University of Stavanger

Faculty of Science and Technology

MASTER'S THESIS

Study programme: Industrial Economics	Spring semester, 2019 Open
Authors: Simen Einarsen and Kevin Jørgensen	.... (signature of authors)
Programme coordinator: Suprevisor(s): Tone Bruvoll, førsteammanuensis II, University of Stavanger	
Title of master's thesis: Studying and comparing 3D technology initiatives in the construction and petroleum industries	
Credits: 30	
Keywords: Digitalization Building Information Modeling Information Sharing Interoperability Company Culture	Number of pages: 101 + supplementary material/ other: 5 Stavanger, 12/06 - 2019

Acknowledgments

This master thesis is the conclusion of a masters degree in Industrial Economics undertaken at the University of Stavanger. The thesis has a scope of 30 credit points and is undertaken in cooperation with Equinor.

We want to thank Tone Bruvoll for excellent advice and guidance throughout the semester. Also, we want to extend our sincere gratitude to Robert Skaar, who has given us valuable insights. Lastly, we want thank all our interviewees for their cooperation and beneficial knowledge of their respective industries.

With a background as engineers, this masters degree in Industrial Economics has given us a valuable economic understanding in addition to our previous technical knowledge. The insight in work processes and utilized technologies in both industries gained from writing this thesis will be helpful for our future careers.

Abstract

The rapid advancements of new technologies paired with an increasing focus on both cutting costs and reducing carbon footprints is driving the world's industries towards a digital transformation. Despite technologically advanced petroleum extraction methods, the oil & gas sector is considered by many to be among the least digitalized industries. Another sector viewed to be lagging in the digitalization era is the construction industry. The introduction of Building Information Modeling (BIM) saw this sector take its first step towards a digital transformation. Enhanced collaboration, insight, and communication has seen BIM technology become widespread and accepted throughout the industry.

The benefits of BIM are investigated and used as an inspiration to see how the oil & gas sector deploy similar technologies and processes. The objective is to compare the use of these technologies and shed light upon potential transferable cross-industry learning. In addition to explicating presently used tools and processes, this thesis answers where initiatives for the use of 3D modeling tools arise and which role company culture plays in the adoption of these technologies. The findings are based on qualitative studies, achieved through interviews with representatives from both the construction and petroleum industry. In symbiosis with a literature review, these findings represent the foundation for the conclusions drawn in this thesis.

Results reveal that the initiatives for employing 3D modeling tools differ between the two industries. However, the main driver within both sectors is enthusiastic individuals attempting to force their firm to adopt new technologies. The findings revealed a corporate culture of resisting these technologies in order to hinder potential changes in work processes. In the petroleum industry, an insufficient inter- and intra-organizational flow of quality information was identified, resulting in a lack of an inter-subjective understanding of available relevant technologies. BIM technology is used in construction as a useful communication tool both within the company and with other companies in the supply chain. Also, the IFC standard was found to have solved problems of interoperability among different applications.

It was concluded that one of the major obstacles for the embrace of technologies like 3D modeling tools, in the petroleum industry, is insufficient awareness of available technologies and how to use them. Also, learning from the implementation of BIM could prove useful for Equinor when attempting to achieve full interoperability of their 3D modeling tools. The UK is reaping benefits from its pole position in the international construction market, as a result of their BIM expertise. Within 3D technology, Equinor has a comparable position in the petroleum industry and could utilize this to achieve similar benefits.

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Glossary

AEC Architecture Engineering and Construction

CAD Computer-Aided Design

CDO Chief Digital Officer

CM@R Construction Management at Risk

CSG Constructive Solid Geometry

DB Design-Build

DBB Design-Bid-Build

FM Facility Management

GC General Contractor

IFC Industry Foundation Class

IPD Integrated Project Delivery

IQ Information Quality

IS Information Sharing

IT Information Technology

NSD Norsk Senter for Forskningsdata

SC Supply Chain

SCM Supply Chain Management

WEF World Economic Forum

1 Introduction

This introduction section will include the background for this thesis, the scope and research question, and necessary limitations. Finalizing this section is an overview of the thesis structure.

1.1 Background

The digitalization wave is presently sweeping over most industries. The oil and gas sector is by many considered to be lagging behind other comparable industries. PricewaterhouseCoopers' 2016 Chief Digital Officer (CDO) Study discovered that the oil & gas sector has the lowest percentage of companies with CDOs of the 13 industries included, with only 3% [PricewaterhouseCoopers, 2017]. A Chief Digital Officers role in the company is to drive the digital transformation across functions. This is done both strategically through constructing and introducing digital strategies, and communicationally through solving cultural struggles [Horlacher and Hess, 2016].

