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MASTER THESIS

TITLE OF REPORT	DATE
BIM implementation and adoption in the Architecture, Engineering and Construction industry.	24.05.2022
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AUTHOR(S) Steinar Strømnes	SUPERVISOR(S) Ann Karina Lassen

IN COLLABORATION WITH	CONTACT PERSON

SUMMARY / SYNOPSIS

BIM is emerging as the industry standard approach to the modelling and management of building lifecycles from design phase until maintenance and demolishing (Lam et al., 2017). Despite the fact that BIM aims to work as an integrator, it is creating a "digital divide" between the large firms and the small firms, even when they both belong to the same industry. The large firms are considered as "BIM compliant" while the small and medium enterprises (SMEs) are perceived to be "BIM complaint"(Dainty et al., 2017).

It has been of great interest to look closer into BIM adoption and implementation in the Architecture, Engineering and Construction (AEC) industry. To address this topic a mixed methodology were approached. The mixed methodology consists of interviews, digital survey and a literature review.

The results revealed that almost all organizations in Norway used some form of BIM in their projects. However, the results showed large variations in levels of use and actual use of BIM, where 3D modelling in the design phase was the dominating feature. When assessing the barriers and driving forces related to BIM adoption and implementation, a large number of various factors were revealed. The results showed that the prevailing culture in the industry had large effects on the BIM adoption and implementation. Finally, it was revealed that although not all SMEs are laggards, all laggards are SMEs based on time of adoption.

KEYWORDS
Building Information Modeling (BIM)
Small and Medium-Sized enterprises (SMEs)
Architecture, Engineering and Construction (AEC) industry

Preface:

This master's thesis was completed spring semester 2022. The thesis marks the end of a 2-year Master's degree in Structural Engineering and Building Technology at OsloMet. The thesis gives 30 credits corresponding to one full semester.

The topic of the thesis is 'BIM adoption and implementation in the Architectural, Engineering and Construction (AEC) industry'. The topic might be considered to belong to past-times, because BIM has been around for quite some time. If considering BIM entirely as a tool for 3D modelling, the presumption might be right. Through increased knowledge about BIM and the benefits BIM can provide if exploited in a proper manner, I have understood that this topic is highly relevant also in 2022. This is due to the fact that BIM is so much more than just 3D visualization and 3D design, even though many organizations seems to consider this to be the fact.

Working with the thesis has been exciting and educational. The knowledge at the start of the thesis was primarily concentrated to BIM as a 3D modelling tool, were I had expertise in relation to the use of 3D modelling tools such as Revit Structure. Through the work on the thesis, I have gained an understanding that BIM is so much more and can bring huge benefits to the whole AEC industry. This new understanding of what BIM really is will be beneficial for me when starting to work in the AEC industry myself. During the work, I have been overwhelmed by the amount of information and different interpretations of what really lies within the term BIM. All this information has sometimes been hard to organize within my own head, but I have tried to prioritize and extract the most relevant information.

I want to thank my supervisor Ann Karina Lassen for professional guidance through the whole process, helping me to understand adoption and implementation of BIM through accepted theories focusing on social science. I will thank Pro-Consult (future employer) for having an office available during the time of the thesis. I will also thank all the interviewees and survey participants for their contribution, which made it possible to conduct the thesis.

I will thank my parents and mother-in-law for helping me out babysitting my youngest son, making it possible for me to finish my Master's degree. Especially my mother in law, coming from Sweden for several weeks has really helped me out in a time with a lot of BIM. Finally, I want to thank my wife and three kids for helping me to focus on other topics than BIM and for support through the entire process.

Hamar, 24. Mai 2022

Steinar Strømnes

Abstract:

The topic for this master's thesis is: "BIM implementation and adoption in the Architecture, Engineering and Construction industry". The topic was originally proposed by SWECO Hamar and has been further developed in collaboration with supervisor Ann Karina Lassen. The thesis is based on a mixed methodology approach, using both quantitative and qualitative methods.

A building description system (BDS) was introduced already in 1975, this is seen as the origin of Building Information Modelling (BIM) (Eastman, 1975). BIM is emerging as the industry standard approach to the modelling and management of building lifecycles from design phase until maintenance and demolishing (Lam et al., 2017). Despite the fact that BIM aims to work as an integrator, it is creating a "digital divide" between the large firms and the small firms, even when they both belong to the same industry. The large firms are considered as "BIM compliant" while the small and medium enterprises (SMEs) are perceived to be "BIM complaint"(Dainty et al., 2017).

Based on the information above, it has been of great interest to look closer into BIM adoption and implementation in the Architecture, Engineering and Construction (AEC) industry, in order to get an overview of the use and level of use of BIM, and to find the barriers and driving forces. There has been a specific focus on the differences between SMEs and the large companies, to reveal whether the "digital divide" also applies to the Norwegian AEC industry. The results from the thesis were analyzed through the use of three different theoretical lenses, making it possible to benefit from the robust knowledge of sociology and psychology, on which the theories were built. According to Hosseini et al. (2015, cited-in:Saka & Chan, 2020), neglecting theoretical lenses when studying any type of innovation seems irrational. To approach the abovementioned topics, three research questions were created. They are intended to cover the following three topics: mapping of BIM use and level of use in the Norwegian AEC industry, barriers and driving forces related to BIM adoption and implementation, and finally looking at whether Norwegian SMEs can be referred to as laggards in the Norwegian AEC industry.

To address the research questions a mixed methodology were approached. The mixed methodology consists of interviews, digital survey and a literature review. Choosing a mixed methodology made it possible to benefit from both the contextualized insights of qualitative data and the generalizable quantitative data.

The results revealed that almost all organizations in Norway used some form of BIM in their projects, where just 5 % answered that they never used BIM in their projects. BIM was primarily used for 3D modelling in the design phase, clash detection and quantity takeoffs. However, 4D, 5D, 6D and 7D were less exploited in current projects. Features meant to facilitate for better collaboration and information management, such as CDE and OpenBIM standards were also less exploited. A correlation between BIM use and project-size was found, where it was clear that larger projects above 200 MNOK exploited BIM to a much greater extent than the remaining projects.

In order to assess the companies' BIM level, the Bew-Richards BIM maturity model was applied. The model divides the BIM maturity into 4 levels (Saka & Chan, 2020). This ranges from level 0 which is considered as pre-BIM stage to level 3 where all data are supposed to be fully integrated into a single interoperable model (Saka & Chan, 2020). It was found that BIM level 1, 2 and 3 were used in 49 %, 46 % and 5 % of the organizations, respectively.

When assessing the barriers and driving forces related to BIM adoption and implementation, a large number of various factors were revealed. The barrier perceived by many organizations was the cultural resistance towards change and recurred in most of the data obtained for the thesis. Differences in perceived barriers according to company size were also revealed. Barriers such as lack of time, concerns regarding return on investment and lack of expertise were perceived to a greater extent among SMEs. Regarding the driving forces for adoption and implementation, many organizations pointed out the innovation attributes, such as better collaboration and improved project information management. Despite this, the literature underlined that the innovation attributes alone might not be sufficient for further adoption for SMEs, and that there was still a need for external factors such as mandate or peer pressure for further motivation or coercion to adopt.

The results revealed that SMEs could not be referred to as laggards based on time of adoption, as a large number of small organizations adopted BIM at an early stage. However, all companies that had not adopted BIM are SMEs. This proves that although not all SMEs are laggards, all laggards are SMEs, based on time of adoption. The results also show that the SMEs may be referred to as laggards with regards to their BIM level.

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List of abbreviations:

AEC: Architecture, Engineering and Construction

Barriers: Constraining factors which is hindering the implementation and adoption of BIM

BIM Maturity Level or BIM-Level: Describes the different levels of maturity of BIM use (Abbasnejad & Moud, 2013). Closely linked to the information management.

BIM: Building Information Modeling

CDE: Common Data Environment

Driving forces: Factors which is considered to increases the adoption and implementation of BIM

DT: Digital Twin

HMS: Helse, miljø og sikkerhet

ICT: Information and Communications Technology

IDM: Information Delivery Manual

IFC: Industry Foundation Class

IFD: buildingSmart data dictionary

MMI: Model Maturity Index describes the maturity of an object in a BIM model.

ROI: Return on investment

SMEs: Small and Medium-sized enterprises

1 Introduction

1.1 Background

A building description system (BDS) was introduced already in 1975, this is seen as the origin of Building Information Modeling (BIM) (Eastman, 1975). BIM is known as a process, a new technology and methodology that provides accurate data and processes for all the involved stakeholders (Kouch, 2018). Building Information Modelling (BIM) is emerging as the industry standard approach to the modelling and management of building lifecycles from design phase until maintenance and demolishing(Lam et al., 2017). BIM aims and functions as a unifying process in a fragmented construction industry (Saka & Chan, 2020). Despite the fact that BIM aims to work as an integrator, it is creating a "digital divide" between the large firms and the small firms, even when they both belong to the same industry. The large firms are considered as "BIM compliant" while the small and medium enterprises (SMEs) are perceived to be "BIM complaint" (Dainty et al., 2017). The firms of different size face different economic and social challenges, which leads to different organizational structures and behaviors. Due to this differences in perceived barriers SMEs have been reported to be lagging behind larger firms in the adoption of BIM(Saka & Chan, 2020). The adoption of BIM is not only necessary but also unavoidable for SMEs in the Architectural Engineering and Construction (AEC) industry, because SMEs that are not "BIM compliant" would lose out of business share (Kouch et al., 2018). This makes them lose out on many possible projects both in the publicly funded and possible private sector(Lam et al., 2017). This trend may possibly continue if SMEs do not start investing in new technology and restructuring their organizations to meet new demands in the industry. MultiBIM presented a survey (2018) conducted by McKinsey where it is stated that the most digitized sectors in US are maintaining a considerable lead over the rest of the US economy, while those who are behind from the beginning and do not join the innovation process often tends to stay behind, while the gap is continuing to increase.

There is no universal definition of SMEs and it varies across different boundaries. However, regardless of definition they have similar characteristics (Saka & Chan, 2020). The European Commission defines micro, small and medium-enterprises as those employing fewer than 10, 50 and 250 people respectively (Dainty et al., 2017). According to the European Commission (2015) about 90 % of the firms are SMEs, including micro, small and medium-sized enterprises with up to 250 employees and 50 million Euros in annually turnovers. "Næringslivets Hovedorganisasjon" in Norway defines SMEs as companies with less than 100 employees and defines small companies as organizations with 20 or less employees(*Fakta om små og mellomstore bedrifter (SMB)*, NA). In Norway 99 % of all companies are defined as SMEs, while 47 % of the total work force are employed within SMEs.

A definition of BIM adoption and BIM implementation are also necessary as they are often used interchangeably in numerous studies (Saka & Chan, 2020). BIM adoption is the decision to either adopt or reject BIM innovation in their organization. A large number of factors (driving-forces and barriers) can affect the decision, this can be factors related to the external environment, the internal environment or from the innovation attributes of BIM (Saka & Chan, 2020). BIM implementation follows the decision to adopt BIM, as it involves implementing BIM in the organization. The implementation can occur in different stages such as object-based modelling, model-based modelling and network oriented integration (Saka & Chan, 2020). To give reference for adoption, the UK government created a BIM maturity model, often known as the BIM wedge diagram, where it divides the BIM maturity into 4 levels (Saka & Chan, 2020). This ranges from Level 0 which is considered as pre-BIM stage to Level 3 where all data are supposed to be fully integrated into a single interoperable model (Saka & Chan, 2020).

The overarching benefits of BIM are well documented, still many SMEs in the AEC industry are not yet convinced about the benefits that BIM brings to the organization, while they remain concerned about possible risks (Hochscheid & Halin, 2020). Many governments across the globe would like to see a higher rate of adoption in the AEC industry in order to progress in their digital economy strategy (Ayinla & Adamu, 2018). BIM is being a core element of the UK Governments Digital Built Britain strategy, where the intention is to improve the industry's performance. The targets is to reduce the initial cost by 33 %, 50 % reduction in overall time for inception to completion, 50 % reduction in greenhouse emission and 50 % reduction in trade gap between import and export of construction materials, all this by 2025(HM government, 2015, cited in:Ayinla & Adamu, 2018). As an aid to reach the goal BIM Level 2 was mandated for all centrally procured assets by 2016. The target in the UK Governments Digital Built Britain strategy has many similarities with the Norwegian equivalent "Digitalt Veikart for Bygg-, anleggs, og eiendomsnæringen for økt bærekraft og verdiskapning". Where the overreaching goal for the report is to make the Norwegian AEC industry fully digitized within 2025 (Byggenæringenslandsforening, 2017). The Norwegian AEC industry is considered among the leading countries regarding BIM adoption and implementation (Edirisinghe & London, 2015).

The construction industry is a complex industry with a lot of stakeholders and many different activities. This, combined with the lack of innovativeness when it comes to applying new technologies, processes and methods, in comparison to other industries has made it difficult for the AEC industry (Azhar, 2011). The outcome is that productivity, efficiency, quality and profit are decreased and waste, risk, duplicating activities and repetitive mistakes are increased. BIM is one of the innovations that are being embraced in many countries due to its overarching benefits to help the AEC industry out of this vicious circle (Ayinla & Adamu, 2018). Even tough SMEs and large firms operate in the same AEC ecosystem, they are quite different in their socio-economic categories and live in separate business habitats. This research aims to shed light on the possible differences between the large companies and the SMEs regarding BIM adoption and implementation.

1.2 Problem statement

Based on the information above, it has been of great interest to analyze the Norwegian AEC industry, to get an overview of the use and Level of use of BIM in addition to finding the barriers and driving forces regarding the adoption and implementation of BIM. There has been a specific focus on the differences between SMEs and the large companies, to reveal if the "digital divide" also is applicable to the Norwegian AEC industry. Especially since there is limited amount of Norwegian literature based on this specific topic.

The barriers and driving forces for BIM adoption and implementation are contextualized and analyzed in a theoretical lens, where the Diffusion of Innovation, Theory of Planned Behavior and Institutional Theory is used. Hosseini et al. (2015, cited-in:Saka & Chan, 2020) underlines the importance of using theories to be able to conceptualize innovation studies and to benefit from the robust knowledge on which the theories were built. The use of theories explaining human actions are important due to the fact that BIM is stated to be 10 % technology and 90 % sociology (Deutsch, 2011).

Rogers(2003) modelled innovation adopters using a normal bell shaped curve and his model has experienced wide acceptance. This model explains that for every new innovation, there are bound to be laggards, late majority, early majority, early adopters and innovators according to their time of adoption. This model has been applied to see if the SMEs could be classified as the "laggards" regarding time of adoption, and also been used to analyze if the SMEs could be referred to as "laggards" regarding their Level of use and general utilization of BIM.

1.2.1 Research question

This paper do not have a main research question. The title is "*BIM implementation and adoption in the Architecture, Engineering and Construction industry"* and the aim for the paper is to unveil the use and Level of use of BIM in addition to find the barriers and driving forces regarding the adoption and implementation of BIM. It has been of specific interest to reveal if there are any differences between the SMEs and the large companies in the AEC industry. To make this possible, three research questions needs to be addressed:

1. In which ways and at which Level is BIM utilized in the Norwegian AEC industry? Are there any differences related to either company size or project size?
2. Which barriers and driving forces exist for BIM adoption and implementation? Are there any differences related to company size?
3. Could Norwegian SMEs be considered laggards regarding BIM adoption and implementation?

1.3 Scope and Limitations

The master's thesis is completed within 20 weeks from the start date 01.01.2022. The thesis gives 30 credits corresponding to one full semester.

BIM is a comprehensive theme. Based on this, it has been necessary to make some limitations for the thesis. The thesis concentrates on BIM adoption and implementation with a holistic approach. Rather than concentrating on specific BIM features.

During the master's thesis, the researcher experienced that new and interesting topics are constantly emerging. Through this work, input, experiences and tips have contributed positively, but also contributed to some confusion and challenges about where to set the limitations for the thesis. Therefore, the author of the thesis had to assess and prioritize which aspects it is desirable to include in the master's thesis.

1.4 Thesis Structure

The master's thesis is structured as follows:

Chapter 1: Introduction

Initially, the theme and background for the master's thesis is presented. This forms the basis for the problem statement, research question and scope and limitations.

Chapter 2: Methodology

In the methodology chapter, a general presentation of the different methodologies will be presented. The second part of the chapter present and explains the choice of methodology in addition to a methodology framework for the data collection.

Chapter 3: Theoretical Lens

Three different theoretical lenses are presented and will work as a basis for the discussion chapter where the results are discussed in a theoretical lens.

Chapter 4: Theoretical Background

A theoretical background regarding BIM are presented. This information works as a basis for the results of the thesis.

Chapter 5: Findings from Literature Review

The key findings from the literature review are presented.

Chapter 6: Findings from interviews

This chapter presents the key findings from the three interviews.

Chapter 7: Results of Surveys

This chapter presents the key findings from the digital survey, which was conducted with 40 companies in the Norwegian AEC industry. This includes organizations with different professions and company-size.

Chapter 8: Discussion of results in a theoretical lens

The results from the three previous chapters are discussed and conceptualized in a theoretical lens.

Chapter 9: Conclusion

In this chapter, the three research questions are answered, and finally recommendations for future work is presented.

2 Methodology

The methodology chapter is included in the master's thesis to document how the work with the report has been completed. Initially, general research methods and research strategies are presented. This is followed by a justification of the chosen methodology and a description of these methods.

2.1 General

Dalland (2007) describes methodology as something that tells us how to proceed to acquire or test knowledge. It describes what needs to be done to respond to the research question. The choice of methodology should be justified to an extent where it shows that it will provide acceptable data and make it possible to enlighten the research question in a professional and interesting way.

2.1.1 Qualitative and Quantitative research

When it comes to collecting data, there is a main difference between quantitative and qualitative methods. According to Dalland (2007), quantitative methods aim to change the information to measurable units, which provides opportunities to perform arithmetic operations such as averages and percentages of large quantities. Qualitative methods are used to capture opinions and experiences of individuals or groups. According to Samset (2014) qualitative information describes the whole picture while quantitative information gives a precise description. Sinaga (2014) explains key aims for the two research methods.

Table 1 Summarizing of key aims for the two methods REF: (Sinaga, 2014)

Qualitative research	**Quantitative research**
To identify new phenomenon.	To gather information from a relatively large number of participants.
Provide deep understanding of processes.	To provide numerical or rating information
Provide information, which can be transferred to numerical form.	Allows generalizing to broader population
	Collected data could be applied with statistical techniques that allow determining relations between variables.

Sinaga (2014) also summarize some of the limitations regarding the two research methods.

Table 2 Summarize of limitations of qualitative and quantitative research methods. REF: (Sinaga, 2014)

Qualitative research	**Quantitative research**
Cannot generalize the population	Difficult to recognize new and untouched phenomenons, specially finding out "why"
Could be difficult to apply with statistical methods	Framed in statistical design, causes limited conclusion
The effectiveness depend on the researchers as an instrument of research	

2.1.2 Validity and reliability

The term *validity* is used to characterize the credibility of the information, and implies by definition that there is a correspondence between reality and interpretation (Samset, 2014). Validity is about the degree to which one can draw a valid conclusion from the results. This requires that the data which is collected is relevant to the research question. *Reliability* is used on stability in measurements. Reliability is about the reliability of the data, and says to what extent the test is reproducible or how large the margin of error the method is encumbered with (Sackley, 1993). If several independent measurements of the same phenomenon give the same or approximately the same result, the test is considered reliable. The validity and reliability are assessed independently for the chosen methodologies later in the chapter.

2.2 Choice of methodology

A mixed method has been approached in order to answer the research questions in this master's thesis. Definition of a mixed-method study is one which the research uses at least one quantitative and one qualitative method to make the collection, analyze, and to report the findings in a single study (Greene et al., 1989). This is completed using literature study, semi-structured interviews and a digital survey. Choosing a mixed method made it possible to benefit from both the contextualized insights of qualitative data and the generalizable quantitative data. This chapter will describe why this method has been chosen and how they are conducted.

According to Fellows and Liu (2021) research methods are not normally exclusive, but due to resource constraints, usually only one or a few methods will be used. The goal of this paper is to create a holistic understanding of BIM adoption and implementation in the AEC industry, with special focus on small- and medium sized enterprises (SMEs). A mixed-method was considered appropriate to be able to provide deep understanding and to gather information from a large number of participants, which both are important aspects required to answer the research questions.

The methodology and research strategy used for the qualitative data in this paper are literature-review combined with semi-structured interviews. By choosing a qualitative method as a basis for data collection, one can choose between several methodological directions. The choice of qualitative research method is made when the main interest is to develop the understanding of phenomenas related to people and situations in their social reality (Dalen, 2004). Qualitative research processes entail that the researchers are constantly standing in the face of choices, and the researchers should have professional and ethical reasons for the choices that are made. Most of the qualitative research have in common that they use interviews alone or together with other methods (Ryen, 2002). Snyder (2019) states that building your research on and relating it to existing knowledge is the building block of all academic research activities, regardless of discipline. Therefore, both interviews and a literature review are chosen as part of the qualitative research strategy. The semi structured interviews and literature review has also been chosen due to the author's familiarity with the two strategies. Autumn 2021 the author completed a project using the two strategies, and experiences from this work are considered to have a positive influence on the master's thesis.

For the quantitative data collection, a digital survey has been completed with different companies from the AEC industry in Norway. The reasoning behind this was to gather data on Levels of use, specific BIM use and the barriers and driving forces related to the adoption and implementation of BIM. This made it possible to obtain a sufficient amount of quantitative data, making it possible to answer the research questions.

A methodology framework for data collection is presented below. The framework addresses which methods that have been used to answer the three research questions.

1. In which ways and at which Level is BIM utilized in the Norwegian AEC industry? Are there any differences related to either company size or project size?
2. Which barriers and driving forces exist for BIM adoption and implementation? Are there any differences related to company size?
3. Could Norwegian SMEs be considered laggards regarding BIM adoption and implementation?

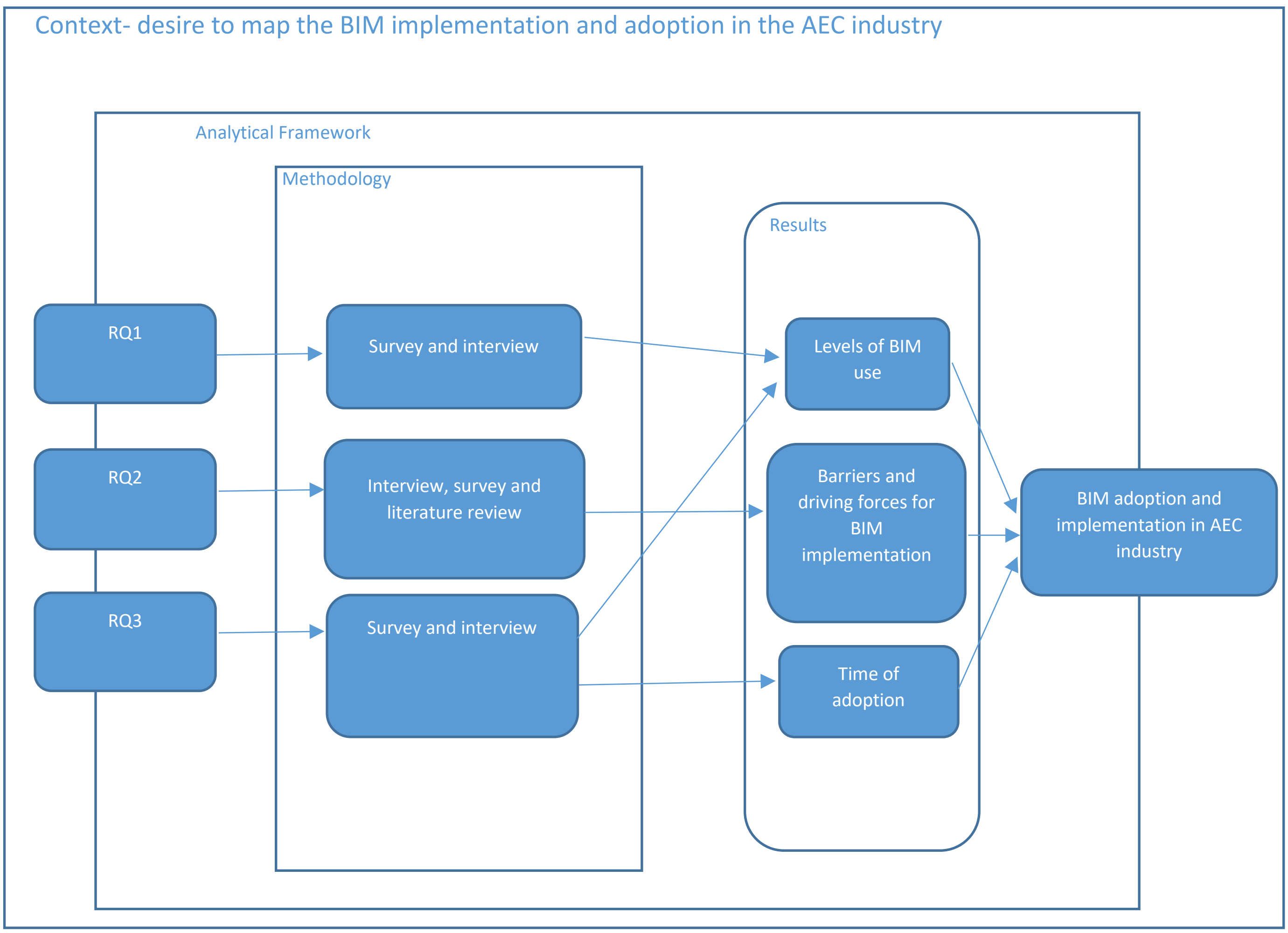


Figure 1 Methodology Framework

2.2.1 Literature review

General

Snyder (2019) states that building your research on and relating it to existing knowledge is the building block of all academic research activities, regardless of discipline. A literature review can be described as, a more or less systematic way of collecting and synthesizing previous research. In context to this thesis there has been conducted a literature review to get a theoretical platform to be able to answer the research questions. The literature review is focusing on what challenges and driving forces the SMEs face when adopting and implementing BIM, both into their company and into projects.

Information Evaluation

When working with the articles, it was important to be critical to the sources and articles in order to find the most relevant articles for the research question. Information evaluation is a collective term for methods used to separate verified information from speculation (Dalland, 2007, pp. 67-68). When working with and finding relevant and professional articles in connection with the assignment, it is important to be source critical.

All the articles in the master's thesis are peer-reviewed. This indicates that the articles have been assessed on the basis of strict scientific guidelines which indicates that the articles are reliable. They are from the period of 2017-2022, which means that the research is up to date. This fulfills the criteria regarding validity and durability of the research. The articles are carefully selected according to general inclusion and exclusion criteria, which will be described more thoroughly later in the chapter.

Evaluation of literature

When evaluating the literature, the reliability and validity of the sources are important measures, which needs to be evaluated. This is fulfilled by complying with the inclusion criteria. Articles, conference papers, conference reviews, book chapters and general reviews are included in the search.

Inclusion Criteria:

- All sources should be peer reviewed
- The literature must have been published between 2017-2022
- The sources should be in either Norwegian or English
- Full access
- The sources should address the conditions in regions comparable to Norway, related to BIM awareness.

Search strategy

Scopus and Engineering Village is used for the structure search, which provides access to a wide range of trusted and credible sources. Full access to the literature was achieved by using the student mail.

Before starting the structured search to identify the most relevant research, the various key concepts were created to narrow the search and making it possible to answer the research question. This contributed to omit the irrelevant studies, and also to limit the number of articles to a manageable quantity. This was done by the use of "Boolean Operators", the keywords in the search were combined with the use of “OR” and “AND”. The concepts in the vertical direction was combined with “OR” and the keywords in the horizontal direction with “AND”.

Table 3 Key concepts for search strings

Concept 1	Concept 2	Concept 3
• BIM • Building Information Modeling	• Implementation • Adoption	• Small project • SME • SMES • Small firm • Small contractor

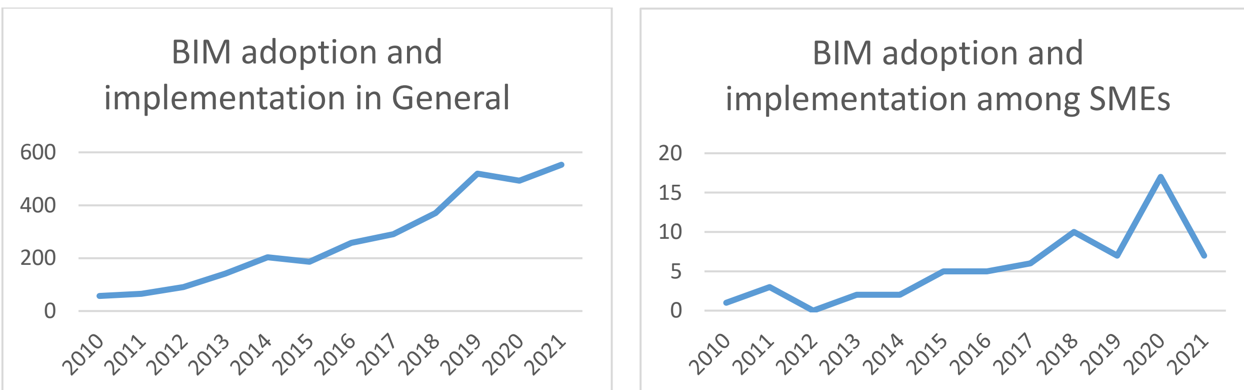


Figure 2 Yearly trend of publications in Scopus focusing on BIM adoption and Implementation.

The main argument for narrowing the search was to make it possible to look at the specific conditions in SMEs. From Figure 2 it is clear that there has been a growing awareness and focus on BIM adoption and implementation among researchers the past years. The same trend could also be seen for the SMEs, although the number of published articles is considerably less. In table 4, the search strings is presented together with the number of hits from the two databases. Considering the amount of hits reported for each search iteration, the effect of the Boolean operators can be seen and how the search gradually evolves when the different concepts are combined. The last search string counts for reports found in the timespan 2017-2022. The search was completed 9th of February 2022, and successfully identified several reviews that were relevant for explaining the adoption and implementation among SMEs.

Table 4 Search strings

	Search string	Engineering Village	Scopus
1	TITLE-ABS-KEY (BIM or "Building information modeling" and implementation or adoption)	3968	2273
2	TITLE-ABS-KEY((BIM OR "building information modeling") AND (implementation OR adoption) AND ("small project" OR sme OR smes OR "small firm" OR "small contractor"))	41	48

The flowchart for the literature review is presented in Figure 3 and shows an overview of how the 14 articles have been selected. Among the 14 final articles, there are two articles, which are included from previous work from last semester (autumn 2021) in the subject Specialization in Structural Engineering and Building Technology at Oslo Metropolitan University. These articles comply with the inclusion criteria, and are considered to be relevant for the thesis, despite the fact that they were not included in the systematic search. In the "Findings from Literature review" chapter, an overview of all the fourteen articles is presented.

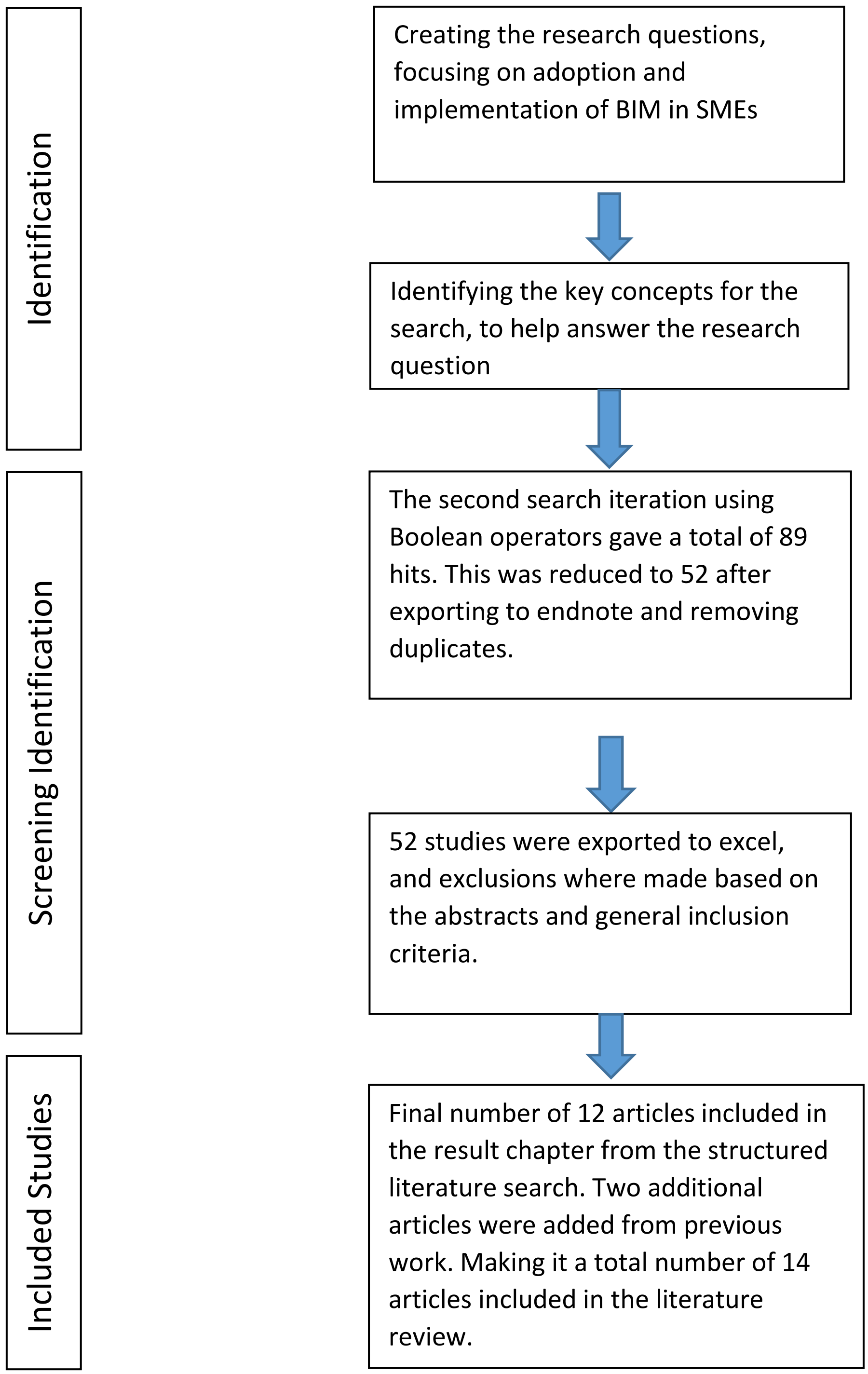


Figure 3 Flowchart for literature review

All the 52 unique articles were put into an excel spreadsheet to get an overview of all the sources. First all articles were evaluated based on the title and inclusion criteria. After this process, the articles were reviewed by reading the abstract and conclusion. This was an effective and clear-cut method, which helped to choose the most relevant studies based on the topic for the master's thesis. This lead to a total number of 12 unique articles. In addition, two articles were included from last semester (autumn 2021), which corresponds to a total of 14 articles in the literature review.

Possible weaknesses and sources of errors

There is a large amount of international research regarding BIM adoption and implementation, which made it necessary to concentrate mainly on the SMEs. A challenge might have been that relevant articles regarding general BIM adoption and implementation were excluded because of the second search string.

Another weakness might have been that none of the 14 articles describe directly the conditions in the Norwegian AEC industry. Even though the literature is not directly comparable to Norwegian conditions, the literature will help provide a good basis for the thesis, and making it possible to make comparisons across regions.

Reliability and Validity

The *reliability and validity* of the literature review is fulfilled through a structured search in reputable databases with peer-reviewed sources. The general inclusion criteria were also involved in raising the reliability and validity of the literature review. Finally, the validity and reliability are rated as high, as the literature is considered consistent and helps to answer the research question in a good manner.

2.2.2 Interview

General

A research interview is a qualitative method and aims to obtain the interviewees' own opinions about their life situation (Dalland, 2007). The purpose of an interview is to obtain descriptive information about how the informants experience their situation, and especially to gain insight into their experiences, thoughts and feelings (Dalen, 2004). This paper is based on interviews with individuals, according to (Kvale, 1994), these interviews are well suited for in-depth topics that require reflection and security.

The goal of the interviews was to get an understanding of BIM adoption and Implementation in their specific organization, but also to get their general perceptions of the Norwegian AEC industry. The interview is semi-structured (based on the interview guide given in Appendices A and B). The interviewees are therefore encouraged to talk more or less freely about the topic, which is covered. The reasoning behind the semi-structuring of the interviews is to facilitate for the interviewee to talk freely about what he or she thinks. Another advantage, which was experienced during the interviews, is that it gives the interviewer the opportunity to ask in-depth questions and corrective questions to ensure that the conversation develops within the defined framework. This was considered an appropriate approach for this report.

Interview-guide

An interview guide were developed and sent to the interviewees prior to the interviews, making them prepared for the upcoming questions. The original interview guide is given in Appendix A. The interview guide is a list of questions that are arranged by topics in order to ensure that all topics are covered in the interview. Some small adjustments were made on the interview guide after the second interview, due to increased understanding of the topic, leading up the interview guide (rev) given in Appendix B.

The interviews were separated into four different main parts: Part (1) included general information about the participant and his/hers company. Part (2) was focusing on their specific organizations BIM adoption and implementation. These included barriers, driving forces and specific use. Part (3) was focusing on general observations about the industry regarding adoption and implementation of BIM, focusing on the differences between SMEs and the larger companies. Part (4) was mainly about the clients' role.

As mentioned, the questions are set up in order and are somewhat detailed, but they are not followed strictly in a chronological order. This is in line with Dalland (2007), who states that the questions do not necessarily have to be followed chronologically. The questions serves as a guide when conducting the interviews, in order to ensure that the main issues are discussed. Some of the initial questions are reformulated during the interview process due to the author's improved understanding of the subject, which has led to the revised interview guide (Appendix B). According to Dalland (2007) it is possible to be flexible in the process, changing the interview guide along the way to contribute to information that is more valid.

Selection of Interviewees

The selection of the interviewees are strategically selected, which according to Larsen (2007) means that the author is conscious when selecting the interviewees that he thinks are most appropriate to shed light on the most important issues. In this report, the interviewees therefore consist of personnel, which are direct involved in projects e.g. project leaders or people in the company, which have a good insight in the projects. It was also desirable that the interviewees had a good overview of BIM use both in their own projects and in the industry in general.

A big advantage of interviewing this kind of professionals is that they have a good understanding of the topic, which reduces the time of processing since they are already on the same page, regarding abbreviations and key themes.

An overview of the interviewees is shown in the table below. The relevant candidates for the interviews was first contacted by e-mail. All the participants are anonymized, which was chosen by the author to increase the credibility for the answers, making everyone able to speak freely. The two last interviews were recorded using "Nettskjema Diktafon", while notes from the first interview were written directly on paper.

