both worlds…"*

BIM 2 .Arc

4.3.5 Necessary and unnecessary drawings

Regarding the necessity of all the generated drawings, there are different opinions. Arc. BIM 4, Const. BIM, Const. Eng. 1, and Eng. BIM believe that all the drawings that are produced today are not needed. Arc. BIM 2 states that they have double delivery, 2D drawings, and 3D model, but only 2D drawings are used as legal documents. Arc. BIM 2 and Const. BIM expressed that they produce too many drawings and too often, while they could save a great deal of time if they could reduce the number of drawings. Moreover, Const. BIM argues that if the 3D models are used better than today, all the information in the 2D drawings could be read from the 3D model. Then the number of generated drawings could be reduced, and trust in information in the model would be increased. However, Eng. BIM mentions that the production of drawings is easy:

"*I think many drawings are generated just because it is easier to generate all the drawings and to exclude some. Because when we set up the drawings, it is usually done in some kind of semi-automatic way...*".

BIM .Eng

On the contrary, Arc. BIM 3 mentions that all the generated drawings are needed. Arc. BIM 1 and 6 also believe that 2D drawings are needed for jurisdiction. But according to Arc. BIM 1 2D drawings can be good for getting a general overview of the model, but they do not necessarily need to be printed on paper for the contractor to build from them. As Arc. BIM 1 and 4 argue that the 2D drawings should not contain certain information and description of specific objects because they can be found in the model.

Arc. BIM 6 and Const. PM look at this from another perspective and insist on the role of the client. Const. PM believes that when the *relationhandlingar* or as-built documents are supposed to be handled by the client at the end of the project, it is difficult to note all changes that occurred during the process in the 3D model. Arc. BIM 6 also believes that when the client wishes to have a BIM project, but the contractor does not use BIM, the architect needs to produce both 2D and 3D drawings. Theoretically Arc. BIM 4 and Const. BIM believe that all 2D drawings could be replaced by 3D models, but Arc. BIM 4 explains that it depends if the client can handle only 3D models. Arc. BIM 5 and Const. BIM highlight that it is too soon to remove all 2D drawings from the construction industry. As Arc. BIM 5 explains that 2D drawings are the simplified, understandable, and flexible types of documents generated for specific persons. Also, 2D drawings are combined with text, but it is not possible to do the same in 3D models with current tools. Therefore, the 2D drawings still needed to be used in combination with 3D models. Const. Eng. 2 also shares the same view as Arc. BIM 5 and believes that removing the 2D drawings is a mistake and the combination is beneficial.

According to Arc. BIM 2 and Const. Eng. 1 there are some types of drawings that are still in need. For example, plan drawings and detailed drawings are needed. Arc. BIM 1, 6, Const. BIM, Const. Eng. 1 and Const. PM also insist that detailed drawings are needed, and managing the details in the 3D model is difficult because the model usually is not developed with details of connections. Arc. BIM 3 adds that it is essential to combine the detailed 2D drawings with the model to have a complete, precise, and trustworthy model used in the construction phase. Floor layouts are also useful 2D drawings that, according to Const. BIM could still be used. Arc. BIM 2, 4, and 6 add that the plan could be produced as one digital complete plan PDF, called Mega PDF, instead of separated drawings plans into A1 or A3 sizes with a 1:50 scale, and this would save a lot of time. According to Arc. BIM 4 many contractors are not using the A1 format today since it is too big to be efficient at the construction site. Furthermore, Arc. BIM 4 explains that with the digital tools and software such as tablets and software such as Dalux, it is possible to use the digital plan on the construction site in which one can zoom in and look for information.

On the contrary, Const. Eng. 1 believes that the overview plans and section drawings could be avoided to be produced because they don’t contain any valuable information. Const. BIM has the same view regarding section drawings that 3D models could replace. Const. PM also argues how important it is to involve the production team with the architects in the early stage to avoid generating unnecessary drawings. This is mainly because it is expensive to produce drawings that are not used later in the process.

4.4 Contracts & Agreements

4.4.1 Types of contracts

According to Const. Eng. 1 ABK09 is the most common type of contractual terms and conditions in the AEC industry that Arc. BIM 3, Const. Eng. 1, Const. PM and Eng. BIM use. Arc. BIM 4 uses the AB04 and ABT as the legal form of contract in their project. However, Arc. BIM 1 explains that the client and the building entrepreneur have specific documents describing how everything should be built and what type of information ought to be handed out.

While Const. Eng. 2 uses Design-Build with Partnering types of contracts in their projects, Arc. BIM 2 uses different types of contracts because there are different workflows in the project stages. Also, since there is no legal framework regarding 3D models, they try to structure and optimize the project depending on the specifications of different projects. Therefore, they try not to lock themselves into predefined contracts such as Design-Build. Const. BIM and Const. Eng. 1 explains that they have direct contracts with the architects, structural designers, and subcontractors in their project because they mostly use Design-Build contracts.

4.4.2 Ways of payment

According to Const. Eng. 1 there is a fixed budget negotiated and determined at the beginning of the project and as Arc. BIM 1 explains, that if any exceptional tasks are added that were not included in the initial budget, they would ask for an extra payment. However, half of the interviewees state that architects' payment is hourly. As Arc. BIM 1,3, Const. BIM, Const. Eng. 2 specify that the payment could be less or more than the beginning of the estimation of cost in the budget, depending on the working hours. According to Arc. BIM 4 and Const. BIM depends on the project, the type of payment is either a fixed price or per hour. However, the risk of the project is playing a significant role here. Therefore, it is easier to sell the design at a fixed price rather than based on the competence of the architect's work, such as the time they spend in meetings and so on.

4.4.3 Contracts and relationships

Regarding the type of contract, Arc. BIM 1 and Const. PM explains that contract type can affect the relationship between architects and contractors in a good way. Their agreements and communication can facilitate the packaging of information that the client wants to be delivered. As Arc. BIM 2 and Const. PM explains the more transparent and clear parties are at the beginning, the fewer misunderstandings will occur. The requirements of different disciplines ought to be very clear to everyone so that the project proceeds flawlessly. Arc. BIM 3 also looks at this from the financial angle and says that the contract and relationship between contractors and architects can be affected by the lower price since it could land into further projects.

According to Arc. BIM 4, to avoid possible prospective conflict, it is better to use AB04, ABT06, or other forms of predefined contracts and not change their content. Changing them unnecessarily would increase conflicts because they have been proven to be efficient and successful over the year. Const. Eng. 2 also insists on the high transparency of the Partnering type of contract and the fact that everyone knows about the economic facts such as risks, profits, and loss. Therefore, in a Partnership, the relationship is honest and open. Eng. BIM also highlights the influence of contract type on the relationship between architects and contractors and explains that in the Design-Bid-Build type of contract, the collaboration is low compared to Design-Build. Because in the Design-Bid-Build contract the drawings are delivered to the contractors when the contractors have just entered the project and have not been involved before.

4.4.4 Contracts and sharing and presenting information

Arc. BIM 4, 5, and Const. BIM believe that in the agreement between architects and contractors, there is a need for the exact information that is supposed to be delivered is specified in the contract to avoid possible further conflicts. As Arc. BIM 4 and 5 state their companies have no willingness to deliver the entire editable model because they don't want to deliver all their techniques, methods, and sources of knowledge. Instead, they are interested in licensing their content. Arc. BIM 4 also states that there has been mostly a conflict regarding the owner of the BIM model and whether the consultant should deliver the entire model, IFC or PDF, to the contractor. Arc. BIM 1 and 4 agree that their consultants can deliver any type of information. Therefore, they should control the limits of delivery. In other words, while delivering information, there is a matter of secrecy. For example, the important numbers, calculations, and templates should not be delivered through the model if they are not paid for because they are considered business secrets. Arc. BIM 5 emphasizes that the information in the model gives value to the business, and they make a profit out of it. Therefore, they should not just give them away.