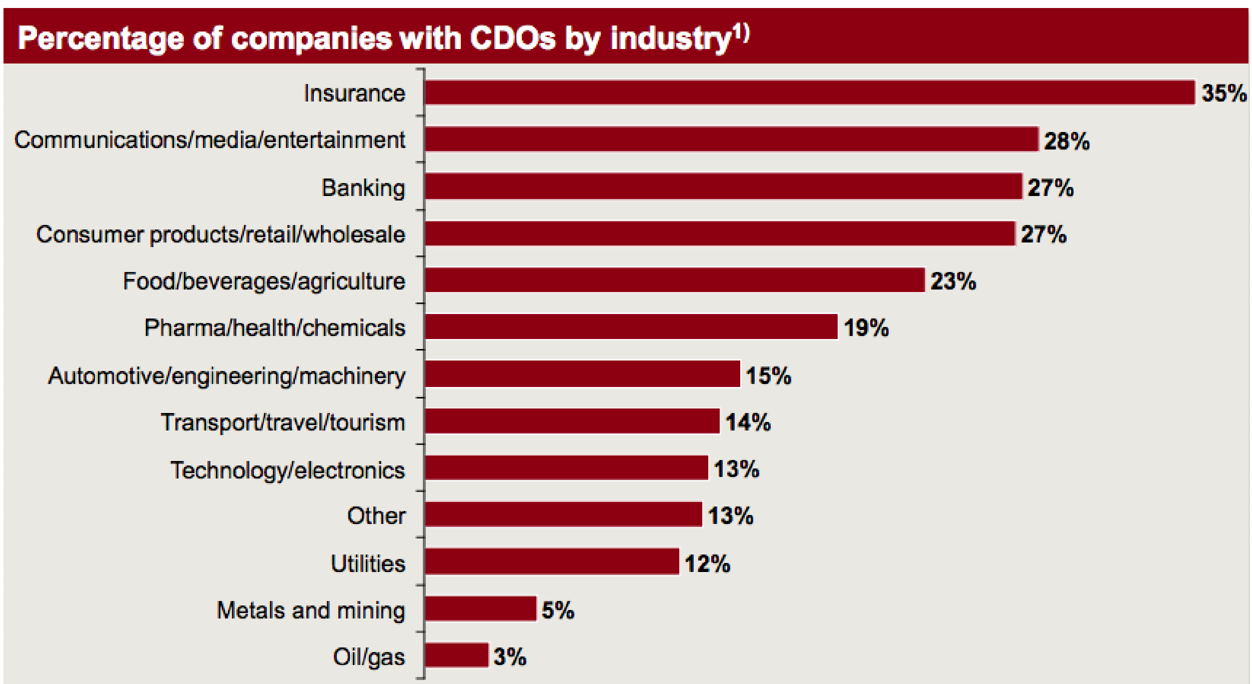

Figure 1: Percentage of companies with CDOs by industry [PricewaterhouseCoopers, 2017]

Equinor has initiated several digitalization efforts, both internally and in collaboration with suppliers. The firm has planned a 1-2 billion NOK investment in digitalization efforts by 2020, in addition to existing IT investments [Equinor, 2017]. Their recently appointed CDO, Torbjørn F. Folgerø, points out willingness for both inter- and cross-industry learning and collaboration as an important criterion for digitalization to succeed [Equinor, 2018].

Digitalization is a general term, encompassing several different areas. For the petroleum industry, widespread implementation of 3D technology is viewed as one of the first steps towards a digital transformation. The use of such technology has already become extensive in the construction industry. Therefore, this thesis will focus on the use of 3D modeling tools in both industries.

1.2 Scope and Research question

Building Information Modeling (BIM), a digitalization effort within construction, has been widely introduced and accepted. This technology gives collaborators improved insight and understanding of the project and thereby serves as a tool for making better decisions. The construction industry's introduction of BIM technology and the processes that accompany it will serve as an inspiration.

This thesis, investigates how BIM technology is used in the construction industry, and how similar technologies are employed in the oil and gas sector. The objective is to compare the use of these technologies and shed light upon potential transferable cross-industry learning.

Three main questions will be answered in this thesis:

1. Where does the initiative for 3D technology arise?
2. Which technologies and processes are presently used, and how are they used?
3. How does culture affect the use of these technologies?