Table 5 Overview of the interviewees

Nr.	**Company**	**Job Title**	**Duration**	**Date**	**Type of interview**
1.	Contractor	BIM Coordinator and project manager	1 hour	08.02.2022	Face to face
2.	Consultant	Structural engineer	20 min	10.02.2022	Teams-Interview
3.	Contractor	Project manager	40 min	28.02.2022	Teams-Interview

Analyzes and interpretation of data

During and after the interview process, the data were transcribed. Such a transfer from an oral conversation to words could be a source to loss of information (Dalland, 2007). The "Nettskjema Diktafon" used to record the interviews provided a correct transcription of the interviews and minimized the chances of losing essential information. The different answers were then processed and arranged into the structure of the result chapter. Some of the key findings in the interviews are later brought up in the "discussion of results in a theoretical lens".

Reliability and Validity

The *reliability* of an interview consist of whether a measuring instrument is unambiguous and reliable, i.e. whether repeated measurements give the same answer regardless of who is measuring. Qualitative method can, however, be characterized as a discovery method without an exact measuring instrument. The reliability therefore lies in whether the researchers clarifies their procedures and the background for the assessments and interpretations made. When using interviews as a method for revealing, opinions, descriptions and experiences, then these can hardly be reliable in the sense that they can be repeated and give the exact same answers. The outcome of the answers will largely be the same, but its expression depends on the context, background of experience and what understanding the person has in the moment of the interview (Kvernmo, 2005). These small facets might have changed in the next couple of days and weeks. It therefore becomes important to uncover and take seriously the interviewees' understanding of the situation without the researcher's conscious impact. Reliability can be maintained in interviews by comparing other, similar surveys within the same area of topic. The reliability has been confirmed through comparing the results with existing literature on the given topic and by comparing the three different interviews. This revealed that there is a common thread between all the interviews and the existing literature.

The *validity* of an interview lies in whether what is being explored really provides information about what the researchers really want to study. It is often easier to secure a higher validity in qualitative methods, since it gives more room flexibility when asking the questions and being able to adjust the questions during the process (Larsen, 2007). During the interviews, it was ensured that the interviewer and the interviewee had a common understanding of the question, so that the results would help to answer the relevant research questions. It was strived for that the interviewer and the interviewees were on the «same page» and talk about the same phenomenons, and that the terms used were understood roughly the same.

Despite minor changes in the interview-guide, this is considered to increase the validity, because the changes happened after gaining increased understanding of the topic. Another important aspect increasing the validity and reliability was the choice of interviewees, which are all professionals within the AEC industry with minimum four years' experience. Finally, the validity of the qualitative interviews is rated as high as the informants have provided answers that help to answer the relevant research questions.

2.2.3 Web Survey

"Surveys are designed to produce statistics about a target population"(Fowler Jr, 2013). In order to obtain sufficient quantitative data, a quantitative web survey were conducted. The survey mainly had closed questions, which means that the options for the answer are given in advance. Despite this, there were some questions where the respondents were able to elaborate more freely. The reasoning behind the closed questions is that it will help to compare the results and draw conclusions out of the collected data, as they are formulated in a similar way, which is in line with Larsen (2007).

The survey were conducted by using “Nettskjema” created by the University in Oslo, which made it possible to make the survey anonymous. The web survey is given in Appendix C. Anonymous web surveys make it possible for the participants to give honest answers, which helps to increase the general credibility of the results. The survey is made up of 35 questions, aiming to help answer the research questions. The number of questions needed to be answered from each participant varies based on the different uses of BIM in the companies.

The questionnaire was prepared in “Nettskjema” and the questions are based on comparable research and was quality-assured in collaboration with my supervisor. The data was collected in excel to make statistical presentations. After the data collection in excel was completed, the key results were then exported into results in the form of different forms of charts. The resulting data is presented in the result chapter “Results of surveys”, further discussed in the chapter “Discussion of Results in a theoretical Lens”, and finally used to answer the associated research questions in the “Conclusion”.

Reliability and Validity

The digital survey was sent to a sample of 66 unique companies. Architects, engineers, contractors and clients were included in the survey. The companies were varying in both size and location. Before the survey was sent out, relevant personnel was identified in each company. This was done by contacting each company to find suitable participants. Finding the right personnel, who were working hands on in projects, were considered essential for both the *reliability* and *validity* of the survey results. Fowler Jr (2013) states that data from a properly chosen sample increases the data quality. The response rate to the survey was 60.1% (40 persons). Although there is no agreed-upon standard for a minimum acceptable percentage rate, Nulty (2008) has found that the overall online response rate is 33 %. This makes our response rate of 60.1 % way above average. Nevertheless, although each respondent represented one company, the obtained sample can be deemed small for a quantitative study.

To ensure a high degree of *validity* in the results of the survey, it was considered important to choose relevant questions, which could help answer the research questions. This is done by choosing appropriate variables and by seeking inspiration from comparable literature, considering BIM Adoption and Implementation. When analyzing the results, the validity of the survey is considered acceptable, as the quantitative data helps answer the research questions in a uniform manner.

According to Larsen (2007) it could be challenging to ensure the *reliability* of quantitative surveys, as inaccuracies can occur due to larger amount of data. In order to achieve a high reliability in such surveys, it is important to be accurate in the design of the question and in the processing of data (Larsen, 2007). To ensure the reliability of the survey, the questions have been accurately formulated with clear response options. The questions and options are based on comparable existing literature, helping to raise the reliability of the data.

The accuracy of the processing of the results from the survey is handled by directly exporting all relevant data directly from “Nettskjema” to Excel. When processing the data into charts and text into the report, errors may occur. The accuracy is ensured by making several quality controls against the original data.

The reliability of the survey results is subsequently perceived as satisfactory, as data from the survey corresponds well with findings from the literature review.

3 Theoretical lens

There are used three different theoretical lenses for this master's thesis. The theory's was chosen in cooperation with my supervisor, in order to help the theories to embrace all the relevant results. The theory chosen for the paper is the Diffusion of Innovation, Theory of Planned Behavior and Institutional theory. The *Diffusion of Innovation* addresses the general implementation of new technology, regardless of industry(Rogers, 2003). *Institutional Theory* is a theory on the deeper and more resilient aspects of social structure and explains the environmental pressure through three different types of environmental factors (Bosch-Sijtsema et al., 2017). *The Theory of planned* behavior is considered one of the most influential and popular conceptual frameworks to study human action (Bosch-Sijtsema et al., 2017). The three theories was used to understand and describe the different barriers and driving forces, and to help explain what phenomenons which lies within implementing new technology. The *Diffusion of Innovation* has been given the most interest in this thesis and explains which internal factors that can hinder or accelerate the diffusion process, these factors are strongly linked to the perceived attributes of the new innovation. The *Institutional Theory* on the other hand emphasizes to a greater extent the external factors in a decision-making process. The *Theory of Planned Behavior* emphasizes the motivational factors and perceived ease or difficult in combination with subjective norm leading up to the behavioral intention and subsequent the actual behavior (in this case BIM implementation). Based on the three theories different approaches, it was considered that all three theories was necessary to cover all the barriers and driving forces which is valid for the adoption and implementation of BIM.

"Diffusion is the process in which an innovation is communicated through certain channels over time among the members of a social system" (Rogers, 2003, p. 11). The communication is focusing on the messages of spreading new ideas and on a process which participants create and share information to reach a mutual understanding of a topic. The communication is considered a process of convergence (or divergence) as two or more individuals exchange information in order to find a common understanding. This is a different type of communication than what can be observed e.g. when a change agent seeks to persuade a client to adopt an innovation. According to Colyvas & Jonsson (2011) diffusion is the spreading of new idea, behaviors or practices.

3.1 General elements in the Diffusion of Innovation

The four main elements in the theory are the innovation, communication channels, time and the social system. These four elements could be obtained in all research and campaigns regarding diffusion.

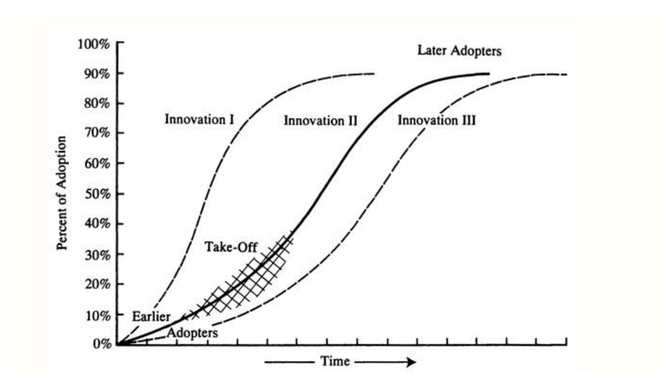


Figure 4 The Diffusion Process (Rogers, 2003, p. 11)

The innovation: "An innovation is an idea, practice, or object that is perceived as new by an individual or other unit of adoption" (Rogers, 2003, p. 12). The perception of whether the innovation is new is based on the objective perception. It may be an older innovation, which is new to the decision maker. A technological innovation have in most cases at least some degree of benefits for its potential adopters, these benefits are not always clear to the adopters. They are not always certain that an innovation represents a better alternative than the existing practice. This uncertainty in the decision-making can be reduced when more information is made available for the decision maker. Decision process is essentially an information seeking and information processing where the information help the decision maker to reduce the uncertainties about the advantages and disadvantages regarding the innovation. Diffusion of software innovations has been investigated, but a methodological problem in such studies is that their adoption cannot be easily traced or observed.

Perceived attributes of innovations are split into five different characteristics (Rogers, 2003, p. 15). Research has shown that these five criteria are the most influential characteristics of innovations in explaining the rate of adoption. Especially the first two attributes are said to have great influence on the rate of adoption.

1. *Relative advantage* is the degree to which an innovation is perceived as a better alternative than the present. The relative advantage is measured in economic terms, social prestige, convenience and satisfaction. The advantages are more aimed towards personnel advantage than the objective advantages. The greater the relative advantage of an innovation is perceived, the faster the rate of adoption will be.
2. *Compatibility* is the factor, which consider the innovation consistent with the existing values, past experiences, and needs of potential adopters. The adoption of an incompatible innovation often requires the prior adoption of a new value system, which is relatively slow process.
3. *Complexity* is the degree which an innovation is perceived as hard to understand and use. A complex and difficult innovation will take more time to adopt and implement.
4. *Trialability* is the degree to which an innovation can be experimented and tested on a limited basis. An innovation that is trialable represents less uncertainty to the new adopters.
5. *Observability* is the degree where the results from an innovation are visible to other people. Innovations that are easy for individuals to see the results are likely to be adopted more quickly.

Communication Channels: A communication channel describes how a message get from one individual to another. "The nature of the information exchange relationship between a pair of individuals determines the conditions under which a source will or will not transmit the innovation to the receiver and the effect of such a transfer"(Rogers, 2003, p. 18). Mass media is considered to be the most effective channel to transfer the information to potential adopters. It is stated that most people base their decisions more on a subjective evaluation rather that scientific studies. The diffusion research show that most individuals do not evaluate an innovation based on objective and scientific data and rather rely on subjective evaluations. Often based on experiences of near peers. The first adopters of an innovation are more likely to depend more on scientific studies and objective data.

Time: Time is the third element in the process of diffusion(Rogers, 2003, p. 20). The inclusion of the time element is considered one of the strengths in the theory, which differs it from comparable research on behavioral science. The time dimension is involved in diffusion of the innovation- decision process by which an individual passed from first knowledge of an innovation through its adoption or rejection. The innovation-decision process normally occur in a time- ordered sequence, seen in figure 5.

A Social system: “A social system is defined as a set of interrelated units that are engaged in joint problem solving to accomplish a common goal”(Rogers, 2003, p. 23). The members of a social system could be individuals, informal groups, organizations, and/or subsystems. The diffusion occurs within a social system. The structure of the social system affects the innovations diffusion in many different ways. The systems social structure affects the diffusion, the effect of norms on diffusion, the roles of opinion leaders and change agents, types of innovation-decision and the consequences of the innovation. The structure of a social system can either facilitate or impede the diffusion of innovation.

3.1.1 The Innovation- Decision Process

Rogers (2003, p. 20) describes the innovation-decision process as a process which an individual (or other decision-making units) goes from the first knowledge of an innovation, to the formation of an attitude towards the innovation, to a decision to either adopt or reject, to implementation and use of the new idea, and to confirmation of this decision. The five main steps are: (1) knowledge, (2) persuasion, (3) decision, (4) implementation and (5) confirmation.

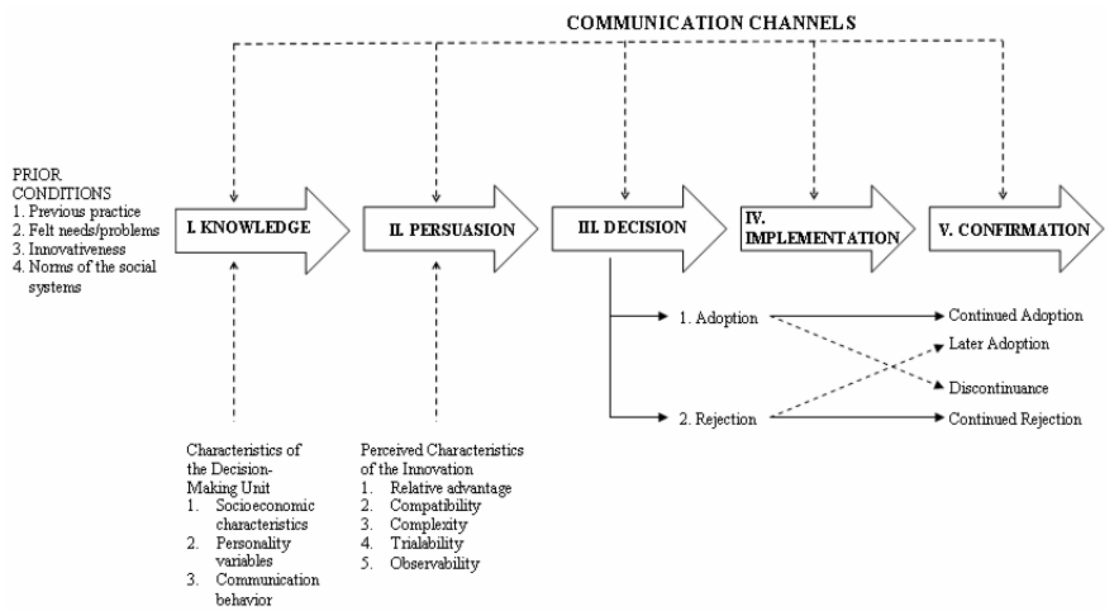


Figure 5. A model of Five Stages in the Innovation-Decision Process (Rogers, 2003, p. 170)

The innovation-decision process could lead to either adoption, a decision to make complete use of the innovation, or a decision not to adopt the innovation. The innovation-decision process involves time since the process normally occur in a time ordered sequence 1-5. Exceptions may occur due to different factors, e.g. if an individual was ordered to adopt by some authority figure.

(1) *Knowledge* occurs when an individual (or other decision-making unit) is exposed to an innovations existence and gains a general understanding of the innovations function. The exposure of the knowledge could be either passive or active. Individuals normally expose themselves to new ideas that are in accordance with their interests, needs, and existing attitudes. Individuals consciously or unconsciously avoid messages that does not fit their existing

predispositions and is called *selective exposure.* Hassinger (1959, cited in,-Rogers, 2003) states that individuals seldom expose themselves to messages about an innovation unless they first feel a need for the innovation. There is three types of main knowledge about an innovation, *awareness-knowledge, how- to knowledge and principle knowledge.*

(2) *Persuasion stage* in the innovation-decision process involves that the individuals forms a favorable or unfavorable attitude towards the innovation. While the mental activity at the knowledge stage was mainly cognitive, the main activity in the persuasion stage is dominantly affective. At this stage, the individual becomes more psychologically involved with the innovation. Important perceived attributes, as previously mentioned, is relative advantage, compatibility, and complexity, trialability and observability. At this stage, an individual seeks information about the innovation, which includes messages that reduce uncertainty about expected consequences. According to Rogers (2003, p. 175) an individual usually wants to find the answer to the question: "What are the innovations advantages and disadvantages in my situation?".

(3) *The decision stage* in the innovation-decision process takes places when an individual (or other decision-making units) engages in a direct activity that will lead to a choice either to adopt or reject the innovation. A way to decrease the uncertainty about an innovations consequences is to try out the new idea on a partial basis. Most innovations are not adopted without first trying it on a probationary basis to determine its usefulness in their own situation. Trial of a new idea by a peer will to some degree substitute this need. There are two different type of mechanisms concerning the rejection of an innovation, this is the *active rejection* and the *passive rejection.*

(4) *The implementation stage* occurs when the innovation is put into use. Until the implementation stage the innovation-decision process has been only limited to a mental exercise of thinking and deciding. While the implementation stage involves overt behavior change when the innovation is put into practice. There is still some degree of uncertainty about the consequences the innovation will have. The stage also includes active information seeking through change agents mainly to provide technical assistance. *Re-Invention* could happen in the implementation stage, and could include minor changes in the original innovation. Emrick et al. (1977- cited in-Rogers, 2003, p. 182) found that 56 % of schools adopting educational innovations only selected aspects of the original innovation. Re-invention can happen du to complex and difficult innovations, which are difficult to understand. Re-invention in such cases may be a simplification of the innovation. Rogers (2003, p. 184) states that re-invention is not necessarily bad. Adopters generally think re-invention is a very desirable quality, having the possibility to make modifications or selective rejection of some components. This will make the process more flexible.

(5) At the *Confirmation Stage* the individual (or other decision-making units) seeks reinforcement for their already made innovation-decision, they also may reverse this decision if they are exposed to conflicting messages about the innovation.

3.1.2 Adopter Categories

The five adopter categories are considered as "ideal types", concepts based on observations of reality that are made to make it possible to make comparisons (Rogers, 2003, p. 282).

1. *Innovators* are often very venturesome. They are interest in new ideas, which leads them into new networks and more cosmopolite relationships. To have control of financial resources is helpful in absorbing the possible losses from an unprofitable innovation, this is an important asset for the persons in this category. To have the ability to understand and apply complex technology knowledge is also needed.
2. *Early adopters* has the highest degree of opinion leadership. People with expertise or influence in a specific area. They are decreasing uncertainty about a new idea by adopting it, and then discussing a subjective evaluation of the innovation with near peers through interpersonal networks. "In one sense, early adopters put their stamp of approval on a new idea by adopting it".
3. *Early majority* adopt innovations and ideas slightly before the average members of a system. They are often communicating with their peers but seldom hold position of opinion leadership in a system. They follow with deliberate willingness in the process of adopting an innovation, but they seldom lead the process.
4. *Late majority* adopts new ideas just after the average members of a system. Economic motives and peer pressure might both be the motivation behind the adoption. They approach innovation with a general skepticism. Due to the lack of resources all uncertainties must be removed before the late majority feel that they can adopt the innovation.
5. *Laggards* will be the last in a social system to adopt an innovation. They possess nothing to little opinion leadership. The laggards often look to the past for their references and decisions are often based on what has been done in the past. Resistance to innovations on the part of laggards may be entirely rational from the laggards viewpoint, as they have limited resources and they have to be certain that the innovations doesn't bring any negative consequences.

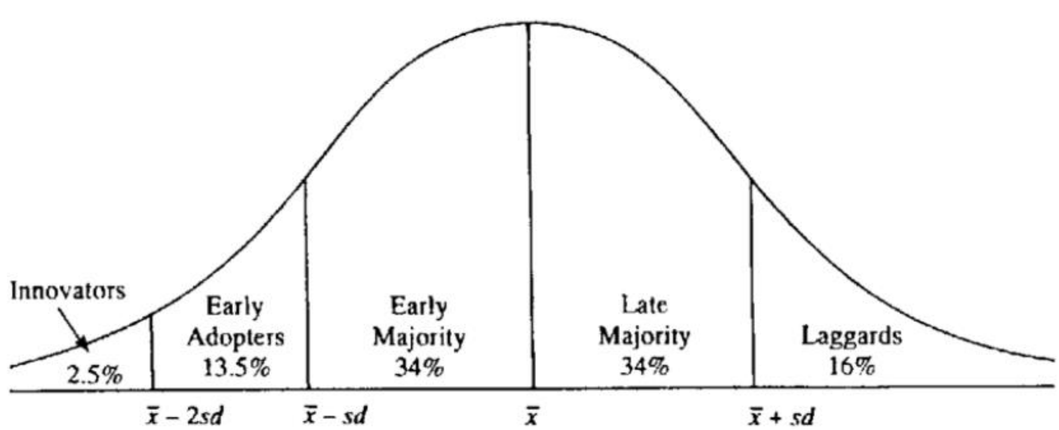


Figure 6 Adopter categorization (Rogers, 2003, p.281)

3.1.3 Champions of Innovation

The role of champions: "A champion is a charismatic individual who throws his or her weight behind an innovation, thus overcoming indifference or resistance that the new idea may provoke in an organization" (Rogers, 2003, p. 414). Just as an innovation champion can play an important role in the innovation process, an anti-innovation champion can make the innovation process more difficult. For the costly, high visible or radical innovations, it is important that the champion of innovation have a central role in the organization.

3.2 Institutional Theory

Di Maggio & Powell (1983) pointed at the critical roles of the institutional environment in driving organizations towards making changes. There is three types of isomorphic pressure (DiMaggio & Powell, 1983):

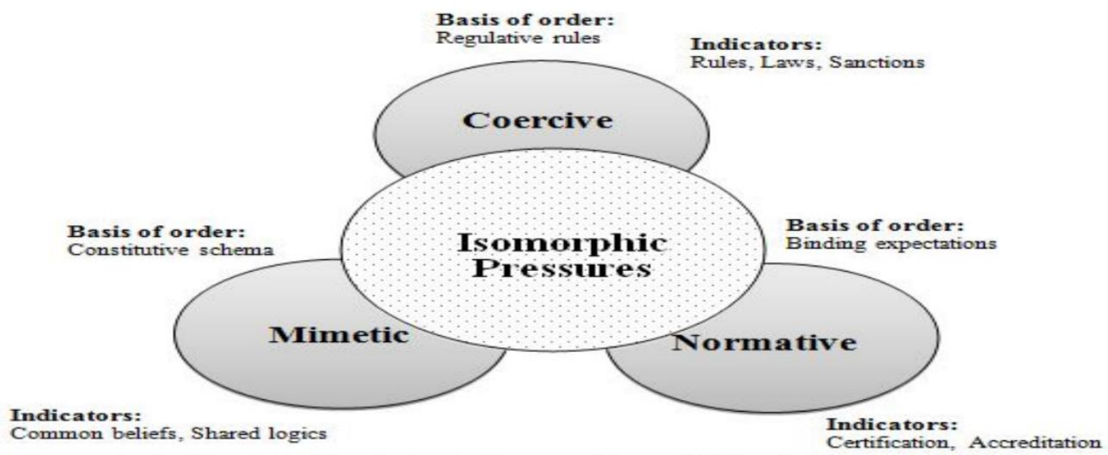


Figure 7 Attributes of institutional isomorphism. REF:(DiMaggio & Powell, 1983. Cited in:Toinpre et al., 2018)

- Coercive pressure. Coercive isomorphism refers to formal and informal pressure on the organization by other organizations that they are highly dependent on in the same context. The pressure could come in form of force, persuasion or invitation to join collusions. In some circumstances, changes in an organization is a direct response to government mandate (DiMaggio & Powell, 1983). Government mandate and political decisions have two characteristics: they often do not experience the consequences of their actions and if the mandate is applicable to entire classes of organizations, this will make such decision less adaptive and less flexible.
- Mimetic pressure. The mimetic isomorphism relates to mimicking or modelling other organizations or competitors as a result of certainty (DiMaggio & Powell, 1983). The organizations that are being modelled are often organizations that are considered more legitimate or successful in their environment. Models may also happen intentionally, indirectly by employee transfer or turnover, or explicitly by organizations such as consulting firms. Uncertainty is mentioned by DiMaggio & Powell (1983) as a force that encourage imitation. This could be the case when organizational technologies are not well understood or when the environment creates uncertainty and might lead to organizations model themselves on other

organizations. There are economic advantages in mimetic other organizations since solutions can be applied with little expense.

- Normative pressure. "A third source of isomorphic organizational change is normative and stems primarily from professionalization" (DiMaggio & Powell, 1983). It is referred to as the "collective struggle of members of an occupation to define conditions and methods of their work" (DiMaggio & Powell, 1983). The change is driven by pressure from professions. The normative pressure are caused when other members of a network define and share norms of the organization. Cao et al. (2014) describes it as a reaction where several professional bodies within specific fields gradually form shared norms and collective expectations with respect to what constitutes desirable behaviors.

3.3 Theory of Planned Behavior

The theory of planned behavior is based on and an extension of the theory of reasoned action (Ajzen, 1991), and is a theory designed to predict and explain human behavior in specific context. The general framework for the Theory of Planned Behavior is shown in Figure 8 and later described in the following subchapters. The main elements of the theory includes the *attitudes toward the behavior, subjective norm and perceived behavioral control* leading up to the *intention* and later the actual *behavior*. The relative contribution of the three pillars leading up to the *intention* is expected to vary from different behaviors and situations. In some cases it is found that only attitudes have a significant impact on intentions, in others that attitudes in combination with perceived behavioral control are sufficient, and in other cases all three pillars make independent contributions to the intention stage (Ajzen, 1991).

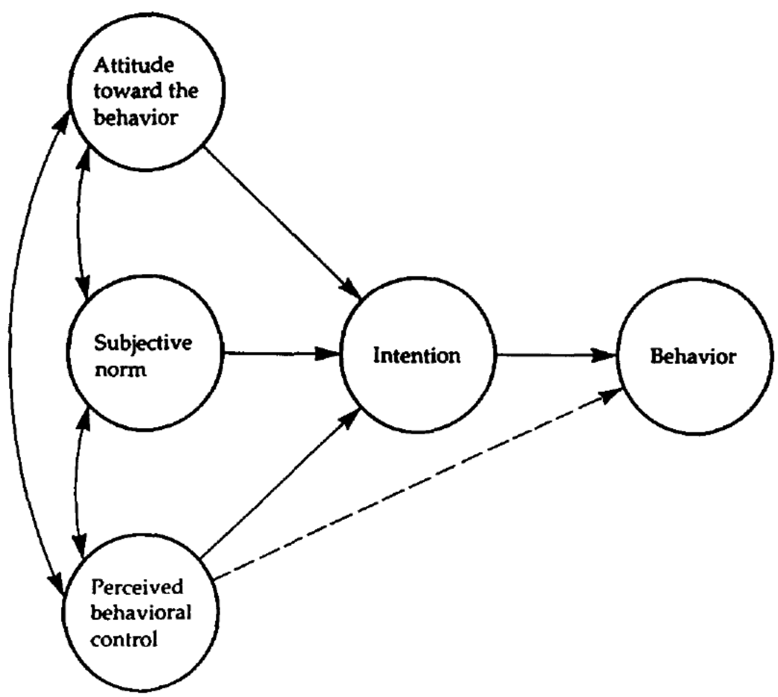


Figure 8. Theory of Planned Behavior. REF: (Ajzen, 1991)

3.3.1 Attitudes towards the Behavior

The first of the three pillars leading up to the behavior is the attitude towards the behavior. This refers to what degree a person has a favorable or unfavorable evaluation or appraisal of the behavior that is considered (Ajzen, 1991). Beliefs are formed about an object by associating it with different attributes, i.e. with other objects, characteristics or events. Regarding the attitudes toward a behavior, each belief links the behavior to a certain outcome, or to other attributes, this could be the cost incurred by performing the behavior. The attributes that are linked to the behavior are already valued in a positive or negative way, this lead us to automatically and simultaneously get an attitude towards the behavior.

Behaviors, which provides desirably consequences, are therefore favored and we form unfavorable attitudes toward behavior we associate with negative consequences (Ajzen, 1991). In some cases it is found that attitudes alone have a great impact on intentions and therefore sufficient for the intention. Findings for different behaviors suggest that personal considerations tends to overshadow the influence of perceived social pressure.

3.3.2 Subjective Norm

The second factor the subjective norm is a social factor and refers to the perceived social pressure to perform or not to perform the behavior (Ajzen, 1991). Findings suggest that the contribution from subjective norms were mixed regarding contributions to the prediction of intentions.

3.3.3 Perceived Behavioral Control

"Perceived behavioral control refers to people's perception of the ease or difficulty of performing the behavior of interest" (Ajzen, 1991). Ajzen (1991) states that the importance of actual behavioral control is self evident, where the resources and opportunities available to a person will to some degree decide the change of behavioral achievement. Despite this Ajzen (1991) argues that the perceived behavioral control is more interesting in a psychological aspect, and the perception of behavioral control and its impact on intentions and actions. It is shown that people's behavior is strongly impacted by their confidence in their ability to perform it, i.e. perceived behavior control. The perceived behavioral control is assumed to reflect earlier experience as anticipated impediments and obstacles. The more resources and opportunities individuals believe they possess, and the fewer barriers or obstacles they anticipate, the higher their perceived behavior control is (Ajzen, 1991). Perceived behavioral control do not concern possible consequences, which is considered a part of the attitude towards behavior.

3.3.4 Intention

An important factor in the theory is the individual's *intention* to perform a given behavior. The intention includes the motivational factors that influence a behavior. The intentions indicates how hard people are willing to try, and how much effort they are planning to put down, in order to perform the given behavior. A high degree of intention and motivation to engage in a behavior are generally increasing the chance that it should be performed (Ajzen, 1991). This is only valid if the behavior is under volitional control i.e. if the person can decide at will to perform or not to perform the behavior. This will only be applicable for a some due to the fact that the performance of most depends at least to some degree on some no motivational factors such as availability of requisite opportunities and resources e.g. time, money, skills and cooperation of others.

4 Theoretical Background

This chapter presents important background information regarding BIM, and is meant to help the reader understand and interpret the results, discussion and conclusion.

4.1 Definition of Building Information Modelling (BIM)

BIM is a revolutionary technology and process that has quickly transformed the way buildings are conceived, designed, constructed and operated (Hardin, 2009). BIM is also called n-D Modelling or Virtual Prototyping Technology. BIM is both a technology and a process. The different technology components of BIM helps the different stakeholders to visualize what is going to be built in a simulated environment to identify potential design, construction or operational issues. The process component enables collaboration and encourages integration of the roles of the stakeholders in a project (Azhar et al., 2012).

Jernigan (2008) states that there is several inconsistencies and misinterpretations in definitions of BIM. Two definitions of BIM is presented below: *"Use of a shared digital representation of a built asset to facilitate design, construction and operation processes to for a reliable basis for decisions".* The National Institutes of Building Sciences (NIBS) define BIM as:

> *"Building Information Model or BIM utilizes cutting edge digital technology to establish a computable representation of all the physical and functional characteristics of a facility and its related project-life-cycle information, and it is intended to be a repository of information for the facility owner/operator to use and maintain throughout the life-cycle of a facility"* (NIBS, 2007).

The definitions often vary depending on the user's point of view, type of organization and their particular work task (Abbasnejad & Moud, 2013). From a design perspective BIM is defined as the digital representation of the physical and functional characteristics of a project, this refers to the process and technologies used to create the BIM model. From a construction point of view, BIM is considered as the development and use of a computer software model to simulate the construction and operation of a faculty. While for the facility managers, BIM could be a tool to enhance the building's performance and to manage operations more efficiently throughout the life cycle of the asset.

There is also a wide range of different uses of BIM in construction projects. In the one-end architects and engineers can utilize BIM to produce better quality design documents without providing the digital model to any other of the stakeholders in the project. On the other hand, contractors can separately create models for estimating, fabricating or simulating construction without sharing their model (Abbasnejad & Moud, 2013). This way of using BIM may not lead to exploiting BIMs full potential. At the other end of the scale, BIM can provide a collaborative framework among all participant in the project, this to allow a better way of data sharing concerning the design and how it will be constructed (Arayici et al., 2011).

The differences in interpretation is clear, while some argue that BIM should be considered as the entire process exchanging, reusing and controlling project information being generated during the whole lifecycle of the building, while other consider it as a simple 3D digital representation of the physical building (Abbasnejad & Moud, 2013).

4.2 What is a BIM project

Due to the different definitions of BIM, BIM projects can also be perceived and defined in different ways depending on the companies' areas of use. In a BIM project, a common 3D model is developed through interdisciplinary work (Westgaard et al., 2010). The interfaces and routines for who is responsible for what in the model must be clarified. In addition, it must be clear what needs to be done in the model at a given time, interdisciplinary control should be established. It is important that all participants in the project takes responsibility for the model. The communication and information exchange in a BIM project has a common point of reference in the BIM model (Rekola et al., 2010). A BIM project can improve communication between the various subjects, which can lead to better coordination. The use of BIM also enables better utilization of available information. Eastman et al. (2011)says that the following types of digital models do not fall under the category of BIM:

- Models that contain only 3D data and no objective attributes.
- Models with no support of behavior.
- Models that are composed of multiple 2D CAD reference files, which needs to be combined to define the building.
- Models that are not automatically updated when making changes in one view.

Integrated project delivery (IPD) is a relatively recent addition to the building process practice. The IPD involves adhering to the early involvement practice so that the price was set later and the companies were to share the financial gain or pain from the project (Lahdenperä, 2012). Early involvement and integration of versatile expertise, systems and business practices for the best of the project are one of the core factors in the IPD. IPD contracts can also be considered to be prepared on an ad-hoc basis for individual projects which will need a more overall implementation and understanding. This will also increase the perception of risk for clients for players how are considering the use of the IPD. The development of project procurement systems based on IPD systems are considered by many as important for effective implementation of BIM and to take advantage of all the potential benefits BIM could bring to the project (Hill, 2014).

4.3 Framework for BIM

Nepal et al. (2014) have conducted a research with the goal to find a common framework which defines the evaluation of BIM- enabled projects. Many research papers defined a so-called “iron triangle” with technology, organization and process (Nepal et al., 2014). Whilst these approaches are handy in analyzing implementation and performance of BIM projects, this approach is lacking the “project context” to provide a more holistic and robust evaluation of BIM-enabled projects.

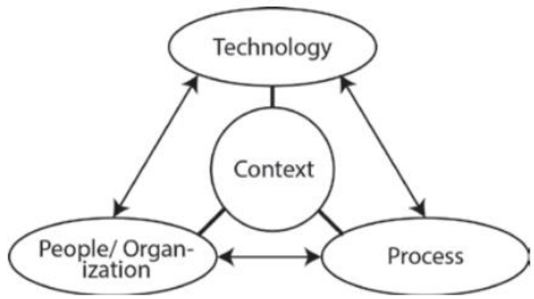


Figure 9 Technology, organization/people, process, and project context. Framework for BIM evaluation. REF:(Nepal et al., 2014)

Technology

Nepal et al. (2014) states that technology, and in particular software, is the key enabler of BIM projects. There are some important issues that must be considered, this includes: how the project team will exchange and share the information, at what level of detail the information should be shared and how the information is stored and updated and accessed. The decision of what software and hardware infrastructure an organization uses is a long-term strategic decision and investment requires analysis of existing business processes, training and education capabilities. In BIM all relevant project information are gathered in the model. Ding et al. (2014) defines a BIM model as a digital representation of the physical and physiological attributes of a building.

People/Organization

The different issues regarding people and organization fall into different facets according to Nepal et al. (Nepal et al., 2014), this includes assembling the right project team, timeline of involvement of key parties, assigning roles and responsibilities, defining BIM deliverables, identifying levels of BIM education and expertise, BIM training and support, and identifying required expertise from external BIM service providers, consultants or software vendors. Some of the hardest barriers seen by many in the industry are change of organizational structure, work practices culture and mindset.

Process

According to Nepal et al. (2014) BIM requires a new business approach and integrated interdisciplinary processes that go beyond existing practices. BIM is a new way of working due to the changes in business processes, collaborative methods, and information sharing. This means that the project team must be willing to work collaboratively across all design and delivery phases. Which will lead to an exchange of reliable and structured information in the required format. Decisions made during the design stage can have large consequences for fabrication, assembly, onsite construction and ultimately operation and maintenance. To have an open and extensive collaboration it is required for the project team to clearly define their workflows and information handover procedures, protocols surrounding model progression and information accessibility for use and reuse (Nepal et al., 2014).

Project Context

"The project context is the environment in which the project is undertaken and would influence the approach to BIM implementation and its subsequent performance" (Nepal et al., 2014). Different variables which defines the context are:

- Client Type
- Project Type
- Project Size
- Expected duration
- Budget constraints
- Project complexity
- Size of project team
- Procurement approach adopted
- Availability of resources to support BIM

Project context could also according to Nepal et (2014) include elements which are external to the projects, including;

- Level of BIM readiness or maturity within local or regional supply chain
- BIM regulations
- Local authority
- State or federal government support for BIM
- Presence or absence of technology service providers

The different contextual environment will also make each project unique. This is due to different sources such as the owners, owner needs/objectives and project goals, legal, regulatory and industry environment, organizations (designers, contractors, suppliers etc.) location and work environment, procurement methods etc. This unique challenges needs to be addressed by the project team.

4.4 BIM standards and BIM Maturity-Levels

The following subchapters describes important standards that supports BIM enabled projects. These standards also works as the basis for BIM-Levels and BIM-Stages.

4.4.1 PAS 1192

In the UK in 2011 the UK Government published the Construction Strategy. The aim for strategy was to reduce cost of public sector assets by up to 20 % by 2016. To be able to achieve this, BIM Level 2 was mandated for all central-procured governmental projects in the UK (Dadmehr & Coates, 2019). Especially PAS 1192-2 sets important requirements to adopt BIM Level 2. BIM Level 2 is a level where information is managed in a 3D environment in which participants adopt a collaborative approach to deliver assets (Abbasnejad & Moud, 2013). The aim was to drive the public sector into BIM Level 2, with the intention to gradually move to BIM Level 3 (Georgiadou, 2019), but has shown to have an impact also on the private sector as well, due to its benefits such as; reduction in CAPEX, delivery and operational costs, reduced risk, improved carbon performance and predictable planning.

The Government mandate resulted in publication of a series of national standards and Publicy Available Specifications (PAS). PAS are rapidly-developed standards, specifications, codes of practice or guidelines (McPartland, 2017). The standards are based on existing codes defined within BS 1192:2007+A2:2016.

An overview of the standards making up the PAS 1192 Framework (McPartland, 2017):

- **PAS 1192-2: 2013**, focusing on the construction (CAPEX) phase, and sets the requirements for BIM Level 2 maturity; this includes setting out the framework, roles and responsibilities for collaborative BIM working; it builds on the existing standard of BS 1192, it also expands the concept of the Common Data Environment (CDE). A CDE is the internet-based platform for the management of processes, information delivery and sharing during the whole life cycle.
- **PAS 1192-3: 2014**, concentrates on the operational (OPEX) phase, which deals with the use and maintenance of the Asset Information Model, for Facility Management. Asset Information Model or AIM is describing the collated set of information collected from all sources that supports the ongoing management of an asset.
- **BS 1192-4: 2014**, is more of a technical code of practice rather than a specification standard. It documents best practice when implementing Construction Operations and Building Information Exchange (COBie).
- **PAS 1192-5: 2015**, is a specification for security- minded building information modelling, smart asset management and digital built environments.
- **PAS 1192-6:** – is a specification to implement collaborative sharing and use of structured health and safety information when using BIM.
- **PAS 1192-7:** – focusing on the Construction product information - Specification for defining, sharing and maintaining structured digital construction product information.