Nevertheless, Const. PM believes that type of contract does not affect how the information is shared between architects and contractors. Arc. BIM 3 agrees with this opinion and believes that using the standardized contract would not affect how the information is shared. Const. BIM also believes that the type of contract itself does not cause any problem sharing the information. Instead, a description of it must be done better. In other words, a common understanding of the contract between the involved parties is important. In addition, Arc. BIM 2 insists that it is essential that the necessity of delivering information in a specific form is discussed at the beginning of the project. As Arc. BIM 2 explains some clients or contractors are not aware of why they demand some information. Therefore, their purpose of them needs to be communicated.

Moreover, Const. Eng. 2 explains that the Partnering type of contract helps them share the information in a shorter time due to the openness and transparency of the work. Eng. BIM also agrees and argues that the collaboration in the Design-Build type of contract helps them share information without any limits. In contrast, in the Design-Bid-Build, they cannot share the drawings and models easily because of their responsibilities regarding their company's loyalty.

4.4.5 LOD and stages of Design

According to Const. Eng. 1, there are three different design stages in the project. They are *Programskede, Systemskede,* and *Bygghandlingsskede,* which are Pre-design, Project Planning Document, and Detailed Design & Construction Document. As Eng. BIM says, as far as the stages of design go further, the details in the projects increase. According to Arc. BIM 6 and Const. PM the Program documents is the very first stage of design in which there is no detail in the model, and it is a kind of sketch of the design which shows zonings. Const. Eng. 2 explains that the architects show the ideas, geometries, volumes, and areas in this stage. In the next stage, as Const. Eng. 1 explains the Schematic Design in which the model is developed based on the general geometrics object with not very exact dimensions. As Arc. BIM 6, Const. Eng. 2 and Const. PM mention that all the building systems, such as the structural system and the installations are defined in this stage. The final stage is the Detailed

Design & Construction Document, in which, as Arc. BIM 6, Const. Eng. 1 and Eng. BIM describe that everything must be modeled accurately with great detail since the contractor will build accordingly.

As Const. Eng. 1 explains that depending on the scale and type of project, the needed level of information can be different. For example, they can construct a simple small-scale building even by the level of information in the Schematic Design. But in a more complex project, there might be almost nothing to be built by the information provided in Schematic Design. In other words, the amount of deliverable information in the three stages of design is very different from project to project. According to Const. Eng. 1, based on the most recent agreement among some of the big companies in the Swedish AEC industry, they have developed a guideline called BEAST, which describes what the model should contain in the early phase of design.

Regarding the relation between LOD and required information, Arc. BIM 2 mentions two common issues. First, the requirements should be considered the basis of LOD and not the other way because the requirements define what needs to be delivered. The second is that, since there is a lack of enough collaboration with the model, contractors do not know how to put specific LOD requirements. Arc. BIM 3, 5, and Const. BIM also adds that no framework specifies how they are supposed to deliver the LOD. Both Arc. BIM 4 and Const. BIM discusses that the LOD is too theoretical and since it does not suggest any framework, contractors, architects, and the clients are not that familiar with it in work.

Arc. BIM 1 emphasizes the contractor's role in requesting LOD and explains that depending on how the contractor will use the model, the LOD could be high or low in the early design stage. Moreover, the model must be developed in detail in the early stage if they are going to calculate and estimate the costs. Both Arc. BIM 1 and Const. BIM agrees that the more the model is detailed, the more accurate the calculations for the quantity take-off. In contrast with Arc. BIM 1, Arc. BIM 2 argues that the model should not be too detailed in the early stages of design because it takes a longer time to change the model later. However, Arc. BIM 2 argues that the CAD programs are one of the drivers of developing models in detail in the early stage of design:

"*...and also one problem is CAD programs, the LOD is higher in the beginning, you cannot avoid that. it's like how the programs are constructed. So, we get the higher LOD. So, for us we need to hide, we need to take the models and take away the data in the early design because otherwise they [contractors] might look at them and they see data that shouldn't really be there..."*

BIM 2 .Arc

Const. BIM explains that since they, as contractors, get involved in the project in the last part of the design, they are not working with LOD because they are constantly dealing with the detailed design.

"... so, we don't have any requirements for how architects should sketch in the early phases and how they should work in the programskede and systemskede, ... there are other actors involved, and when we come to detailed design, then much of the work is done and the model is done...".

BIM .Const

4.5 Future

4.5.1 Sharing and presenting information in future

According to Const. Eng. 1, transferring information in BIM through different software, even though IFC format could result in losing some of the information. Therefore, everyone will use the same software in the future. Arc. BIM 6 and Const. Eng. 1 believe that this problem will be solved in the future by software developers through probably open format, although Eng. BIM believes the software developers are not fond of open format development because it might not be aligned with their business interests. The open format could be a solution when contracts force users to use a specific program such as Arc. BIM 4 mentions. Half of the architects and Eng. BIM, have the same opinion regarding the importance of using the model in an open format by which one can open the model without the program.

"...I think it [BIM model] should be kept in open data base format, or it's very easy for any application to bring out geometry, facts, classification, any information you want, and not lock it up in files, mainly keep it in the databases, instead of file-based format."

BIM .Eng

Arc. BIM 2 and 5 also see the future in software transformation. They believe through web solutions there would be no need for current CAD tools since the CAD programs could connect to a portal. Arc. BIM 2 explains that through the web-based BIM, one can manage the model and its history and control which people have been responsible for different parts. Arc. BIM 5 also describes that the current software will be replaced by web-based or cloud-based software packages. Through web solutions, the model would be universally available, and one can customize the experience depending on the role in the project. In addition, virtual reality will be widely involved in BIM in the future. Arc. BIM 2 expresses that the technical part of the model is good today, but the interface is not efficient yet. The interface should be able to filter everything to extract information easily. Therefore, in the future, through standardized requirements, there would be a possibility to validate the model automatically by uploading the model. The result is a full proof issue of management.

According to Const. BIM, the property set in the IFC model, is a good solution for quality checks and sorting information. However, IFC could be developed and implemented in a better way. Depending on the projects, they will use more types of property sets for different purposes in IFCs.

4.5.2 Limitations of becoming model based

Regarding the current limitations in the AEC industry, Const. Eng. 1 argues that architects and structural designers are good at working with BIM. But most of the interviewees emphasize, that people cannot, do not want, or are afraid of using the 3D models to take the information from and use at the construction site. The reasons are many, namely lack of technical equipment and computer knowledge. Arc. BIM 3 believes those limitations are a combination of adapting tools, culture, and traditions. Arc. BIM 3 and Arc. BIM 6 argues that since people want to have their old habits, the result is falling back to the methods they are comfortable with. Const. Eng. 1 also adds that the younger generation is better at using the 3D model than the elder. One reason might be that the current applications are not user-friendly enough with better features such as Arc. BIM 3 argues. Although, as Const. BIM, Const. Eng. 1 and 2 agree that the construction industry has the knowledge, but it has not been fully implemented.