1.3 Limitations

Due to the broad scope of this thesis, it is necessary to include some restrictions to make it more manageable. To make the best possible comparison between BIM and similar technologies in the petroleum industry, there will be a focus on the construction of offshore platforms as they have the most in common with a construction project.

There are many different types of firms, both in the construction and the petroleum industry. It was therefore decided to focus on the entrepreneurs in construction and Equinor in petroleum. They outsource both design and engineering in the type of projects in focus in this thesis. The entrepreneurs in construction and operators in petroleum do have different roles, which provides another limiting factor in terms of which aspects of the technologies and processes are relevant to compare.

Due to limited time, interviews with firms throughout each industry was not possible. The results are based on interviews with representatives from Equinor and representatives from entrepreneurs in the

Norwegian construction industry. These firms will be used as examples to represent their respective industries.

1.4 Thesis structure

This thesis consists of five sections. Section 2 aims to provide an overview of the research methods available and those chosen for answering the questions from section 1.2. Afterward, section 3 provides the theoretical framework for this thesis. The theory consists mainly of the industrial revolution 4.0 and the subsequent digital transformation era, Building Information Modeling, and Information Sharing. Section 4 consists of data from interviews along with discussions of the results with corresponding theory. The fifth and final section consists of the conclusions made, which are based on section 4 and the research questions of this thesis.

The thesis structure is outlined in figure 2.