BS 1192 is a standard, which provides a "best-practice" method for the development, organization and management of production information for the AEC industry. It is meant to set out a disciplined process for collaboration and naming policy. It also contains a template for common naming conventions and describes approaches to facilitate collaborative work in the AEC industry. It will also help to facilitate efficient use of data in facility management (McPartland, 2017).

PAS 1192-2:2013 describes requirement for attaining BIM Level 2 during the project delivery phase (Dadmehr & Coates, 2019). In this stage most of the graphical data, non-graphical data and documents, also known as the Project Information Model is gathered (Dadmehr & Coates, 2019). It also details different requirements, first to define the statement of need, moving across the five stages of information from procurement, through post-contract award, mobilization, production and maintenance of the Asset Information Model, which are all a part of the handover.

They key concept of the approach is the idea of "beginning with the end in mind". This makes it possible to identify possible later uses of information collected from the start of the project to facilitate for appropriate use within the whole lifecycle of the built asset (McPartland, 2017).

BIM Maturity Levels are made upon the basis of the PAS 1192-2:2013. BIM is being used in a number of different levels of maturity (Abbasnejad & Moud, 2013). Maturity is an important point to clarify the level of ambitions in an enterprise (Godager et al., 2021). It is essential to specify the information management and modelling requirements for a project and not just refer to BIM Level 2 as a requirement (*UK BIM Framework-Frequently asked questions*, 2021). This is an unwanted practice, which has evolved with the BIM Level 2 mandate. The UK government endorsed a BIM maturity model proposed by Bew and Richards as shown in Figure 10 (Bew & Richards, 2008). This is often referred to as the BIM wedge diagram; it divides BIM maturity into 4 levels (0-3). These have become widely adopted definitions of criteria which needs to be fulfilled for a project to be considered BIM-compliant.

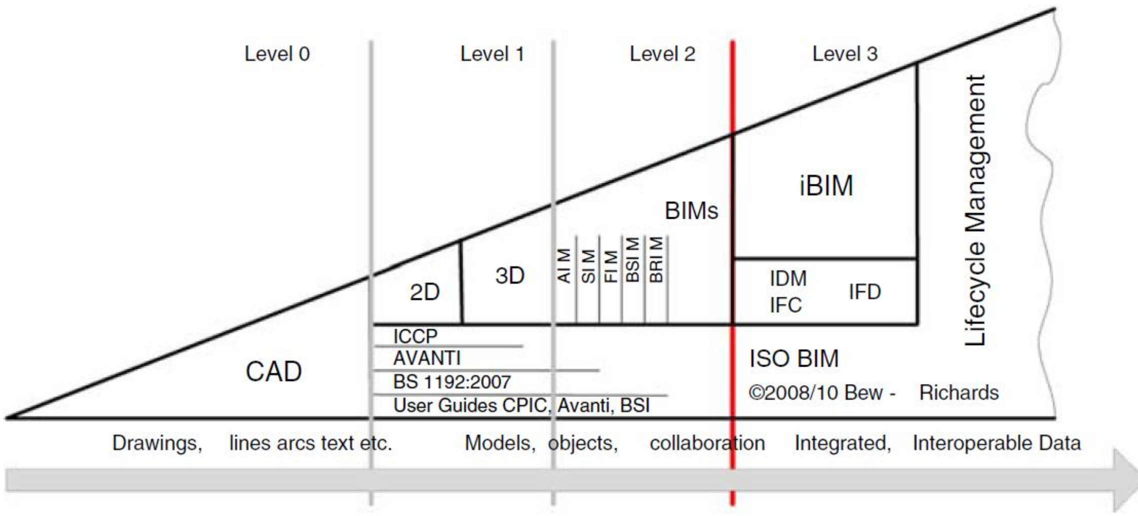


Figure 10 Bew-Richards BIM maturity model REF:(Bew & Richards, 2008)

Level 0 is the pre-BIM stage; referring to a stage where the different participant in the project make use of drawing plans and sections in paper or digital form to exchange information without any common digital standards or processes (Ayinla & Adamu, 2018).

Level 1 is a level where 2D and 3D information are created in a digital environment that contains standards and govern the model development (Ayinla & Adamu, 2018). There is still a limited level of information exchange between the participants in the project. It could be considered as closed BIM with partial collaboration (Kumar, 2015).

Level 2: Information is managed in a 3D environment in which participants adopt a collaborative approach to deliver assets (Abbasnejad & Moud, 2013). Managed 3D environment with data attached, but created in separate discipline-based models integrated to a federated BIM model. Data may include construction sequencing (4D) and cost (5D) information.

Level 3: All data are supposed to be fully integrated into a single model and applications are fully interoperable without data loss (Ayinla & Adamu, 2018). It should also be compliant with emerging Industry Foundation Class (IFC) standards. This level of BIM will utilize 4D construction sequencing, 5D cost information and 6D project lifecycle management information.

Figure 11 by Pengfei et al. (2019) shows increased benefits and decreased cost when BIM reaches higher maturity levels. This is supported by Ayinla and Adamu (2018) which states that there is generally accepted that the level of implementation should be level 2 or above to gain the benefits from BIM.

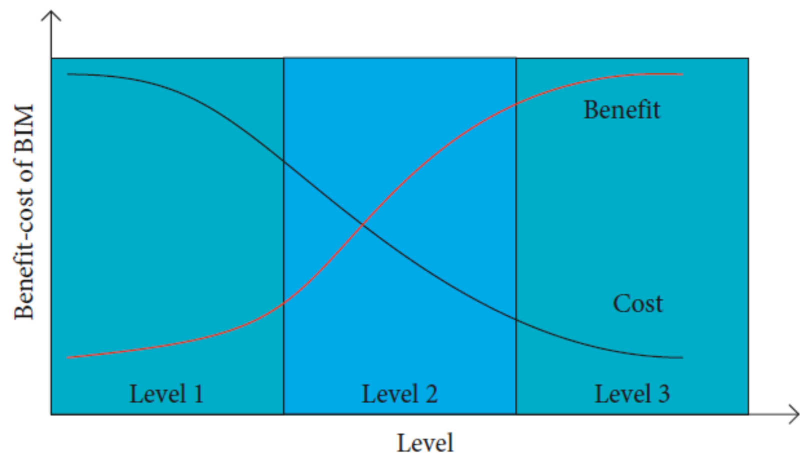


Figure 11 Benefit-cost curve of BIM. REF:(Pengfei et al., 2019)

4.4.2 ISO 19650

The ISO 19650 standard is based on the PAS 1192 standard (Godager et al., 2021). The benefits of PAS 1192 was seen internationally by owners and client, this made requirements for an international standard (Shillcock, 2019, Cited-in:Dadmehr & Coates, 2019). Due to evolution towards more international collaboration and a negative development in the use of the term "BIM Levels" varying countries demanded from International Organization for Standardization (ISO) to elevate the PAS 1192 series at an international level. This lead to the ISO 19650 series, "*forming an international series of standards creates a level playing field for organizations and suppliers from around the world to compete, innovate and collaborate, regardless of where those companies are located" (Dadmehr & Coates, 2019).* The ISO 19650 series is an important standard to define relevant roles and responsibilities (Godager et al., 2021). There will also help to facilitate the managing of information of the whole life cycle of a built asset by the use of BIM. All stakeholders in the project is covered by this standard, such as the asset owner, client, design team and construction team.

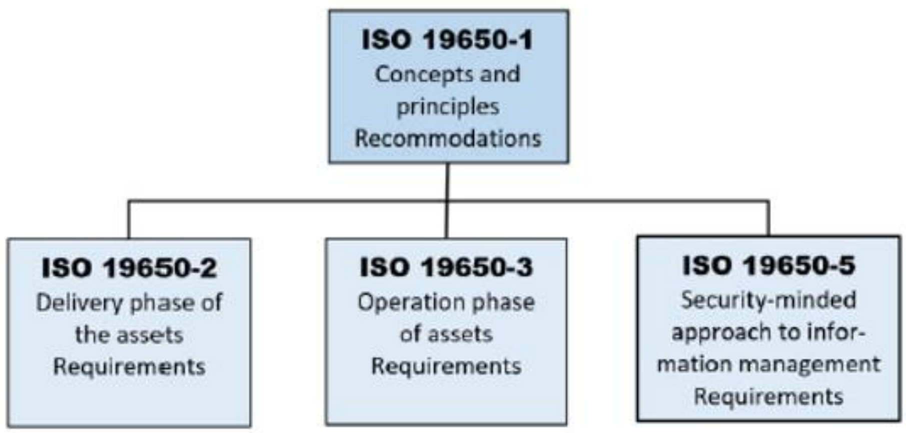


Figure 12 Framework of the ISO 19650 standard. REF: (Godager et al., 2021)

ISO 19650-1 specifies the concepts and principles for the building information through the life-cycle (Godager et al., 2021). The standard is stated to be applicable to built assets and construction projects of all sizes and all levels of complexity (Standard-ISO, 2019a). There is still recommended that the principles included in the standard should be applied in a manner that is proportionate and appropriate to level of complexity and scale of the asset or the project. In particular when SMEs are appointed for asset management or project deliver.

The NS-EN ISO 19650-1 (2019a) underlines the importance of new and improved ways of working due to new collaborative environments. *"Collaboration between the participants involved in construction projects and in asset management is pivotal to efficient delivery and operation of assets".* Different organizations wants to achieve a higher level of quality and a better re-use of existing knowledge and experience. The positive consequences of this collaborative environment is the potential to communicate, re-use and share information in a more efficient way, and also to reduce the risk of loss, contraction or misinterpretation. To achieve a high grade of collaboration it requires a mutual understanding and trust and a deeper level of standardized process than has been typical in the past. To achieve the information management in the ISO 19650-1 it is suggested that all parties participate in the implementation of the standard, such as the appointing, lead appointed and other appointed parties. To be able to comply with this the information that is produced should be made available in a consistent timely manner and be passed along the whole supply chain. With the present workflows a large amount of the resources are spent on making adjustments or corrections to unstructured information or incorrect management of information by people who doesn't have the right training. By adopting the principles from NS-EN ISO 19650-1 these delays can be reduced(Standard-ISO, 2019a).

Asset Information Models (AIM) and Project Information Models (PIM) are important principles in the NS-EN ISO 1950-1 standard. The two models are the: "structured repositories of the information needed for making decisions during the whole life cycle of a built environment asset"(Standard-ISO, 2019a). The PIM includes information regarding the delivery phase, while the AIM has information concerning the operational phase. The AIM and PIM models can include both structured (geometrical models, schedules and databases) and unstructured (documentation, video clips and sound recordings) information. The standard has different information requirements that contributes to the AIM and PIM as shown in Figure 13.

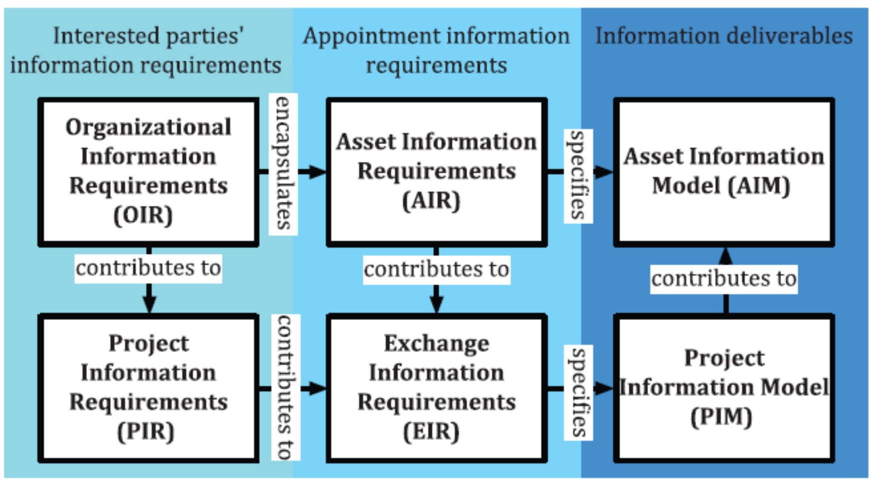


Figure 13 Different information requirements for the information models. REF: (Standard-ISO, 2019a)

NS-EN ISO 19650-1 (2019a) describes the various components in the following way:

- **Organizational information requirements (OIR)** explain what kind of information that is needed to answer or inform high-level strategic objectives within the appointing party. The requirements can arise for different reasons such as; strategic business operation, strategic asset management or portfolio planning.
- **Asset Information requirements (AIR)** sets out managerial, commercial and technical aspects of producing asset information and should include the information standard and the production method and procedures, which is going to be implemented by the delivery team. The information will be delivered at the project handover phase, and are mainly for operations and facility management for the built asset.
- **Project information Requirements (PIR)** explains the information that is needed to answer or inform high-level strategic objectives from the appointing party regarding a specific built asset project. PIR is based on both the project management process and the asset management process(Standard-ISO, 2019a). According to Radhakrishnan (2020) PIR can be related to the details of facility spaces (the various room which are functional within the building) the services

(the operational and maintenance activities that occur in these rooms) and various equipment properties such as maintenance requirements, type, location and the replacement period and costs.

- **Exchange Information Requirements (EIR)** set out managerial, commercial and technical aspects of producing project information(Standard-ISO, 2019a). The EIR is specified by the appointing party and seeks to regulate data and information that the appointed party is expected to fulfill during the handover (Scheffer et al., 2018). The EIR might be sub-divided and delivered to other sub-appointments, to cover the whole supply chain.
- **Asset Information Model (AIM)** seeks to support the strategic and day to day asset management processes which is established by the appointing party(Standard-ISO, 2019a).
- **Project Information Model (PIM)** supports the delivery of the project and contributes to the AIM as purpose to support asset management activities(Standard-ISO, 2019a). PIM also serves the purpose as a long-term archive of the specific project and auditing purposes. PIM can contain different details regarding project geometry, location of equipment, performance requirements during project design, method of construction, scheduling, costing and details of installed system, components and equipment, this includes maintenance requirements, during the project construction.

Information management according to ISO 19650 series are presented in the standard as a sequence of maturity stages from 1-3, seen in Figure 14. The standards is most suitable for the Stage 2 maturity, but is also partly applicable for stage 1 and 3. Stage 2 is described as a stage where: “manual and automated information management process are used to generate a federated information model. The information models includes all information containers delivered by task teams in relation to an asset or a project” (Standard-ISO, 2019a)

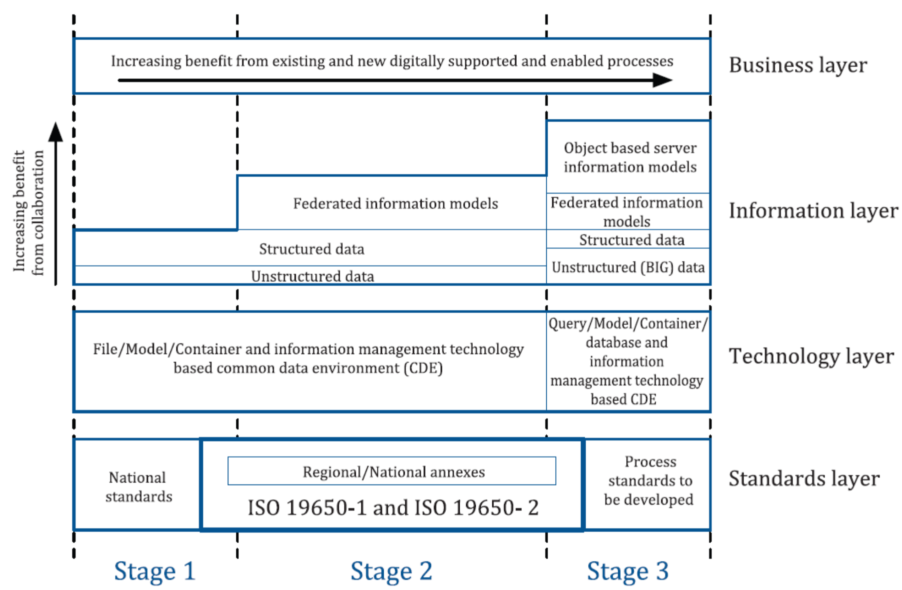


Figure 14 Maturity stages for information management. REF: (Standard-ISO, 2019a)

BIM stages are now being defined in the new ISO 19650 standards (2019a), which are being developed on the basis of the BSI PAS 1192 standards. This new standard will replace the previous known "BIM Levels" with "BIM stages" (Godager et al., 2021). Where the standard layers used for information management are changed from the PAS 1192 to the international ISO 19650 standards. Because of the increased possibilities within the technology, there is a growing focus on BIM maturity stage 3. The different BIM maturity stages are shown in Figure 15. The level of collaboration is increasing for each maturity stage. The collaboration is based on the level of interaction between the people, technology and process involved.

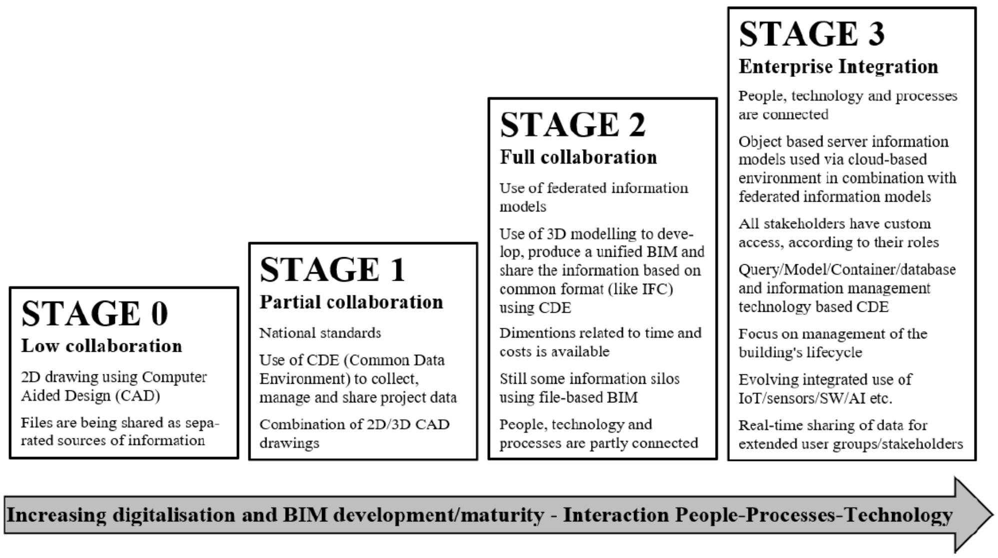


Figure 15 BIM maturity stages based on terminology in ISO 19650-1 standard developed by Godager et al. (2021).

Information delivery Cycle in ISO 19650-1 are built upon four main principles (2019a). (1) Information is needed for decision-making during all parts of the asset life cycle. (2) Information is specified progressively from a set of requirements defined by the appointing party, and the delivery of information is planned and progressively delivered by the delivery teams. (3) In a delivery team containing more than one participant the information requirements should be sent to the most relevant party or the point at which the information can be most easily provided. (4) The information must be shared and coordinated through the use of Common Data Environment (CDE), using open standards when this is possible and well defined operating procedures to enable a consistent approach by all organization that are involved in the project.

ISO 19650 is based on the idea that information deliveries in construction projects operates in a circular process. The AIM and PIM are produced throughout the information life cycle. These models are as mentioned earlier used during the asset life cycle for making different asset-related and project-related decision. This is shown in the figure below illustrating how the AIM and PIM is connected together. The model contains three key points A (start of deliver phase), B (progressive development of the design intent model into the virtual construction model) and C (end of delivery phase).

Figure 16 Generic project and asset information management life cycle. REF: (Standard-ISO, 2019a)

Common Data Environment (CDE) plays an integral part of the information delivery and information management in ISO 19650, and is important to reach Stage 2 of BIM maturity. A CDE is according to McPartland (2016) a central repository where the information in a project is housed. The information stored in the CDE is not limited to assets created in a "BIM environment" and it will therefore include documentation, graphical model and non-graphical assets. By using a single source of information the collaboration between project members should lead to less mistakes and duplications should be avoided. It aims to produce a platform where current project information is shared between the participants in a project group. This makes it possible for all actors to have access to the correct project information at all times. A project might have deliverables from varying parties such as the architect, electrician and structural engineer and these will be added to the CDE as data drops at specific point in the project. ISO 19650-1 (2019a) describes the CDE both as a solution and a workflow and that it should be applied for managing information during asset management and project delivery. In the delivery phase, the CDE solution and workflow support the information management process according to the ISO 19650-2:2018 (2019b).

The CDE platform is based upon information containers, where information can be stored, the containers includes all types of relevant information, such as the three-dimensional model, written documents, schedules and tables (Scheffer et al., 2018). At the end of a project, information containers required for asset management should be moved from the PIM to the AIM. The rest of the information containers should be retained as read-only in case of any disagreement and to help lessons to be learned.

According to ISO 19650-1 (2019a) the information containers should be in one of the three following revision statuses: work in progress, shared or published. In addition, there should be an archive, which provides a journal of all information container transactions and an audit trail of the development. When the information is to be transferred from one state to another it should go through a process of approval and authorization.

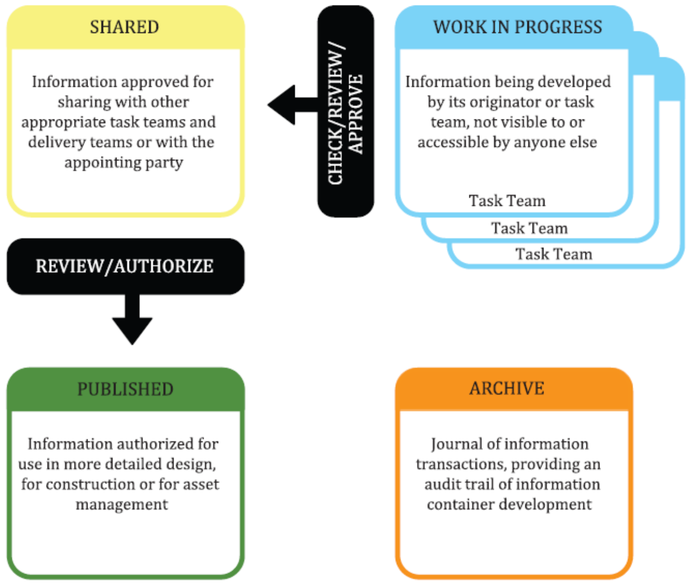


Figure 17 Common data environment (CDE) concept. REF: (Standard-ISO, 2019a)

The main advantages of adopting a CDE solution and workflow is (Standard-ISO, 2019a):

- Clear responsibility for the information within each information container, and the responsibility remains with the organization that produced it, and even though it is shared and reused, changes are only allowed by the specific organization.
- The shared information containers reduces the time and cost in producing coordinated information.
- A full audit trail of information production is available for use during and after each project delivery and asset management activity.

ISO 19650-2 specifies the information management requirements with the associated information exchange in the delivery phase of assets off all different types (Godager et al., 2021). The document can be applied to all types of projects and by all types and sizes of organizations, regardless of the procurement strategy adopted in the project.

According to Rudden (2019) the BIM Execution Plan (BEP) is the most integral document for BIM implementation in a project. The BEP seeks to address all aspects of BIM implementation in the project, from BIM uses and their integration into project management processes, over specific deliverables, analyses, interface management, communication, coordination plans facilitated by BIM, level of information needed, file formats and interoperability. The pre-appointment BEP is issued at the tender stage, and gives the guidelines for the BIM use, and what type and Level of BIM implementation that will be delivered in accordance with the requirements from the appointing party (Standard-ISO, 2019b). The actual BEP is later confirmed by the lead appointed party in agreement with each of the appointed parties (Standard-ISO, 2019b).

According to ISO 19650-1 (2019a) the level of information need of each information deliverable should be determined according to its purpose. This includes to determine the quality, quantity and granularity of information. There exists a wide range of metrics to determine levels of information need. Two complementary but independent metrics can define the geometrical and alphanumerical content in terms of quality, quantity and granularity. After the metrics are defined, they should be used to set the level of information need for the whole project or asset. This should be described thoroughly in the OIR, PIR, AIR or EIR. The level of information need are determined by the minimum amount of information needed to answer each of the specific requirements. Information beyond this minimum is considered as waste.

ISO 19650-3 sets according to Godager et al. (2021) out the requirements for information management using BIM during the operational phase of an assets life. This makes it possible for the appointing party to establish requirements regarding the information management for the operation and management phase of the assets.

ISO 19650-5 decides the requirements for security minded management of the sensitive information within BIM and helps organizations to understand important security vulnerabilities and the measures that is required to limit existing security risks to acceptable level (Godager et al., 2021).

4.4.3 OpenBIM

In recent years, it has become increasingly important in the industry to focus on the interaction and collaboration between the different stakeholders in projects. It is important with good communication between all stakeholders in a project to make the most out of the possible advantages from the BIM technology (Westgaard et al., 2010). OpenBIM makes collaboration within a BIM project as open and simple as possible. This method has implemented an "open" file format, which many different software can use when exporting their individual files. The file format is called IFC (Industry Foundation Classes), and provides for the exchange of object based models between programs (Selvær, 2011). Selvær (2011) states that "The IFC format has been created to be a bridge and information platform between the various programs on the market".

BuildingSMART in Norway have developed their own openBIM system. The system is based upon three main components that they suggest needs to be in place to gain the maximum effect of the use of open BIM. (1) IFC- Industry Foundation Class (ISO 16739), (2) IDM – Information Delivery Manual (ISO 29481), (3) IFD (bSDD)– buildingSMART Data Dictionary based upon ISO 12006-3 (buildingSMART, nd). (1) IFC is an industry-specific file format for exchanging building information modeling (BIM). (2) IDM is a standardized process and delivery specification that makes the subjects work effectively together. It describes participants, procedures and requirements for deliveries in projects. (3) bsDD is a dictionary or a terminology library. The key concepts are units of measurements and properties uniquely defined with their own unique identity, a so-called GUID (global unique identifier), which is a machine-readable code. This makes it possible for example a door to remain a door regardless of language or national regulations. The civil state client Statsbygg in Norway mandated the use of IFC and IFD by 2010 (Edirisinghe & London, 2015).

Closed or lonely BIM is the definition of the use of BIM when the various stakeholders work with the BIM model in separate software, where the information is stored in a closed format that cannot be shared with all the participant (Eastman et al., 2011). In closedBIM it is mainly the geometric information that are exchanged, while the additional information produced by a consultant is only available in the same software that the consultant has used. This inhibit the information flow and sharing in the design process.

4.5 Enterprise BIM

This is an emerging concept that places BIM use in a holistic structure through the whole life-cycle of the building assets (Godager et al., 2021). The purpose of EBIM is to utilize the building related information to strengthen collaboration, coordination, transparency, utilization and management across and between all stakeholders and support throughout the whole life-cycle of the built assets. Godager et al. (2021) defines EBIM as "*a virtual holistic representation of the life-cycle of the built environment adapted for optimized enterprise management, knowledge-sharing, and collaboration".* EBIM is built upon an integrated and shared cloud environment integrating a Common Data Environment (CDA) and Computerised Maintenance Management (CMMS). A cloud based CDE is an agreed source of information for a given project or asset, this is often provided and managed by the appointing party.

Digital Twins (DT) in EBIM. The use of DT is considered as a revolutionary way of integrating and managing built assets throughout their life cycle, which can possibly lead to a revolution in the Architecture, engineering, construction and operation (AECO) industry. Several industries such as aerospace and transport have been using DT for several years (Grieves, 2016). Most definitions of DT includes a digital representation of a physical concept, but is varying in terms of the level of integration between the virtual and the physical. Godager et al (2021) represent some typical characteristics of DT, such as:

- Updated 3D geometry, including materials and attributes
- Connectivity to connect objects/static data
- Connectivity to sensors using indoor positioning and navigation systems that provide live streaming data
- Computing and analysis capabilities
- Defined data structures organized on a CDE platform
- User interfaces for applications that connect everything together, including visualization and human interaction for all operators or permitted users.

The purpose of DT is to be a comprehensive virtual and functional description and operational model of physical components, products or systems, this includes all information that can be used for different purposes during the life-cycle (Boschert & Rosen, 2016).

4.6 Different uses of BIM and BIM- benefits

According to (Eastman et al., 2011), effective use of BIM may bring several positive impact to the project outcome through improved design, improved constructability, quicker project completion, saving time and money both for the owner and for the project team. The new technology is also emerging as a solution to reduce waste and inefficiency in building design and construction.

4.6.1 Specific BIM use

There are different uses of BIM in the construction. Some important uses of BIM includes 3D, 4D, 5D and 6 D BIM. These are described as the followings by Eastman et al. (2011):

3D - Model:

1. **Model walkthroughs.** This tool provides a good visualization tool make it possible for the designers and contractors to collaborate to identify and resolve problems with the help of the model. This could be done before walking on-site.

2. **Clash detection.** In traditional workflow, many clashes are identified when the contractor receives the design drawings and everyone is on-site and working. This could lead to delays and decisions need to be made quickly in order to provide a solution. The BIM technology enables potential problems to be identified early in the design phase and resolved before construction begins.

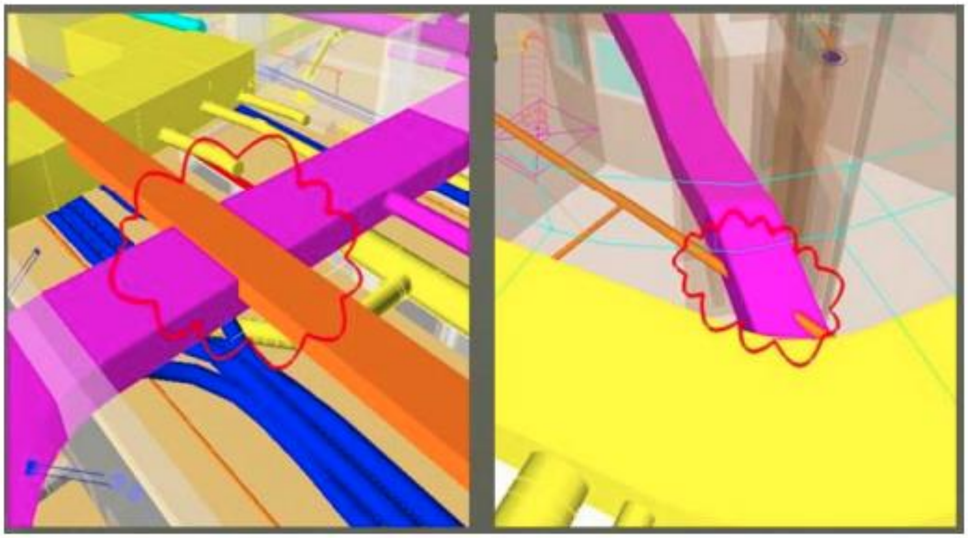


Figure 18 Visualization of Clash Detection REF: (Azhar et al., 2008)

3. **Project visualization.** Making simulations of the schedule, which can show the owner what the building will look like as construction progresses. This works as an effective marketing tool for all involved stakeholders in a project.
4. **Virtual mock-up models.** The virtual mock-ups can replace the physical mock-up models, which are often requested in larger projects. This could be made and tested for a fraction of the cost.
5. **Prefabrication.** BIM facilitate for more utilization of prefabrication components. The technology increases the chance that the components will fit once on-site. As a result, more construction work can be performed offsite, cost efficiently, in controlled factory conditions and then efficiently installed.

4D - Time

1. **Construction planning and management.** The BIM models can provide a visualization to verify site logistics by including tools to visually depict the space utilization of the job site throughout the construction process of the project. This can also be used to enhance the planning and monitoring of health and safety precautions needed on-site in the progress of the project.
2. **Schedule visualization.** By doing a schedule based on the visualization, different project members will be able to make decisions based upon multiple sources of accurate real-time information. The BIM model is able to produce a chart, which can show the critical path and visually show the dependency of some sequences on others. When the design is changed, advanced BIM models will be able to automatically identify the changes that will affect the critical path, and show the corresponding impact on the overall delivery of the project.

5D – Cost

1. **Quantity Take-offs.** A produced BIM model includes information that allows a contractor to accurately and rapidly generate a wide range of important estimating information, such as material quantities and cost, size and area estimated. When changes are made, the information will be automatically adjusted, this facilitate for greater contractor productivity.
2. **Real Time cost estimating.** In a BIM model, cost data can be added to all objects enabling the model to automatically calculate and estimate the material costs. This helps the designers to conduct value engineering. It should be noted that overall project pricing would still require expertise from a cost estimator.

6D – Sustainability assessment

1. **Lifecycle management.** The model created by the designers and updated throughout the construction phase will have the capacity to become an «as built» model. Which can be delivered to the owner and used for facility management.
2. **Data capture.** Different sensors can record relevant data for the operation phase of a building, enables BIM to be used to model and evaluate energy efficiency, monitor a buildings life cycle costs and optimize its cost efficiency. It also makes it possible for the owner to evaluate the cost-effectiveness of any proposed upgrades. The use of the BIM model also makes it possible to quantify the CO2 footprint by conducting LCA analyzes based on the material from the model (Soust-Verdaguer et al., 2017).

7D- Facility Management

The last standard dimension mentioned in the literature is the *7D BIM* (United-BIM, 2020). 7D is about operations and facility management by building managers and owners. The 7D dimension is used to track important asset data such as its status, maintenance/operation manuals, warranty information, technical specifications, etc. According to United-BIM (2020) "7D is a unique approach where everything related to the facility management process is collated at a single place within the building information model". This will help to improve the quality of service delivery during the whole lifecycle of the project. Using the 7D dimension will help to facilitate that everything in the project stays in the best shape from the first day until the day of demolition. Some benefits of using 7D are according to United-BIM (2020).

- Optimized asset and facility management from design stage to demolition
- Simplified and easy replacement of parts and repairs anytime during the entire life of a building
- Streamlined maintenance process for contractors and subcontractors

In addition to the seven standard and regulated dimensions, there is three new dimensions of BIM that is not described further in this thesis. The following dimensions are: 8D- Safety during design and construction, 9D- Lean Construction and 10D- Industrialization of construction.

The figure below shows an overview of the different uses of BIM technology.

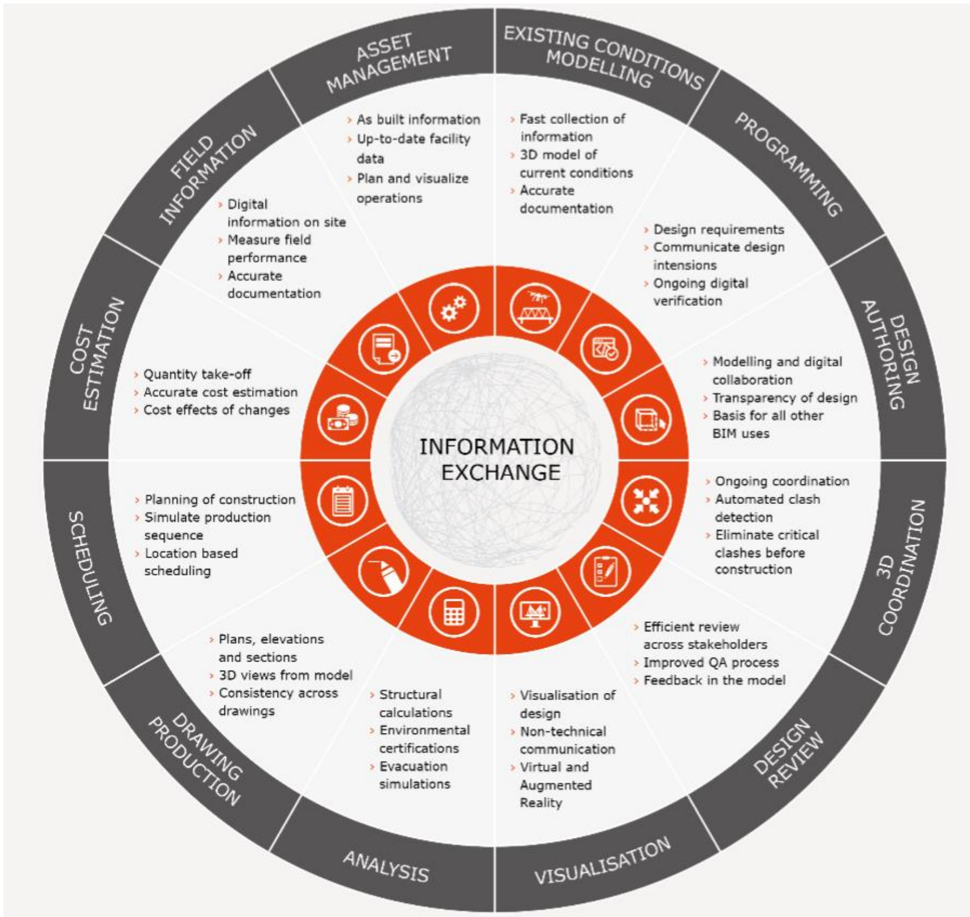


Figure 19 Overview of different uses of BIM. REF: (Christensen, 2018)

BIM and Automation.

Kouch et al. (2018) explains that BIM can efficiently provide the required information and accurate data that is required for different types of automation in the construction industry. This could be used for model simulation and machine control in construction automation and robotic construction. BIM is therefore important for the firms who are seeking to increase their competiveness, productivity and also their existence in the future era of the building industry.

Extended reality: Virtual- and Augmented Reality.

Extended reality is a collective term for immersive technologies, this includes virtual reality (VR) and augmented reality (AR). These technologies have enormous potential to improve the efficiency and productivity in AEC (Alizadehsalehi et al., 2020). Even though the implementation of XR is rather low in the AEC, the potential is widely accepted. BIM has revolutionized the AEC industry, and by integrating BIM and XR more of the potential in the technology can be exploited (Alizadehsalehi et al., 2020).

Virtual Reality (VR) refers to computer technologies that use software to generate realistic images, sounds in combination with other sensations to represent an immersive environment and to simulate the users physical presence in this environment (Alizadehsalehi et al., 2020). It is proven that VR are effective in construction safety training, project schedule control and for optimization of the site layout of construction projects. It could also facilitate for better collaboration among different stakeholders helping them to understand a complex design and to solve issues regarding the design and make the user's familiar with the project so that better design decision can be taken in collaborative decision making.

Augmented Reality (AR) is an overlay of computer-generated content on the real world that can superficially interact with the environment in real time (Alizadehsalehi et al., 2020). AR is expected to have the most significant impact on the AEC industry. Especially on construction operations, in four different ways: by reducing rework, by improving safety improvement, by lowering labor cost and to make sure that the schedule is being followed.