Therefore, as most of the interviewees agree, there is a need for a generation shift and better software and technical equipment. However, regarding the size of companies, Arc. BIM 1, 4, and 6 mention that smaller companies are most willing to use 2D drawings. It is hard to demand small companies to provide advanced equipment, for example, because as Arc. BIM 6, Const. Eng. 2, Const. PM and Eng. BIM mention providing BIM software and tools is very expensive. Another limitation today, according to Arc. BIM 1 is the system of using the model since it is hard to determine which part of the model is still in progress and which part is ready to build from. Although, Eng. BIM blamed software developer companies like Autodesk, which have no strategy or goal for developing standards and common open formats like IFC.

Moreover, Arc. BIM 5, Const. Eng. 1 and 2 state that, in the future, the BIM model needs to be legally binding because today, one cannot get a building permit with only a 3D model. Const. Eng. 2 also emphasizes a need to have evaluated frameworks, which describe what information must be included in the model. Arc. BIM 2 also highlights the importance of having common standards for the whole AEC industry, making everyone use a similar approach. Arc. BIM 6 also stresses the client's role and that the client's requirements should be clear from the early stages of the project. Otherwise, the model throughout the project would be changed several times, which is a limitation for the project's development. Arc. BIM 3, 4, and Const. PM also adds that there is a common problem with clients who do not have enough knowledge of BIM software, and there are mostly facing technical issues.

4.5.3 Necessities for change

Const. Eng. 1 and 2 believe that similar to 2D drawing, there is a need for a guideline to know how to make 3D models. Also, there is a need for standardizations to, for example, name the parameter so that the models can also be legally binding. Arc. BIM 3 emphasizes that the model should be placed as a more important document rather than 2D drawings so that everyone put BIM development in their approach. Arc. BIM 2 also shares the same opinion with Const. Eng. 1 and 2 emphasize the importance of standardization for having an efficient business. BEAst is the latest try from the big players in the AEC industry who tries to get everyone to work in the same direction. Also, there is a need for a kind of agreement by which people know how to deliver the information so that the trust in the BIM model and among different parties increases. Arc. BIM 5 looks at trust from another angle and believes that the trust in the model would increase by using a quality management system. As Arc. BIM 3 explains the first step for change is to plan it very carefully so that all the involved people know the approach from the beginning. Arc. BIM 4 also states that there is a need for education for everyone to learn and know BIM better to develop their competencies. Moreover, the younger generation should be hired more to use their technical competence.

4.5.4 Expectations of the future

Const. BIM, Const. Eng. 1, 2, and Const. PM believe that moving toward a fully model-based process will happen partly in the future, and as Const. BIM believes this transformation will not happen very soon, and it will take time. According to Arc. BIM 1 and Const. PM, in the future, they will not print the documents, and they will use the digital format of drawings. Const. PM also adds that the clients will know the value of 3D models in the future, and they will request it. Arc. BIM 2 and 3 expect that in the future, the process of the project will be based on the open format, and the tools will be developed in the cloud-based environment in which all the communication and information consumption will happen very efficiently. In addition, Arc. BIM 3 emphasizes the role of big contractors as leaders of the AEC industry and believes they need to expect what they need to provide specifically from the architect. Arc. BIM 4 and 5 believe that the other technologies will be used in BIM in the future, such as Artificial Intelligence (AI), because more data types will be used. They believe that these new technologies will mainly help in the cost calculation. Arc. BIM 5 also predicts that the BIM infrastructures will be expensive in the future, and the BIM section in the consultant companies will expand widely.

5. Discussion

In this section, based on the findings in theoretical studies and empirical part, the discussion regarding the topic is provided. The information is provided according to the comparison between the information acquired from interviewees and the literature studies in five parts. First, the definition of BIM is discussed, followed by the advantages and drawbacks of using BIM, then the information and the needs and demands regarding it are discussed. In this part, the ways of sharing and presenting information plus the necessity of drawings are discussed. Then the discussion around the contracts and their influence on implementing BIM from different angles is discussed. Finally, the future of BIM, containing its expectations, limitations, and necessities, and sharing and presenting information in the future is discussed.

5.1 BIM

5.1.1 Interpretation and current use of BIM

BIM is a concept that is comprehended differently by every individual and group. Regarding the definition of BIM, Jongeling (2008), Borrmann et al. (2015), and most of the interviewees share the same view that BIM is a common 3D model for gathering and managing information for several activities for different purposes. During the interviews, it was realized that BIM is interpreted differently, namely, BIM as a producer and connector of data, BIM as a facilitator of collaboration, or BIM as a tool for filtering and managing information and tasks. It could be argued that its implementation could be hindered due to different interpretations of BIM. In other words, to solve an issue, one needs to have knowledge about it properly in the first place.

According to Lindström (2013), there is a chance of losing knowledge of a project by excluding all 2D drawings. Also, Disney et al. (2021) explain that when it is difficult to describe some details in the 3D model, the 2D drawings could be used as a complement to the 3D model, which can be produced as 2D-PDF. Therefore, combining the 2D drawings and 3D models would be beneficial. This aligns with the BIM experience of most of the interviewees, in which there was a combination of both 3D models and 2D drawings. However, Arc. BIM 5, 6, and Eng. BIM expressed that they had been involved in projects which consisted exclusively of 3D models. Similarly, as Van Berlo & Natrop (2014) state, the number of such projects is low. These interviewees described that it was a particularly challenging process, but, in the end, they thought it was successful. One could claim that omitting the 2D drawings is hard, and it is difficult to exclude them entirely because of the specific information they contain. Therefore, 2D representations and 3D models ought to be combined.

Olsson & Arvidsson (2012) argue that the BIM model is mainly developed for the design stage of a project, and implementation of the 3D model on the construction site is not common. Similarly, most interviewees mentioned that BIM is, at present, mainly used in the design stage, but it is becoming more common in production. Moreover, Const. PM emphasized that using the BIM model on the construction site in small-scale projects is problematic due to its high costs.

According to Czmoch & Pękala (2014), Sebastian (2011), Merschbrock & Nordahl-Rolfsen (2016), Arc. BIM 2, 5, Const. BIM, Const. Eng. 2 and Const. PM clash detection and quantity take-off are the widespread use of the BIM model in AEC projects. In addition, the other common uses of BIM have cost calculation and time estimation, which Arc. BIM 3,5, Const. BIM, Const. Eng. 1, Jongeling (2008), Sebastian (2011), and Azhar (2011) agree. BIM could take these actions more accurately and faster if the model and structure of information had the right quality, as half of the interviewed architects, Const. Eng. 1 and Const. PM discussed. Const. Eng. 1 and Eng. BIM also mentioned that the correct quantities could be extracted from the model, resulting in decreased extra use of material. Using BIM to extract the right amount of material for a project is a more sustainable approach than estimating the use of material through 2D drawings.

However, as Jensen (2012) expressed, the named functionalities of BIM could ease the communication and visualization in a project. Some of the interviews use BIM to communicate by exchanging and delivering information between different disciplines, learning the project, and seeing the whole reality-based picture. Furthermore, most of the interviewees stated that one of the main benefits of using 3D models is that it facilitates for the employees to see how all the objects are connected, providing an overall understanding of the project. Despite this, the BIM model is not being used during the production stage, which could help the workers to understand the building more clearly.

5.2 Benefits and drawbacks of using BIM

5.2.1 Benefits of using BIM

According to most of the articles and interviewees, one of the most important benefits of BIM is the collaboration among different disciplines. Arc. BIM 5 insists that the direct collaboration between architects and constructors is of great value, which can be the support from architects to the construction site like updating the information regularly and answering questions. As Ramirez & Kreaker (2019) and Czmoch & Pękala (2014) mention, through inter-disciplinary collaboration in BIM projects, the information is accessible to everyone. This aligns with what Const. Eng. 1 believes that in the 3D environment, the collaboration is easier because they can understand it better. Furthermore, Const. BIM mentions that accessibility to information helps track and control the process and increases the quality.