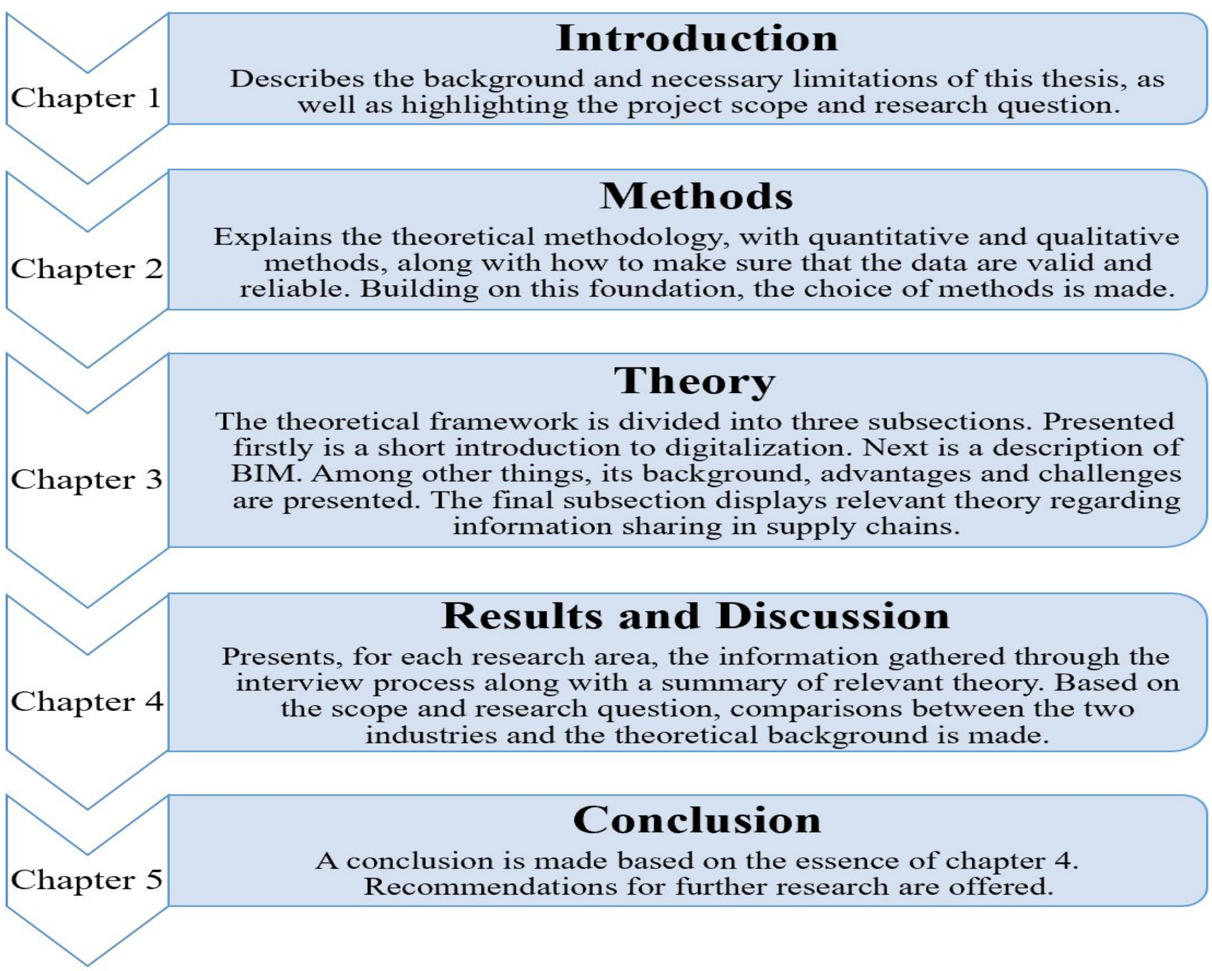

Figure 2: Thesis Structure

2 Methods

This thesis is based on a field that has a relatively large amount of data available from the construction industry, but relatively limited research in its applicability in the oil industry. It was, therefore, necessary to conduct an extensive literature review. Also, interviews were conducted with employees from both industries.

2.1 Research and Methodology

Methodology can generally be described as a guideline for solving a problem with the use of specific phases, tasks, methods, tools, and techniques [Ishak and Alias, 2005]. Buckley et al. (1976) define research methodology as *"the strategy or architectural design by which the researcher maps out an approach to problem-finding or problem-solving"* [Martin, 1976, Page 2]. They have provided a framework for research methodology, which includes six steps. The first two steps are related to problem finding while the next four steps are linked to problem-solving. An illustration of the framework is displayed in figure 3. As can be seen, the six-step framework can be summarized to five steps: problem genesis, mode, strategy, domain and techniques. Problem genesis replaces the first two steps in the six-step process [Martin, 1976]. An explanation of the five steps is provided below.

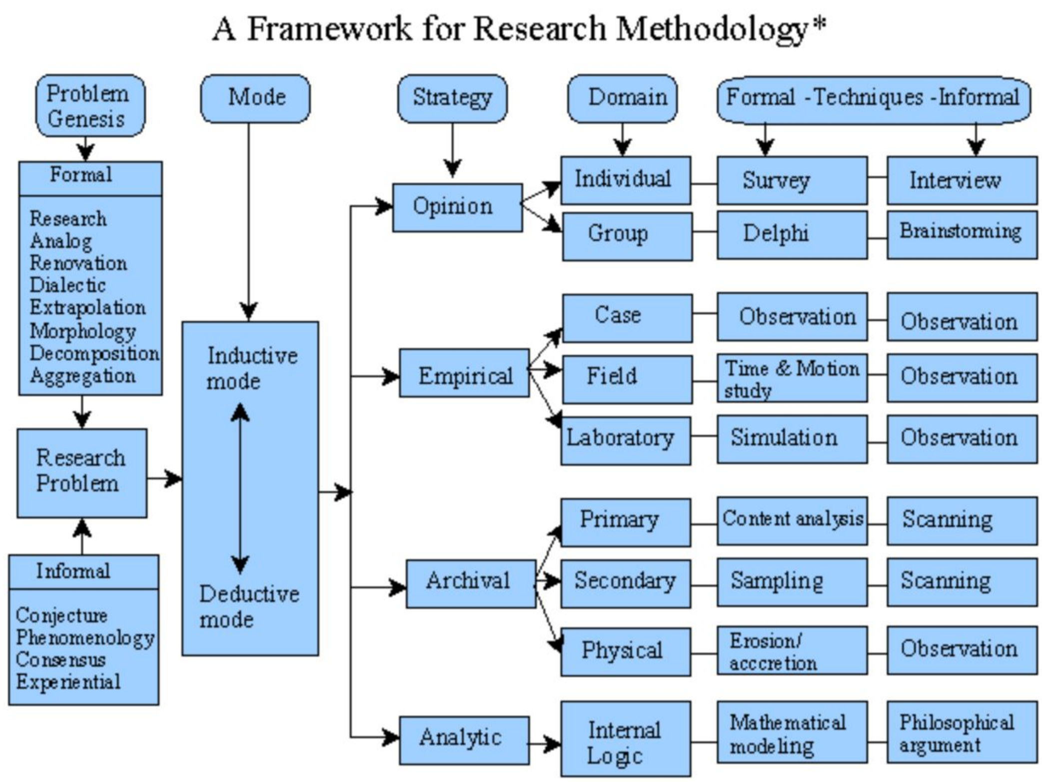

Figure 3: Framework for Research Methodology [Martin, 1976]

The first step (which includes the first two in the six-step framework) includes problem finding and research problem. Problem finding has two approaches, formal and informal. In this phase, the research problem has to be created with five criteria in mind [Martin, 1976]:

1. Properly defined
2. Capable of being solved
3. Logically connected to the situation it was drawn from so that it can be applied to this situation
4. Checked against existing literature to make sure it has not already been solved
5. Potentially significant contribution

The second step in the framework is to become familiar with what type of research mode that should be used, induction or deduction [Martin, 1976]. These two modes will be explained in further detail in the research method subsection, (2.2).