Paperless construction-site and construction-site without drawings.

The principle of paperless construction sites is to remove all printed drawings, and rather use tablets and other handheld devices for visualization. Paper drawings are still used at a great extent in the Norwegian AEC industry, this is in contrast to the society in general where most of the communication is digital (Andreassen & Beste, 2020). They observed that messages on the construction-site were still written on planks and drawings. A major challenge using drawings on the construction-site is that a drawing has a validity when it is sent for printing, but when a change occurs on the basis of the drawing and adjustments are made on the construction site during the construction, the validity is quickly weakened. This might lead to work on an outdated version. In 2016 the civil state client Statsbygg started to use "BIM-kiosk" on their projects. This was a simple concept, which made the digital model available for the workers on the construction site. This was used as a support to their traditional 2D-drawings. Drawing free construction-site on the other hand takes this a step further and the intention is to build directly on the 3D model using tablets, mobile phones or VR and AR glasses (Statsbygg, 2018, Digitale kontraktskrav, cited-in:Fakhrzad, 2020).

4.6.2 Benefits of BIM

Georgiadou (2019) conducted an literature review and revealed some key benefits of BIM in practice, which are presented in five categories:

Cost efficiency. BIM has the ability to update, maintain, store and share data in many various dimensions (Georgiadou, 2019). This leads to increased efficiencies at each stage of the project lifecycle, thus leading to cost reduction. BIM helps to provide information that is more accurate, this leads to reduced risk of making decisions based on assumptions from outdated drawings. BIM also facilitate improved design through collaboration and information sharing which can eliminate waste in material supply and human resources (hence, costs).

Quality assurance and on-time delivery. BIM can enhance efficiency and accuracy leading to real-time scheduling and on-time delivery (Georgiadou, 2019). The traditional closed system often leads to a gap between the designed and the actual scheduling, which often leads to inaccurate forecasts, especially projects lasting for a long period.

Collaboration and communication improvement. The adoption of a shared set of standards and the use of CDE sets the framework for a new integrated collaboration approach. According to Georgiadou (2019) many researchers argue that BIMs greatest contribution is the ability to update models in real-time, eliminating clashes, solve iterations in an early stage of the design process and exchange important project information over the whole lifecycle. This facilitate for effective communication and conflict resolution both within the organization and between the different stakeholders in the project. This is done by placing the BIM in the center of the communication.

Design optimization. BIM enables inspection of the building from various angles including sub-structures, intersections and other building performance characteristics (Georgiadou, 2019). The architects can integrate conceptual design using e.g. ArchiCAD and engineers can make detailed 3D structural design using e.g. AutoDesk Revit. The visual representation of the design enables accurate decision –making through clash avoidance and clash detection. Hence, the risk of rescheduling construction methods is reduced and the risk of expensive rework is eliminated.

Lifecycle thinking and sustainability. The role of BIM account for the whole lifecycle for the project. According to Georgiadou (2019) 85 % of total lifecycle costs of a building occur after the construction is completed. Making the clients and facility managers (FM) benefitting the most from BIM implementation. A visual replica of the building with "as-built" documents and drawings maintained through the whole lifecycle can help the FM teams. It could contribute to both preventive maintenance and corrective maintenance. The civil state client Statsbygg have mandated BIM use for the lifecycle of their buildings (Edirisinghe & London, 2015).

4.7 Model Maturity Index – MMI

MMI describes the maturity of an object in a BIM model. The index describes how far the objects have come in the model, from concept to as built. The elements in a BIM model will go through the phases shown in the figure below before they are built or placed in the building. Previously, this was solved through revision of paper drawings and was a time consuming task. Through MMI in BIM, this interdisciplinary work is streamlined, and uncertainty about the maturity of the objects in the model can be virtually eliminated (Fløisbonn et al., 2018).

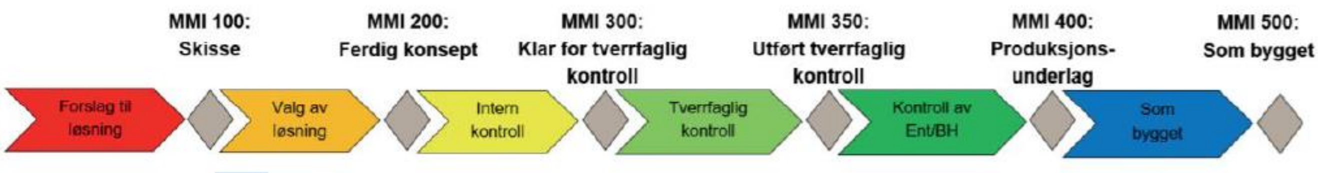


Figure 20 Process for MMI REF: (Fløisbonn et al., 2018)

Table 6 Steps in MMI. REF: (Fløisbonn et al., 2018)

MMI 100 : Sketch or Pre-concept	Several different proposals for a solution is presented. In this phase, it is natural to make large and small changes in the process up to MMI 200
MMI 200 : Finished concept	The objects included in the model are almost final, but small changes can occur.
MMI 300: Ready for interdisciplinary control	The interdisciplinary objects in the model must be modeled and placed in the correct size. In addition, these objects should not create conflicts.
MMI 350 : Finished interdisciplinary coordination	The objects in the model are controlled interdisciplinary with respect to all related objects. An iterative process that eventually achieves MMI 350 status.
MMI 400 : Basis for production	All conflicts or other input that changes the design are reported for review. After all feedback, the item has achieved MMI 400 and orders for production can be completed.
MM 500 : As-built	To achieve MMI 500, the objects must be built, and the model must be updated to be in accordance with the built asset.

5 Findings from Literature review

The following subchapters will summarize the key findings from the fourteen final articles (seen in table 7). The subchapters are used to describe the key findings from the literature and to get an overview of the topics in the existing literature, this was considered to provide a comprehensive overview of the existing literature. The following subchapters concerns the following topics:

- 5.1 General
- 5.2 Level of maturity and use of BIM among SMEs
- 5.3 Barriers for BIM adoption and implementation among SMEs
- 5.4 Driving forces and strategies for BIM adoption and implementation among SMEs
- 5.5 Digital Divide
- 5.6 Framework for BIM implementation for SMEs
- 5.7 Suppliers Chain
- 5.8 BIM in residential projects in the UK

Table 7 Overview of literature with corresponding topic.

Nr	Title :	Author :	Year :	Main topic :	Main contribution to subchapter:
1	Adoption and implementation of BIM in SMEs : a review and conceptualization	Saka & Chan	2020	Systematic review regarding BIM implementation and adoption among SMEs.	5.1
2	Assessing supplier capabilities to exploit building information modelling	Wang et al.	2019	Assesing the BIM maturity within contractors supplier base.	5.7
3	A Three-Step BIM Implementation Framework for the SME Contractors	Kouch	2018	Framework for BIM implementation	5.6
4	BIM adoption and implementation : focusing on SMEs	Vidalakis et al.	2020	Barriers and driving forces for BIM adoption and implementation	5.1 5.3 5.4
5	BIM and the small construction firm : a critical perspective	Dainty et al.	2017	Investigating the Digital Divide in the AEC sector between SMEs and large companies.	5.5
6	BIM divide : an international comparative analysis of perceived barriers to implementation of BIM in the construction industry	Saka & Chan	2021	Investigation of perceived barriers in BIM implementation among SMEs.	5.3

7	Barriers and facilitators for BIM use among Swedish medium-sized contractors (From previous work)	Bosch-Sijtsema et al.	2017	Investigating barriers and driving forces for BIM use among Swedish medium-sized contractors.	5.2 5.3 5.4
8	Bridging the digital divide gap in BIM technology adoption	Ayinla & Adamu	2018	Investigating the digital divide in the AEC industry	5.3 5.4 5.5
9	Critical Challenges for BIM adoption in SMEs : Evidence from China	Pengfei et al.	2019	Barriers and driving forces for BIM adoption	5.3 5.4
10	Evolution within the maturity concept of BIM	Martin et al.	2019	BIM maturity-Level and driving forces for SMEs	5.2 5.4
11	An overview of benefits and challenges of BIM adoption in UK residential projects (From previous work)	Georgiadou	2019	Investigating benefits and challenges of BIM adoption in UK residential projects.	5.1 5.2 5.3 5.8
12	Generic and SME-specific factors that influence the BIM adoption process : An overview that highlights gaps in the literature	Hochscheid & Halin	2020	Overview of gaps in literature and barriers for adoption.	5.1 5.3
13	Investigating benefits and criticism of BIM for construction schedeuling in SMEs : an Italian case study	Malacarne et al.	2018	Investigating barriers of using BIM 4D among SMEs	5.3
14	Key Factors of an Initial BIM Implementation Framework for SMEs	Kouch et al.	2018	A BIM implementation framework for SMEs	5.1 5.3 5.6

5.1 General

Definition of SMEs varies across different regions and boundaries. Regardless of the definition they have some similar characteristics (Saka & Chan, 2020) such as a limited number of employees and a limited turnover. The differences between the SMEs and the large firms makes a single approach to BIM non-viable (Saka & Chan, 2020). According to O'Regan and Ghobadian (2005cited in ; Saka & Chan, 2020) SMEs spend around 3 % of their turnover on innovations which is smaller compared to that of larger firms. Implementation of innovation transfer can often fall outside the ‘comfort zone’ of many SMEs when involving too much investment and risk, often making this process unsuccessful (Sexton et al. 2006; cited in-Saka & Chan, 2020).
Regardless of the considerable development of BIM tools, the AEC industry and in particular SMEs, hesitates to employ BIM, impeding its technical and financial benefits from being fully exploited (Kouch et al., 2018). Thus the large potential effect the SMEs can have in the global market and especially in the construction market, Kouch et al. (2018) emphasizes the importance of addressing the issues regarding BIM adoption and implementation for the SMEs.

Hochscheid & Halin (2020) states that SMEs are often more flexible than the large enterprises, and they have shorter communication lines internally which allows them to reduce their response time for problem solving. The larger enterprises often face significant inertia due to the organizational complexity. A flat hierarchy in many SMEs are also said to facilitate the internal collaboration and information sharing. Despite this the implementation in SMEs is commonly considered a daunting task (Ghaffarianhoseini et al., 2016 cited in:Hochscheid & Halin, 2020). The BIM report from National Building Specification (NBS) (2017, cited in:Vidalakis et al., 2020) stated that BIM is not just for larger organizations, but small organizations are less likely to have adopted BIM. Where it was revealed that small organizations are approximately 65 % less likely to have adopted BIM than larger companies. NBS 2017 also revealed that 62 % of construction professionals are currently aware and use BIM (Georgiadou, 2019), stating that the adoption of BIM follows a normal adoption curve, which was at 13 % in 2011.

Saka & Chan (2020) describes the importance of defining BIM adoption and BIM implementation as they are often used interchangeably in a large numbers of studies. BIM adoption could be considered as the decision by the SMEs to either adopt or reject BIM innovation within their own organizations. While the implementation follows the decision to adopt BIM, and it involves implementing BIM in their organization.

There are different types of SMEs with respect to their professions such as contracting, architectural and civil engineering. The level of awareness and adoption rate varies across these professions, the highest level of adoption and awareness are often found among the consultants due to their familiarity with CAD (Saka & Chan, 2020). Hochscheid & Halin (2020) says that the average size of firms in the construction sector is not representative of that of architecture firms, which often have extremely small structures. The architects are often at the heart of the BIM process due to their early involvement in the project, and they frequently produce the first model exchange.

Despite that the SMEs accounting for a larger percentage of the firms in the AEC industry, Saka & Chan (2020) states that there has been a dearth of research studies on the adoption and implementation of BIM among SMEs. An increasing trend in the extant studies is to generalize the findings without considering the size of the companies. According to Saka & Chan (2020) the publications focusing on the SMEs ranges from awareness, adoption to implementation of BIM in SMEs. While there has been limited papers on the empirical evidence regarding BIM benefits, risk, cost and legal issues related to BIM implementation in SMEs. Few of the publications are also through the use of theoretical lenses of innovation and knowledge, most of the publications have none. Hosseini et al. (2015, cited-in:Saka & Chan, 2020) states that "neglecting theoretical lenses which have been built upon the robust of knowledge from sociology, psychology and communication by studies aiming at investigating any aspect of innovation seems irrational". The same research also revealed that the identified benefits from using BIM are often non-tangible, such as improving project collaboration, improving stakeholders understanding, and improving project information management. Most of the studies regarding BIM benefits are on perceived benefits, based on survey approach rather than case study based approaches. This approach is stated to may not be representative of the actual benefits. This survey approach is also used to map different challenges and barriers, and the perceived challenges are often exaggerated and do not depict the actual challenges (Saka & Chan, 2020). Another deficiency in the existing literature is mentioned by Hochscheid & Halin (2020) which says that most of the studies are too generic and should now focus on specific professions (e.g., architecture and engineering firms).

5.2 Level of Maturity and specific use of BIM among SMEs

***Reasoning of topic**: It was considered interesting to see at what BIM maturity level the SMEs were conducting their projects and see which BIM tools where exploited the most by SMEs. However, not much of the literature addressed this topic. The topic does not directly address any of the research questions, but are used as comparison with the survey results in the discussion.*

Martin et al. (2019) conducted a survey among different organizations in the France construction industry. The survey resulted in 104 responders, where 79 % were included in the category SMEs (less than 250 employees). The respondents were asked to place themselves in the Bew Richards maturity wedge. According to Martin et al. (2019) the results were as expected, since the maturity level 2 now is widespread within the AEC industry. The low degree of level 3 is not surprising because of the difficulties for SMEs to access this level. Three quarters of the results reveals that BIM is recently adopted (less than four years).

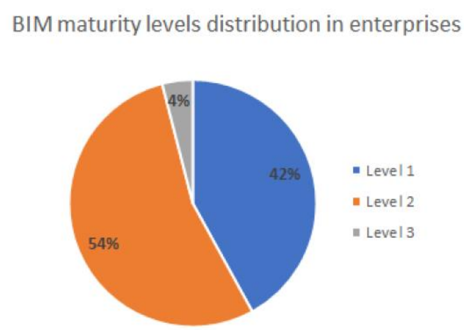


Figure 21 BIM maturity distribution in companies. REF:(Martin et al., 2019)

Bosch-Sijtsema (2017) performed a survey among Swedish medium-sized contractors (50-500 employees) where they found the extent in which BIM was used for the following activities. The answers were ranked from 1 (never uses) to 5 (always used). We can see from the responses that the visualizing capabilities were exploited by most of the participants, both for visualization in the detailed design and visualization for users.

Table 8 BIM use among Swedish medium-sized contractors. REF: (Bosch-Sijtsema et al., 2017)

Activity	Rank	Mean	Max	Min	SD
Visualization in the detailed design	1	3.61	5	1	1.01
Visualization for users	2	3.44	5	1	1.34
Clash controls	3	3.00	5	1	1.45
Visualization for production planning	4	2.83	5	1	1.57
Quantity estimation	5	2.56	5	1	1.57
Logistics on site	6	2.39	5	1	1.57
Site lay-out	7	2.11	5	1	1.52
Prepare the model for facility management	8	1.78	5	1	1.27
Cost estimation	9	1.50	4	1	0.96
Time planning	9	1.50	5	1	1.01
Generating purchase plans	11	1.44	4	1	0.83
Staffing plans	12	1.28	4	1	0.73

5.3 Barriers for BIM adoption and implementation among SMEs

***Reasoning of topic**: It was considered essential to look at what kind of barriers SMEs face when adopting and implementing BIM, being able to answer research question 2.*

The findings of the barriers for SMEs for adopting and Implementing BIM is sorted in the framework created by Nepal et al. (2014). The barriers are considered to be constraints for a BIM-enabled project. The four categories are (1) Technology, (2) People/organization, (3) Process and (4) Project context.

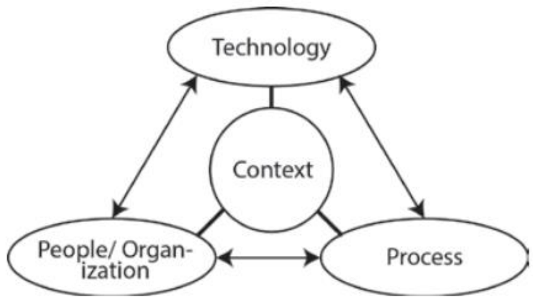


Figure 22 Technology, organization/people, process, and project context. Framework for BIM evaluation. REF: (Nepal et al., 2014)

1. Technology

Interoperability and complexity of technology: Interoperability is a major concern among SMEs. They are concerned about the inefficiencies and interoperability issues of existing software (Ayinla & Adamu, 2018; Georgiadou, 2019; Vidalakis et al., 2020). The barrier regarding how to operate BIM technologies e.g. utilizing the software was especially seen as a threat to adoption of maturity Level 3.

The use of the 3D BIM model for quantity take-off makes the construction scheduling more intuitive and precise (Malacarne et al., 2018). Despite this, the process remains linear, fragmented and therefore with a rather low degree of automation, due to unidirectional software, which is hindering the interoperability. The model and the scheduling files evolves separately along the process and are only combined during the final stage of the process, and they still work as two separate entities in the same environment. This might lead to a restart of the process from the beginning if changes occur, this includes re-modelling, re-extracting quantities, re-calculating task durations and re-visualizing the 4D model. Only sophisticated software support a holistic and integrated process (Malacarne et al., 2018). It is stated that this software is currently not suitable for local SMEs, due to cost and complexity.

Malacarne (2018) also observed other limitations in the interoperability when investigating scheduling using BIM 4D. The research team found limits in the interoperability of software that were not developed in the same solar year. E.g. Navisworks®2016 did not support any file formats from Revit® 2017. This could be a barrier for SMEs when implementing BIM, since they often don't update their software every year (Malacarne et al., 2018).

Bosch-Sijtsema et al. (2017) revealed that some medium-sized contractors are experiencing the software quite complex and difficult to use in combination with bad usability. Georgiadou (2019) also reported on disadvantages regarding the use of BIM software. Such as the reliability and performance of the technology was reported to be disadvantageous. The BIM models should ensure availability of information, system and processes (Georgiadou, 2019), despite this, many of the existing systems do not support openness of data, which is considered vital for good collaboration within a BIM project.

Number of software solutions: A large amount of software solutions required for the BIM scheduling process is another critical factor(Malacarne et al., 2018). Four software solutions were required to reach the main objective. The software solutions required were Autodesk Revit®, MS-Excel®, MS-Project®, and Autodesk Navisworks® and each of the software solutions has a specific objective (modelling, calculating, visualizing durations, combining the visualization of durations with the BIM model). This leads to a high level of commitment and could become very time consuming (Malacarne et al., 2018). This is supported by Bosch-Sijtsema (2017) which stated that the need for several actors to be aware with many different types of software made the process more difficult and complex.

Data security: According to Abd Jamil and M.S. Fathi (2018, cited-in:Pengfei et al., 2019) there are concerns regarding storage of data and information. BIM models stores a large amount of data, involving input, output, and updates. The accuracy of the data transmission among different stakeholders in the project must be ensured. Enterprises are not willing to upload data if data security cannot be granted. This is stated to hinder the collaboration and could be solved through encryption or the use of secure file exchange servers during transmission.

2. People/organization

Cultural resistance*:* Saka & Chan (2021) conducted a international survey to discover the main barriers for SMEs and large firms. They revealed that although SMEs and large firms are in the same AEC industry and have som similaristies, there are differences in perception regarding BIM barriers. The highest ranked barrier among both SMEs and large firms where '*resistance to change*'. However, the resistance to change is perceived higher among the SMEs. This is supported by Ayinla & Adamu (2018) which states that the traditional nature of the construction industry is considered a significant barrier. Older persons in the AEC industry are often more traditional than youger professionals . The older professionals are often included in the top management in many organizations and hence the decision makers in the organization. The top managements perception of BIM and its technology is considered to have a knock on effect on an organistaions view on innovations (Ayinla & Adamu, 2018). Hochscheid & Halin (2020) says that SMEs prefer to work with well tested technologies in an artisanal way, and are more cauttios to taking risks (Hochscheid & Halin, 2020) due to economic vulnerability. Bosch-Sijtsema et al. (2017) explains a prevailing culture in the construction industry where the main focus is on the financial aspects of projects in conjunction with a resistance to change. "The competition is highly based on price (Bosch-Sijtsema et al., 2017)". The resistance to change is in may ways summed up in their heading, which are taken from one of the interviews "we wait until someone tells us to use it". The resistance to change could be a possible obstacle for effective collaboration between different stakeholders in a project (Georgiadou, 2019). Due to the intersection of established knowledge, experiences and behaviour of individuals and organizations when adopting and implementing a novel concept such as BIM, which requires a change in the established mind-sets and practices (Rostami et al. 2015: cited-in:Georgiadou, 2019).

Georgiadou (2019) argues that the cultural resistance involves challenges related to people and establsihed cognitive practices. Which involves shifting from traditional procurement methods to integrated procurement methods more suited for BIM projects. The contractual limitations in traditional procurement methods is a hinder for effective implementation of a performance-based system: i.e the system should be based on whole life cycle assessment in project design and delivery. The employees working with a traditional procurement approach often do not see any short-term financial benefits which jusifys the use of BIM, which leads to a slower adoption rate.

Cost of hardware and software: It could be argued that cost barriers arises due to the need for new technology and therefore should be placed within the technology factor. It is still chosen to be arranged within the people/organization, because the barrier evolves due to the limited resources within the organization and needs to be solved by the organization it has emerged within.

The cost variable includes the cost of obtaining software, where too many new versions of software emerging frequently, and licensing fee and high set-up cost (Ayinla & Adamu, 2018). Georgiadou (2019) on the other hand says that BIM software packages are similar in price to that of common CAD software. Saying that some vendors are selling packages that include both BIM and CAD platforms at the same price that what used to be for CAD-only packages. On the other hand Georgiadou (2019) says that the total of CAPEX and OPEX for BIM adoption is considerably higher, especially for SMEs. BIM is a relatively new way of working in the AEC and it is generally lacking additional resources to finance its implementation.

Cost of training employees in new technology: SMEs often have limited resources, the training of staff is capital intensive, and the SMEs may not be able to afford it. It is reported from 55 % of the companies in the AEC industry in the UK that there is an increase in costs related to training of staff (Georgiadou, 2019). When new BIM technologies continue to merge the staff needs to be constantly retrained on the way of using the software. SMEs are highly dependent of having cost considerations, making this an even greater barriers for the SMEs. Having a lower cash flow is also considered a constraint for the SMEs (Ayinla & Adamu, 2018). This is emphasized by Hochscheid & Halin (2020) which states that SMEs often report that they don't have budget or time to afford the implementation of hardware and software.

Belvedere et al. (2009, cited-in:Pengfei et al., 2019) found that SMEs cannot invest in the latest manufacturing practices and technologies which can increase their performance. SMEs often have a risk-averse attitude towards new technology and often adopt reliable methods to ensure the ROI. Due to lack of sufficient evidence, SMEs consider BIM too risky due to the limited resources. Pengfei et al. (2019) points out that SMEs often are short on project resources, this leads to them not being able to afford extra overheads on infrastructure construction and training people to support new technology. Companies with limited resources regarding human, time and financial resources are forced to focus on what they consider to be important criteria for success. Bosch-Sijtsema(2017) also points at the cost barrier for Swedish medium sized contractors. All their interviewees stated that it was expensive for medium-sized construction firms to invest in BIM, which was confirmed making this the third highest ranked constraint in their surveys. Both the cost of education in BIM and the cost of investing in computers and software where mentioned. They also stated that it was hard to predict the cost involved when BIM is used in a construction project.

Georgiadou (2019) states that practices of all sizes can meet the UK Government mandate and that the additional costs are also achivebale for small practices. Particulary for the involved training, this cost should be considered as an investment rather that a cost. A implementation in the internal organization will later help to eliminate or reduce the training costs when the learning curve is established through experience within the company.

The software necessary for a circular and integrated BIM 4D process is not suitable for local SMEs according to Malacarne (2018). The price of the software making 4D an integrated process is high compared to more common tools used for BIM 4D, such as Navisworks ® and Synchro®. Some software vendors also provide plug-ins such as Dynamo® for Autodesk Revit® that makes it possible to develop object-oriented scheduling functionalities. However, the use of this plug-ins often requires strong skills in parametric design.

Uncertainty regarding BIM benefits: A lack of understanding of the benefits from using BIM leads to a resistance to change as some stakeholders are not sure about the reason why changing their practices and processes is necessary (Ayinla & Adamu, 2018). This is backed up by the findings of Bosch-Sijtsema et al. (2017) which revealed that many medium-sized contractors were unclear about the benefits of the use of BIM in production, and that investing in BIM was risky if the benefits were not clear in economic terms. This is demonstrated in the following quote by a site manager interviewed: “It is a good aid (BIM), but everything depends on if we collect the money, there is economics in all of it. ….. we cannot produce a large amount of drawings and we see that oh it costs so much… We must ensure that there is an advantage, then we can go for it.”

Lack of BIM awareness: BIM has been adopted and applied by large enterprises and is also being combined with project management and enterprise management. This is not the case of SMEs which lack the awareness of BIM and neither understand what BIM is nor how BIM is combined with their current methods of work (Pengfei et al., 2019).

Lack of BIM knowledge: Vidalakis et al. (2020) revealed that *Lack of in-house skills* was a major constraint for BIM adoption and implementation, this correlates with Saka &Chan (2021) which found that “lack of staff training and development” is the second highest rated barrier in their international survey. Limited in house-skills is also mentioned by Georgiadou (2019) which stated that lack of internal skills results in additional training costs. Lack of BIM expertise and low interest or expertise of their partners is often mentioned by SMEs as an obstacle to BIM implementation (Bataw et al., 2014 cited-in:Hochscheid & Halin, 2020). Bataw et al. (2014 cite-in:Hochscheid & Halin, 2020) states that the reason for this is due to the slow adoption of education/training programs and points on the importance of simultaneous progress by all players in the sector. Companies are reliant on up-to-date skills or need to upskill the existing workforce (Hochscheid & Halin, 2020). SMEs are having difficulties attracting qualified and specialized employees (Hochscheid & Halin, 2020), especially micro entreprises. Due to the approach from larger companies that often offer better salary and career development prospects. SMEs have in many cases more polyvalent roles, where the larger firms often have the opportunity to divide work into more specialized tasks or departments.

All seven swedish mid-size contractors interviewed by Bosch-Sijtsema et al. (2017) mentioned that there was lacking competence and knowledge with respect to BIM and especially in the use of BIM in production. The interviewees mentioned a general lack of knowledge related to IT in the AEC industry. They mentioned that expertise and knowledge were insufficient from both clients, consultants and within the internal organization.

Time: The time barrier is mentioned among several medium-sized contractors (Bosch-Sijtsema et al., 2017). Time is an important aspect in the AEC industry and for other project- based sectors, which highlighted the lack of time as a strong reason for the inability to learn how to work with BIM. Due to a high workload and few opportunities to develop new knowledge regarding BIM.

Internal organizational structure: Bosch-Sijtsema et al. (2017) reported that the organizational structure internally was discouraging the development of BIM and its use. The medium-sized contractors in Sweden considered it to be important to work on projects rather than spending time on strategic and long-term planning within the organization. It was also stated in the interviews with the contractors that due to the limited amount of human resources they had to take a lot of different tasks within the projects. Which made it more difficult to learn new skills and specialize within certain areas such as BIM. This is confirmed by the quote: "So a little blended mix is what I do" (Bosch-Sijtsema et al., 2017)

3. Process

Collaboration: There was shown to be a significant difference between the SMEs and large firms regarding the *collaboration* barrier (Saka & Chan, 2021). Lack of collaboration will have a higher effect on the SMEs that often work in collaboration with other similar firms with limited resources. This is emphasized by Hochscheid & Halin (2020) which says that each project is handled by a large number of actors, and teams change with projects, which leads to difficulties to develop a sustainable process. Larger companies will be less exposed to the change than SMEs because they can more easily control a larger proportion of the project and have higher opportunities to adapt its staff competencies over projects, and reduce issues regarding competency and interoperability

The larger companies are also more likely to make the use of change agents to manage organizational change whereas SMEs normally adopt the processes from learning by doing, which will lead to a lack of strategic vision for the implementation (Kouch et al., 2018).

The fragmented nature of constructions industries might lead to difficulties regarding sharing information and collaboration among different stakeholders in a project. Having the will to share the information among different project participants is considered as a critical factor for good collaboration (Pengfei et al., 2019). Lack of cooperation in addition to 2D- based work habits leads to a decrease in production efficiency of the AEC industry compared to other industries (Pengfei et al., 2019).

According to Bosch-Sijtsema et al. (2017) the respondents in their interviews indicated that it was difficult to work across functional boundaries and share both knowledge and information between different actors involving different disciplines, knowledge, and practices. It could sometimes be difficult to understand the different stakeholder in a project because it involved different settings, backgrounds and goals within the project for each participant.

Lack of standard procedures: Malacarne et al. (2018) observed that standardized procedures was missing when using BIM 4D and says that this might be the reason for the fragmentation of the entire process. This problem could have fundaments in the traditional approach often used during the development of construction scheduling. Every construction company develops its own procedures, based on previous experience and knowledge. This also makes it difficult for software vendors to develop a standardized process. Pengfei et al. (2019) says that design information generated in collaboration among various stakeholders, identifying inaccurate responsibilities can be problematic. There is no law that explicitly addresses BIM disputes, this makes SMEs worried about their own interests.

Legal barriers and cyber security: When using BIM as a collaborative tool it will raise challenges, regarding legal issues related to the provision and exchange of electronic data. As the AEC industry evolve towards a more digitalized environment, it is vital to consider confidentiality, integrity of information models and data availability related to liability for the shared data (including the subcontractors) and classified information on various sharing platforms (Georgiadou, 2019). Some of the common issues includes: IP rights and protection related to the ownership in the cloud model and information management responsibilities (BSI Group. 2015; Cited-in:Georgiadou, 2019). With shared data management, it will also evolve cyber security risks due to technology failure. Wang et al (2013; Cited-in:Georgiadou, 2019) argue that the BIM evolution has not yet found appropriate mechanisms to address the different risks regarding cyber security threats. The British Standards Institution (BSI) Group (2015; cited-in:Georgiadou, 2019) found different factors which could help to address these risks:

- Implementation of cyber security policies and procedures.
- Increase the awareness regarding cyber security through education within the organization.
- Protection and monitoring of the technical infrastructure in the projects such as network security and malware protection.
- Ongoing monitoring and protection of operational BIM data to secure confidentiality when personnel or collaborators change, integrity when models are updated, and data availability when storage technologies change during the projects lifecycle.

4. Project Context

Lack of government mandate: Saka & Chan (2021) found “lack of government mandate and support” to be the fourth highest ranked barrier to BIM implementation. This underlines the findings of Dainty et al. (2017) for the need to be conscious of the cultural differences between the SMEs and larger firms in making BIM policy. Often SMEs have the perception that the BIM mandate doesn’t apply to them, and they feel a lack of support from the government, except the insinuation that BIM is suitable also for SMEs from the government. Lam et al. (2017, cited in:Saka & Chan, 2021) states that SMEs are often not affected by government mandate because they may not work on public projects with demands regarding the use of BIM. SMEs are lacking the “push effect” from the government and are lacking the government support and public policies (Hochscheid & Halin, 2020).

No client demand: Ayinla & Adamu (2018) tells about not just a lack of demand, but also a lack of interest from the clients regarding BIM Level 3, this is supported by Bosch-Sijtsema et al. (2017). Which states that a lack of knowledge and expertise leads to a lack of requirements in BIM. Clients are not yet to realize the benefits, which lies inside BIM level 2, and moving another level seems far-fetched for the clients. Bosch-Sijtsema et al. (2017) revealed that all seven interviewees with Swedish mid-sized contractors mentioned that the clients possessed significant power, and that the clients did not require or request for the use of BIM in their projects. This major constraint is effectively summed up in the headline of the article saying: “We wait until someone tells us to use it”. This is also supported through their survey which rated lack of client demand as the highest ranked constrain for BIM adoption and implementation. Especially during renovation projects, the contractor incurs high costs when these renovation projects did involve a client, which did not request for 3D modelling. It is important for the clients that the use of BIM will add value to the project both in a cost and future use perspective.

According to Georgiadou (2019) National Building Specification (NBS) conducted a survey in the UK where they revealed that 65 % of the clients do not understand the benefits of BIM which underlines the need of a client education. However, the client's role is changing through the Digital Built Britain agenda. The Government Construction Strategy 2016-2020 discusses the potential benefits for enhancing "intelligent" client capabilities, where they underline the importance that clients take a leadership in the digital design through early involvement of the supply chain and to improve a collaborative culture.

Lack of BIM standards: Lack of standards in BIM raised concerns among medium sized contractors in Sweden (Bosch-Sijtsema et al., 2017). This is supported by Georgiadou (2019) which stated that BIM is not sufficiently standardized in the UK. Especially regarding the standardization framework of the internal data such as databases, spreadsheet and 3D drawings to enable software and companies collaborate with each other. At the moment security, interoperability and shared language is based on PAS 1192-2, which is acting as a basis for ISO 19650-1: Information management of construction works (concepts and principles), and ISO 19650-2: Information management of construction works (delivery phase of assets).

Contracts: Ayinla & Adamu (2018) highlights issues relating contracts and procurement routes as a source of possible legal consequences. A protection of intellectual properties in a shared and open BIM platform is considered difficult and discourages good collaboration. Pengfei et al. (2019) states that resolving legal and contractual disputes is essential to SMEs. SMEs are often more concentrated on the immediate interests than the larger firms. If there is a potential risk, SMEs often tend to select the traditional project delivery over BIM to ensure the interests of their own company. BIM projects are full of collaboration, where individual persons coordinate their work by using objects created or designed by others. The conventional legal framework used in BIM projects seldom suits the collaborative nature that is generated by BIM.

Projects are to small: Saka & Chan (2021) was surprised to find that the least ranked barrier for both SMEs and larger firms was "*the projects that we work on are too small in scale*". However, the size of the project barrier is perceived to be more significant among SMEs than larger firms. Pengfei et al. (2019) does on the other hand state that projects which involves SMEs might be too simple to being able to determine the benefits of BIM.

Level of BIM readiness or maturity within local or regional supply chain: Bosch-Sijtsema (2017) revealed in their survey with Swedish medium-sized contractors that "our partners do not use BIM" was the second largest constraint regarding the implementation of BIM.

Overview of barriers:

Below is twenty perceived barriers by SMEs, arranged by their mean value 1-5, where 5 is strongly agree(Saka & Chan, 2021). The result is from an international survey of 116 SMEs in all types of practices and professions.

Table 9 Overview of barriers among SMEs REF: (Saka & Chan, 2021)

Rank	Barrier	Mean value (1-5)
1	Resistance to change	3,96
2	Lack of expertise	3,86
3	Lack of government mandate and support	3,84
4	Lack of staff training and development	3,83
5	Lack of freely available BIM objects	3,73
6	Lack of top management support	3,73
7	High Cost of investment (software and training)	3,71
8	No clients demand for BIM use	3,7
9	No established contractual framework for working with BIM	3,68
10	Differences in expertise among collaborating parties in a project	3,67
11	Adopting BIM requires change in our workflow, practices or procedures	3,67
12	Lack of BIM awareness	3,56
13	Lack of awareness of BIM benefits	3,53
14	Lack of collaboration	3,52
15	Legal uncertanties	3,46
16	Lack of standarized tools and protocols	3,44
17	The industry is not clear enough on what BIM is	3,26
18	Non- interoperabiblity of BIM tools	3,2
19	The projects that we work on are too small in scale	2,88
20	BIM is not relevant to the projects that we work	2,33

Bosch-Sijtsema et al. (2017) also provided an overview of constraints in mediums-sized contractors in Sweden. The constraints and mean values are shown in the table below.

Table 10 Overview of perceived barriers. REF: (Bosch-Sijtsema et al., 2017)

Statement (1 totally disagree, 5 totally agree)	Rank	Mean	Max	Min	SD
No demands from the clients	1	3.71	5	1	1.22
Our partners do not use BIM	2	3.61	5	1	1.10
High investments in hard- and software	3	3.50	5	1	1.09
No internal demand in the company	4	3.48	5	1	1.34
Problem with the user-friendliness	5	3.08	5	1	1.03
High demands for technical competence	6	3.07	5	1	1.00
Partners do not always give access to the 3-D model	7	3.00	5	1	1.24
Does not give any clear competitive advantages	8	3.00	5	1	1.37
Difficult to integrate with other systems	9	2.91	5	1	1.06
Takes a long time to learn	10	2.83	5	1	1.00
Expensive operating and maintenance costs	11	2.67	5	1	1.31
BIM-models are too complex	12	2.63	5	1	1.22
The information in the model is often wrong	13	2.38	5	1	0.79
Major internal resistance in the company	14	2.32	5	1	1.15
Difficult to know if BIM will persist in the future (a fashion)	15	1.90	5	1	1.03

5.4 Driving forces and strategies for BIM adoption and implementation among SMEs

Non-financial factors: To facilitate for further adoption non-financial factors such as peer education, industry initiatives and effective leadership were highlighted as being the most important non-financial facilitators for further adoption (Vidalakis et al., 2020). Ayinla & Adamu (2018) identified gaining *competitive advantage* and *pressure by peer organizations* as their company's motivation of adopting BIM. This was underlined by the interviewees saying, "the competition" and "everyone else is doing it", this emerged in many of the interviews. "By using BIM we can follow the technical development" was found by Bosch-Sijtsema et al. (2017) to be the most influential driving forces among Swedish medium-sized contractors regarding the adoption of BIM. They also found that having enough internal competence in combination with a strong network of external actors who support BIM was important factors to facilitate further BIM implementation.

Financial factors: Pengfei et al. (2019) states that incentives are major drivers of new technology, and underlines that an increased efficiency is not enough to change business behavior. The government should play an integral role at the early stages of BIM adoption among SMEs. The barriers regarding high education cost and high-economic investment in the firms, must be solved through mandatory legislation and supervision (Pengfei et al., 2019). Different compensation institutions should be provided to help reduce the concerns regarding implementation and maintenance costs, so that the usefulness outweighs these concerns.

Government support: There is a need of *government support* in training SMEs staff and bring incentives for the SMEs to implement BIM on projects (Saka & Chan, 2021). It is suggested that the government mandate should be inclusive of the SMEs in a way suitable to avoid a widening of the digital gap between SMEs and the larger firms. In interviewees Ayinla & Adamu (2018) revealed firms motivations behind their adoption and implementation of BIM. They found out that some organizations were adopting BIM mainly because of the pressure of government mandate. This motivation showed to be applicable for both small and large firms. With strong statements like "push from the government". Pengfei et al. (2019) states that the interest and willingness of project managers and engineers to use BIM has an important role regarding the adoption of BIM in SMEs. Based on this governments should strengthen BIM training. This could be solved by the government to force the SMEs to set up a BIM department (with e.g. 1-2 people) and then train the new BIM staff responsible for the training within their own enterprises. This will lead to a change in SMEs attitude towards new technology, creating positive perceptions, and promoting BIM adoption in SMEs.