Furthermore, Alassadi & Khallouf (2020) explain that the information is shared and updated through BIM among the involved participants more efficiently, contributing to less time consumed in a project's process. Arc. BIM 1 and 2 share the same perspective and agree upon the high availability and accessibility of information, increasing the time efficiency. Arc. BIM 5 and 6 have the same opinion as Alassadi & Khallouf (2020) regarding the easiness of updating and correcting the information through the BIM model in a short time. However, Const. Eng. 2 emphasizes that the model should have a sufficient quantity of information to facilitate its use. One could argue that if the model does not contain enough information, it would be difficult for the workers to use the model on the construction site as the only source of information. Arc. BIM 5 has been involved in the Celsius project, which was finished in a much shorter time with higher economic benefits. It is a successful proof of an actual project that employed BIM in which they involved all parties early in the project and communicated and exchanged information in a good way. Therefore, it could be argued that the good amount of information in the model could result in an efficient collaboration through BIM.

5.2.2 Drawbacks of using BIM

Today, according to Alassadi & Khallouf (2020), Sundquist et al. (2020), and Jongeling (2008), the 2D drawings are the most used construction documents in the AEC industry. The reason is that the 3D models are not legally binding documents and are used as complements to 2D drawings nowadays, as Disney et al. (2021) mention. As Azhar (2011), Arc. BIM 2 and Const. Eng. 1 agree that the legally binding issues regarding 3D models are the most common barrier preventing the full implementation of BIM in the AEC industry.

Another issue today, as Arc. BIM 1 and 2 mentioned that the 2D drawings could be approved easily by stamping the document and making it officially ready. At the same time, there is not the same affirmation for the 3D model, which makes it challenging to implement the BIM model in construction. The result is unclear on which part of the model is ready to be constructed. However, as Arc. BIM 5 discusses the communication tool that could be used to avoid confusion. As Disney et al. (2021) explain, the 3D model was the Celsius project's only legally binding construction document. This project was a successful project in which all the workers were obliged to use the 3D model only. Therefore, it could be claimed that it is possible to specify the ready-to-built parts in the model, and there might be some features in the BIM tools that help the workers to use. Moreover, since the 3D model was the only source of information in the Celsius project, they had to develop a high-quality model including all the required information. Arc. BIM 5 highlights that having a high amount of information about every stage of a project is necessary for the people working with the model. However, Norberg & Brantitsa (2018) argue that there might be a lack of trustworthiness and accuracy in terms of relation to components in the model. Therefore, the designers cannot develop detailed drawings when they are unsure about the model's accuracy. Arc. BIM 3 also confirms that there are uncertainties about the model's accuracy regarding working with the BIM model. Therefore, it could be argued that using BIM as the single source of information with linked illustrations or production-oriented views describing detailed technical components is hard to model or describe in 3D.

Another barrier to BIM implementation is the level of willingness and competence of the project's team, such as their skills and knowledge. Eastman et al. (2011), Czmoch & Pękala (2014), Arc. BIM 4 and 5 also mention the willingness and competence of the project's team as barriers to BIM implementation. According to Eastman et al. (2011) and Jongeling (2008), the user-friendliness of the BIM software is of great importance. Because all project participants need to be able to work with BIM software and develop their competence to increase their willingness. Also, Norberg & Brantitsa (2018), Eastman et al. (2011), Sundquist et al. (2020) and Arc. BIM 3 explain that the software today is complicated and not user-friendly enough. For instance, they do not have a proper feature for filtering information. However, Arc. BIM 5 mentioned that they use several property sets in which one can filter the project's information for the users. Although it is a very time-consuming process to define those property sets. It could be discussed that instead of allocating time for making 2D drawings, this time could be spent evaluating and determining the property sets to make them more suitable for the workers on the construction site.

As Alassadi & Khallouf (2020) discuss, another issue with BIM software is that they are constantly updating their version, making it difficult for users to maintain both software competence and willingness. Const. Eng. 1 believes that the BIM software is user-friendly enough for the designers' team, consisting of architects and structural engineers. According to most of the interviewees, it is on the construction site that the workers are having difficulties using BIM software since they lack competence and willingness to use it. Therefore, one could claim that the BIM software developers must focus on enhancing the features which improve the experience and use of the construction site workers. According to Russell et al. (2014) and Zakaria et al. (2014), lack of skill is an underlying reason for resistance to change. As Arc. BIM 3, 6, and Const. Eng. 1 argue that the younger generation is performing better in this regard since individuals tend to return to their former work habits. However, in some cases, maybe the young generation does not have the knowledge related to good design solutions. Const. BIM agrees and mentions that different drawbacks such as type of project, lack of competence, right people, and proper tools have hindered BIM implementation. One reason for these drawbacks could be the lack of obligation to use BIM models in projects, which prevents people from being ready for the change. Const. Eng. 2 also insists on the obligation of using BIM and explains that using BIM as a requirement in their projects from the client has facilitated BIM implementation. Arc. BIM 5 had the same experience, but their team found it very challenging to adapt to obligation. In the Celsius project, in which Arc. BIM 5 was involved, since the workers were forced to use the 3D model, they were prohibited from using 2D drawings and could not go back to their old habit of working. Therefore, it seems that the client's obligation is one way of not letting people fall back to their comfortable and old working habits and could help the implementation of BIM regardless of the lack of willingness of workers.

One of the most reflected facts about BIM is the client's knowledge of BIM. As Dakhil et al. (2019), Arc. BIM 5 and Const. PM highlight that it is of great importance that the client has enough knowledge, experience, and understanding of the whole process of BIM. Otherwise, the client might not be able to request the necessary information to produce suitable BIM models. Furthermore, Arc. BIM 1 emphasizes that the level of BIM implementation depends on how much the client has knowledge about BIM and if they can use the BIM software or not. As Adam & Lindahl (2017), Dakhil et al. (2019), Arc. BIM 5 and Const. PM argue the client has a very influential role in employing BIM in a project due to their power and position. In AEC projects, a client who is not positive toward the implementation of BIM is a common barrier, as Ivory (2005), Chan (2014), and Hartmann et al. (2008) discuss. Arc. BIM 5 shared the same perspective and mentioned that in understanding the BIM tools, the willingness and capability of the client are beneficial. Const. Eng. 1 reflects that since some clients believe that the use of BIM is an expensive approach, they are hesitant to use it. Although Const. Eng. 1 disagrees with this interpretation and believes that using 3D would save costs and time in the end. It could be argued that the expenses of investing in BIM could be compensated by the time and economic efficiencies that the use of BIM can bring.

5.3 Information

5.3.1 Needs and demands regarding information

Almost all the interviewees believed that the same information is needed to produce 3D models and 2D drawings. According to Eastman et al. (2011), the design process in projects with 2D drawings or 3D models for activities such as estimating costs, planning, and coordination is based on the same information. Jongeling (2008) also shares the same view but emphasizes that in 3D models, the accessibility of information is entirely different. However, according to half of the architects, Const. Eng. 1 and Const. PM there is a need for more detailed and accurate information when producing 3D models. Therefore, it could be claimed that there is a need for setting higher demands on the design process. Arc. BIM 4, 5, 6, and Const. Eng. 2 insists on the planning and framework for the model. In fact, it is needed to know what information could be extracted from the model and how advanced the model is going to be. Hence, it could be discussed that there is a need for information management from the beginning to coordinate the project better.