The third step relates to data generation and what classification the information gathered has. Opinion, empirical, archival and analytical are the four classifications of data that are used in Buckley et al.'s (1976) paper [Martin, 1976].

The fourth step is to know which domain the different strategies have. The fifth and final step is to be aware of which techniques for data sampling are appropriate for each of the strategies [Martin, 1976].

The following describes the different strategies with their domain and techniques [Martin, 1976]:

- Opinion is the case where views and judgments of individuals or groups are used with no direct observation of the facts. Techniques for gathering this type of information are questionnaires, opinion polls, interviews, etc.
- Empirical data is where the researcher either experiences the phenomena or is an eye-witness and observes the events. It includes case, field, and laboratory studies.
- Archival data utilizes recorded facts, where there are no direct observations. The domains of archival are: primary, such as original documents; secondary, such as journals and ledgers; and physical, such as fingerprints and footprints.
- Analytic data are based on the internal logic of the researchers themselves. This includes both inductive, from specific to general, and deductive, from general to specific, arguments.

In this thesis, an inductive mode is used where opinions will have a central role to play in the data generation along with an archival strategy. This will be achieved by using interviews and data generated from recorded facts.

All four different methods of data generation have their strengths and deficiencies. They will be explained more thoroughly in the succeeding subsections for the relevant methods, opinion, and archival.

2.1.1 Strengths in methodology

The opinion and archival methods each have their strengths. The opinion method can use large samples, is easy to use, and can be used on many different types of data analysis. The archival method is well suited for tasks such as analyzing data in documents, historical analyses, and extrapolation of trends [Martin, 1976].

2.1.2 Deficiencies in methodology

As stated, the main methods used in this paper are opinion and archival. Therefore, it is crucial to be aware of the deficiencies of these methods.

Opinions should not be mistaken for facts; they are perceptions that can be different from reality. When using an opinion-based method, being aware of possible bias is vital. These opinions may also change over time. In addition, it can be difficult to gather and analyze the collective opinion of a group [Martin, 1976].

The archival method can be subject to a selective deposition, which means that only some things are recorded. The same goes for selective survival, where there is a possibility for data to be lost with time, or remain unpublished. There might also be biases of researchers, or skill deficiencies. One should, therefore, demonstrate the ability of critical thinking when choosing which sources to trust [Martin, 1976].

2.2 Modes

Induction and deduction are referred to as strategies by Jacobsen (2005) and modes by Buckley et al. (1976). To avoid confusion with the strategies in Buckley et al.'s (1976) framework, they will hereby be referred to as modes.

A method is a way to collect empiricism or data from the real world. The method will indicate which course of procedure that should be used to get the best representation of the real world. The identification of whether the best course of action is to use a deductive or an inductive mode forms the basis for deciding which procedure to use [Jacobsen, 2005].

The deductive mode introduces a set of assumptions or expectations about the real world, before data is collected, and proceeds to see if these presumptions are correct. It is the process of testing a theory or testing a hypothesis against a theory [Jacobsen, 2005]. The deduction mode includes questions of the type: will questions, such as will that work?; is questions, such as is that a good idea?; if questions, such as what will happen if we do that?; etc [Martin, 1976]. This mode is also referred to as ”from theory to empiri.” The assumptions are based on existing empirical data and theories. One of the critiques of this mode is that it can cause the researcher only to include data that fit the assumptions. This can cause negligence of important data, which in turn will skew the research [Jacobsen, 2005].

The inductive mode is opposite to the deductive and is referred to as ”from empiri to theory” [Jacobsen, 2005]. It is a process for generating theory, from specific facts to generalizations. The induction mode includes questions asked to search for the truth, such as which, why and who, and avoids subjective theories or opinions [Martin, 1976]. The researcher tries to collect data with no pre-existing assumptions. The data are then systematized, and theories are then generated based on these data. With this mode, the goal is to include all data, with no restriction on the collection process. The critiques against this strategy is that it is highly unlikely that the researcher will be able to conduct data sampling with a fully open mindset, with no pre-existing assumptions. Likewise, it is close to impossible to collect all data available, and defining some restrictions for the parameters of data sampling is usually required [Jacobsen, 2005].