To help mitigate the challenges regarding collaboration Pengfei et al. (2019) suggest a *legislation* to help specify the information that different players in the project are responsible to communicate. This will help to identify inaccurate responsibilities and help to share the risk equally. When the risk is shared also the return must be shared. The money saved by the client should be shared with the participating project members due to better productivity. This should be specified in the contract to help improve the BIM adoption in SMEs.

Innovation attributes: A major motivation for using BIM was linked to cost and time savings in addition to collaborative advantages (Ayinla & Adamu, 2018). Majority of the respondents found this reason as a driver for their organization to adopt BIM. Even if this was a large factor, it was seldom listed as the only motivation and they still required other external factors like mandate and peer pressure to further motivate or force them to adopt. Bosch-Sijtsema et al. (2017) also found in their survey that the belief of competitive advantages from using BIM was the second highest driving force.

Martin et al. (2019) revealed in their survey that the three main advantages coming from BIM was promote exchanges (61%), minimize errors (61%) and improve quality (34%). These findings are in line with the survey conducted by the European Construction Sector Observatory (CSTB) barometer in 2018 (Martin et al., 2019). An interesting point was that only 14 % of the answers was gaining current profit from the 5D cost and 4D schedule, but many of the respondents were expecting great benefits with these tools in the future. The current profit from using BIM was largest for making a high-quality model for production, quick problem solving and team collaboration.

The IPD concept is widely supported in the literature as a method to mitigate the collaboration challenges within BIM projects (Pengfei et al., 2019). The use of IPD increases the amount of people involved in the early design stage of the project. This leads to a good understanding among all the stakeholders at an early stage. This involvement stimulates people to be involved in a project, which will lead to a benefit for the project as a whole.

5.5 Digital Divide

Dainty et al. (2017) says that benefits from ICTs are inequitably distributed. Normally the issue has been portrayed as gaps between developed and developing countries, as well as domestically along different variables such as gender, education, age, geography and socio-economic aspects. These gaps have been known as the "digital divide". The original definition was only considering the material access differencing between those "who have" and those "who have not". The Government Construction Strategy in UK has set a target 'To introduce a progressive program of mandated use of fully collaborative BIM for Government projects by 2016'. BIM is being a core element of the UK Governments

Digital Built Britain strategy, where the intention is to improve the industry's performance. The targets is to reduce the initial cost by 33 %, 50 % reduction in overall time for inception to completion, 50 % reduction in greenhouse emission and 50 % reduction in trade gap between import and export of construction materials, all this by 2025 (HM government, 2015, cited in:Ayinla & Adamu, 2018). The UK government has mandated BIM to level 2 for all public sector constructions.

Despite the BIM mandate, surveys reveal that reform policy has failed to engage SMEs with BIM, and have not accounted for the digital divide that will follow. Today the "digital divide" includes four main parts: attitudes, access, skills and types of usage (van Deursen & van Dijk, 2014,cited in:Dainty et al., 2017). These issues normally include the degree of physical and material access, sufficient motivation, appropriate skills and usage opportunity. The four digital access barriers describes generic ICT implementation.

Generic Digital access barriers:

- ***Motivational access*** is the motivation for the potential users, this could include owners, managers and employees to adopt, acquire, learn and use new technology. There are many reasons behind the lack of motivation, and they could be at both an individual and collective level. They are often formed by cultural, material, mental, social and temporal resources. The reasons could in some cases be rather straight forward such as lack of interest, time, money and skills. It could also be more complex reasons like technophobia, computer anxiety and lack of self-confidence.
- ***Material access*** comes after the motivation access. This stage is a necessary condition for the development of the skills and ability needed to use the technology (Fleet, 2012, cited in-Dainty et al., 2017). This stage includes physical access to hardware, software and services. The material access has for a long period of time been the main focus for the digital-divide research and policy-making, and the prevailing view has been that the material divide will decrease over time when technology become more mature and the prices goes down.
- ***Skills access*** is the need for development to use the new technology. This includes that some effort needs to be made to operate and use the new medium, normally through practice or formal education (van Dijk,2005-,cited in Dainty et al., 2017). It is generally accepted in the literature that differences in skills makes up a larger contribution to the digital divide than that of material access (van Dijk,2005-,cited in Dainty et al., 2017). It is also widely accepted that the education not only comes from formal education, but also from practical implementation.
- ***Usage access*** is the goal when implementation of a particular information and communication technology (ICT). Having the three previous mentioned skills does in reality doesn't matter if there is no need, occasion, obligation or effort actually to use the technology (Wielicki & Arendt, 2010, cited in:Dainty et al., 2017).

Digital access barriers in BIM implementation, explaining the four parts of the "digital divide" based on the specifics of BIM implementation.

- **Material:** Dainty et al. (2017) states that the BIM agenda and policy discourse in UK has been mostly focusing on the material access barrier. There seems to be a general perception that once all companies have the relevant hardware and software they will use BIM, and be BIM compliant. The reason for the large focus on material could be that it provides a clear definition of the problem and a very easy solution in terms of investment. Dainty et al. (2017) consider this as a rather static view of what BIM is and effectively looking past that BIM is dynamic in nature.

- **Motivation:** In the UK, the motivational access barrier is not given much consideration in the policy debate. The arguments put forward in the policy debate rests on the fact that given the size of the public sector, the remaining construction market will follow in line and invest (Dainty et al., 2017). The literature on the digital divide clearly shows moving from awareness to actual use is a huge step (Bach et al., 2013 cited in:Dainty et al., 2017), especially when the only real motivation comes from coercion. From the individual worker (employee) perspective, it could be considered a temporary problem that will reduce as the current workforce is gradually replaced with individuals who have grown up with ICT. Dainty et al. (2017) says that the workforce in UK as in many other countries is ageing, but for the foreseeable future a large part of the workforce will continue to be made up of people who haven't grown up in a 'digital world' and who still follow highly structured ingrained non-digital methods of working. This way of working form an important part of their personal and professional sense of self-esteem. Dainty et al. (2017) states that this might lead to a blur of responsibilities, create new roles and reduce professional autonomy. This will in turn provide challenges at both a rational and an emotional level and require a substantial degree of unlearning.
- **Skills:** Dainty et al. (2017) points out that there is a strong link between motivational access, the propensity to use ICT and the skills required to do so. From the BIM mandate perspective, the skills access barrier is looked at as an investment issue in terms of training the existing staff or hiring new and competent staff. That the costs and effort involved in this process are not the same across different organizations is often forgotten. Training is neither high on the agenda for SMEs nor is it considered to be effective in developing digital skills.
- **Usage:** The last general barrier is the lack of usage opportunities. From the general perspective this is considered as a matter of free choice, and not considered a problem (van Dijk & Hacker, 2003 cited in:Dainty et al., 2017). Despite this general consideration, usage access in terms of getting to work on BIM projects remains a considerable problem for many firms. There are large differences in financial resources of firms in the construction sector and many SMEs are blocked from working on major projects. Some companies might have the capacity, but are still in a position where regular use of the technology cannot be guaranteed due to competition with larger firms. This could lead to an inclination to invest in the material and skills necessary to be BIM compliant.

Ayinla & Adamu (2018) tries to explain the digital divide by looking into the Diffusion of Innovation and to find out what differs the SMEs from the large firms in the AEC through conducting a global survey of over 240 respondents as well as semi-structured interviews with nine experts. This is done by merging the Bew-Richards BIM maturity model with the Rogers classification of adopters, by making a composite model. Where they try to find out if "most large AEC firms are Innovators/Early adopters and most SMEs are considered late majority or laggards". Ayinla & Adamu (2018) observed that most participating organizations are comfortable being in the lower levels of BIM maturity and being among the lower layers regarding technology adoption in general. They also found that small and large organizations are in many ways similar based on their levels of BIM technology used and their speed of adoption. Interviewees affirmed that moving upwards in BIM maturity levels would be tougher for the SMEs, due to the increased sophistication involved in the technologies associated with the different maturity levels. There are in addition to this extra costs needed for the development of new skills and talent, which are required to operate successfully at higher maturity levels (Ayinla & Adamu, 2018). It is also stated that making the move from level 0 to level 1 is easier than moving further upwards on the BIM-wedge. A move from 0 to 1 is mostly about the implementation of new software. Where level 2 BIM includes a use of CDE, which requires implementation for more collaborative processes. Ayinla & Adamu (2018) says this contributes to the industry's reputation and culture of change resistance.

The surveys revealed that firms located in the UK and enjoy the government patronage were still "looking forward" to adopting 3D , 4D or 5D BIM, CDEs and clash detection technologies. This result was unexpected when both 3D and CDEs are central component to level 2 BIM. This suggests that these organizations were not presently operating at BIM level 2 and could not be considered as early majority or above. There was found a widespread of different levels of BIM in various projects inside the same organization, with some firms executing different projects using Level 0, Level 1 or Level 2. The government mandates on BIM was a key driver to their use of the more mature Level 2 BIM (Ayinla & Adamu, 2018).

Ayinla & Adamu (2018) found seven constraints that make up the digital divide irrespective of the size of the company. This includes cost, culture, expertise, training, lack of client demand, legal requirements, and technology/interoperability. It is stated that overcoming the constraints and moving to higher maturity is very difficult, because they are often acting in synergy. On the basis of the constraints Ayinla & Adamu (2018) suggest ten different solutions for closing the digital divide. The same strategy might not work for all types of organizations, because Innovators would probably not require or wait for a BIM mandate, while the laggards might need mandates and incentives in order to adopt a higher Level of BIM.

Table 11 Pre-requisities for closing the digital divide gap based on Ayinla & Adamu (2018)

Topics	**Solutions**
Mandate	The Government BIM mandate is considered to be a vital factor for closing the gap. This will be necessary for the organizations to move away from their traditional processes.
Nudge (incentives, subsidies, tax breaks, etc.	Given subsidies for training, education and software licences.
Awareness	Increase the familiarity regarding BIM will help to prevent reistance from people.
Clear standards and protocols	Having clear and concise standards and protocols which allows everyone to operate on the same basis regarding implementation and understanding. Many people perceive todays BIM standards as difficult which makes them reluctant to adopt.
Client demand	Firms could be reluctant to invest in technology that the clients are not interested in. This could be done by a push from the governemnt as they are the biggest construction client in many countries.
Evidence-based benefits	It is important for people to perceive or belive something is worth it before they make an attempt to try it. This could be done by pilot

	projects which can give them the sufficient evidence motivating them to moving to the next level of BIM. Where they can see the evidence that moving to next level BIM would give them better results than remaing at their current level.
Change management	Change management was identified as an effective way to refresh traditional minded people in an organization. This should be done through a top down motivation approach from top managers.
Technology	Trying to avoid the complications in BIM technology so that problems regarding requiring special knowledge or expertise to use the technologies can be minimised.
Expertise	Having the right skills is an essential part for closing the gap in BIM adoption. A solution could be to focusing on the training for young professionals from the universities so that upon graduation, all sorts of organizations (SMEs and large) can take the advantage of their knowledge and skills for BIM implementation.
Legal aspects	This is a crucial aspect for BIM adoption going forward. Provide a protection of intellectual properties on a shared BIM platform is required to facilitate collaboration.

- **Late majority or laggards:** Organizations in this category are those mostly affected by the "gap" constraints (Ayinla & Adamu, 2018). The constraints will exert a force threatening to push them into categories. A "forceful push" through a mandate might be an effective tool to avoid it. Lack of resources will also increase their change resistance; a nudge will also be helpful to motivate them.
- **Early Majority:** Organizations in this category will only adopt BIM when the market is at its peak(Rogers, 1983- cited in:Ayinla & Adamu, 2018). This might lead to a slower adoption process. To increase the speed of adoption they will also be in need of mandates or nudges.
- **Innovators and early adopters:** Are considered to be the risk takers and opinion leaders who are enthusiastic about new technology and have the resources to make the investments needed. These organizations might not be dependent on a government mandates to use BIM, they might only be nudged with the industry recognition and leadership roles in the industry.

Ayinla & Adamu (2018) was surprised to see that among "opinion leaders" (i.e. large firms) who might be considered as "Innovators", are many that are lagging behind regarding the adoption, while among the supposed late majority or laggards (i.e. small firms) were many catching up with state-of-the-art technologies. "No clear differences between large firms and small firms in the types and sophistication of BIM technology used" (Ayinla & Adamu, 2018). The statistical data suggested that in the AEC industry, the size of the firm did not necessarily make it an innovator or laggard. "Therefore, the AEC industry probably has some nuances that make it deviate from the norm when it comes to diffusion of innovation" (Ayinla & Adamu, 2018).

5.6 Framework for BIM implementation for SMEs

Two similar studies (Kouch, 2018; Kouch et al., 2018) have conducted literature reviews to reveal the most cited barriers to make a framework for BIM implementation among SMEs. The goal of these articles was to define and introduce BIM as a modeling system that could help to increase return on investment (ROI) and competitiveness of the SMEs.

Kouch et al. (2018) conducted a literature review in order to find the key factors in BIM implementation in order to suggest an initial framework for SME to adopt BIM. Key factors discovered in the literature are shown in the figure below. The numbers are based on percentage of cited factors.

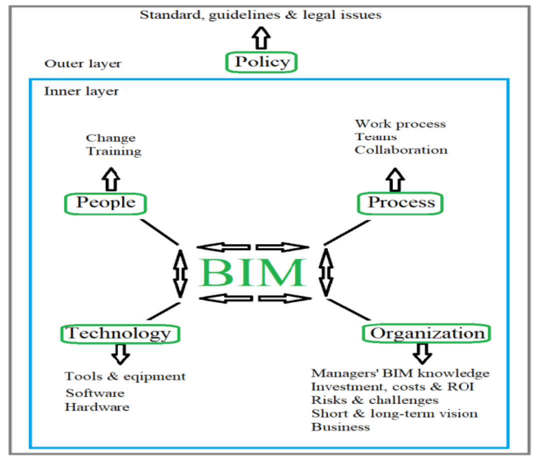


Figure 23 Key factors and BIM fields for BIM implementation, distributed by percentage. REF: (Kouch et al., 2018)

According to Kouch et al. (2018) the people category includes training human resources (HR), organizational culture and change management issues. The process involves how the technology and people execute the activities and tasks. The technology category implements the factors including tools, software and hardware. These three factors are all a part of the organizations that decision makers are involved with financial decisions such as investments, costs and ROI as well as organizational risks, challenges of business changes and processes. This analysis proves that the organization possesses a major role for in the BIM adoption and implementation. The organization is in this case represented by top managers including CEOs and board members. The organizational key factors include business challenges and risks as well as investments and financial factors. The financial factors include the costs and ROI. Kouch (2018) points out the importance of the top managers understanding and support, which means that only using the technology without a strategic plan, might decrease the effectiveness of the adoption process and hinder the implementation.

Framework: Kouch et al. (2018) states that BIM implementation is a complex process, due to the previous mentioned key factors. This framework is applicable for SME contractors, but due to similarities and differences between design, construction and other firms, the framework can also be beneficial for others with some modifications.

Kouch (2018) points out that studies have covered a wide range of different key factors, but have not yet found a basic implementation model or a simple practical BIM implementation framework. He states that the studies in a large degree are theoretical and academic. Which makes it difficult for many SME contractors to harvest the benefits of the studies, due to being theoretical and providing to detailed and advanced knowledge. Kouch (2018) therefore suggest a basic approach which covers the key factors and challenges previously described. The model is meant to be a practical and effective model to provide better implementation. The framework includes three main steps and each of these steps includes sub-steps addressing challenges, activities, planning, communication, integration and collaboration in the categories organization, people, process and technology.

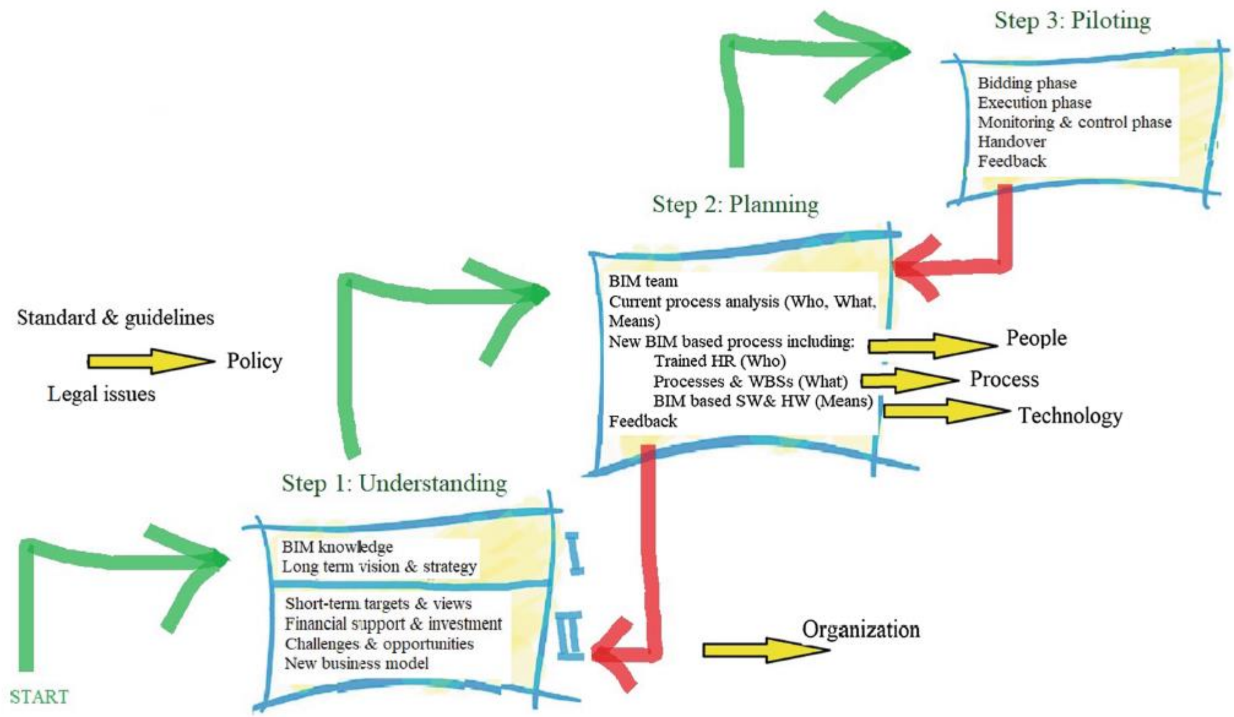


Figure 24 A general 3-step BIM implementation framework. REF: (Kouch, 2018)

The general framework is meant to satisfy all mentioned aspects of an effective simple and practical implementation framework (Kouch, 2018; Kouch et al., 2018).

1. *Understanding:* This first step is important for the top managerial level to learn the impacts, challenges, benefits and opportunities that BIM can provide in both short- and long-term for the companies. This includes defining a new strategy for the company to help exploring business opportunities and a more integrated delivery approach. The second part of this step is meant for directors and middle level managers, which are responsible for change management in their section, to address challenges, legal issues, BIM teams and short-term strategies.
2. *Planning:* The assigned BIM teams including the current team and BIM experts should analyze the current activities, processes, tools and resources to be able to create a new BIM based approach of the processes. Current standards and guidelines should be used. It is important to

communicate the progress of this step and send the feedbacks to the organization to adopt and support new decisions aligned with the short and the long-term strategy.

3. *Piloting:* In the third and final step, it is time to execute what has been planned in the earlier stages. This is a practical step with software for preparing quantity takeoff list and cost estimation in the bidding phase, used instead of using traditional methods. Clash detections will also be examined by appropriate tools to decrease construction time and increase the accuracy of the execution plans. Different tools such as VR and AR can also be used to assist the execution, monitoring and verification of all ongoing activities on and off site. A dynamic evaluation process between the steps is important to improve the process and improve the productivity and efficiency in the company.

Vidalakis et al. (2020) warns about the 'one-size-fits-all' type of solution for collaborative BIM adoption by SMEs. He argues that each SME and its associated supply chain should be closely examined before recommending any strategies regarding BIM adoption and implementation. If this is not done the BIM implementation may lead to failures that can be counterproductive. Vidalakis et al. (2020) recommends that the sector comes together to exchange ideas and work together to build BIM capacity throughout the whole supply chain.

5.7 Suppliers chain

According to Wang et al. (2019) the progress towards achieving BIM targets has been slow, based on a UK survey. This is particularly the case for subcontractors, where only 10 % believed that the construction industry is ready to deliver on it, and 25 % of the respondents feeling they were lacking the skills and knowledge. Wang et al (2019) recommends a framework to divide suppliers into groups, so that tailored action plans could be develop. This should contain development and provision of education, training and knowledge transfer around collaborative working practices, contractual arrangement and performance measurements. All this could help them in accelerating the BIM adoption. This model was used back in 1998 in the automotive sector, helping the large organizations to develop their supply base.

For the supplier at the lowest level of BIM awareness with limited capabilities and vision, the main contractor needs to center efforts on further awareness raising, education and training programs (Wang et al., 2019). The main contractor should also raise the awareness of the different benefits BIM contributes to the project and clearly communicate the requirements for implementation of BIM among the suppliers. The support should be a much hands-on project-based support from the main contractor. This will make the suppliers see the benefits of using BIM, the suppliers will then need to create a change management program in place for further take-up to be able to increase their BIM maturity. Wang et al (2019) points out that for some contractors, it might demand too much of an investment in order to do this kind of competence development. Instead they might favor suppliers whom are not fully capable, but are fully committed and have a strategic intent to deploy BIM (Wang et al., 2019). They might consider them as their "preferred suppliers" and actively use them in a variety of projects. For this group of suppliers, the main contractor may need to set a clear contractual term depicting the expectations, information sharing and process integration protocols and different measurements on BIM performance leading up to possible rewards.

5.8 BIM in residential projects in the UK

***Reasoning of topic**: BIM use in residential projects were mentioned in the semi-structured interviews in this master's thesis, and therefore been included in this literature review.*

Georgiadou (2019) conducted a mixed method including a survey (71 responses) and three semi-structured interviews with different participants involved in residential projects in the UK. The web survey revealed that only 45 % where currently using BIM in their residential projects and 63 % of these indicate that they are operating at BIM level 2. The survey also shows that the group of respondents with between two to fifteen years of experience have higher BIM knowledge then the senior managers with more than 15 years of experience. The senior employees often have combined poor or fair knowledge of BIM and by this reason, they are still cautious to invest in digital capabilities.

It was stated by one of the interviewees that BIM contributes with more than just monetary value to an organization (Georgiadou, 2019). This was expressed through the following quote: "BIM is the source of project information and with BIM we are on top of the curve, being able to talk intelligently to the client and to be seen ahead of other practices".

Perspectives on building information benefits: 48 % of the respondents in the survey answered that "a shared building model" and 42 % said "communication and coordination with other disciplines" are the key advantage of using BIM (Georgiadou, 2019). Particularly among architects where 50 % emphasized the communication and coordination. Two out of the three interviewees pointed out that BIM could have an impact on Governments commitment to reduce GHG emissions by 80 % by 2050. BIM embraces the whole lifecycle asset management, by reducing errors, rework and general waste in the construction. Machado et al. (2016; cite-in:Georgiadou, 2019) claims that BIM can address the duplication of information, overproduction, waiting and/or defects, which are considered as waste which ultimately leads to rework.

The findings in the survey suggest that BIM benefits are not only associated with larger projects. This is also shown by Watts's (2015; cited-in:Georgiadou, 2019) who argues that BIM adds value to all construction projects, this includes the smaller projects. Only 10 % of the respondents in the survey believed that BIM should be used only in projects above £3M.

Perspectives on building information challenges: Georgiadou (2019) revealed in his interviews that even tough BIM provides the basis for new dwelling designs and construction capabilities, it is not largely adopted by the residential sector to date. Respondents of the survey were asked to priorities the key reasons why BIM has not been adopted in the residential sector. The two most mentioned barriers were "high capital cost" in software, technical maintenance and training and lack of client demand. High cost is often difficult to finance due to the lack of resources, particularly for SMEs. The lack of client demand demonstrates that clients do not realize potential benefit of BIM. The interviewees also points on the "resistance to change" among clients (Georgiadou, 2019). It is stated that there is an overall "unwillingness to change" and the "fear of the unknown" which is considered to be a result of the short-term mind-set especially of senior management. With a large degree of focus on cost rather than the lifecycle value of the investment. One of the contractors interviewed said that there is no perceived need to change, "residential developers are almost always guaranteed 20 % profit and occupation and therefore they do not want anything different". House building companies and their supply chain are also described as reactive to change in combination with housing projects being generally not to complex leads to the belief that it is not beneficial to implement BIM due to the time and resources required for BIM.

Sharing information is also a challenge, this is stated in one of the interview by Georgiadou (2019) saying that: “not all organizations are geared up to manage information in a traditional manner, let al.one a digital environment, or if they are they do not share the information”. Some BIM models also might contain a too large amount of information, where a lot of the information might not be relevant for all the stakeholders in the project. This leads to a problem regarding data validation and liability of shared data entered or interpreted incorrectly by other participants in the project lifecycle. Different interpretations of the information leads to data reliability and security issues (Georgiadou, 2019).

6 Findings from interviews

Semi-structured interviews were conducted with three different companies in the AEC industry all based in "Innlandet", where they also conduct the majority of their projects. The interviews were conducted orally either face to face or via Microsoft Teams®. The questions are represented in the following subchapters. They consist of both summarization and direct quotes from the interviews. The interviewees are referred to by their number found in the table below. The results are represented in the same order as the literature review, starting with general information about their perception of BIM in the AEC industry, before a mapping of their current use of BIM and ending with barriers and motivations of the use of BIM.

Table 12 Overview of interviewees

Nr.	Company	Job Title	Duration	Date	Type of interview
Int.1	Contractor	BIM Coordinator and project manager	1 hour	08.02.2022	Face to face
Int.2	Consultant	Structural engineer	20 min	10.02.2022	Teams-Interview
Int.3	Contractor	Project-manager	40 min	28.02.2022	Teams-Interview

6.1 General perception of BIM in the AEC

Motive for the topic: This theme is brought up in the interviews to get a closer look at thoughts regarding the industries innovativeness. Especially the conditions in smaller projects and SMEs are discussed during the interviews. To be able to understand how BIM is exploited among SMEs and to discuss a possible digital gap in the AEC industry. There was particular interest in the specific topic "cultural resistance", where I hoped to unveil whether the perception from the interviewees was the same or if it differed from what was found in the literature review. The interviewees are referred to as Int.1, Int.2 and Int.3.

When talking in general about the AEC industry Int.1 explained that he felt there is a general skepticism for changes among contractors. This is often due to uncertainty associated with potential benefits.

> *"I have a perception that many contractors are skeptical to changes and need to see the clear benefits before the make the step to implement the new technology. (Int.1)"*

He also talks about the many senior employees who are often working as project managers within the organization. Which gives them a large responsibility for setting the BIM requirements for the projects that they are working on, even though they have internal processes in the organization.

> *"The senior project-manager wants to do things in the same way they have done in several previous projects, in order to stay within their comfort zone. I even suspect that some senior managers want to change companies, so that they can be able to work within their safe environment. (Int.1)"*

Int.2 talks about his general perception of the culture in the industry and describes it as a slow culture which is not open for change. He underlines the consultant's lack of possibilities to affect the projects and follows up with saying that the contractors have a large role in the transformation towards more BIM use.

> *"The contractors, they don't see a reason to change and make investments, when there is no demand from the clients. The current system works well enough for them, giving them good enough control and they consider that sufficient. The positive consequences need to be highlighted clearer for them. (Int.2)"*

A general trend towards a completely digital delivery is observed by Int.2, he states that there are opportunities to work in these kinds of projects, but maybe not in Innlandet.

When describing the engineering consultants Int.1 states that he has the impression that they generally are curious to new technology and have come a long way regarding BIM in projects, even though the internal competence is varying a lot from person to person. This is mentioned to have huge impact on the way different projects are conducted, and a general rise in minimal competence for BIM will help the whole AEC industry.

> *"Not everyone needs to be experts, but a minimal degree would be desirable. (Int.1)"*

Regarding the architects Int.1 had the perception that they lag somewhat behind regarding the use of BIM. This was based on the models received for cost estimation and pricing, which are often very deficient. Making it very difficult to make a tender digitally based on the models.

Int.2 had the perception that the biggest difference regarding BIM innovation in the AEC industry is the gap between clients and contractors and the designers. The consultants and designers are more on the same page, independent of size.

> *"The bigger the contractor or client is, the more curious they are about innovations. Which is naturally due to their resources. (Int.2)"*

The structural engineer (Int.2) followed up with a story, which underlines the lack of innovativeness among small contractors.

> *"We have started to offer 3D reinforcement, but not many contractors want it. In the beginning, they want a price, but when it comes down to the decision to use it, they very often chose the 'traditional way'. This is mostly due to insecurity regarding the implementation on site and the complexity of the process. (Int.2)"*

He then elaborates this quote by saying that moving to 3D reinforcement will definitely reduce the mistakes, but they still choose the 'traditional way'. Things are often more difficult than initially foreseen, especially for the workers on site who need to operate an IPad, which they are not used to. He has little faith that a change will come by itself and believes that the change will not come before there is coercive demand for the whole industry.

Int.3 also describes a misconception that is common among several contractors:

> *"Now when contractors have started to use the 3D model, everyone thinks they have become digital. When we implemented 3D in our projects, I heard some say: now we are digital. (Int.3)"*

This shows the different perceptions of what BIM actually is. It was mentioned that many of the seniors in the industry look at BIM exclusively as a visualization tool.

Future use of BIM in SMEs:

There was of great interest to see how the interviewees consider the future regarding the use of BIM. The decision to increase BIM levels among SMEs is seen as a necessity among the two contractors interviewed. This is underlined by the following quotes:

> *"When we really learn to exploit the potential which lies inside the BIM process, those who choose not to adopt it will no longer be competitive. Nokia all over again! (Int.3)"*

> *"In the future I think the digital gap will be grater and in the end they will have no choice, either they will change their way of working or they will be phased out or bought by larger companies. (Int.1)"*

> *"The biggest companies have the resources and opportunity to be early adopters. If smaller companies don't dare to be innovative, they will miss out on a lot of projects when new demands are set from the clients. A coercive change is the only thing that will make them change their workflow. (Int.1)"*

6.2 Mapping of the current use of BIM

Motive for the topic: The topic was brought up to find out what degree BIM is being exploited in the different companies and what argumentations lie behind their choices. *It was considered of great interest to see in which way BIM is utilized, both in terms of nD BIM use and to look at how the information in the projects was shared between the project stakeholders. There was particular interest if the contractors exploited 4D BIM and CDE. Especially the use of CDE, which is considered to be one of the key factors for achieving BIM Level 2.*

<u>**Key findings:**</u>

General:

Int.1 told that he works for a contractor, which is a part of a big national company. He said he came to the company in 2018, from a larger contractor, which used different and more innovative methods.

He explained that he tried to turn the project workflow around and was met by some internal resistance. Luckily, they saw the positive consequences pretty quickly, which helped them make the transition. He also underlines the importance of being part of a larger national organization when it comes to dealing with new technology and innovations. This removes both the lack of internal competence and the cost for investing in software and training. It is underlined by the following quote:

> *"This means that we have access to internal competence and technology, which is crucial for BIM implementation. (Int.1)"*

Int.1 also talks about their decision to be innovative being able to meet new demands and technology.

> *"This will help to position us for the upcoming years. (Int.1)"*

He also explains that their projects are varying in cost from 25-270 million NOK, and their goal is to follow the same internal BIM manual and same procedure for all their projects, but he has experienced that this varies a lot from project to project. This is often because of different project managers, who set their own BIM level for the project, in combination with a varying client demand.

Int.3 also works as a part of a national company, which facilitates technical support and software to their own department. They carry out their projects using the same processes regardless of the size of their projects.

> *"We use the same tools and processes regardless of whether there is a project of 20 or 300 MNOK. It's usually the same employees doing the projects and they want to use the same processes. (Int.3)"*

Information management:

It was stated that they use 3D modelling on all projects for all the different consultants involved in the project (Int.3). Everything in the project is modelled and handled through stream BIM. This is common and is accessible for all stakeholders in the project.

> *"Having a common environment is where we see the benefits of BIM as a contractor. Where we use it for common visualization and understanding. (Int.3)"*

Regarding information management Int.3 states that they are sharing their information on StreamBIM or Dalux. Where all models, drawings and information are meant to be shared internally in the project, otherwise e-mail is used as a tool for information sharing. Dalux is also used by Int.1 for handling the construction on-site and to increase the collaboration between the different stakeholders. This is done by uploading IFC files to a CDE environment, but no specific standards are used to specify the information management. The use of StreamBIM and Dalux are based on some of the same principles as CDE, but it is not used in a way, which satisfies the requirements for CDE made in ISO 19650 or PAS 1192 according to Int.3. He also states that there is a lack of awareness on the new ISO 19650 standard for information management in their daily workflow. Nor are the standards the basis for decision about new digital steps for the company.

> *"This is one of the biggest challenges companies face in terms of the digitization process. It is not a coordinated process where you have a clear overall scope and strategy that acts as a guide in decision-making situations. This means that companies do not get the most out of the investments they make when taking a new digital step. (Int.3)"*

3D model:

Int.2 states that even though they are a part of a big national engineering company they don't have much decision making when it comes to the degree of BIM used in projects. He states that the client or contractor set most of the criteria for the project. Due to a large amount of turnkey projects, the contractor sets the requirements in collaboration with the client. They are only asked to deliver their 3D model, they seldom ask for any special level of data to be attached to the different objects. The model is later used for 3D clash controls. The collaboration cannot be considered fully integrated, since the different consultants are not working together in one single integrated model.

Int.1 stated that they use 3D models on all their projects and are being used for quantity take offs and prices when making the tender. As mentioned, Int.1 uses Dalux as their project tool for production on site. This including collaboration with sub-contractors, request for information (RFI) could also be sent and assigned through the app. It is also used for checklists and safety issues, which could be distributed instantly. Solibri is used for crash controls for the different consultants involved in the design and quantity estimations. In some projects we build a complete 'Digital Twin (DT)' to use for the production and later in the project lifecycle, such as for facility management (Int.1). The DT is not "smart" with many implemented sensors, but it involves monitoring the concrete moisture which can be used for documentation for the client.

> *"We can see that using a 'Digital Twin' is a trend that is being used more and more in our industry, it's been used for several years in other industries, such as the automotive industry. We are at the beginning, but has not yet exploited the full potential, which lies within the use of DT. (Int.1)"*

4D and 5D BIM

Regarding the use of 4D scheduling technology Int.1 states that the technology is not ready to be used. The 4D scheduling was considered a process with too much manual input and the margins of errors was too high. Also, the 5D cost technology was considered insufficient, where there was still a great need for professional calculators, to be able to implement all variables that implies in the calculations for making a tender. Variables such as differing building heights, where the extra cost and time for crane and installation is not implemented. Which makes them dependent on personal with the right skills to do the process manually.

> *"We made a cost/benefit assessment, and we decided not to move forward with this process. We must wait until the technology is more suited for our work. (Int.1)"*

When following up with a question on whether there was any quantitative data on this, it was stated that it was not, and the decision was made mostly out of assumptions. Int.1 told that they have gone back to the 'traditional way' of making the time schedule, but told that they still use the 3D model as a basis for scheduling. When discussing the implementation of higher nD BIM, such as 4D and 5D with Int.3 it is stated that they are still working on gaining the maximum benefits out of the 3D model before they will concentrate on implementing new technology and processes. Int.3 mentions that especially the 4D dimension including scheduling will be highly beneficial for the contractors. Int.2 supports this and says that he thinks the contractors will gain huge benefits when implementing 4D and higher dimensions. While he is rather skeptical to whether change will come any time soon. This is underlined by the statement:

> *"The contractors will not change before there is a requirement from the client. (Int.2)"*

Int.3 states the following regarding the implementation of 4D BIM:

> *"Having a 3D model of the product, in our case a building, makes the product better. Both for the clients and the users. For us as a contractor the 4D scheduling is what will help us in our job. We are supposed to be good at building. I meet a lot of resistance when it comes to implementing this technology and process, both internally and externally. As human beings we don't stand a chance to process all factors which are included in a good schedule. Thinking 700-800 steps forward is not possible for the human brain, still we rely on our one brains and its capabilities of visualization. (Int.3)"*

3D scanner:

Int.1 had invested in a 3D scanner, which makes it possible to control what is actually is built with the design. This will make it possible to reveal possible errors and deviations. The investment of approximately 400.000 NOK was already economically justified after just 2-3 months. The scanner revealed an 80 cm displacement of the location of the building compared to the 3D BIM model, this was done at an early stage and the consultants were able to change this before the building started. This saved a tremendous amount of money on this specific project.

> *"I was arguing for some time that buying a 3D scanner was good use of the money. Know I get praise every time this is brought up in different meetings. It is worrying that 80 % of what is built is not checked against the actual design. (Int.1)"*

AR glasses:

AR glasses have also been tried to handle discrepancies, but the technology was considered not to be 100 % ready for use at this stage (Int.1). They saw great future advantage in such a tool to utilize the 3D model even more.

Sustainability 6D:

The 3D model is also utilized for more prefabrication and LCA analysis (Int.1). This requires that the model has a high MMI to be able to make prefabrications based on the model. This makes it possible to have a better schedule and minimize the deviation on site. It is stated that they are using a manual created by RIF (Rådgivende Ingeniørers Forening), EBA (Entreprenørforeningen Bygg og Anlegg) and "Arkitektforeningen", which helps to set the requirements for information level and how much information the model should contain.

> *"This moves the time and the money to the design phase, and is a clear trend in the AEC industry. Regarding the LCA analysis, we saw big savings in the CO2 emission by changing the construction system to a solid wood construction. (Int.1)"*

It was suggested that the environmental consequence could help clients to see great benefits, which could facilitate for more requirements on how the 3D BIM model is being utilized.

Construction on-site

When it comes to the on-site construction, the process goes back to the more traditional 2D approach using paper drawings and the model is only used as a quality control against the updated 3D model (Int.3). When followed up with the question: "When is your company planning to move to a paperless construction?" It was stated that they are not planning to make digital step only for the sake of doing it.

> *"Many processes are digitalized only because it is possible and that the technology is available, but it will not help us build any cheaper or faster. (Int.3)"*

6.3 Barriers in BIM implementation

Motive for the topic: It was desirable to look at the barriers that the various companies experienced regarding BIM adoption and implementation and what prevailing factors are hindering BIM being exploited to its full potential. It was interesting to map which of the four elements in Nepal et al. (2014) framework being most prominent, hindering BIM-enabled projects.

1. Technology:

Technological challenges:
One of the reasons for Int.3 going back to traditional 2D drawings on the project site was because of different challenges regarding operating an IPad on site.