There are different opinions about who decides on needed information since it depends on the type of project. Most of the interviewees and Dakhil et al. (2019) share the same opinion that the client has a very influential role in deciding what information needs to be produced in a project. One of the reasons might be that the client is the most influential party in the project due to the overall power of the client, such as procurement and financial control. However, the interviewees also highlight that other participants, such as architects, contractors, subcontractors, and property owners, can influence the client's decisions with their competence and willingness. In addition, both Const. PM and Mäki & Kerosuo (2015) highlight the project managers influence in directing the project to implement BIM and decide what information is supposed to be produced. In other words, the willingness and experience of project managers are very influential on the decision taken regarding information and implementation of BIM. Eng. BIM highlights that the BIM managers influence this process and their responsibilities regarding the classification of information and that it is the project manager who decide what information could be extracted from the model. One can claim that all involved parties have an influential role, knowledge, and expertise in their area. Hence, for sharing the knowledge, the collaboration between these parties must start already at the beginning of a project when the decisions are made in terms of BIM implementation. All the decisions and agreements between the parties in the project are described in the contract, therefore as Arc. BIM 2 and Const. Eng. 2 argue that the type of contract could affect the decision-makers and what information is going to be produced. Const. BIM and Eng. BIM add that rules and regulations can also impact on the decision-making regarding information about the project.

According to Lindström (2013), the main tasks of the contractors are quantity take-off and time and cost estimations of the project for which they need the exact information to provide accurate estimates, for example, the amount of material. Eastman et al. (2011) discuss that the contractors ought to be involved from the early design stage. The BIM model should contain sufficient detailed information when delivered from the architects to the contractors. However, Arc. BIM 5 believes that the level of information that the contractor demands depends on the stage of a project, the further the stage of design is, the more information is required. Furthermore, most of the architects emphasized that the requirement and amount of information highly depend on the size of the project and the company. Arc. BIM 3 mentioned that large contractors usually have higher requirements. In addition, Const. Eng. 2 and Const. PM discusses that the type of project can influence the required information. For example, the requested information from clients for a residential project compared to a hospital project are entirely different. Arc. BIM 6 and Eng. BIM also highlights that the higher level of knowledge contractors have, the more requirements they have. The interviewees had a hard time answering what the contractor's demands were regarding the information. It could be argued that the demands of the contractors are not necessarily the same in different projects. Depending on the size and type of project and the contractor’s experience and knowledge, the requested level of information could be different. The size and type of project also influence the demands from contractors regarding the level of development and details in various stages of the design.

5.3.4 Sharing and presenting information

Const. Eng. 1 and Jongeling (2008) insist on the fact that the BIM model is the main source of information, and all the users can have an overall view of the model. According to Bucher & Hall (2020), the 3D model is stored in a shared location in which everyone in the team has access to it. As Disney et al. (2021) explain, this shared location can be cloud-based. Jongeling (2008) describes the more information the model has, the less request for information would be from the users. Arc. BIM 2 and Const. Eng. 2 stated that Dalux might be the best tool today for showing and communicating information. Const. BIM and Arc. BIM 5 adds that both 3D models and 2D drawings are being used for sharing information, and they have not removed the 2D drawings entirely from their projects. Half of the interviewees mentioned that IFC is the most common file format for 3D models shared between different users, while PDF is for 2D drawings. In addition, half of the architects describe that they are using different portals to share information with each other.

During the interviews, it appeared that there were different opinions regarding whether the information in the BIM model is presented efficiently. Arc. BIM 1, 6, and Const. PM are satisfied with how the information is presented. Eng. BIM partly agrees but believes that the BIM models are more developed in housing projects than in road and railroad projects. On the contrary, Arc. BIM 3 and Const. Eng. 1 believe that the model should contain more information. Arc. BIM 4 adds that the BIM model is not being used to its total capacity at the construction site due to the lack of knowledge of BIM. Arc. BIM 2 and Const. BIM agree and believe that the model is good for using the information of one component, but when it comes to property sets (filtering information feature in BIM), organizing and extracting quantities is complicated. However, according to Arc. BIM 5, if the property sets are named, defined, and divided clearly from the beginning of a project and the way of using them is communicated in a good way, it facilitates the possibility for workers to filter information and extract the right quantities. Disney et al. (2021) also emphasize that the feature of filtering information regarding the BIM objects based on subcontractors' interests increases the interoperability aspect of BIM. Arc. BIM 6 highlights the benefits that the feature of filtering could add to the model in a way that the participants can find the correct information related to them in a short time. It can be argued that the property sets today seem to be complicated as a feature of BIM tools. By developing more suitable property sets designed for different users, it might be possible for workers to use the BIM model regardless of their level of knowledge and experience.

Another issue today as Const. BIM discusses, is trustworthiness, since it is hard to know if the model has been quality checked and its information has been verified for production. Both interviewees and the literature argued the issue of trust in the model. Arc. BIM 2 and 5 believe that trust would increase in the model by a proper agreement for delivering the correct information and a quality management system. One could argue that having the BIM model as a legally binding document might increase trustworthiness and make the involved parties rely on the BIM model. As mentioned earlier by Const. BIM and Arc. BIM 5, both 3D models and 2D drawings are being used. Still, to the trustworthiness of the BIM model, it may be argued that having 2D drawings as a reliable source of information would discourage individuals from attempting to create a trustworthy 3D model.

5.3.6 Necessary and unnecessary drawings

Half of the interviewees emphasize that too many drawings are being produced that are not necessarily needed and require much time and effort to make. According to Nemati & Engman Otréus (2022) study, the architects spent around 30% of their design time making 2D drawings. The other half of the interviewees believed that these drawings are needed for legally binding documents, having a general overview of the project. Disney et al. (2021) also mention the necessity of having 2D drawings as legally binding documents since the 3D models are not considered legal documents. Ongoing work in Sweden has shown that BIM could be used as a legally binding document. Luo & Xu (2014) argue that people use 2D drawings easier because they know where the information is located and are comfortable using 2D drawings. However, a recent study showed that using BIM is less time-consuming and more efficient since it is fast and easy to take the information (Nemati & Engman Otréus, 2022).

Arc. BIM 6 and Const. PM believe that it is difficult to remember and note every change in a 3D model, which the 2D drawings are needed for. Therefore, there might be a need to develop new BIM software or applicable plugins to the current software which support identifying and noting changes in the 3D model. Nemati & Engman Otréus (2022) suggest that by having 2D drawings as an underlying layer, using the BIM model could be easier since the advantages of 2D drawings could be used in the 3D model. It could be argued that it would be essential to add the functionalities of 2D drawings to the 3D models to decrease the need for using 2D drawings as a supplementary source of information. However, Arc. BIM 4, 5, and Const. BIM believe that it is theoretically possible to exclude all 2D drawings and only use 3D models, but in practice, the industry is not there yet. According to Van Berlo & Natrop (2014), the projects in which they used 3D models only are very few, such as the Celsius project, which used 2D drawings to a certain extent as Arc. BIM 5 states. Arc. BIM 3, 5, Const. Eng. 2 and Lindström (2013) believe there is a need to combine the 2D drawings and 3D models to have a trustworthy model. Sundquist et al. (2020) and Disney et al. (2021) argue that this combination has already happened, and completing 2D drawing with the 3D model is a common approach in the AEC industry. One might claim that moving from 2D drawings to the fully model-based AEC industry is a time-consuming transition that will not happen immediately. These long-term transitions have started with the combination of 2D drawings and 3D models, and it needs to decrease the 2D drawings gradually to reach an entirely model-based AEC industry. It is possible by improving the functionality of BIM models.