2.3 Research Methods

In the literature, two distinct types of data are mentioned, qualitative and quantitative. Roughly defined, numerical forms of data are quantitative, while qualitative is non-numerical [McLeod, 2017]. Respectively, ”that person is smart” and ”that person has an IQ of 140” is a qualitative and quantitative description of a person’s intelligence.

Both the inductive and deductive modes have their pros and cons, and it is favorable to use something somewhere in-between. The modes vary in terms of how restrictive the guidelines for data sampling are. The knowledge of how restrictive one should be in the data collection process is the basis of whether a quantitative or qualitative method is to be preferred [Jacobsen, 2005].

2.3.1 Quantitative methods

In a quantitative method, the questions that need to be answered are:

- How will the information be collected?
- How to choose respondents?
- How should the data be analyzed?

- How valid are the findings and conclusions?

The quantitative research approach is an objective and formal approach that uses a systematic process where numerical data are used. This data is used to quantify or measure phenomena in order to produce conclusions [Carr, 1994]. All observations are qualitative in the beginning. Some can be converted to quantitative data afterward [Babbie, 2013].

The quantitative method is most appropriate when there is existing knowledge about the subject and a clearly defined hypothesis or problem to solve, ensuring that the relevant questions are asked [Jacobsen, 2005].

There are many advantages to the use of quantitative methods:

- Data can be represented by using statistical techniques, which in turn makes it appear to be based on objective laws [Denscombe, 2014].
- Due to the nature of quantitative research, the investigator maintains an objective view which avoids involvement from the researcher and guards against biased results [Carr, 1994].
- The data gives a solid foundation for descriptions and analyses, and interpretations are based on quantities rather than impressions. It is also relatively easy and time-efficient to analyze a large volume of quantitative data [Denscombe, 2014].
- The obtained data can usually be replicated and checked by others, resulting in lessened ambiguity [Carr, 1994].

With these advantages in mind, it is also important to be aware of the disadvantages of quantitative methods:

- The quality of data is only as good as the methods used, and questions asked [Denscombe, 2014].
- Researchers may become too focused on the techniques of the analysis rather than the underlying research [Denscombe, 2014].
- Although a large amount of data can strengthen the analysis and is considered to improve credibility, it can also be one of its weak points. If the data volume is too extensive and complex, it could overload the researcher [Denscombe, 2014].
- Quantitative data are supposed to be objective. However, the researchers may still have an opportunity to influence the findings in their subtle way, making them less scientifically objective than what is generally assumed [Denscombe, 2014].
- Often, the participants cannot explain their choices or interpretations of the questions, which could lead to a lack of context information [Carr, 1994].

2.3.2 Qualitative methods

The qualitative research approach does not use any numerical method to conclude the findings. It has an inductive approach to develop the theory [Carr, 1994]. Qualitative approaches have to deal with interpretations, and perceptions in the process of analyzing the data gathered [Croom, 2010].

In a qualitative method, a few questions needs to be answered [Jacobsen, 2005]:

- How will the information be collected?
- How to chose respondents and interviewees?
- How should the data be analyzed?
- How valid are the findings and conclusions?

This type of method often focuses on obtaining different nuances and going more in-depth on a limited amount of subjects [Jacobsen, 2005].

Advantages of qualitative research include its depth of understanding as a result of how involved the researcher is in the data collection. It allows for rich and detailed data, where intricacies of the situations can be better dealt with than with a quantitative method [Denscombe, 2014].

Qualitative analyses better capture ambiguity and contradictions that might be present in the data. It also allows for alternative explanations as it is dependent on the interpretive skills of the researcher, which will vary from one person to another [Denscombe, 2014].

As with the quantitative methods, qualitative also have its disadvantages.

- The data from qualitative methods might be less representative as the few, but detailed instances are more difficult to generalize than well-conducted quantitative research [Denscombe, 2014].
- The researchers' background and beliefs heavily influence qualitative analyses. This can cause the findings to be more unreliable due to the researcher's effect on them. Findings are a product of the researcher, rather than a discovered fact [Denscombe, 2014].
- There is a real danger of oversimplifying the explanation. The researcher may feel some pressure to identify themes in the data, which may result in an underplay or disregard of data that does not fit the theme [Denscombe, 2014].
- The analysis can be quite time-consuming. Quantitative analyses may result in a considerable amount of data. However, there are often statistical procedures available to analyze significant amounts of

data with relatively little effort. In general, no such procedures exist for qualitative analyses. Upon collection, qualitative data are usually unstructured. Even though computer programs can be used to simplify the analyses, it usually is more time consuming than for quantitative analyses [Denscombe, 2014].