> *"We experience many challenges regarding the use of IPad on site, such as operating the IPad in direct sunlight. This makes it very difficult to see and makes quality control challenging. Rain and low temperatures also cause problems, it is largely paper that can be trusted in such situations. (Int.3)"*

Talking about technological issues Int.2 said that these are not hindering aspects in Norway.

> *"It is going in one direction, but the big players in the industry need to carry the burden. There is also a need of stricter demands. (Int.2)"*

2. People / Organization

Lack of expertise:

Int.1 points at challenges involving the construction workers on site and their ability to read and analyze the 3D model, especially when a DT has been used on site. It was also pointed out that DT models often contain irrelevant information.

> *"When we have decided to use construction site without drawings, the construction workers and the supply-chain need to build directly from the model. This has sometimes led to misinterpretations of the model, which have led to extra work and cost. (Int.1)"*

Int.2 states that syncing coordinates and making sure the model is placed at the right height when exporting to an IFC model in streamBIM is a recurring problem. Greater expertise can decrease this problem.

> *"It is time-consuming, but when it first is in place, the problem is solved. This is very important especially for the RIE and RIV. (Int.2)"*

The following statements show the lack of time to invest in new skills and get familiar with new processes and software. It is stated that currently the 'traditional way' of manually extracting the quantities is the fastest way of conducting the quantity take-offs, maybe in the long term they will be able to download the quantities digitally. The tools are available from the central organization, but there is a lack of competence in using it.

> *"In my experience as project manager, it can be difficult using the resource persons in the company. You have to know how to use it yourself. (Int.3)"*

Cultural resistance in the AEC industry:

The rather cautious mindset towards innovation within the industry is supported by the following quotes:

> *"We are probably a bit conservative in our way of working. (Int.3)"*

> *"We are lagging a bit behind in this region. (Int.3)"*

Int.3 states that everyone is interested in working more effectively, but people might be afraid of leaving their 'traditional processes'. He points at the inevitable generational change that will come and says that he already in his four years seen an improvement and change in attitude. It is argued that the newly graduated professionals in the AEC industry have the technical competence, but are somehow trapped in an industry where old processes still apply.

Time:

There is a lot of investment involved in learning new processes and technology (Int.3). It is stated that they could have taken the step to use the model for quantity takeoffs, but they have chosen not to do it. All the necessary data is in the model, but they continue do it in the traditional way. The following quote states that they do not have sufficient time to gain the needed level of skills to improve their BIM competence. It also describes that employee's in smaller companies are needed to have varying tasks, making them unable to gain expertise in specific areas of work.

> *"When we come to the quantity takeoff stage we are back to traditional methods. The way our days are set up in the company makes it easy to go to the processes we know, even though we doubt these processes. (Int.3)"*

<u>3. Process</u>

Lack of process to support the technology:
In contrast to what earlier stated regarding the positive effects of having support from a national company, Int.3 states that having support from a central organization also could have some negative

consequences. Even though both software and appropriate skills are available in the central organization as support. The following statement confirms this:

> *"We have the tools and software, but we lack the processes which supports it. (Int.3)"*

It has been experienced that the use of resource personnel within the company is difficult due to their lack of project specific information and process knowledge. Which makes it difficult to extract the exact project specific data (Int.3).

> *"To increase our efficiency we must get the knowledge, we must dare to change the processes. The processes must facilitate for new technology, without new processes there will be less reward. (Int.3)"*

It is further said using the tools without a supportive process or expertise will not help the BIM implementation within the organization. The digital steps are extensive and requires change management, they should be involved from the start to make it possible to see the advantages. When introduced to new tools and procedures from the central department in the organization, there is a lack of focus on knowledge and the relative advantages. There is also a lack of interaction between the overall goals in the organization and how BIM will help them to achieve their local goals.

> *"How does this make us better? (Int.3)"*

If the digitization process starts without any real opportunity to influence the decision, it is stated that there is a chance for a dramatically drop in the motivation. The motivation is needed due to the enormous amount of time required to invest in learning new tools. Another factor mentioned by Int.3 is that tasks are digitized separately and is missing an overall strategy for how the processes should make it possible to achieve their goals. Some of the new BIM processes are said to be much needed, but time consuming. This is supported by earlier statements regarding the lack of awareness of the relatively new ISO 19650 standard, which is stated to be a good tool to help support the entire process of integrating BIM.

Sharing of information:

Int.3 mentioned that many of the vendors are working in 3D with proprietary software. Some are making a 3D model with all the necessary data, but the models are not included in the digital model. This makes the digital model uncomplete, with only an architectural drawing of e.g. railing, where there actually is a model with all associated data.

> *"Everything should ideally be incorporated into our digital model. I feel many of the vendors are working in 3D, despite not being incorporated in the CDE. Some due to unwillingness to share data and some because we are not sure about their competence to work on a big and complex model. (Int.3)"*

4. Project context:

Client demand:

The lack of client demand and understanding is a clear hinder for the BIM implementation according to Int.1. Some of the bigger clients are told to be BIM compliant such as Statsbygg, who have their own BIM manual, which needs to be followed (Int.1). Int.3 groups the types of clients into three different types; the public clients (Statsbygg, Forsvarsbygg), professional private clients and one-time clients. The public clients are told to be the drivers in the industry regarding BIM implementation (Int.3), this is supported by the structural engineer (Int.2). However, the professional clients set some requirements regarding BIM e.g. 3D modelling, but nothing more is being asked for (Int.3). They are said to appear unwilling to make any investments to develop BIM maturity and drive a development process in their projects, and their focus is mainly on having an immediate economic gain. The one-time clients do not possess the competence and rely heavily on the contractor. This underlines the contractor's important role regarding the development of BIM and technology use in the AEC industry (Int.3).

> *"I have a feeling that some clients are afraid to set strict requirements for the project, because of the chance of excluding some of the contractors which are not ready to work in a higher BIM environment. (Int.1)"*

Int.2 underlines the importance of the client to make requirements for the projects. It is stated that the lack of demands is due to the size and complexity of the project. For schools and commercial buildings the requirements are stricter due to the importance of facility management.

> *"The client is not active, they only want the residential buildings as fast and financially favorable as possible. On the larger and more complex projects, there are often requirements for a complete digital delivery. At the moment the client does not see the benefits of evolving into more complex BIM use. (Int.2)"*

The structural engineer (Int.2) also points at their lack of influence in the projects. Due to the high number of turnkey projects, they have little to none influence on the project's requirements. In turnkey projects with a passive client, the contractor will set all demands and detail level of the project. This was mentioned to be especially applicable in those cases where the client is only concerned in getting short term provision.

> *"When we enter the project at a later stage, the client and the contractor have generally already set the BIM standard and protocol for the project. (Int.2)"*

Size of the project:

The issues regarding project size, discussed in chapter 5 is also mentioned by Int.3. Where many organizations are pointing at the fact that there is no utility for BIM in small projects due to less complexity and less need of collaboration within the project group. Int.3 argues against this with the following quote:

> *"Small projects will in the future use the same processes which supports the new technology. Then the processes and technology also will be applicable for smaller projects. (Int.3) "*

6.4 Motivation and driving forces behind the use and evolution of BIM

Motive for the question: This theme is brought up in the interviews to get an overview of what kind of motivation and driving forces which lies behind the decision to start adopting, implementing and evolving their use of BIM.

As earlier mentioned, Int.1 came from a larger company, where he had experienced the positive consequences of working in a BIM enabled environment. He explains that he tried to turn the project workflow around and met some internal resistance in the beginning, but this was changed rather quickly when they saw the benefits it provided to the company, which helped them to make the transition.

Int.1 states that they see the importance of being among the early adopters in the industry, to be set to meet up with new client demands. The importance of being an early adopter combined with the great benefits regarding time saving and improved collaboration was mentioned as their main driving forces.

> *"We can clearly see the importance of being an innovator in AEC industry. Believing that BIM is a bubble that will go away is not realistic, the technological development will continue to evolve. (Int.1)"*

An example showing their innovative approach is shown through their decisions to join different pilot projects, which makes it possible to exploit new technology (Int.1). In one of the projects, semi-autonomous drilling robots are used. This will operate on exact coordinates from the BIM model and improve the progress of the project. The robots being able to do the work before human personnel can enter the building due to security measures. The robots will also make it possible to finish the work at night, making it possible to carry out the project with a shorter duration. It is also considered positive in a "HMS" perspective, saving the workers for many unwanted working positions. This was considered a possible solution for all their projects in the future.

Int.1 told that they could see a growing BIM awareness among many clients, and that the clients have started to see the real benefits in the technology. Especially the environmental benefits regarding the use of the model for facility management, LCC and LCA analysis was considered potential game changers in the Norwegian AEC. Due to Norway's large focus on greenhouse gas emissions and environment in general.

> *"Technology and environment fit together, hand in hand. If we are smart in the way we conduct our projects we will be able to minimize mistakes and general waste. (Int.1)"*

Int.1 also points to the fact that having a large organization behind them "pushes" them to take new BIM steps and help to provide their internal organization with the right skills and the necessary software.

The structural engineer (Int.2) says that working with 3D is standard for almost every project. Delivering the 3D model is a standard procedure in the company, which also implies for almost all their peers.

It is stated that they are using a 3D model on all projects, where models from all the consultants are put together to a single model (Int.3). Everything in the project is being modelled and handled through stream BIM. This is common and is accessible for all stakeholders in the project.

> *"Having a common environment is where we see the benefits of BIM as a contractor. Where we use it for common visualization and understanding. (Int.3)"*

Int.3 also explained how the central organization mandated certain new methods that needed to complete by their local organization. However, they had little to none influence on the implementation process.

7 Result of surveys

The survey was answered by 40 organizations, with a predominance of contractors, making up for 54 % of the total respondents. This was considered appropriate due to their important role in setting the BIM requirements for the projects, since they are often the lead appointed party in many projects and thus plays an integral part in the evolution of BIM. The contractors are also often involved in many parts of the project from tender until the handover of the project.

I have chosen to use BIM levels rather than BIM stages, which is now the new terminology in ISO 19650. This has been done due to the fact that BIM levels is a more well-known method that has been in the industry for several years, and also making it possible to compare with the existing literature which is built upon BIM levels. This is considered to have a small impact on the result due to the fact that both terminologies are based upon PAS 1192.

The results are presented in the following arrangement, general information about the participants, BIM levels and use of BIM, barriers for BIM adoption and implementation, and finally driving forces for adoption and implementation of BIM is presented.

7.1 General information about the participants

The figure below shows the distribution of the types of firms that contributed to the survey.

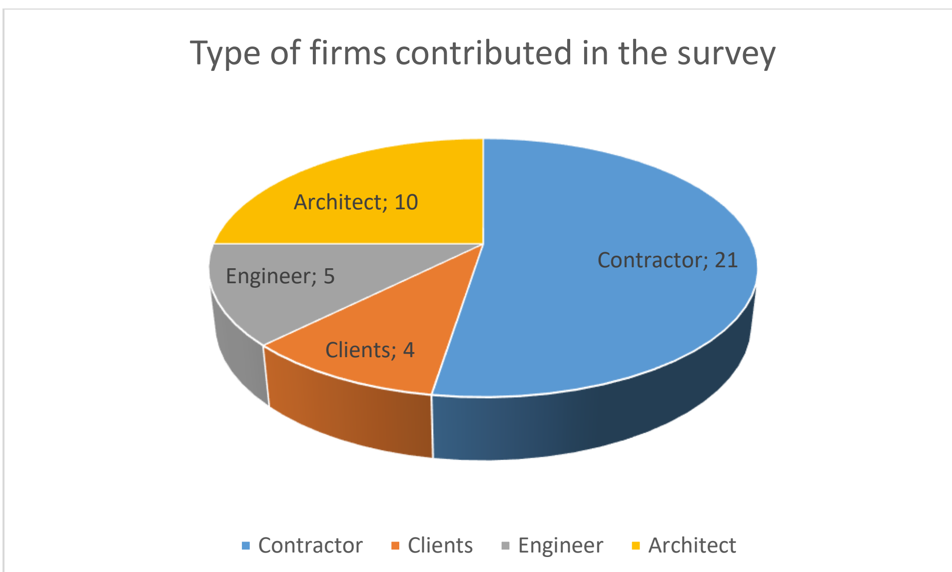


Figure 25 Type of firms that contributed to the survey

The years of experience among the participants varies. This enables us to capture both the experienced and the newly graduates. This will give a comprehensive picture of the use of BIM with different points of view and interpretations.

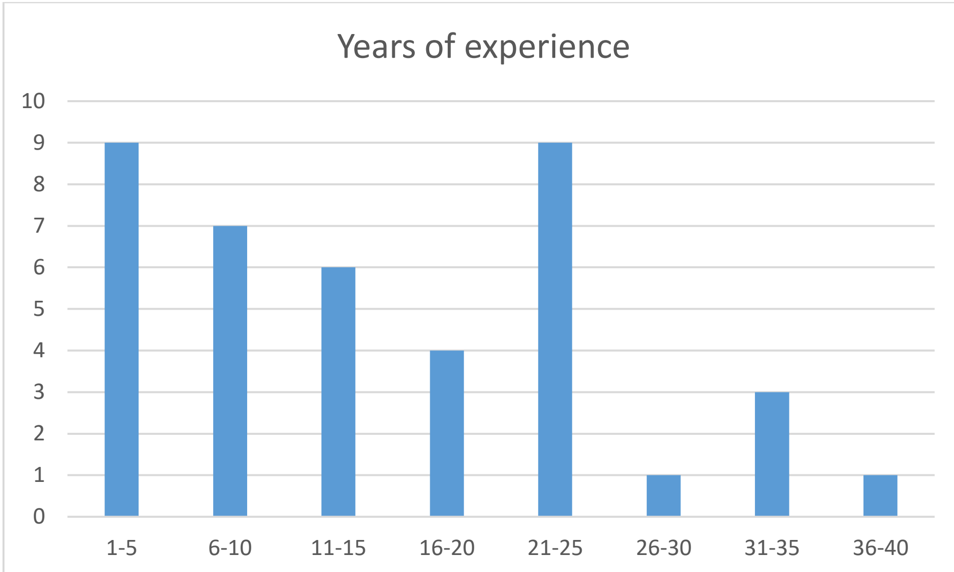


Figure 26 Years of experience of the 40 participants in the survey

By Norwegian standards for SMEs, there was 12 small companies, 22 medium sized and 6 large companies participating in the survey. The SMEs makes up for 85 % of the participants in the survey. This is considered as a good starting point for being able to map the possible differences between the SMEs and the large companies.

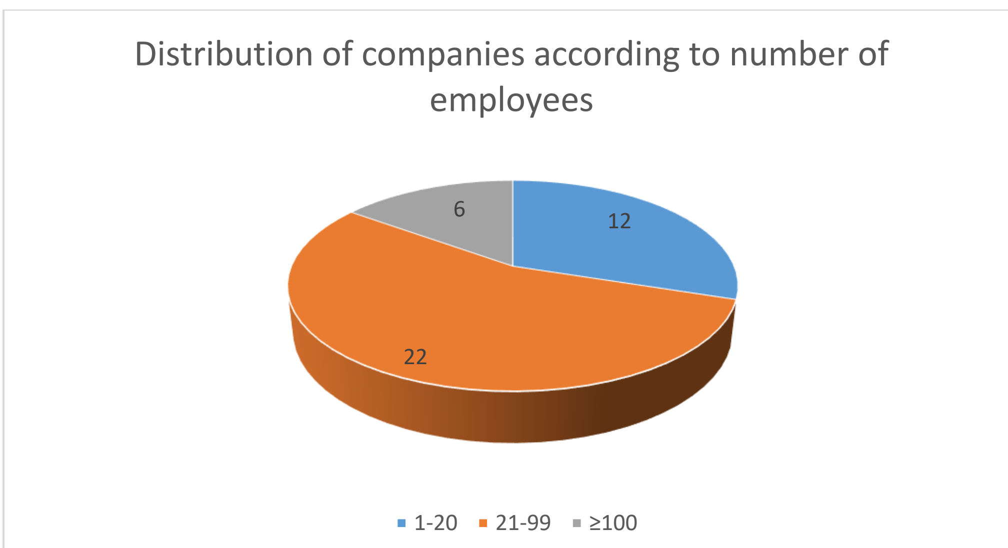


Figure 27 Distribution of companies according to number of employees

It was also of interest to see the organization mean project values the last 5 years. There was 37 companies that submitted their average project size. This made it possible to relate the different barriers, driving forces, level of use and actual use according to project size.

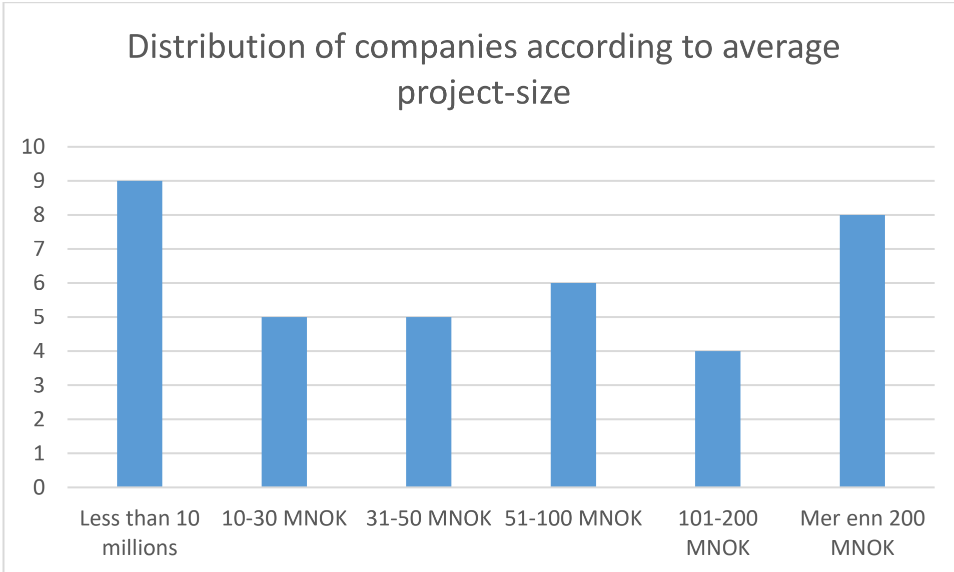


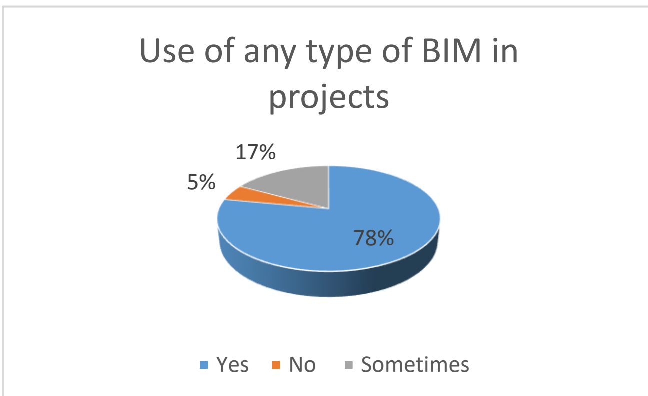
Figure 28 Distribution of companies according to average project size

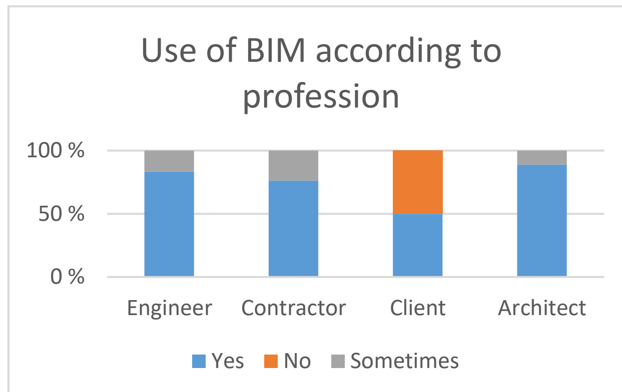
7.2 BIM Level and use in the different organizations

Motivation behind the questions: It was of interest to map what extent BIM is used in their projects. To find the correlations between the use of BIM and different factors such as employees and project size.

7.2.1 General use of BIM

By the results we can see that the large majority of companies use BIM to some degree in their projects. 78 % of the respondents uses some type of BIM tools on all their projects. Of the 22 % percentage that answered no or sometimes all where in the category of the SMEs.





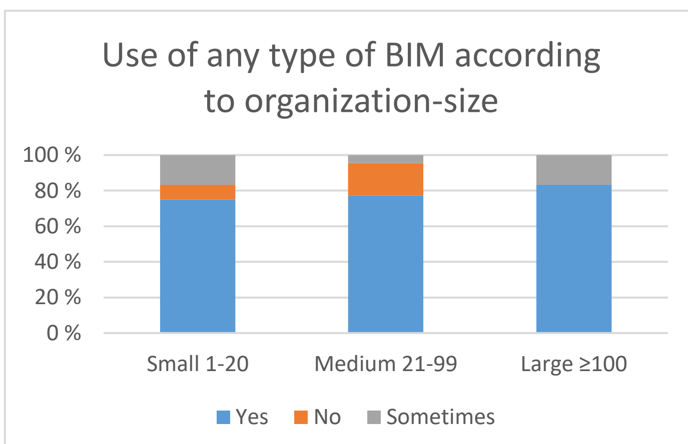


Figure 29 Use of BIM

7.2.2 Time of adoption

Motivation for the topic is to find out if the Rogers bell curve for innovations is also applicable for the adoption of BIM, with successive groups of consumers (or in this case organizations) adopting the new technology. The curve is broken into different sections of adopters. The adopter categories are based on relative time of adoption of innovation.

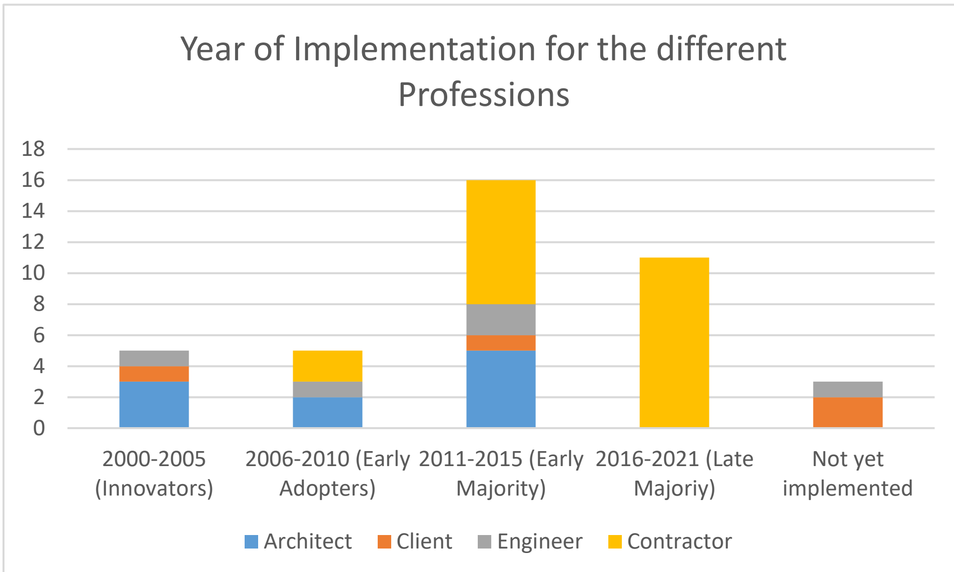


Figure 30 Shows the year of Implementation for the different professions

From the result, we can see that the time of implementation somewhat follows a normal, bell-shaped curve when plotted over time, as suggested by Rogers. Three out of five organizations in the first period are small architectural companies with between 5 and 18 employees. This clearly shows that architects are early innovators and shows that 3D modelling, which is the most common use for architects, has been around for quite some time.

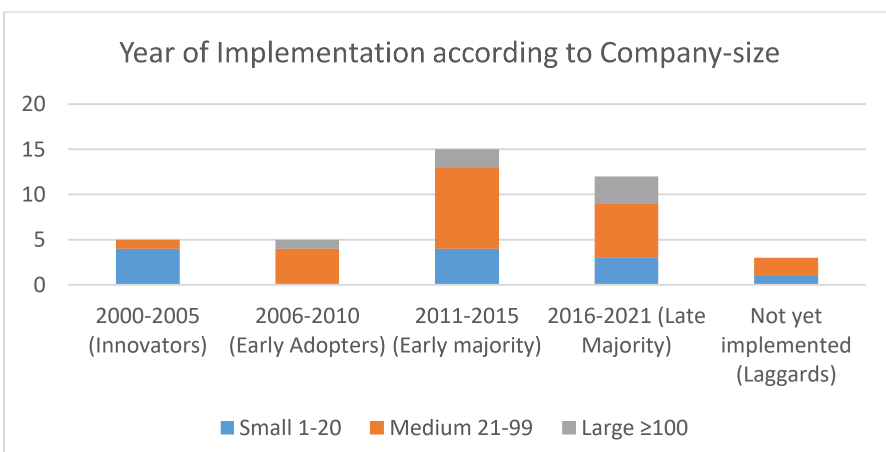


Figure 31 Year of implementation for the different companies

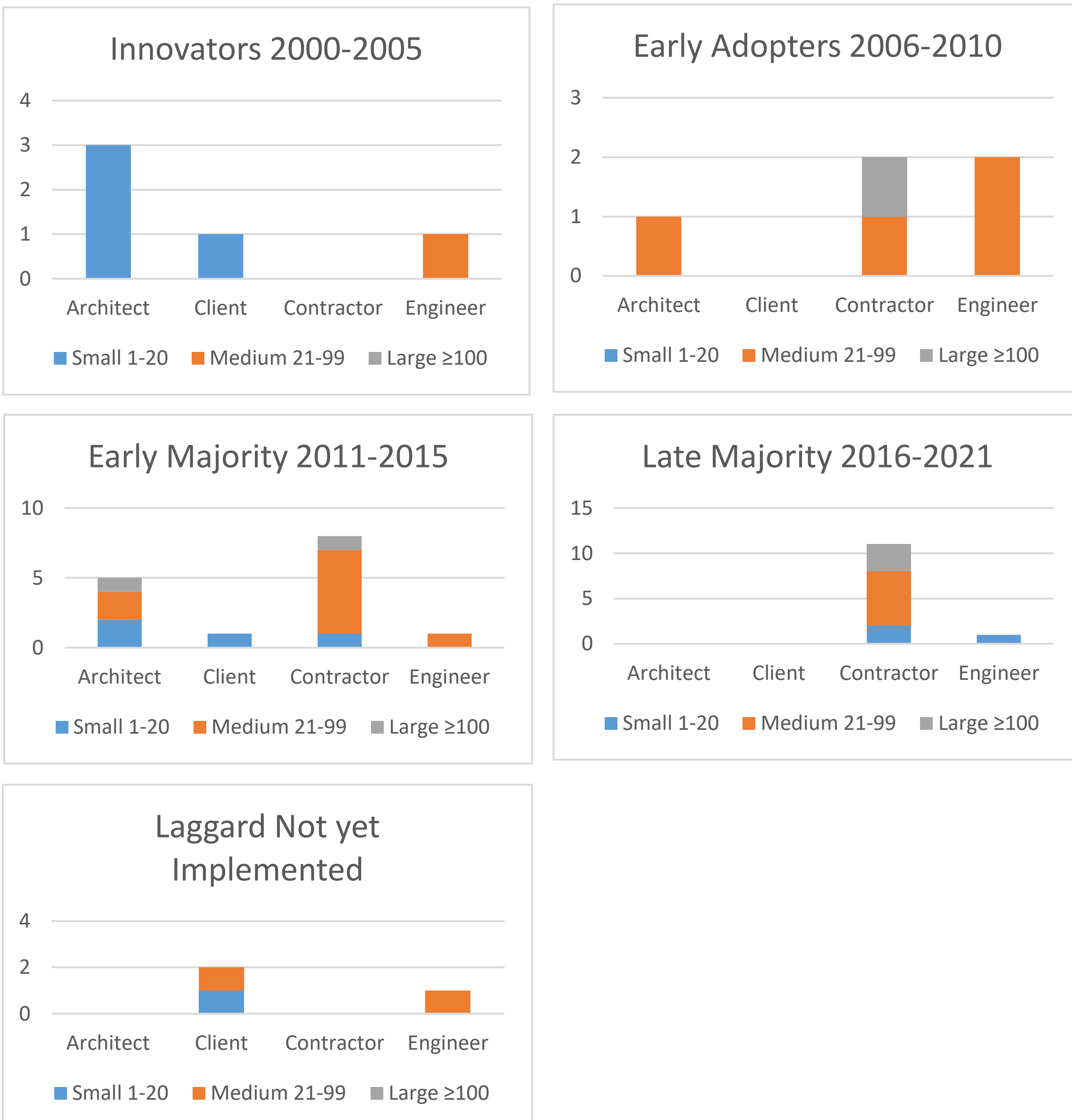


Figure 32: Shows the company characteristics in each adopter category

In Figure 32, there is an overview of when the different professions in the AEC industry have adopted BIM. From the results, we can see that the architects have in many ways been the innovators when it comes to adopting BIM into their workflow. The results shows that almost 100 % of architects and consultants implemented BIM before 2015. All the architects that implemented BIM tools in their workflow in the timespan 2000-2005 are SMEs. This supports the findings in the literature that architects are different in many ways than the other professions in the AEC industry regarding size of their structures. It is also interesting to see that most of the contractors have been rather late when it comes to implementing BIM into their workflow. This shows that the technology and workflow for the architects and engineers start to be well implemented in the AEC. Analyzing this closer, it is interesting to notice that both the contractors which implemented BIM in the early adopter's period are both working on large projects, with a total project cost above 200 MNOK and are parts of national or global companies. The two companies are also currently conducting their projects at BIM level 2.

7.2.3 BIM maturity Level (Bew-Richards Maturity Level)

The survey participants were asked to position themselves in the BIM wedge created by Bew and Richard to see in what whey they carry out their projects (the once uncertain about their level is removed). The Bew-Richards maturity model was chosen due to its recognition and dissemination in the existing literature, even though it is not 100 % transferable to Norwegian conditions. The results shows that 95% of the companies place themselves in either level 1 or 2.

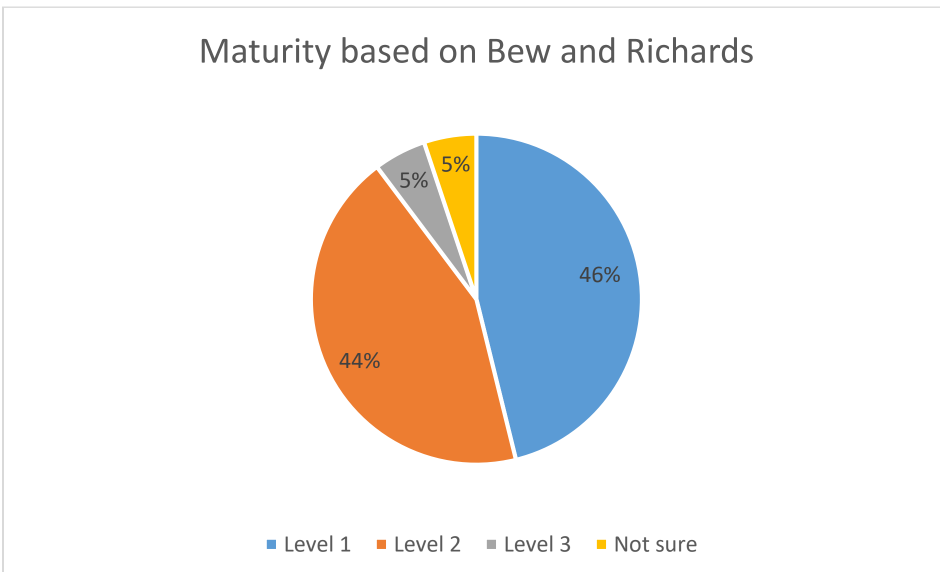


Figure 33 An overview of the companies self-determined placement in Bew and Richards BIM wedge.

Maturity level according to size of the organization: By comparing the company's size with the given maturity level, we can see an increased level based on the company size from the figure below. In the figure below there is seen a significant increase of maturity in the larger companies. In larger companies, 84 % of the projects are conducted at either Level 2 or Level 3, this is in stark contrast to the small and medium sized organizations where the percentage is respectively 42 and 47 %. Only the companies, which are aware of their maturity level, are included in the comparison. Despite these uncertainties in the interpretation of BIM levels there is reasons to believe that BIM is used at a higher maturity level in the larger companies.

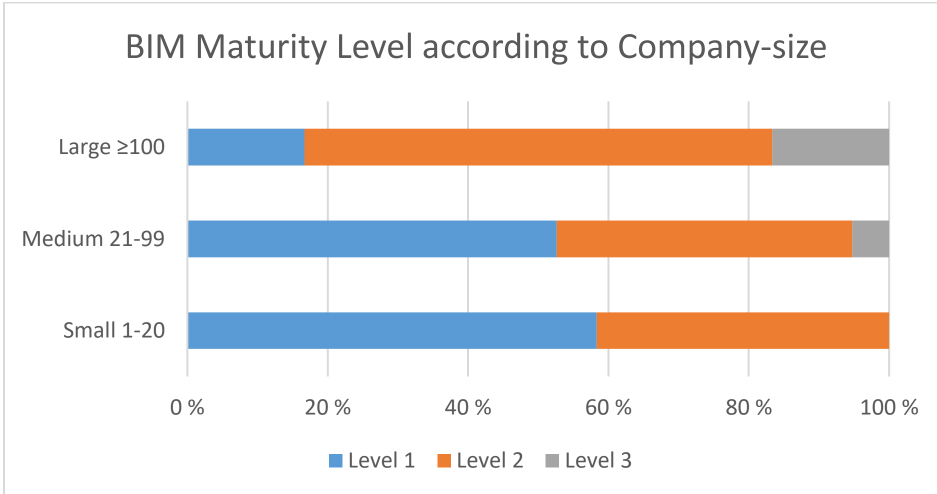


Figure 34 BIM maturity Levels according to company size

Champion of Innovation: The Diffusion of Innovation underlines the importance of having personnel within the organization who can overcome indifference and resistance towards change. The results shows that the organizations which have an internal champion of innovation are conducting their projects at a higher BIM level than the once that does not have a champion of innovation in their organization. Proportion of the companies that had a champions of innovation in their organization were 50 % of small companies, 64 % for medium, 100 % for large companies.

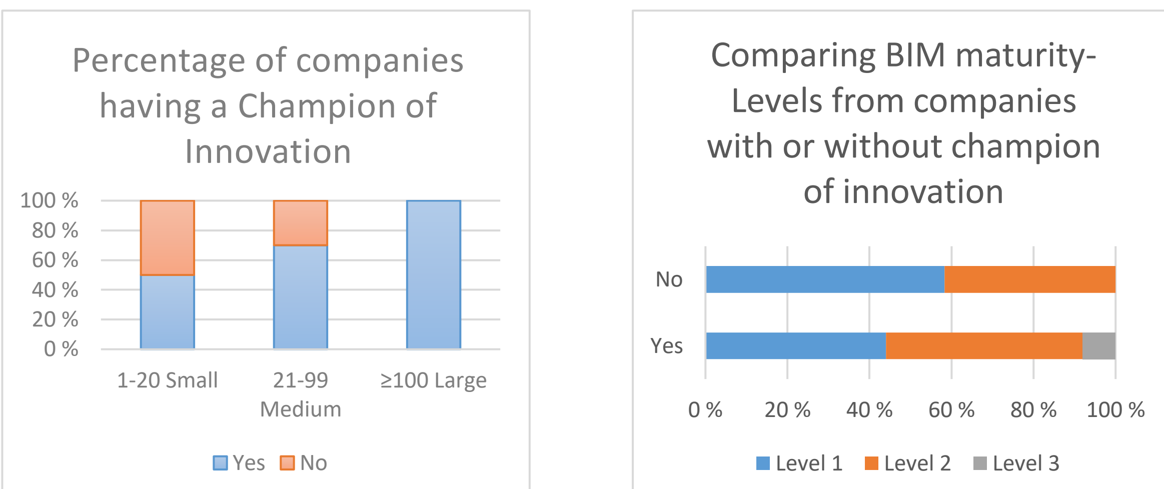


Figure 35 BIM maturity-Levels in organizations with or without "Champions of Innovation"

BIM coordinator: The percentage of companies with their own BIM-Coordinator was 25 % for the small, 55 % for the medium and 83% for the large companies. There is also found significant increase in BIM level for the organizations which have a BIM-coordinator employed in their organization, where over 70 % of the projects are conducted at either Level 2 or above in companies with their own BIM-coordinator.

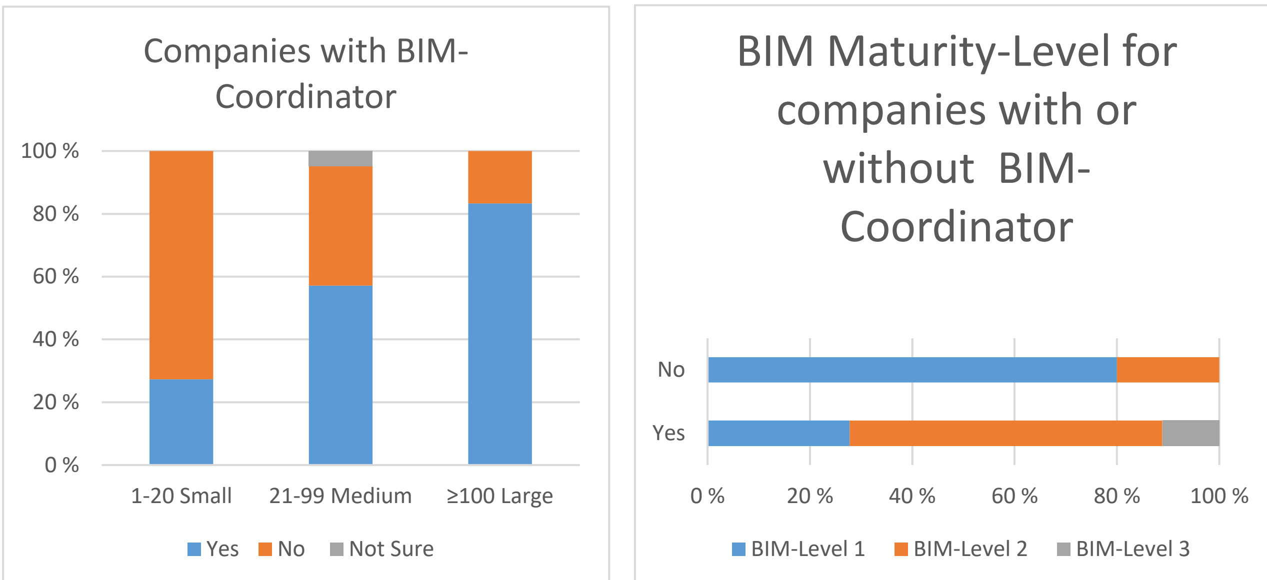


Figure 36 Comparing BIM maturity levels for companies with or without BIM-coordinator

7.2.4 Utilization of specific BIM features:

Using the BIM maturity levels by Bew-Richards could be somewhat challenging, since the levels are based on the British standard PAS 1192. Based on this there was also of interest to map the actual use of BIM in the projects to see what BIM features are used and to see how the information is exchanged among the project participants.