Const. PM argues that the collaboration between contractors and architects from the beginning of a project helps avoid producing unnecessary drawings. Disney et al. (2021) emphasize the importance of creating relevant drawings, particularly for the construction site, to save time by avoiding producing unnecessary drawings. While Const. BIM and Const. Eng. 1 believe that section drawings are not needed, more than half of the interviewees and Disney et al. (2021) insisted that detailed drawings are necessary because managing and describing the details in the 3D model is difficult. Const. BIM adds that, for instance, floor layouts are needed. However, four of the architects explain that the drawings do not need to be printed out and separated into different paper sizes, instead, they can be presented in a mega PDF which is only viewed digitally, since it is not an efficient approach to use A1 format at the construction sites. Arc. BIM 4 believes Dalux is an efficient tool to view and use the digital plan on the construction site. It could be argued that creating a mega PDF of detailed drawings, for example, the floor view is a way of minimizing the production of sub-plan views of a floor view. This mega PDF can be combined with Dalux as a viewer and manager of a 3D model and would be a good practical use for combining these two.

5.4 Contracts and agreements

Almost all interviewees' agreements between architects and contractors are hourly based on the payment. According to Arc. BIM 1 and Const. Eng. 1 there is an initial budget at the beginning of the project, and if the working hours are more than expected at the beginning, the architects will be paid more. However, Arc. BIM 4 and Const. BIM uses the fixed price method depending on the projects.

5.4.1 Contracts effect on collaboration

Regarding the fact that if the contract's type can affect the relationship between the client, contractors and architects Ramirez & Kreaker (2019) and Bragança et al. (2014) believe that depending on the type of contract, the relationships could be affected. According to the interviewees, depending on the projects, variety of companies, and interviewees' roles, they use different contracts, mainly AB04, ABT06, ABK09, and Partnership.

Arc. BIM 2 and Hooper & Widén (2015) share the same belief that there is no standard or legal framework in Sweden specifying BIM in contracts. Hooper & Widén (2015) argue that all the contracts, specifically ABK09, support the requirements of 2D drawings and not BIM. One can argue that the lack of a legal framework for implementing BIM would hinder the AEC industry from implementing BIM more with the help of contracts.

Most of the architects, Const. BIM and Const. PM explain that the required documents are supposed to be clearly and transparently described by the client in the agreement. This could facilitate communication, collaboration, and delivery of information and reduce misunderstandings. Const. Eng. 2 believes that the Partnership contract could be a proper type of contract for these goals. This aligns with what Hardin & McCool (2015) and Hartmann & Bresnen (2011) argue that in the Partnership contract, the relationship is based on mutual understanding and trust, which results in a high level of collaboration. Eastman et al. (2011) agree that IPD is the most suitable type of contract for using BIM because the contractors are involved in the design stage, and the architects have the opportunity to be involved in the construction. These involvements increase the collaboration which is needed for BIM.

Although Eng. BIM and Hooper & Widén (2015) argue that ABT06 is a better type of contract for having collaboration. This is in line with Eastman et al. (2011) in the way that ABT06 is a proper type of contract for collaboration between architects and contractors because they are working together in both the design and construction stages. Therefore, ABT06 is a supportive type of contract regarding a collaboration that can happen through BIM. However, Arc. BIM. 4 emphasizes that to avoid conflicts and have a collaborative relationship between parties, it is better to use AB04 and ABT06. To avoid further conflicts, the standard content ought not to be changed. In contrast, as Su-Ling et al. (2018) argue, the AB04 is not a useful contract to achieve collaboration because, in AB04, the responsibilities of participants are clearly defined. Therefore, they are mainly motivated to do their own and not collaborate. Ramirez & Kreaker (2019) agree that AB04 is not a proper contract for providing collaboration specifically regarding BIM since the contractor is involved in the project in the production stage, which is relatively late. According to the interviews, since AB09 is for consultancy and only supports 2D drawings, this type of contract is not helping implement BIM. Regarding the different types of contracts, one could discuss that ABT06 and partnership contracts in Sweden have the potential to be reformed to support BIM to have the different parties in full involvement and collaborative relationship.

5.4.3 Contracts effect of sharing and presenting information

The endeavor for increasing the level of collaboration is to avoid conflicts, although one of the most common conflicts according to Arc. BIM 4 is regarding the ownership of the model. As Hooper & Widén (2015) agree, in the current types of contracts, it is not described who is the owner and responsible for the digital information since they are not supporting BIM usage. Arc. BIM 4 and 5 explain that there is no willingness from the consultant side to deliver the entire model because it is the source of knowledge and information that contains their work methods. Half of the architects mentioned the matter of secrecy, that they should control the limit of information delivery due to the business secrets. It is because of the importance of adding value to the company and making a profit. Therefore, the ownership and handling of the exact type of information should be discussed at the beginning of a project and described in the contract. While Const. Eng. 2 believes that the Partnership contract can help them to share the information in less time, Eng. BIM argues that ABT06 is a suitable contract type that lets the parties share the information without limitations, regardless of risking the company's loyalty, as using AB04 might cause.

5.4.4 LOD and stages of Design

The classification of design stages is somehow related to LOD. In other words, the three stages of the project, Pre-design, Schematic Design, and Detailed Design & Construction Document, are relatively related to the six levels of development which vary from LOD 100 to LOD 500 as Const. Eng. 1 and Beetz et al. (2018) argue. According to Arc. BIM 6, Const. Eng. 2, Const. PM, Eng. BIM, Berner et al. (2016), and Eastman et al. (2011), the Pre-Design is the first design stage with basically no details in the model. Instead, it is only design sketches containing ideas, volumes, areas, and zones. According to Berner et al. (2016), the Program document's content is the basis for future decisions.

The next stage of design is Schematic Design which, according to Arc. BIM 6, Const. Eng. 1, 2, and Const. PM, the structural and installation systems are defined. According to Berner et al. (2016), Roos (2021), and Eastman et al. (2011), the materials and technical systems are also investigated to know the advantages and disadvantages of each. According to Berner et al. (2016) and BCA (2013), in this stage, the model has more detail with approximate dimensions, shape, location, quantity, and orientation compared to Pre-Design This stage is the basis for the cost calculation according to both Arc. BIM 1 and Projektledning (2018). As Arc. BIM 1, Const. BIM, Latiffi et al. (2015), Broberg (2018), and De Cos Castillo (1997) explain that the more the model is developed in detail, the more accurate the calculations for quantity take-off, time scheduling, and cost calculation will be. Therefore, with precise calculation, the future changes will be less, and the budget will be saved.

The last stage of Design is the Detailed Design & Construction Document, which is according to Arc. BIM 6, Const. Eng. 1, Eng. BIM, Roos (2021), Projektledning (2018), Eastman et al. (2011) and BCA (2013) the most detailed stage among all. In this stage, the model is accurately developed, which contains exact dimensions and information according to the requirements, and it is what is going to be built. According to De Cos Castillo (1997), Haines (2012), Eastman et al. (2011), and BCA (2013) in Detailed Design & Construction Document, the architects and contractors are in direct continues contact to inform changes to each other until the model is finalized and the cost estimation and scheduling are provided.