2.3.3 The open and individual interview

The open and individual interview is a data collection method that is best suited:

- When relatively few subjects are investigated.
- When the individual correspondent's answers are of interest.
- When it is of interest what the correspondents intend and read into a specific phenomenon.

An interview is often conducted in a face-to-face manner but can also be conducted over the phone or internet. A completely open interview is conducted with no pre-established interview guide. This can be rather difficult to interpret, and it is recommended to create the aforementioned interview guide. The interview guide can be of differing structure from entirely open to completely closed [Jacobsen, 2005]. This is displayed in figure 4, where the orange box represents the format that was used in this thesis.

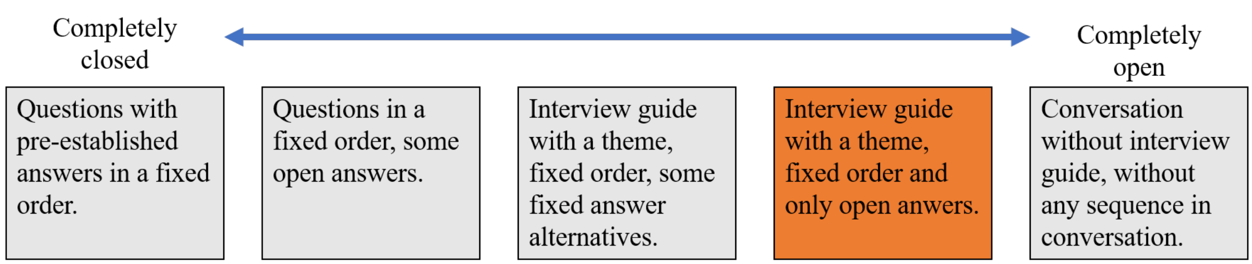

Figure 4: Degrees of interview structure (inspired by figure 8.1 [Jacobsen, 2005]).

2.3.4 Ethics of interview

In research, three ethical principles have to be upheld. These can be summarized to [Jacobsen, 2005]:

- Informed agreement: The respondent is participating voluntarily and is adequately informed about possible prizes or dangers which could occur, as a result of participation.
- The right to privacy: The respondent has the right to remain anonymous. The information acquired should not be used in a way where it is possible to identify the person who said it.
- The right for proper presentation of the data: The goal is not to lose the intent of answers obtained. Answers should not misrepresent the respondent or be taken out of context. An analysis of an interview is always a reduction of details and diversity. Therefore it is vital to understand when it is necessary to present complete data to give the reader a full understanding of the results.

There are different factors that affect whether a project should be reported to the Norsk Senter for Forskningsdata (NSD). There are no indications of who the interviewees are, and they are perfectly anonymous in this project. Therefore, it is not necessary to report it to the NSD [NSD, 2019].

2.4 Primary and secondary data

In a data collection process, there is a distinct difference between primary and secondary data [Jacobsen, 2005].

Primary data is gathered directly from the source. This can be done with the use of interviews, observations, or questionnaires. The researcher here has direct access to the source [Jacobsen, 2005].

Secondary data is when the researchers base their data collection on information that is collected by others first. Information-based on studies performed by others need to account for the fact that these studies have often been performed for a different purpose. A crucial aspect of using secondary data is to be able to critically evaluate the validity of the data source [Jacobsen, 2005].

2.5 Reliability and validity

It is crucial that the empiricism is both valid and reliable. The methods used should capture relevant data. In addition, it is imperative to ensure that the information captured by a few subjects can be extrapolated and represent the entire population. This gives the basis for using the results to identify themes [Jacobsen, 2005].

A way to improve the validity and credibility of the data and conclusions is to use triangulation. It implies that a combination of various methods verifies data and conclusions. Different researchers register and analyze the data in varied contexts. This ensures that the results are not based on the subjective opinions of the researcher, but it is an objective observation of the phenomena. A common criterion to test if the results are objective is to see whether other researchers can replicate the results.

The qualitative method is heavily criticized as it is very reliant on context. The results may differ from situation to situation, and it is close to impossible to replicate the qualitative methods completely [Jacobsen, 2005].

2.6 Choice of method

The choice of method is related to the research question, and which techniques are most suitable to analyze it. As mentioned in the opening part of this section, there has been relatively limited research when it comes to the implementation of BIM or similar concepts in the oil industry. It is necessary to use both primary and secondary data to grasp the full context of the scope.