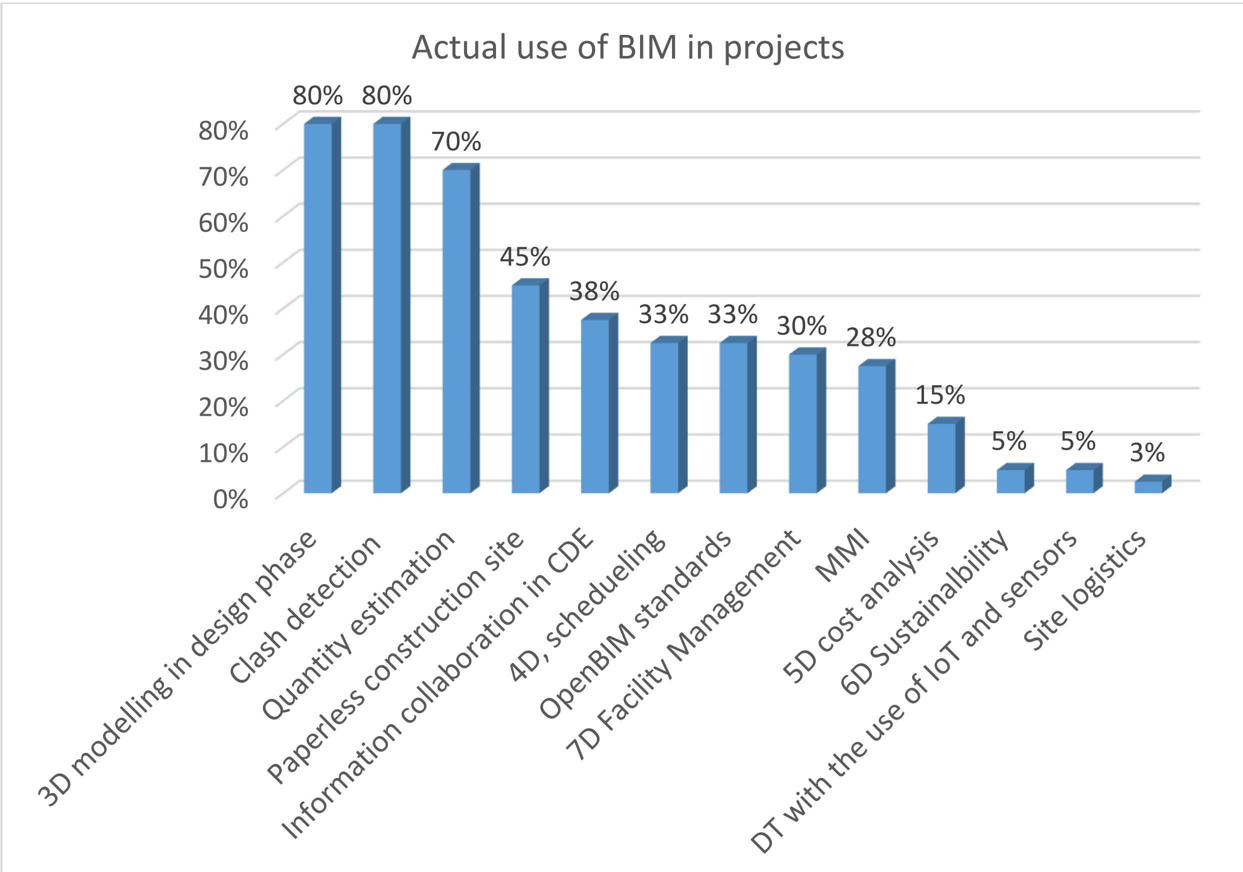


Figure 37 Different uses of BIM in projects

As we can see from the results, the dominating areas of use are strongly linked to the visual aspect of BIM and less focus on the collaborative and information exchange in the projects. In both ISO 19650 and PAS 1192 the CDE stands as one of the corner stone to reach level or stage 2 of BIM in a project. It could therefore be argued that only 38 % of the projects are carried out in a BIM compliant procedure. Also, the use of openBIM are rather low with 32,5 %.

From the results, it was revealed that the usage of some features of BIM was closely linked to the project size. Below some of the features, which differed the most are presented. This proved to correlate at a higher level than comparing the company size with the actual use.

The use of *MMI* is an important instrument to control the project progress and to set the project requirements; this is only implemented in 28 % of the projects. Interesting to see is that MMI is only used regularly by 11 companies, where as many as seven of these companies are working on projects above 200 MNOK. Where almost 80 % of the projects above 200 MNOK are conducted using MMI..

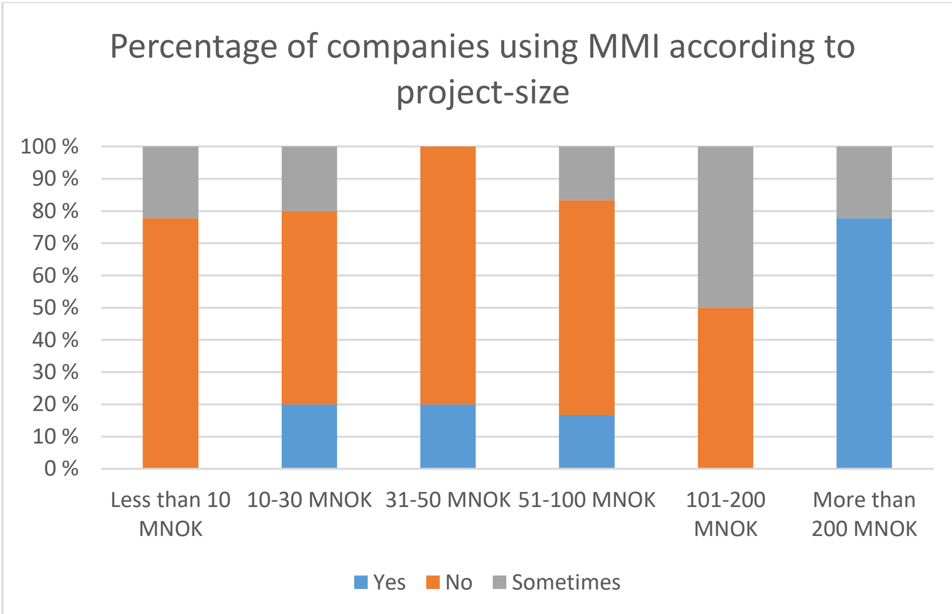


Figure 38 Percentage of companies using MMI according to project size.

There is also a rather modest use of both *4D*, *5D, 6D and 7D BIM* in the different projects, with a corresponding 33, 15, 5 and 30 %. Showing that the contractors, clients and facility managers do not exploit the great possibilities which lie within BIM. However, when relating the use to project size, large differences appeared especially concerning 4D scheduling. The results showed that organizations working on projects above 200 MNOK, 4D scheduling was used to a much greater extent, corresponding to 78 %, compared to just 20 % in the projects below 200 MNOK.

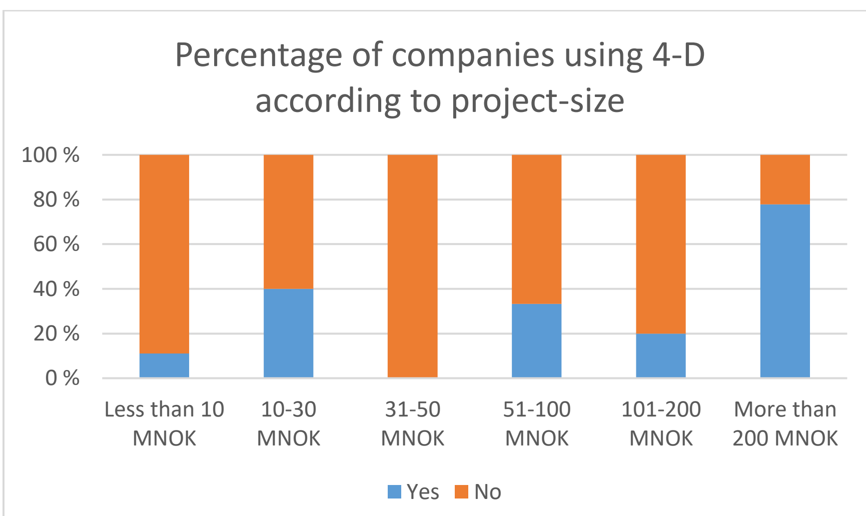


Figure 39 Percentage of companies using 4D according to project size.

The use of *paperless construction site* also correlated with the project size. Paperless construction-sites in general were used by 45 % of the total respondents. When analyzing the use among the companies working in projects above 200 MNOK, it revealed that almost 90 % of these project-sites were paperless, compared to 30 % for the remaining projects.

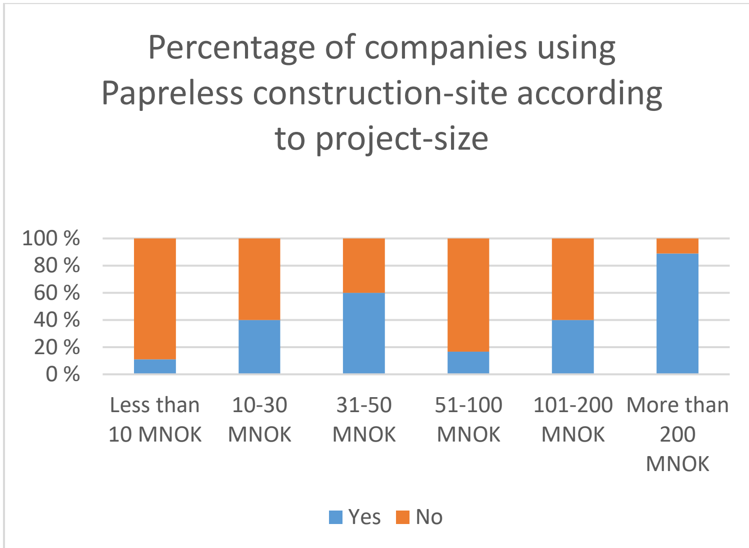


Figure 40 Percentage of companies using paperless construction site according to project size.

7.3 Barriers for Implementation and further Adoption

Motivation for the topic was to find out what kind of barriers that were considered as hindering factors regarding BIM adoption and implementation in their projects. The barriers are sorted in the framework made by Nepal et al. (2014). The reason for this is to identify the barriers that are hindering BIM-enabled projects. When categorizing the different barriers, it could be argued that, they could be placed in different stages of the framework. In this thesis, the cost variable both regarding software and training of staff in new software, has been chosen to be placed within people/organization section. The reasoning behind this is that the cost barrier will influence the organizations differently dependent on resources and skills. The different barriers will be discussed further in a theoretical lens in the discussion chapter.

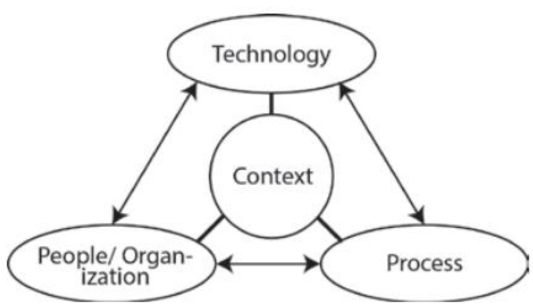


Figure 41 Technology, organization/people, process, and project context. Framework for BIM evaluation. REF:(Nepal et al., 2014)

The figure below shows the perceived barriers from the survey participants. Some of the key barriers are discussed and all barriers are arranged in the framework by Nepal et al. (2014) where relations between size of the company and barriers are highlighted.

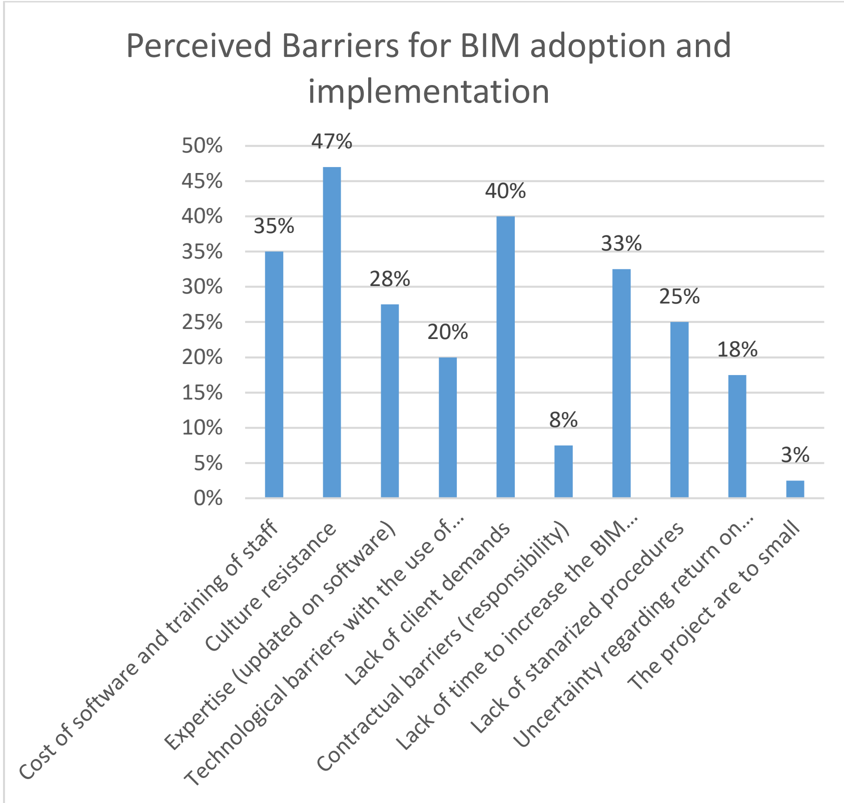


Figure 42 Overview of perceived barriers for BIM adoption and implementation

Technology

Technological barriers with the use of new technology are perceived by only 20 % of the respondents and there are no differences considering the size of the company.

People/Organization

The single highest barrier for BIM implementation in projects is perceived as the *cultural resistance* in the AEC industry, 47 % of the survey respondents perceived this as a hindering factor for conducting BIM- enabled projects. This is supported in the statement by one of the survey participants saying that there is a need for more young people to be employed in their organization. This barrier is evenly distributed among all companies independent of size.

Economic barriers also have a negative impact on the BIM implementation where the cost of training and software is mentioned by 35 % of the respondents. From the figure below, it is clear that the cost barrier is perceived more frequently by smaller companies.

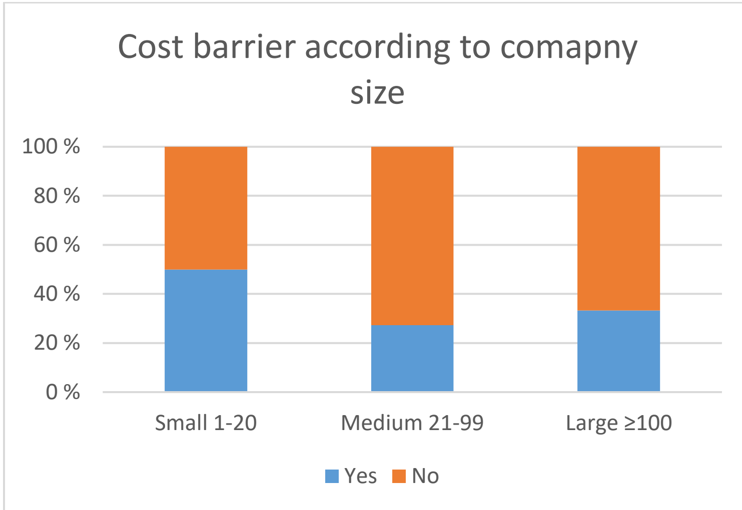


Figure 43 Cost barrier according to company size

The concern regarding *ROI* is only perceived by 18% of the total respondents. Related to size of the organization the ROI barrier shows that all seven respondents, who perceived this barrier, all were employed in organizations with 40 or less employees. This makes ROI a concern that is only applicable for the SMEs.

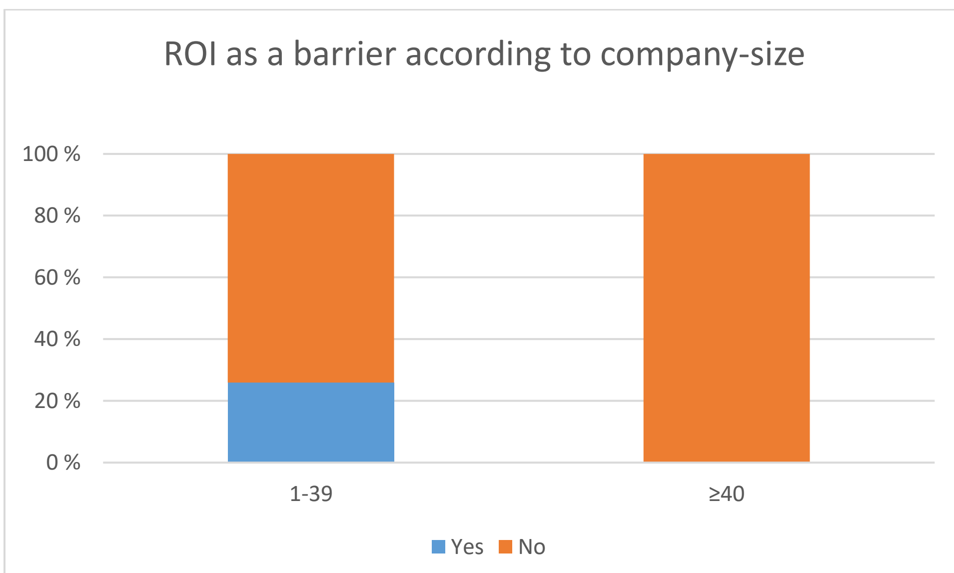


Figure 44 Concerns regarding ROI according to company size

The lack of time to raise the BIM knowledge is only perceived by one out of the large companies. As shown in the figure below the lack of time is more applicable for the SMEs. When analyzing the results more closely it appears to be a separation between the companies with 40 or less employees and the remaining companies. The companies with less than 40 employees seems to perceive the lack of time as a major constraint to their further adoption and implementation of BIM. As shown in the figure below.

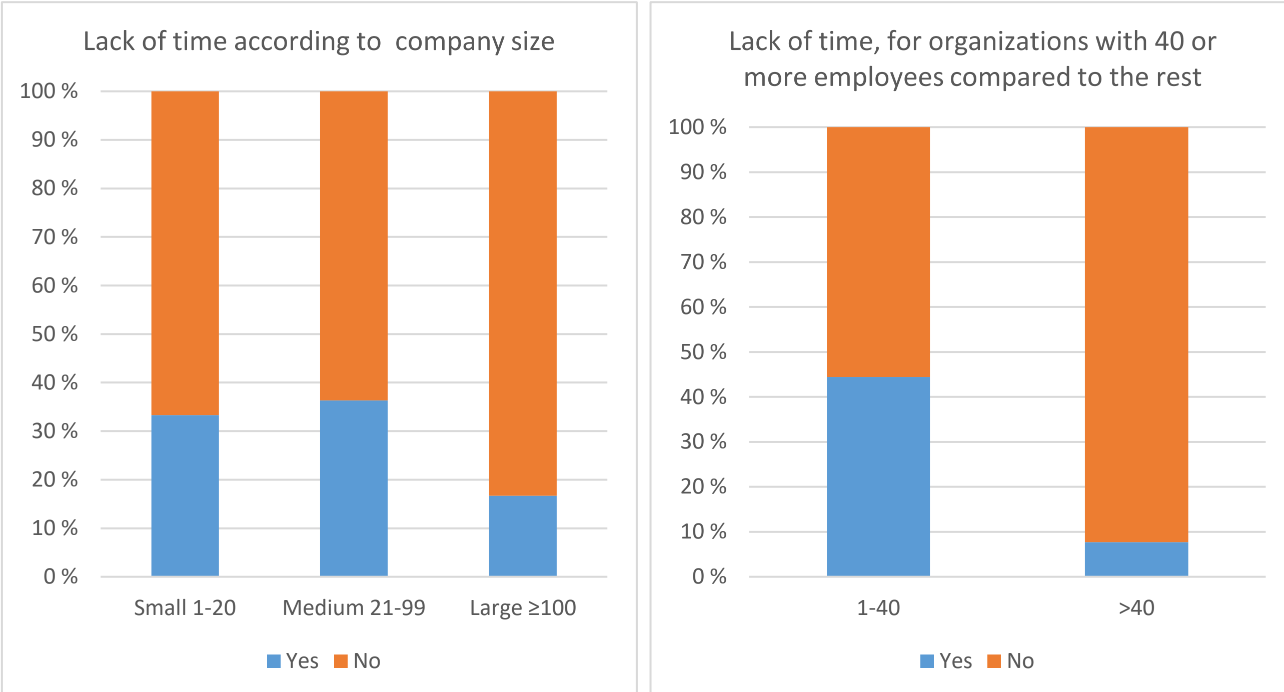


Figure 45 Perceived lack of time according to number of employees

Process

Lack of standardized procedures were mentioned by 25 % of the respondents and was evenly distributed among all companies independent of the size.

Project Context

The second highest barrier was the *lack of client demand* with 40 % of the respondents mentioning this factor. The client sets the requirements in most of the projects, where a total of 75 % of the participants in the study answers that the client (often in cooperation with others) sets the requirements for the project. The importance of requirements is underlined by the following quote from the survey:

> *"The client needs to be the one who sets the requirements and need to see the benefits of using it. In regard of better quality, less waste and to track the progress in the project according to the contract, and not only look at the short-term cost."*

This shows the importance of an active client who are aware of what BIM means to a project in the whole life-cycle of the asset. Other survey participants emphasize the importance of organizing the projects as a BIM project from the start, and the importance of setting the framework at an early stage.

It is interesting to see that only 3 % mention that the size of the project has any negative consequences on the BIM implementation.

Structuring of Barriers: The barriers are arranged in the following way, according to the framework by Nepal et al. (2014).

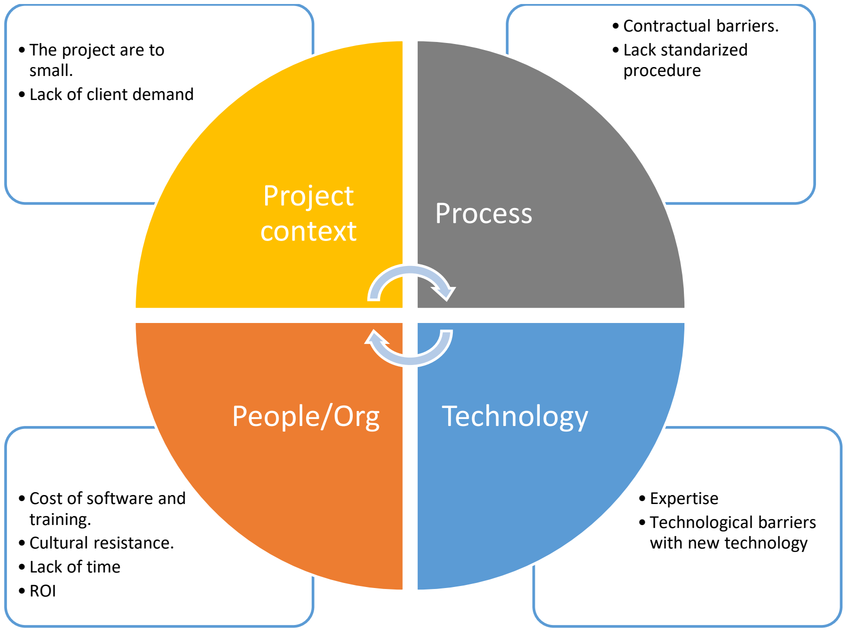


Figure 46 Barriers arranged according to the framework by Nepal et al. (2014)

In the figure below the different factors are arranged, and weighted by the amount of organization which perceived the different barriers, in the framework by Nepal et al. (2014). As we can see from the results the people/organization, makes up for large proportions of the total barriers hindering BIM enabled projects.

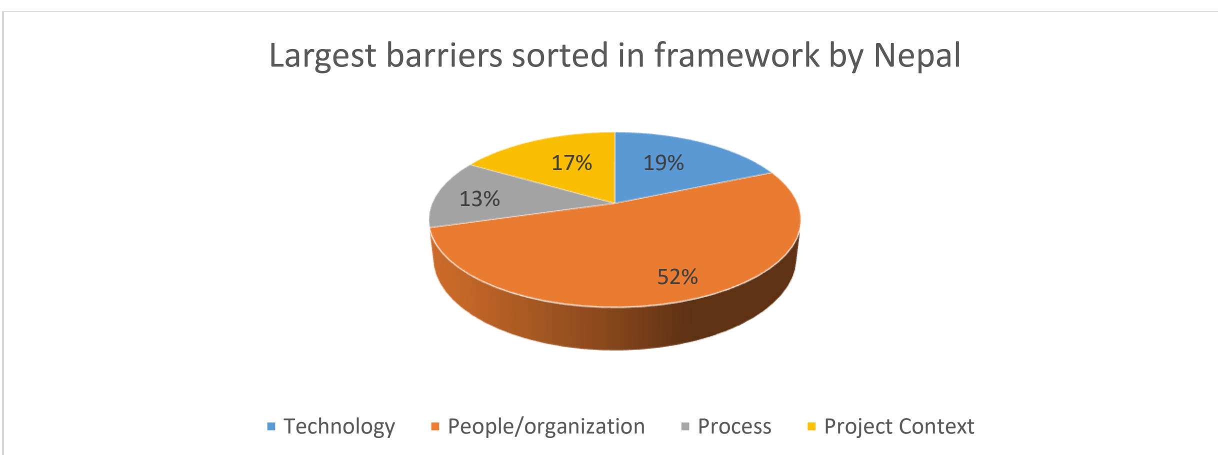


Figure 47 Barriers arranged in the BIM framework by Nepal et al. (2014)

7.4 Driving forces for BIM adoption and implementation

The motivation for the topic was to map the different motivations and driving forces, which lies behind the use of BIM. The various driving forces are later arranged and analyzed based on the three theoretical lenses in chapter 8 "Discussion of results in a theoretical lens".

From the results, it is clear that the driving forces for BIM implementation are closely linked to the innovation attributes and the benefits from using BIM. The highest rated driving forces among the survey participants are the wish for better collaboration between the stakeholders in the project mentioned by 85 % and better understanding of the project for all stakeholders with 83 %.

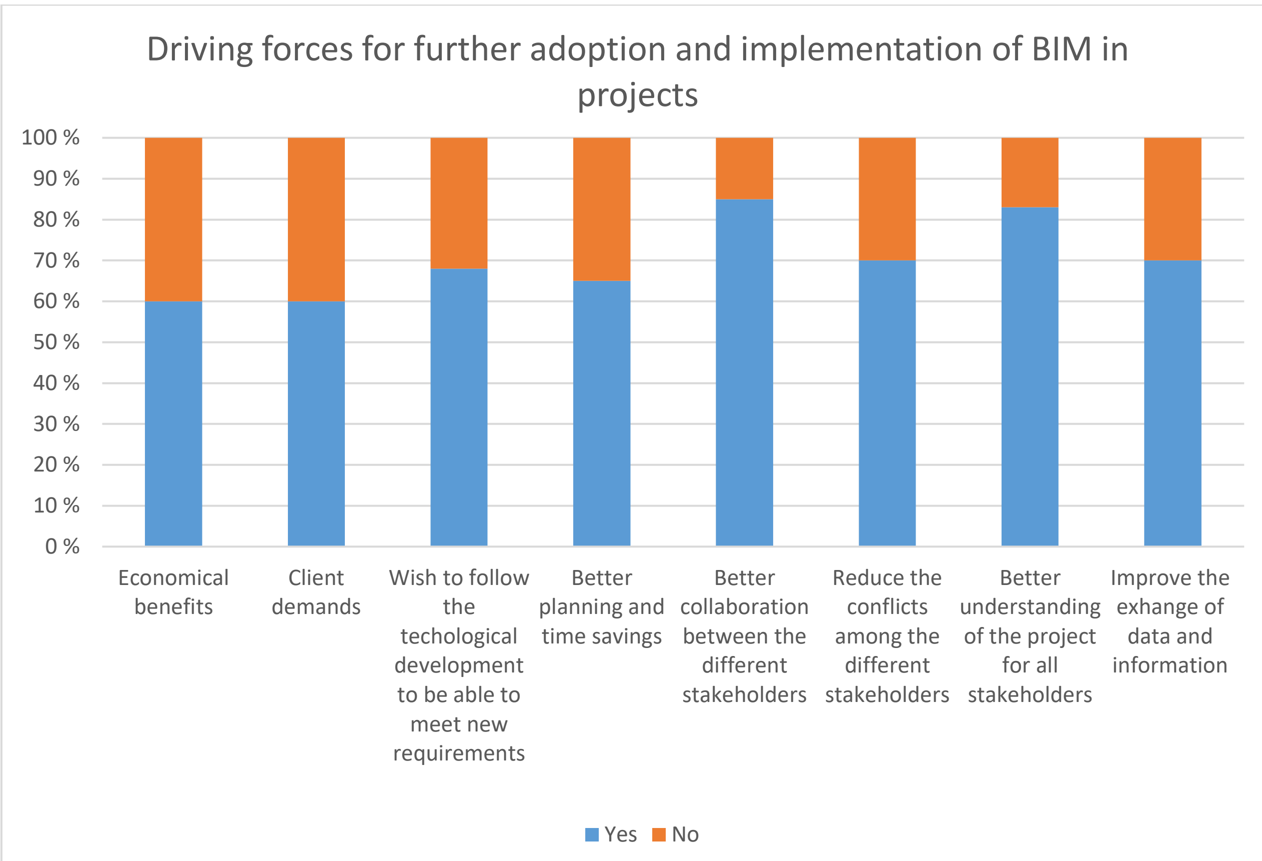


Figure 48 Driving forces for BIM adoption and implementation

Driving forces according to company size: The driving force that differs the most related to company size is the "wish to follow the technological development being able to meet new requirements". This factor is perceived by 100 % of the thirteen largest organizations (>45 employees) as opposed to just approximately 50 % among the remaining 27 survey participants. (≤40 employees).

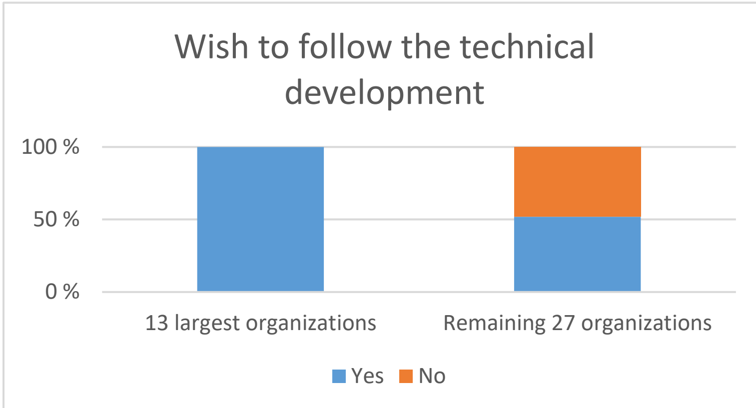


Figure 49 Wish to follow the technical development as driving force for implementing BIM.

The *economic benefit* from implementing BIM is also ranked higher among the largest companies. Where approximately 80 % of the largest company's state this as a reason to implement BIM, as opposed to just shy of 40 % for the small companies.

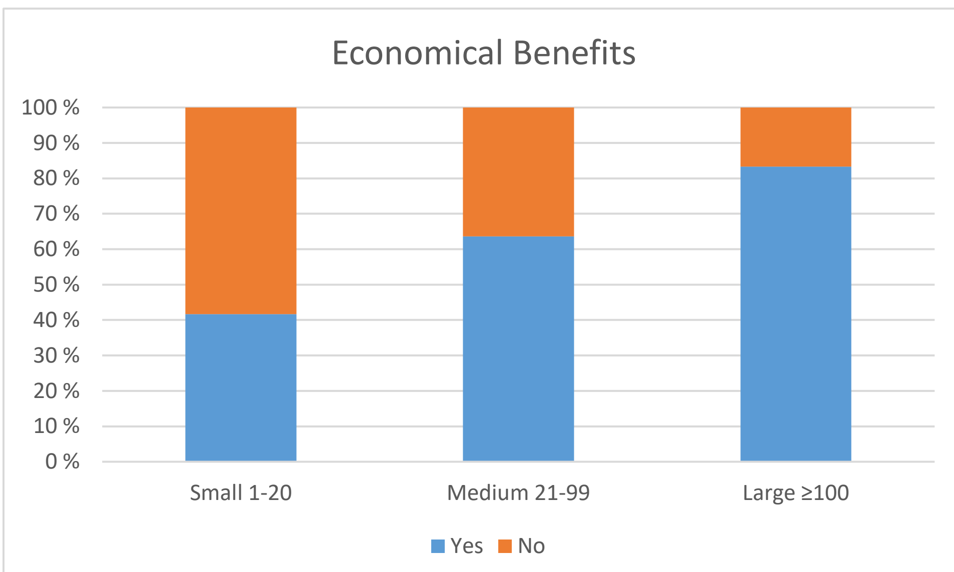


Figure 50 Economical benefits as driving force for implementing BIM

Possibilities to increase their BIM competence: When asked to elaborate how the organization could be able to increase their BIM bevel both internal and in projects many of the survey participants were pointing on the fact that they needed to increase their internal level of BIM competence. This could either be through courses or to employ relevant personnel with the right skills. The importance of being able to learn from other companies at a higher BIM level was also emphasized.

8 Discussion of results in a theoretical lens

The discussion chapter will adress two main topics: "*General use of BIM*" and *"conceptualizing of barriers and driving forces".* The general part discusses specific use of different BIM-features and the maturity levels, where these aspects are assessed mainly on the basis of the Diffusion of Innovation. The conceptualizing of barriers and driving forces are assessed and compiled in a framework based on the three theories presented in chapter 3. These three theories are: Diffusion of Innovation, Theory of Planned Behavior and Institutional Theory.

8.1 General use of BIM

During the thesis there has been an growing understanding that the most interesting aspect regarding BIM implementation is to assess at which maturity level and at which extent the different organizations are utilizing different BIM features. This has been necessary due to the fact that most of the organizations have adopted some kind of BIM-tools, especially the 3D modelling which is a standard procedure at almost every project in the AEC industry. This is clear from all the collected data which the thesis is built upon, where it shows that only a very few organizations are carrying out their projects without any kind of 3D modelling or said in another way, without BIM at the lowest level.

Different uses of BIM:

It is clear from the findings that the use of BIM today is mainly linked directly to the visual aspect of the 3D modeling by different designers, where the different models are put togheter and used for clash detection. This corresponds to the findings of Bosch-Sijtsema et al. (2017). This one-sided use of BIM have lead to a misperception of what really lies within the use of BIM, this is somewhat summed up by the following quote in one of the interviews: "Now we have a 3D model, now we are digital". Where people tend to consider BIM only as a visualizasing tool. However, the visualizing capabilities could also be considered as an aid for better coordination and communication. This is supported by the survey results where improved collaboration between the different stakeholders were stated as the main driving force for implementing BIM.

The use of higher n-D levels such as 4-,5-,6- and 7D BIM and CDE on the other hand is more widespread in the Norwegian AEC industry. Despite the fact that structured information management, by the use of CDE is one of the corner stones for achieving BIM maturity level 2. This is an interesting point since it is generally accepted that the BIM level should be at least at level 2 in order to gain the benefits from implementing BIM. This should be a wake up call for those organizations which at the present are conducting their projects with no structured information management and BIM related requirements in their projects. The UK has been in the driving seat when it comes to facilititating BIM in projects through requirements for structured information management. In the UK, there has been great emphasis on the collaborative aspect through the use of CDE which is highlighted in PAS 1192-2, this may seem somewhat different from the Norwegian perception where only a few organizations use this for structuring the information in their projects, this is reinforced in the interviews where it is stated that ISO 19650 is not implemented in their workflow. The well implemented PAS 1192 could be the reason behind the differences. With a change to the international ISO 19650 standard, one can hope that other countries will see the benefits and increase the awareness of this critical aspect of BIM. This is a strong argument for organizations in both Norway and in other countries to start exploting the opportunities which lie within the ISO 19650. Todays approach could be, in many ways considered to be starting at the wrong end, where implementation of software is prioritized rather than having a proper framework for how the projects are arranged.

An interesting point in the context of BIM use is Rogers (2003) focus on *observability*, where this has an important role in the innovation process. Here he argues that where innovations are visible to the average person they are likely to be adopted more quickly. It can be argued that the 3D model itself is the visible aspect of BIM, and therefore have been implemented faster in the companies than the features inherent in BIM that are more associated with processes and procedures, which cant be easily traced or observed. The results from both of the surveys and literature supports this, where the more hidden features are less exploited and is implemented at a lower degree.

Another interesting aspect is connected to the *compatability*, which plays an important role in the Diffusion of Innovation. Switching from 2D to 3D modelling is more about changing software than changing processes, this is in line whith the statement by Ayinla & Adamu (2018), which describes that moving from level 0 to 1 as the easiest step as it can be described as just implementation of new software. Such a change of software will not lead to much concerns regarding the compatability of the innovation. Where changes to higher levels of BIM on the other hand requires a change in the actual project collaboration and how information is shared and managed in the project. Changes in such processes will require a major change in organizations value system, which is described as a relatively slow process. According to Rogers (2003) these compatability factors will decrease the tempo of the innovation process, which seems to be the case based on the collected data.

BIM maturity levels:

It can be problematic to draw a solid conclusion about BIM levels in various organizations and projects in the Norwegian AEC industry. There could be a lack of awareness linked to BIM levels in Norway compared to UK, due to the fact that BIM levels are based on the British PAS 1192. This is also reinforced in the numbers of articles published on this topic, where a large percentage are British articles. Despite this only 5 % of the respondents in the survey answered "not sure" on the question regarding their BIM level. There is countless definitions of both BIM Levels and BIM in general, this is not appropriate for an industry that is accustomed to adhering to clear ISO standards to be followed. The ISO 19650 is therefore seen as a solid framework to help assess the BIM Levels (stages in ISO 19650) of different companies and projects. A common understanding of BIM levels will be beneficial for all stakeholder involved in a construction project, being able to map their internal organizations maturity level, but also being able to increase their level. It will also be beneficial for the clients, making them able to appoint the right project team capable of delivering at a certain level. As opposed to todays measurement of maturity levels, the stages should be built on clear criteria which need to be fullfilled in order to comply with different levels.