Arc. BIM 1 and Const. Eng. 1 discusses that depending on the project's size and how the contractor will use the model, the LOD in the Project Planning Document could be high or low regardless of developing the Detailed Design & Construction Document. Also, Arc. BIM 3, 5, and Const. BIM mention that there is no framework for using LOD in the projects. Therefore, it seems that the lack of guidelines for developing the model in detail could confuse how much the model should be built in detail in the different stages of design. In other words, as Blomberg (2019) argues, with this lack of framework and classification regarding LOD in the 3D models, the trust in the model could be decreased, and the contractors would be unsure if the model is developed with enough detail or not. Although, Const. Eng. 1 argues that BEAST is a newly developed guideline for this issue. The interviewees barely knew if there were any demands or requirements of LOD in their projects, and their expectations from the project's development were based on their experience. Therefore, it could be argued that which a proper framework for using LOD in the different stages of design, the unnecessary development of the project in the early stages would be avoided.

Arc. BIM 1, 2 and Eastman et al. (2011) argue that the early stage of design ought not to be developed in detail because there are often many changes that happen in the early stage, and if there are lots of details, it takes much time and effort to change everything. Nonetheless, Arc. BIM 2 believes that the common BIM programs are developed so that designers need to develop the early stages in detail. At the moment, Const. BIM explains that contractors do not set any requirements on how the architect should sketch until the last part of the design. Therefore, they are not involved when the architects develop Program documents and Project Planning Documents. Thus, the AB04 is not a proper contract for collaborating contracts and architects regarding LOD. Because in AB04, the contractors are involved in the project where the design has been developed much further. Then, when the contractors want to construct the building, many things need to be adjusted, which takes a long time and effort for the contractors to do. Hence, there is a need to employ other types of contracts, such as ABT06, ABK09, and Partnership, in which the contractor can put the requirement on LOD for architects from the early stages of design.

5.5 Future

Regarding the future of BIM, most interviewees referred to the software and mentioned that transformation in BIM software is necessary. Half of the architects and Eng. BIM emphasize that the future of BIM is the open format in which the BIM any software does not bound to BIM. Arc. BIM 2 and 5 also believe that the BIM model will be controlled in a web interface format that will be available by connecting to a portal.

One of the limitations of implementing BIM is the high cost of the software and tools according to Arc. BIM 6, Const. Eng. 2, Const. PM and Eng. BIM, which makes it difficult for small companies to apply it. Lindblad (2013) and Norberg & Brantitsa (2018) also believe that the current software is complicated and not user-friendly in order to get the desired information from them. Arc. BIM 3 agrees that the users, specifically the older generation, have difficulty using the software and tend to fall back in old habits. Const. Eng. 1 believes that the young generation is better at using BIM software. Hence, almost half of the interviewees believe there is a need for a generation shift and better software and technical equipment because the old generation lacks competence in using BIM software and is less willing to change. However, Arc. BIM 4 mentions that it is essential that education is available for everyone to increase the employees' competencies of BIM. According to Sundquist et al. (2020), Arc. BIM 2 and Const. BIM, the feature of filtering information could be a solution for the lack of user-friendliness in BIM software. As most of the interviewees mentioned, the BIM software is needed to be developed more for people on construction sites since, as Const. Eng. 1 emphasizes that they work well for architects and structural designers. In the future, it is expected that an open format might be a solution for having the BIM model on the construction site due to the accessibility.

Another limitation regarding BIM, which hinders the transition of becoming entirely model-based and needs to be solved in the future, is the necessity of having the BIM model as a legally binding document as Arc. BIM 5, Const. Eng. 1, 2, and Disney et al. (2021) discuss.

Const. Eng. 1, 2 and Josefsson & Lindhe (2020) share the same perspective that having guidelines, standardizations, and parameter classifications in using the model would solve many issues such as miss-communication and the absence of the BIM model as a legally binding document and problems in transferring knowledge. Eckerberg (2017) also discusses having the standards for classifying information in the model could minimize administrative work and improve sharing of information in the design phase. As Arc. BIM 2 and Const. Eng. 2 argue, that by the framework and common standard, people could know what information needs to be in the model and have the same approach towards the BIM model. One could argue that this could solve the problem as Arc. BIM 1 describes it is hard to determine which part of the model is ready to be built. According to BEAst BIM (n.d.) and Arc. BIM 2, BEAst could be a solution toward having the same goal by providing instructions, templates, and guides applicable in the AEC industry.

Arc. BIM 3, 4, Const. PM and Dakhil et al. (2019) argue that the client, in many cases, lacks knowledge regarding the BIM software and Arc. BIM 6 adds a lack of clear demands and requirements from the client at the beginning of a project. It can be argued that the client's lack of knowledge, demands, and requirements complicates the cooperation between the different parties, which affects the project. It would be difficult for the client to be involved in the process and give the contractors and architects clear demands of what information is needed in the BIM model when the client does not have enough knowledge about BIM.

Another common issue discussed by both the literature and the interviewees is the trust in the BIM model. It could be discussed that one most likely will not use the model if one does not have confidence in it and believes that it works. Arc. BIM 2 and 5 believe that by a proper agreement for delivering the correct information and checking the model's accuracy regularly, the trust in the model would increase. Chon et al. (2017) also explain that the intellectual right of the data needs to be defined from the beginning of the project and handling the BIM data ought to be clearly mentioned. The intellectual right is in terms of the privilege of being the owner of BIM data and being responsible for information taken out from it.

Const. BIM, Const. Eng. 1, 2, and Const. PM believes that moving toward a fully model-based approach will happen partly in the future. Const. BIM adds that this transformation will take time and not happen very soon. Arc. BIM 1 and Const. PM believes that people in the AEC industry, in the future, will not print the documents and will instead use the digital format of the needed drawings. Const. PM adds that the clients will know the value of 3D models in the future, and they will demand it to ensure that the 3D model will be archived for the future. One could argue that in the case of accepting the BIM model as a legally binding document, the model can be used as the archive documentation of the buildings in the future instead of 2D drawings. In other words, if the client demands BIM implementation in the design and construction process, later, the model could be used for digital twins, which is helpful for subsequent referrals. The digital twin is a technology used to maintain buildings that monitor the buildings to improve the operations and increase efficiency through real-time data collecting. (Khajavi et al., 2019)

Arc. BIM 3 emphasizes the role of big contractors as leaders of the AEC industry and believes that they must put demands on the architects regarding what they should produce and deliver in the BIM model. Therefore, it could be argued that there is a need for a framework that defines the demands on architects from the contractors. Arc. BIM 4 and 5 believe that the other technologies will be used in BIM in the future, such as Artificial Intelligence (AI), because more data types will be used. They believe that these new technologies will mainly help with cost calculation. Arc. BIM 5 also predicts that the BIM infrastructure will be expensive in the future, and the BIM department in consulting companies will expand. It could be claimed that, since the adaptation to the fully model-based industry is a time-consuming process, the new technologies might be used through BIM in the AEC industry. Also, these new technologies probably can facilitate the use of BIM and might increase the pace of this adaptation.

6. Conclusion and suggestions

The study aimed to examine what is missing to achieve a fully model-based AEC industry and investigate the relationship between architects, contractors, and clients from different perspectives and how their relationship might affect the implementation of BIM. In addition to this, the thesis also intended to find out the different perspectives regarding the presentation of information and if it is presented efficiently through the model and, if not, how it should be in the future.

It was discovered that there is confusion about BIM and that various people describe BIM differently. This variety could be because of the lack of frameworks for using BIM and because people do not know how to handle BIM information. Depending on the size and type of both companies and projects, architects, engineers, and contractors face BIM with different approaches and at different levels of use.

Contracts play an important role in the relationship between the named parties. In fact, this is the contract that defines their relationship and their responsibilities towards one another. However, regarding BIM, the contracts are not helping the architects to sell their tasks through BIM because current common standards of contracts only support 2D drawings. Moreover, it was found that the involvement of all the parties from the beginning of the project to the end is essential, but some types of contracts do not support this full involvement. This issue is very much hand in hand with the expectation of the contractors from the architects and the model they provide. If the contractors intend to use the BIM model on the construction site but are not involved at the beginning of the project, they would not be certain about the LOD of the model, which might result in a low level of trust in the model. Therefore, it is essential that the contractor and architects work together from the early stages of design and that the contractors require a specific LOD at different levels of the project to develop a trustworthy BIM model.

Furthermore, the different stages of design demand different expectations, levels of development, and details. It was discovered that there is no framework or guideline to help the architects and contractors know how the BIM model should be developed in different stages of design. However, the BEAst was the earliest endeavor for developing this guideline exists, but it has not been proven regarding its effectiveness.

Another finding was that there are uncertainties about the ownership of the BIM model while the standard contracts do not support the rights of architects, contractors, and clients. The architects and engineers do not want to give away their models because it is their source of information, and the contractors want to have the entire BIM model so that they have more freedom to use its the information. In this context, it is essential that the BIM model becomes part of the contract, and that the client owns it to be used throughout the project by all actors. Furthermore, the clients believe that they are the owner of the whole model because they pay for it. Hence, the involved parties prefer not to use the BIM model and are more partial to traditionally obtaining the information since it is more secure. Unless they use contract types such as Partnership, all the risks and profits of the project are shared among all.

By analyzing the empirical part, there are no precise demands on required information from everyone to produce the BIM model. However, it is assumed that the same information for developing 2D drawings is required for creating 3D models. But there is a big problem because today, architects put too much time and effort into producing both 3D models and several 2D drawings. Most of the interviewees believed that some 2D drawings are unnecessary to produce, and the clients and contractors do not know exactly why they demand specific types of drawing that they probably do not need. A solution for this issue can be that the 2D drawing is provided as a mega-PDF and the specific necessary 2D details are produced as a supplementary with the BIM model, which Dalux can view.

When analyzing the findings, another identified factor behind the slow transformation towards being entirely model-based in the AEC industry is the absence of user-friendly software. One solution for this is the property set, a valuable feature of the IFC model. It helps users filter the model's information and facilitates their work to increase efficiency. Also, the solution of the cloud-based version of BIM was introduced that gives access to the model to everyone without any limitation of software types and computer tools and high costs, regardless of their location.

Moreover, it was found that not having the BIM model as a legally binding document is one of the main barriers to implementing BIM. This barrier demands a fundamental change in the jurisdictions of the AEC industry, which requires effort from large companies as significant players in this industry to make this change happen. In the case of transformation in legally binding documents and accepting the BIM model as one of the documents for the building permit, the client's requirements would change entirely. Since the clients' knowledge about BIM is limited today, the clients need to enhance their understanding of BIM tools and their capacities. It was also noticed that there is a lack of willingness and knowledge in the older workers in the construction sites towards using BIM. However, an increase in requiring BIM from clients would result in obliging the older generation to align themselves with the overall change. The old generation is one of the reasons why this transformation is taking so long. Employing the younger generation might be the simplest and most cost-effective approach to making this transformation. Therefore, a generation shift is necessary for implementing BIM in the AEC industry that needs time to take place. Although, the generation shift can result in the loss of knowledge and experience of the older generation, which has been gathered over the years. Today's AEC industry is still on the way to becoming fully model-based, and this significant change will take time. However, it might not happen ultimately, and the BIM model will be used with the combination of 2D drawings in the near and far future.

Moving from 2D drawings to the fully model-based AEC industry is a time-consuming transition that will not happen immediately. These long-term transitions have started with a combination of 2D drawings and 3D models. It needs to decrease the 2D drawings gradually to reach an entire model-based AEC industry. It is possible by improving the functionality of BIM models.

The list of the findings according to the research questions is as follows:

RQ 1: What is lacking in the construction industry to transform towards being entirely model based?

- Absence of BIM model as a legally binding document
- Lack of frameworks:
  - Frameworks of demands and requirements in the design stage
  - Frameworks of LOD
  - Framework of property sets
  - Framework of developing BIM model in the design stage
- Trust in the BIM model
- Lack of knowledge, competence and willingness for both workers and client
- Lack of clear demands on required information to produce the BIM model
- Lack of user-friendly software

RQ 2: How should the relationship between architects, contractors and clients be to achieve fully model based design and construction?

- They should discuss at the beginning of the project about handling the BIM model and what information should exactly be delivered
- Avoid requesting information and documents that are not necessary for contractors
- They should make decisions about the ownership of the model
- Using ABT06 and Partnership types of contracts
- The contracts should support BIM implementation
- Communicating, sharing and exchanging the experience and knowledge of BIM

RQ 3: How should the information be produced, shared and presented efficiently?

- Developing information in different stages of design according to LOD
- More user-friendly property sets in IFC models
- Open format
- Could-based BIM
- Mega PDF
- Using software for viewing BIM model such as Dalux

Considering the literature and the results of this study, investigating the areas of "Open format" version BIM and "Property sets" in the IFC model could be supplementary studies to this thesis. Another suggestion for further studies could be to investigate smaller companies that are less familiar and established using the technology. A study that can explore the barriers to implementing BIM by small companies and the challenges that they would face. The other improvement area that could have been interesting for further studies is studying the client’s perspective to see their perspective and their current level of knowledge regarding BIM. Moreover, regarding “BEAst” as the latest framework for the use of BIM in the design stage, further research could be essential to examine if the framework is being used efficiently or not. As mentioned in the discussion, the BIM model after the construction stage could be used for archiving and being used for later referrals. Therefore, studies in “Digital Twins” could be an additional study investigating the further steps of using the BIM model after the building’s construction is finished.

7. References

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Appendix I

Interview Questions for Construction Companies

Background questions

1. What is your profession in the company?
2. For how long you have been working in the industry?

The Current stage of BIM

3. What is BIM to you?
4. Have you any experience with working in a project that is based on only BIM like 3D-models?
    a. How do you use BIM in your projects?
    b. Do you only use BIM in the design phase or in the production phase as well?

Main questions

5. What benefits does 3D models have in comparison with 2D drawings?
    a. In the design phase
    b. In the production
6. What are the drawbacks of only using 3D models in a project?

Information

7. What information is needed to produce 3D-models/BIM compared to 2D-drawings?
8. Who decides what information have to be produced in the design phase?
    a. What are the contractors' demands regarding needed information from architects?
9. How is the information shared between architects and contractors?
10. How is the information presented and handled today in the BIM model?
    a. Is it presented in an efficient way in the BIM model?
11. Are all the drawings generated today needed?
    a. Which one is not needed?
    b. Which 2D-Drawings cannot be replaced by 3D models?

Contracts, Agreement

12. What type of contract do you usually use in your projects?
    a. How is the agreement between architect and contractor, regarding the way of payments etc.
    b. Does the type of contract affect the relationship between architects and contractors?

c. Does the type of contract affect how the information is shared?

13. What levels of Development (LOD) is required:
    a. In the Pre-Design/Conceptual Design (Programskede)
    b. In the Schematic Design (Systemskede)
    c. In the Detailed Design/Construction documents (Bygghandlingsskede)

Future

14. How should the information in 3D models/BIM be shared and presented in the future to be more efficient according to you?
15. What limits the construction industry? What is lacking to transform towards being entirely model based?
16. What needs to be changed in order to reach a fully model-based design and production?
    a. Is the legally binding an issue, skills, knowledge, software, cost, trust.
17. What are your expectations for model-based design and production in the future?

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