Champions of Innovation and BIM-Coordinator:

According to Rogers (2003) Champions of innovation are crucial to help the companies in implementing new technology. In the survey results, it is shown that all large companies had a champion of innovation regarding BIM. Some of these champions might not succeed with implementing their ideas in the smaller companies, which means that they in some cases will look for new environments that are further ahead in the use of BIM. This means that the expertise is gathered in some large companies, which leads to even greater distinction between the companies. Another aspect of this is that there might be no room for a champion of innovation in the small companies due to the fact that the SMEs are highly dependent of employees having several different work tasks. Which means that they do not have the opportunity to specialize in a particular field, in this case BIM. There is a correlation between the companies with a champion of innovation and the companies BIM level. There is also a correlation in increased BIM level and those who have a BIM-coordinator. Even if a BIM-coordinator does not have to meet all the characteristics of a champion of innovation, there is little doubt that a BIM-coordinator works to facilitate for the use of BIM. This clearly shows the importance of having internal specific expertise. This is often not the case in SMEs, where employees are required to act as "Jack of all trades". This factor is probably one of the main reasons why there are generally higher BIM levels in the large organizations.

Categorization of organizations according to Rogers Diffusion of Innovation:

The results from the survey showed that all the organizations that still havent adopted any type of BIM are all SMEs. With respect to the Rogers technology adoption model, the quatitative data from the survey suggest that the size of the organization does not necessarily make it an innovator or laggard both in terms of time of implementation and level of use, this is in line with the findings of Ayinla & Adamu (2018). Even though all of the laggards which havent adopted any form of BIM are all SMEs. The arcithects seem not to have any correlation between the company size and level and time for implementation. Where many of the small architectural companies are among the innovators and early adopters both regarding time of implementation and maturity level. The time of implementation was expected due to the fact that 3D modelling in the design phase has been a industry standard for quite some time. However, it was interesting to see that there was increased BIM level with increased size of the organization. Where a total of 84 % of the large organizations were conducting their projects at either level 2 or 3, compared to below 50 % for the SMEs. Also when analyzing the maturity level it could be argued that all laggards are SMEs, despite the fact that there are large variations within the AEC industry. The fact that almost 50 % of the projects in the survey is conducted at level 1 is a clear signal that there is a need to increase the BIM level in the Norwegian AEC industry, making it possible for everyone to benefit from the use of BIM. When comparing to the results of Martin et al. (2019), where it was revealed that 54 % of French organizations conducted their projects at Level 2, it raises the question of whether Norway actually can be reffered to as a pioneering figure regarding the use of BIM. Or if this is only the case for those who are working with large civil state clients such as Statsbygg.

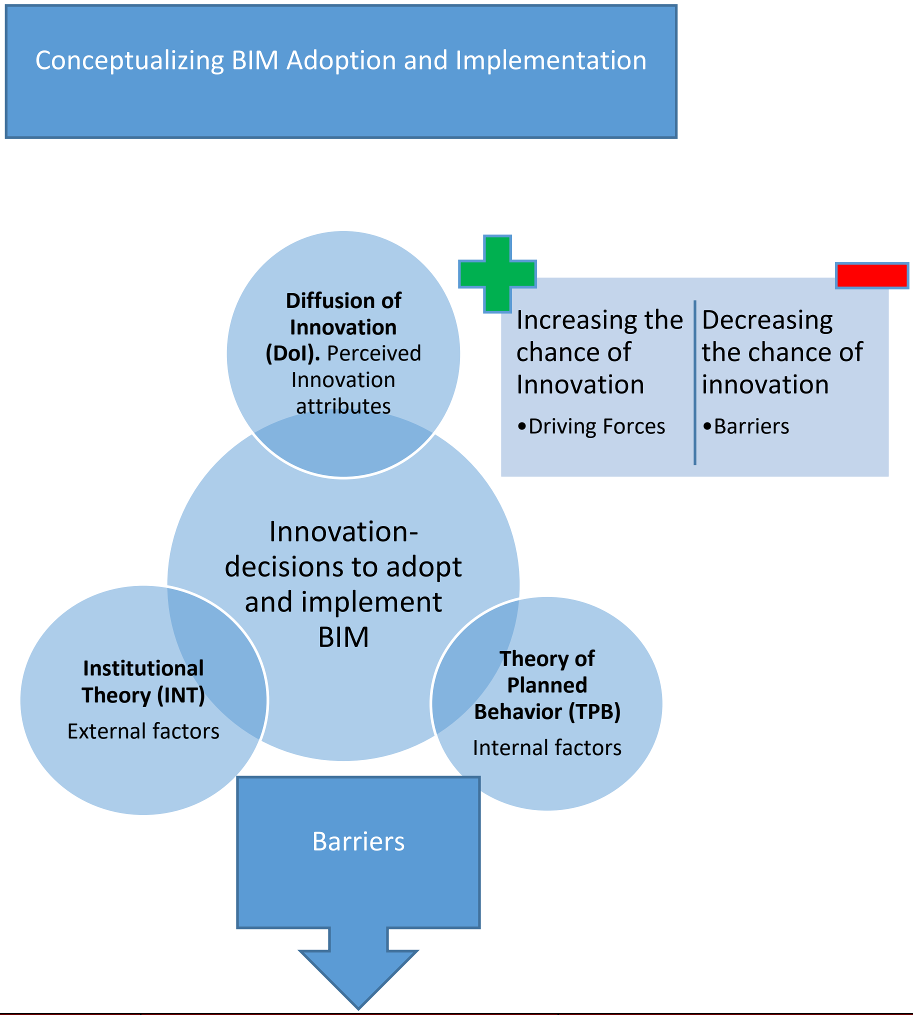
Regarding the actual use of different BIM-features the results revealed a strong correlation between project size and specific use of different BIM-features. It was shown that organizations working on projects above 200 MNOK are utilizing BIM at a greater extent than smaller projects. Where the majority of projects above 200 MNOK uses e.g. 4D BIM, paperless construction-site and MMI at a much greater extent. When analysing and interprating the survey results, it would be more appropriate to call the contractors and clients late adopters or laggards. This assessment is made based on both the time of implementation, but also by looking at the specific BIM use in projects. When analysing the use of BIM it is clearl that the tools aimed at contractors and clients are utilized less than those developed for architects and designers. This includes the use of 4D, 5D, 6D and 7D in addition to paperless construction-site and MMI. As previously mentioned one of the reason could be that implementing these tools requires a change in processes and not just a change of software which is the case of changing to 3D modelling. It could also be argued that the contractors along with their supplier chain represent the most traditional part of the industry. As they are the ones who work hands-on with the actual construction on-site and it might be challenging for them to accept that more money must be moved from the production-stage over to the pre design- and design-stage in order to be able to complete a full-fledged BIM project.

Increasing the awareness of BIM enabled projects:

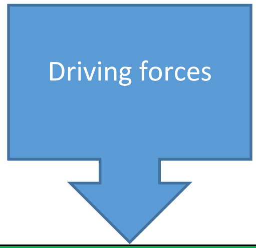
BIM is not just 3D, it may be a matter of course for many companies, which is supported by the findings in the interviews, where one of the contractors told about the general perception in his organization saying that “now we are digital” after they have implimented 3D into their workflow. A strength to the UK BIM mandate is that it has been a great focus on information management and the whole life-cycle. Even tough, they encountered problems when there was inflation in the term “BIM Level 2” among the clients, who set this as their only requirement for the project. The new ISO 19650 sets requirements to the clients to involve in the projects to a greater extent than what seems to be the case in many projects. The ISO standard can be a great tool if it is used to educate clients and increase the understanding of how a BIM project should be executed to get the most out of the technology. If this is not done, large parts of the construction industry which are not affected by a BIM mandate, will continue to operate in an unwanted symbiosis between, the clients who set none to few requirements, and the appointed parties who thus see no reason to change. This will lead to a industry where old processes are still considered sufficient and the only focus is on short-term economic gain, rather than looking forward to see what will be the best solution in the long run, both in terms of the environment but also considering efficency and economy. An increased awareness and use of ISO 19650 could be a good aid to get the whole AEC industry on the same page regarding BIM adoption and implementation in projects. This might help the Norwegian AEC industry to focus more on the ‘Information’ aspect included in BIM, helping them being more in line with the British approach to BIM.

8.2 Conceptualizing of barriers and driving forces

The thesis conceptualizes the BIM barriers and driving forces in three theoretical lenses presented in chapter 3. ‘Theoretical Lens’. There is limited literature, which consider the barriers and driving forces with the use of theoretical lenses of innovation and knowledge. According to Hosseini et al. (2015, cited-in:Saka & Chan, 2020) it is important using theories to conceptualize innovation studies to benefit from the robust knowledge on which the theories were built. The three theories mainly describe the following conditions: Diffusion of innovation describes the innovation attributes, Theory of Planned behavior describes the internal conditions and the Institutional Theory seeks to explain the external impacts. The conceptualization is inspired by the work of Saka & Chan (2020). All three theories contribute with both barriers and driving-forces as shown in the framework below.



Diffusion of Innovation	**Theory of Planned Behavior**	**Institutional Theory**
Complexity: **-Interoperability** **-Complexity of technology**	***Negative attitudes towards the behavior*:** **-Cultural Resistance** **-ROI**	***Coercive*:** **-Lack of government mandate** **-Lack of client demand**
***Compatability*:** **-Lack of standarized processes and standards** **-Legal Barriers**	***Perceived Behavioral Control*:** **-Complexity of technology** **-Cost of training and software** **-Lack of Skills and Expertise** **-Time**	***Normative*:** **-Lack of BIM standards** **-Appropriate contracts**
Relative advantage: **-ROI** **-Project are to small to use BIM**	***Subjective Norm*:** **-Cultural Resistance**	***Mimetic*:** **-Risk averse sector**



Diffusion of Innovation	Theory of Planned Behavior	Institutional Theory
Complexity: -Supported training decreases perceived complexity	**Positive Attitudes towards the behavior:** -Competitive advantage -Follow the technical development -Perceived benefits of use -Economic benefits	**Coercive:** -Mandatory legislation -Client demand
Relative advantage: -Competetive advantage -Economic benefits -Follow the technical development -Innovation attributes	**Perceived Behavioral Control:** -Governemnt support increasing skills. -Nudges or subsidies -Supported Training	**Normative:** -Industry initiatives -Government support -Push within the organization to take new BIM steps
Trialability: -Participate in pilot projects	**Subjective norm:** -Pressure by peer organizatoin	**Mimetic:** -Peer education -Pressure by peer organizations

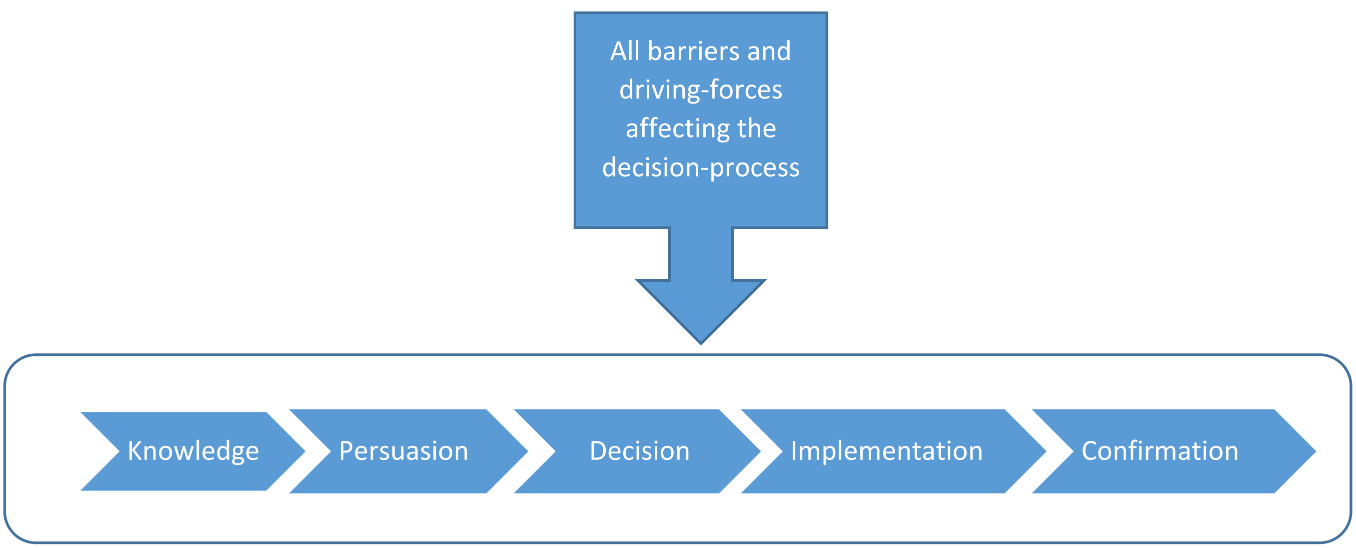


Figure 51 Conceptualizing barriers and driving forces of BIM adoption and implementation

The culture in the AEC industry:

From both the literature and survey it is stated that the cultural resistance towards change is one of the largest barriers both for SMEs and larger organizations, Saka & Chan (2021) revealed that the constraint was perceieved higher among the SMEs. The cultural resistance plays an integral role in the people/organization category in Nepals framework. People/organization was also the most prominent category hindering BIM enabled projects according to the data both from the survey and the literature. The cultural resistance is applicabale both in the Institutional Theory and the Theory of Planned Behavior. Where it is influencing the internal organization, contributing negatively towards both attitude towards behavior and the subjective norm. The attitudes towards behavior is especially important due to the fact that this factor often in itself can have great impact on the final decision making. A better word than "cultural resistance" might be defining the AEC indsutry as "satisfied with status quo". This satisfaction might lead to a symbiosis where all the stakeholders are relatively pleased and comfortable with how things are going at the moment and choose to spend less time and effort on innvotions and development.

Cultural resistance can easily be described as lack of motivation, this can lead to the fact that implementation and development of BIM in organizations can be stopped already at the "knowledge" stage where individuals expose themselves to new ideas. According to Rogers (2003) individuals seldom expose themselves to messages about an innovation unless they first feel a need for the innovation, which people seldom do when they are "satisfied with status quo". This may be a contributing factor to companies not even wanting to explore the possibilities which lies within a higher utilization of BIM. The change of behavior and attitude could in many cases be the most time consuming making it reasonable that this specific barrier is the most perceived barrier for all companies in the AEC industry independent of size.

Coercive pressure

It is easy to argue that a BIM mandate is the solution to close the digital divide in the AEC industry by creating coercive pressure towards all players in the industry. In the UK, BIM Level 2 has been required for all cetral-procured governments projects since 2016, while there has been requirements from governmental clients in Norway for several years. In the case of the UK mandate it could be argued that this mandate is only applicabale to a few selected companies and has led to an unwanted digital divide between the SMEs and the larger companies which are often involved in the larger governmental projects. This has led to a divide where some organizations choose to continue with their same processes and wait until a demand also applies for them before they make any changes. This seems to be the case also in Norway where there is a significant difference between the large projects and the rest. This might be due to the fact that there is no client demand and by this reason BIM is not chosen to be fully exploited. Underlining the importance of having BIM-aware clients to be able to push for a BIM enabled project. The companies that choose to wait until there is client demand and then close the gap to the rest of the sector might struggle, due to the fact that once you are behind, the differences are likely to increase. The statement made in Bosch-Sijtsema et al. (2017), "we wait until someone tells us to use it" could therefore be a risky strategy for many companies in the AEC industry. This should be a wake up call for those companies who are comfortable being at the lower levels of BIM maturity and being among the lower layers regarding technology adoption in general.

The goal for the BIM mandate in UK was to reduce the initial cost by 33%, 50 % reduction in overall time for inception to completion, 50 % reduction in greenhouse emission and 50 % reduction in trade gap between import and export of construction materials by 2025. Achieving this by focusing mainly on the centrally procured assets could be considered to be somewhat naiv. There is a necessity to involve the whole AEC industry, also the SMEs which account for a large proportion of the projects in UK, but also in Norway and the rest of the world. If these goals are to be achieved it is necessary to look beyond the "high class buildings" and start focusing on the whole industry. Due to the fact that the SMEs are not influenced by either the mandate or the subjective norms of the "high class" building projects. Negative consequenses from Government mandate and political decisision are said to be that the politicans often do not experience the consequenses of their actions and if the mandate is applicabale to entire classes of organizations, will lead this decisions to be less adaptive and less flexible. It can be argued that this has been the case for the UK BIM mandate, as many of the results points to the fact that the mandate have created a digital divide in the AEC industry between the SMEs and the larger companies. The policy has been mostly focusing on the material access, with the general percetion being that once all organizations have the relevant hardware and software, they will use BIM. This is a failed strategy that is reinforced in interviews where it is said that having all available software dosen't matter if the skills and processes are not there to support it. This is underlined by Kouch (2018) which points out the importance of the top managers understanding and support, which means that only using the technology without a strategic plan, might decrease the effectiveness of the adoption process and hinder the implementation.

A forceful push in alone will not lead to any increased motivation, organizations can instead lose motivation by feeling something is decided without their influence, which is confirmed in one of the interviews. Also the literature review states that moving from awareness to actual use is a huge step (Bach et al., 2013 cited in:Dainty et al., 2017), especially when the only motivation comes from coercion. To achieve the goals for the AEC industry there should be used a combination of push and pull factors to embrace all the abovementioned factors which lies within the conceptualizing of barriers and driving forces.

Differences between SMEs and large organizations regarding perceived barriers:

The survey clearly shows the differences between the SMEs and large companies regarding perceived barriers. Where 100 % of the large companies had a *wish to follow the technological development to be able to meet new requirements*. This shows that they have understood the importance of being innovative in order to meet the future in the best possible way. These organizations are not dependent on a mandate to increase their BIM Level and might only be nudged with the industry recognition and leadership roles in the industry.

When considering BIM implementation among SMEs one can not ignore the internal factors including the differences in attitude and perceived behavioral control between the SMEs and the large companies. One important aspect deciding the perceived behavioral control is the *internal expertise* in the company. The survey showed that this barrier was perceived higher among the SMEs than for the large companies.

Another aspect, which differs the SMEs and the larger companies, according to the survey results, are the *concerns regarding the ROI*. This might be because leaders for SMEs often have small economic margins, which leads them to be rather careful towards change. This is a worrying consequence given that leaders in organization have an integral role when it comes to implementing new technology in the organizations. The concern regarding ROI also affects the companies' ability to try and fail on innovations. Which reduces the trialability for the innovation, in our case BIM. Pilot projects could work as a way to decrease the uncertainty about the consequences of innovations, to be able to try the new idea on a partial basis. Most innovations are not adopted without first trying it on a probationary basis to determine its usefulness in their own situation. Whether the conditions are present for SMEs to participate in pilot projects to reduce the risk is rather uncertain, both due to their own reluctance or their lack of availability for pilot projects. Reducing risk is considered to be especially important for the laggards as they have to be certain that the innovations doesn’t bring any negative consequences.

9 Conclusion

This study looked into BIM implementation and adoption in the AEC industry by the use of a literature review, online survey and interviews. This made it possible to map the barriers, driving forces and general use of BIM in different organizations. In the conclusion, each of the three-research questions are answered by summarizing the key findings for each topic. Finally, proposals for further work are presented.

BIM utilization in the Norwegian AEC industry:

When considering the *utilization of specific BIM features and the level of use* in the Norwegian AEC industry, it was shown that 78 % of the participants used some form of BIM in their projects, while 17 % and 5 % respectively answered sometimes or no. This shows that some forms of BIM is implemented in a large proportion of the organizations. 3D modelling in the design phase (80%), clash detection (80%) and quantity takeoffs (70%) stands out as the most common used BIM features. While, 4D (33%), 5D (15%), 6D (5%) and 7D (30%) is less exploited in current projects, although many point to the fact that implementing 4D will have great potential benefits for contractors. Many of the less exploited BIM features are linked to the contractors and clients. This reveals that these professions miss out on many of the benefits these BIM features will provide to their professions. Areas of use that help to improve and structure information management are also currently less exploited, this is evident from the rather modest use of CDE (38%) and OpenBIM (33%).

In terms of company size, there was a large degree of varying use among both small, medium and large organizations. Nevertheless, there was seen a significant increase in BIM-utilization with increased project size. This especially applies for the use of 4D, paperless construction site and MMI, which are implemented to a great extent in the vast majority of projects above 200 MNOK compared to the smaller projects. 4D is implemented in 78 % of the projects above 200 MNOK, compared to just 20 % in the remaining projects below 200 MNOK. Implementation of paperless construction site is 89 % for projects above 200 MNOK compared to 30% for the remaining projects. While the implementation of MMI is 78 % for projects above 200 MNOK, compared to only 10 % for the remaining projects.

BIM maturity-levels in the Norwegian AEC:

Assessing the *BIM Levels* in the Norwegian AEC industry is a difficult task, due to the fact that BIM levels are based on the British PAS 1192 and are not as well established in Norway as in the UK. Despite this fact, only 5 % of the respondents answered “not sure” on the survey question regarding their companies’ BIM level. The results showed that among the companies that were aware of their BIM level, the majority of organizations completed their projects at either Level 1 (49%) or Level 2 (46 %), while the remaining 5 % were conducting their projects at Level 3. Despite the uncertainties of the definitions, there are reasons to believe that there are great potential benefits for many organizations by increasing their BIM level. Based on the common understanding that the BIM level should be at least level 2 in order to gain the potential benefits from implementing BIM. It was revealed a strong correlation between BIM maturity level and number of employees, where 84 % of the large organizations conducted their projects at minimum Level 2, compared to only 42 and 47 % respectively for the small and medium organizations.

When assessing BIM maturity level according to companies with BIM-coordinator a strong correlation were revealed. More than 70 % of the organizations with an employed BIM-coordinator were conducting their projects at minimum maturity level 2. As opposed to just 20 % for the organizations without a BIM-coordinator. This clearly shows the importance of having internal competence in the organization to facilitate for BIM enabled projects.

Barriers and driving forces:

The *barriers* that rank highest vary to some degree in the literature. However, there are recurring factors that are included in most of the data obtained for the thesis. The recurring barriers in both literature, surveys and interviews are cultural resistance towards change, lack of client demand, lack of expertise, cost of training, cost of software and lack of time. All these barriers have a negative impact on the perceived behavioral control and the attitudes towards change, except the lack of client demand, which could be referred to as lack of coercive pressure. The lack of client demand is highly rated both in the survey and the literature. The lack of client demand hinders the development of BIM. This underlines the clients' central role in facilitating BIM enabled projects, confirmed by one of the participants in the survey:

> *"The client needs to be the one who sets the requirements and needs to see the benefits of using it. In regard of better quality, less waste and to track the progress in the project according to the contract, and not only look at the short-term cost."*

Differences regarding company size and perceived barriers are significant based on the results from the survey. Lack of time, concerns regarding ROI and lack of expertise proves to be significant barriers for the SMEs compared to the larger organizations, in particular the organizations with less than 40 employees perceived these barriers to a greater extent than the remaining organizations. There was expected to be no clear difference between the small, medium and large organizations regarding their perceived barriers. However, there seems to be a ledge at 40 employees, where many barriers are perceived higher for the organizations with less than approximately 40 employees.

One barrier, which was perceived to be of small relevance in both the literature and the survey, was "the project is too small". Despite the fact that BIM is perceived to be suitable for all types of projects, independent of size, it was revealed that BIM is exploited to a much greater extent in larger projects. This may indicate that there are other reasons, beyond the actual utility value of BIM, behind the fact that BIM is not utilized in the same way in smaller projects.

The most prominent factor in Nepal. et al (2014) framework was clearly the People/organization, where a large proportion of the constraints can be placed within the people/organization. This confirms the saying by Deutsch (2011) who states that BIM is 10 % technology and 90 % sociology.

Considering the *driving forces* behind the adoption and implementation of BIM, several factors behind companies' motivation for implementing and further adoption of BIM were pointed at. The innovation attributes were highlighted as motivations for both SMEs and the larger companies. The innovation attributes recurring in both the literature and survey were: improved project collaboration, better understanding of the project for all stakeholders and improved project information management, all leading up to cost- and timesaving's. Despite this the literature underlined that the innovation attributes alone might not be sufficient for further adoption for SMEs and that there was still a need for external factors such as mandate or peer pressure for further motivation or coercion to adopt. The survey results revealed that there was a much larger proportion of the largest companies, which had a "desire to follow the technological development to be able to meet new requirements" compared to the smallest companies. All of the 13 largest companies (all above 40 employees) stated this as driving force for BIM implementation and further adoption. This shows that the larger companies need to be more innovative in order to meet new mandates and requirements. These mandates and requirements might not apply to the SMEs, due to clients not setting any BIM requirements for the project. This makes the innovation attributes their main driving force, which according to the literature could be insufficient for further adoption. This is also supported by Pengfei et al. (2019) saying that increased efficiency is not enough to change business behavior.

Could Norwegian SMEs be considered as laggard regarding BIM adoption and implementation?

Categorizing SMEs as *laggards* based on size only is a challenging task, which was expected not to give a fully consistent answer. With respect to Rogers's technology adoption model, survey results showed that in the Norwegian AEC industry, the size of an organization does not necessarily make it a laggard based on time of adoption. Small architectural firms turned out to be among the innovators based on time of adoption. This was expected due to the fact that 3D modelling has been a standard in the industry for many years. However, the data showed that all companies that haven't implemented BIM on a permanent basis are ones with less than 35 employees, placing them all in the SMEs category. This shows that although not all SMEs are laggards, all laggards are SMEs. Rogers and the Diffusion of Innovation suggest that plotting an innovation with respect to time of adoption will show a bell-shaped normal curve. This statement is also valid for the BIM adoption as seen in Figure 30 Shows the year of Implementation for the different professions

When assessing the BIM maturity levels there was shown to be large variations related to the size of the organization. However, when analyzing the results closer there was found a distinction between the large firms and the SMEs. Where the large companies conduct 84 % of their projects at either level 2 or 3. This was a large contrast to the small- and medium sized organizations, where this was the case in 42 and 47 % of the cases, respectively. Based on this, there is evidence to define Norwegian SMEs as laggards based on their BIM maturity level.

It was considered important to assess the specific use of different BIM features, due to the fact that BIM maturity levels are a British definition that are not as well implemented in the Norwegian AEC industry. Also, because the BIM levels are mainly related to the information management in projects. There are no clear differences between SMEs and the larger organizations regarding use of specific BIM features. However, the BIM features connected to the clients and contractors seems to be utilized to a very small extent. This includes the use of 4-, 5-, 6-, and 7D BIM, paperless construction site and MMI. Based on this, it would be appropriate to define these two professions as laggards regarding utilization of specific BIM features.

9.1 Recommendations for Future work

Regarding recommendations for further work, there are several elements, which can support both categorization of BIM Levels/Stages and support the adoption and implementation of BIM. The data in this thesis points to the fact that there is a need for a common definition and understanding of BIM Levels/Stages, especially outside of the UK. The definition of BIM Levels/Stages should be based on clear requirements which are easy to measure e.g. by the use of standards. Having a common understanding regarding this topic could have positive consequences for the AEC industry where it will help to point out the right direction when an organization aims to increase their BIM level. This is considered important for an industry that today holds many different perceptions of both BIM and BIM Levels/Stages. The ISO

19650 could be a useful framework for forming a common understanding of how a BIM project can be arranged and carried out to accommodate the requirements for a specific level or stage. This could work as a way to standardize the process, especially for the SMEs which do not have the ability to develop their own strategy, due to different constraints, such as time and lack of skills.

In terms of barriers and driving forces, it seems that there is a need of quantitative data from case specific studies. A large part of today's literature is based on generic studies, which are often built on perceived barriers and driving forces. This case specific approach might help to reduce uncertainties, making it easier for organizations to make decisions based on empirical data rather than perceptions and assumptions. Much of the existing literature also does not differ between the architects, engineers, contractors or clients. In spite of widely different tasks, usage and characteristics regarding BIM. A solution could be moving from a generic approach to a more specific approach considering both different professions and different sizes of companies. This will be necessary to be able to embrace all the different peculiarities and interests that exist in the AEC industry.

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Appendix A: Interview guide (org)

Interview guide: Original

Steinar Strømnes

Subject: Master's Thesis spring 2022

Mapping of the use of Building Information Modeling

Introductory question:

1. What is your role in the company?
2. How many years have you worked in the AEC industry?
3. How many employees are there in your company?
4. In which regions are you conducting your projects?
5. Average total project cost last 5 years?

Mapping of BIM use in their internal organization:

1. Does your company use BIM in projects (If yes, when and why was it adopted)? Is the use varying from project to project?
2. What kind of BIM tools are you using in your projects? Clash detection, 4D, 5D, CDE etc.
3. Is there a champion of innovation within your company, seeking to develop the use of BIM within your internal organization?
4. What is your driving forces for adopting and implementing BIM? Economic motives, better scheduling, follow the technological development. Did the positive consequences come directly.
5. What is perceived as the greatest barriers when using BIM in your projects?
6. Who sets the requirements in the project regarding use of BIM?
7. Are there any differences related to procurement route? IPD.

General perception of BIM use in the AEC industry:

1. Do you perceive small firms as less open for innovations regarding new technology? Do they want to continue with their traditional methods? Due to uncertainties regarding cost of software, complex technology, cost of training. Do perceive BIM to be less applicable for smaller projects.
2. Are differences in BIM use only based on project-size or is it regional differences? Are the central regions further ahead regarding BIM use? What might be the reason for this?
3. What is hindering the use of BIM in the AEC industry? Cost, cultural resistance, technological barriers, lack of client demand, ROI, Contractual challenges, lack of standards, lack of time. What can be done to remove these barriers?
4. What should be done to make all organizations join in on BIM adoption and further implementation.

5. Is it desirable that all projects are being conducted at a high BIM level?
6. How do you see the future for AEC industry regarding technology adoption?

Contractual issues

1. Is there requirements regarding BIM in the contracts? Is BIM used without requirements from the client.

2. How do you perceive the clients BIM awareness?

Appendix B: Interview guide (rev)

Interview guide: Rev

Steinar Strømnes

Subject: Master's Thesis spring 2022

Mapping of the use of Building Information Modeling

Introductory question:

1. What is your role in the company?
2. How many years have you worked in the AEC industry?
3. How many employees are there in your company?
4. In which regions are you conducting your projects?
5. Average total project cost last 5 years?
6. What do you mean by the expression "BIM project"?

Mapping of BIM use in their internal organization:

1. Does your company use BIM in projects (If yes, when and why was it adopted)? Is the use varying from project to project?
2. What kind of BIM tools are you using in your projects? Clash detection, 4D, 5D, CDE etc.
3. Is there a champion of innovation within your company, seeking to develop the use of BIM within your internal organization?
4. What is your driving forces for adopting and implementing BIM? Economic motives, better scheduling, follow the technological development. Did the positive consequences come directly?
5. What is perceived as the greatest barriers when using BIM in your projects?
6. Who sets the requirements in the project regarding use of BIM?
7. Does the supplier chain have a role in the implementation of BIM? How do you perceive the supplier chains competence.
8. Is there support in your internal organization if there is a wish to change traditional processes?

General perception of BIM use in the AEC industry:

1. Do you perceive small firms as less open for innovations regarding new technology? Do they want to continue with their traditional methods? Due to uncertainties regarding cost of software, complex technology, cost of training. Do perceive BIM to be less applicable for smaller projects.
2. Are differences in BIM use only based on project-size or is it regional differences? Are the central regions further ahead regarding BIM use? What might be the reason for this?

3. What is hindering the use of BIM in the AEC industry? Cost, cultural resistance, technological barriers, lack of client demand, ROI, Contractual challenges, lack of standards, lack of time. What can be done to remove these barriers?

4. What should be done to make all organizations join in on BIM adoption and further implementation? Is there a 'digital divide'?

5. Is it desirable that all projects are being conducted at a high BIM level?

6. How do you see the future for AEC industry regarding technology adoption?

Contractual issues

1. Is there requirements regarding BIM in the contracts? Is BIM used without requirements from the client.

2. How do you perceive the clients BIM awareness?

Appendix C: Web Survey

Use of BIM in the AEC industry

Do you want to participate in the survey?

This is a question about participating in a research project where the purpose is to map the use of Building Information Modeling (BIM) in the AEC industry. This text provides information on what participation will mean for you. This is a master's thesis performed by me (Steinar Strømnes) who is on the last semester of the master's program Structural Engineering and Building Technology (Master of Science in Engineering). OsloMet is responsible for the project. If you choose to participate, it involves filling out a survey. It will take approximately 10 minutes. Your answers from the survey will be registered electronically and will be anonymously. UiO's 'Nettskjema' has been used to make the survey, and the answers will not be connected to you personally. If you choose to participate, you can withdraw your consent at any time without giving any reason. The information will be processed based on your consent. On behalf of OsloMet, NSD- Norwegian Center for Research Data AS has assessed that the processing of personal data in this project is in accordance with the privacy regulations.

○ Yes

○ No

First part of the survey will contain questions about your organizations use of BIM.

1. What type of company are you working in?

Client, consultant, contractor, architect etc.

Company name shall not be specified.

2. What is your role in the company?

Project-engineer, project manager, BIM coordinator etc.

3. How many years have you been working in the AEC industry?

4. How many employees is it in your company?

Want the number from your organization, if you are working within a national or global organization.

5. Is your organization a part of national or global company?

Yes

No

6. How many employees is it in your national or global organization?

This is only answered if «Yes» is chosen in question 5.

7. In which regions do you conduct most of your projects? (Innlandet, Oslo, national, etc)

8. What is the average size on your projects the last five years? Total project cost.

Less than 10 MNOK

10-30 MNOK

31-50 MNOK

51-100 MNOK

101-200 MNOK

More than 200 MNOK

9. Is your organization using BIM when conducting their projects?

Yes

No

Sometimes

10. When did your company starting to use BIM? (Year)

This answer is only answered if ‘yes’ or ‘sometimes’ are answered on question 9.

11. Is your company planning to use BIM?

This question is only answered if ‘No’ is answered on question 9

- Yes
- No

12. What does it take for your company to use BIM?

This question is only answered if ‘No’ is answered on question 11

13. When are you planning to use BIM?

This question is only answered if ‘Yes’ is answered on question 11

14. What is the reason behind your wish of adopting BIM?

This question is only answered if ‘Yes’ is answered on question 11

- Better collaboration between all stakeholder
- Client Demand
- Better productivity

☐ Competetive advantage

☐ Wish to follow the technological development, being able to comply with new requirements

☐ Other

15. Other reasons why you want to adopt BIM?

This is only shown if ‘other’ is answered on question 14

16. What is the reason for your company to not use BIM in their projects?

This question is only answered if ‘No’ is answered on question 9

☐ Lack of internal expertise

☐ Our projects are too small

☐ Cost of software

☐ Uncertanties concerning return on investments

☐ Lack of client demands

☐ Cost of training staff

☐ Have not had the opportunity to participate in a project were BIM has been used.

☐ Technological barriers related to the use of new technology

☐ Cultural resistance in the AEC industry

☐ Lack of time to increase the expertise

☐ Contractual challenges, related to responsibilities

☐ Other

17. Other reasons for your company to not use BIM?

This is only shown if ‘other’ is answered in question 16

18. Does your company have their own BIM coordinator?

This question is only shown if ‘sometimes’ or ‘yes’ is chosen in question 9.

○ Yes

○ No

○ Not sure

19. Is there one or more persons in your company, which is interested in BIM, and striving to develop BIM use and increase the competence.

- [ ] Yes
- [ ] No
- [ ] Not sure

20. In what way are you normally using BIM in your projects?

This question is only shown if 'sometimes' or 'Yes' is answered in question 9.

Multiple choice.

- [ ] 3D modeling in the design phase
- [ ] Clash detection
- [ ] 4D scheduling
- [ ] OpenBIM
- [ ] 5D Cost
- [ ] Quantity estimations
- [ ] 6D sustainability
- [ ] 7D (FDV)

☐ CDE

☐ Paperless construction site

☐ Digital Twin using IoT/sensor etc

☐ Other

21. In what other ways is your company exploiting BIM?

This question is only shown if ‘other’ is answered in question 20.

22. Is your company using MMI when conducting their projects?

This question is only shown if ‘Sometimes’ or ‘Yes’ is answered in question 9.

☐ Yes

☐ No

☐ Sometimes

☐ Not sure

23. At what BIM level is your company conducting their projects?

Level 0. AD – 2D DAK, where information is exchanged through the use of e-mail.

Level 1. 2D and 3D – structured DAK in 2D or 3D with the use of project hotel, which gives a «common data environment» where standard are used for structuring of information. File based collaboration. Closed BIM.

Level 2 BIM – structured use of 3D for all staheholders, with specific BIM tools were the objects contains parametric data. Federated model. 3D collaboration models through CDE, file based collaboration. 5D and 4D BIM related to cost and schedueling. OpenBIM.

Level 3 Integrated BIM Hub. iBIM and lifecycle management– including 4D, 5D, 6D and 7D

Level 0

Level 1

Level 2

Level 3

Not sure

24. What is the reason for your company to use BIM in your projects?

This question is only shown if 'Sometimes' or 'Yes' is answered on question 9.

Multiple choice.

Financial gain

Client demand

Wish to follow the technological development, being able to comply with upcoming requirements.

Better scheduling and time savings

☐ Better collaboration between all stakeholders

☐ Reduce conflict between all stakeholder

☐ Better understanding for all stakeholders in the project

☐ Better data management and data exchange

☐ Other

25. What other driving forces lies behind your companies choice of using BIM?

This question is only shown if 'other' is answered on question 24.

26. What measures could be taken for your company to being able to increase their BIM level? (If desirable)

27. Who or what sets the requirements for BIM in your projects? Possibly decides that it should not be used.

Client, contractor, contract etc. (Profession, not person)

28. What is being perceived as the largest barriers regarding BIM implementation in your projects?

Multiple choice.

This question is only shown if ‘sometimes’ or ‘Yes’ is answered on question 9.

☐ Cost of trainig and software

☐ Cultural resistance in the AEC industry.

☐ Expertise (keeping up-to-date on software)

☐ Technological barriers related to use of new technology.

☐ Lack of client demand

☐ Contractual challenges related to responsibilities

☐ Lack of time to increase the internal expertise

☐ Lack of standardized process

☐ Uncertanties regarding retur on investment

☐ Other

29. Other perceived barriers regarding BIM implementation

This question is only shown if ‘other’ is answered in question 28.

The second part of the survey, contains general questions about the use of BIM concerning the AEC industry in general.

30. To what extent do you perceive that BIM is used in small and medium projects (below 50 MNOK)?

1 is no use, in other words 2 D DAK and information management through the use of e-mail.

10, conducted at BIM level 3, with the use of 3D-7D, integrated BIM Hub

1
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Value

31. Do you perceive that the BIM technology is better suited for larger projects? Above 50 MNOK.

1-Totally disagree

10-Totally agree

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Value

32. In what way are BIM not suited for smaller projects?

Is only answered if you feel this is the case.

33. Which measures could be done to increase the use of BIM in smaller projects?

34. Do you consider Integrated Project Delivery (IPD) as a method, which could help increase the implementation and exploitation of BIM in projects.

1- Totally disagree

10- Totally agree

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10

Value

35 . Further relevant information.