In the process of gathering primary data, it was decided to use a qualitative method with an inductive approach. Interviews in multiple stages were conducted with representatives from both Equinor and employees in the construction industry. These interviews were open with a theme and fixed order as described in figure 4. The interviewees will, by request, remain anonymous throughout this thesis.

A broad specter of secondary data is used in this thesis. The articles used are both of a quantitative and qualitative nature and serves as the theoretical background for this thesis.

The triangulation mentioned in 2.5 was achieved by the use of a qualitative method with an inductive approach and a comprehensive literature review. The secondary data are, as mentioned, of both qualitative and quantitative nature and gives a broader specter of data for this thesis.

2.7 Literature review

As mentioned in 2.5, it is critical that the sources of data collected are reliable. Secondary data are often collected for a different purpose to what they are used for, and this can lead to difficulties in the comparisons. In this thesis, emphasis has been put on appropriate sources of the secondary data. In table 1 the most important secondary data from websites are listed with a description of why these sites are reliable.

Owner	Description
BuildingSMART www.buildingsmart.org	buildingSMART aims to make standards for workflows, processes, and procedures for BIM.
Simply Psychology www.simplypsychology.org	A psychology site which was initially designed for A-level psychology students from the UK.
National Institute of Building Sciences www.nationalbimstandard.org	NIBS serves as an interface between government and the private sector, supporting advances in building science and technology.
Norsk Senter for Forskningsdata www.nsd.no	NSD aim to improve the opportunities for empirical research through a broad offer of data and support services.
Oxford Dictionaries en.oxforddictionaries.com	Oxford Dictionaries is an English site that offers free access to the largest current English dictionary and thesaurus.
USPTO https://www.uspto.gov/	United States Patent and Trademark Office is a US federal agency issuing trademarks registrations and patents.
BIM-level2 https://bim-level2.org/	A BIM-Level 2 informational site hosted and maintained by British Standard Institution (BSI).
McKinsey www.mckinsey.com	An American management consulting firm with offices worldwide.
Equinor www.equinor.com	A multinational energy company with a primary focus on petroleum and wind energy.
Forbes www.forbes.com	An American business magazine featuring original articles on finance, industry, investing, and marketing topics.
The Norwegian Petroleum Directorate www.npd.no	NPD is a government specialist directorate and administrative body.
National Building Specification https://www.thenbs.com/	NBS provides the tools for engineering and architecture firms to work smarter, by helping them to manage their projects better.
S&P Global https://www.spglobal.com/en/	Formerly McGraw Hill, S&P Global is a New York-based firm that primarily deals with financial information and analytics.
SCM World http://www.scmworld.com	SCM World is a Gartner community and a part of their Supply Chain.

Table 1: Website descriptions

2.8 Interview

As mentioned previously, an interview is a qualitative method for gathering data and is one of the opinion-based techniques used in this thesis. It is a ubiquitous way to collect data due to its flexibility and because of the opportunity to get both broad and in-depth information. It is an appropriate form of data collection when the researcher intends for the respondents' to have a high degree of freedom to express themselves. As mentioned, an interview is an opinion-based technique, which means that the information gathered is heavily influenced by the respondents' opinions and thoughts [Johannessen et al., 2016].

Since the focus is on BIM and how it might be applicable in the oil industry, it follows that performing interviews is a suitable method. The interviews were conducted with pre-established open style questions. This allowed the respondents the opportunity to elaborate on their thoughts as well as giving them the freedom to mention everything they felt was relevant to the question. It also opened up new topics to discuss in the form of follow up questions. A combination of audio recordings, with the respondents permission, and note taking was used to keep track of what was said in the interview.

As previously mentioned, having reliable and valid data sources is a necessary requirement for the results to have any bearings. To ensure that these interviews give valid and reliable data, there was a high emphasis on the role and background of the interview objects. There were five respondents from Equinor and two from different entrepreneur firms from the construction industry. Their roles can be seen in table 2.

Petroleum	Construction
• Leader of the 3D models of oil platforms. • An employee working with historical data for the planning of all projects that are in the execution phase. • Project leader for digitalization initiative. • Leader for the fusion program and responsible for project control within digitalization. • Project manager within oil and gas projects and IT.	• Discipline leader for project management and BIM. • Leader for digitalization within the firm.

Table 2: Interviewees

2.9 Research process

The starting point of a thesis is independent on which methodology that is going to be used. First, the research scope and question is to be established, then the methods of research and methodology are determined. Lastly, the results are analyzed, and conclusions are derived.

The research process conducted in this thesis is summarized in figure 5

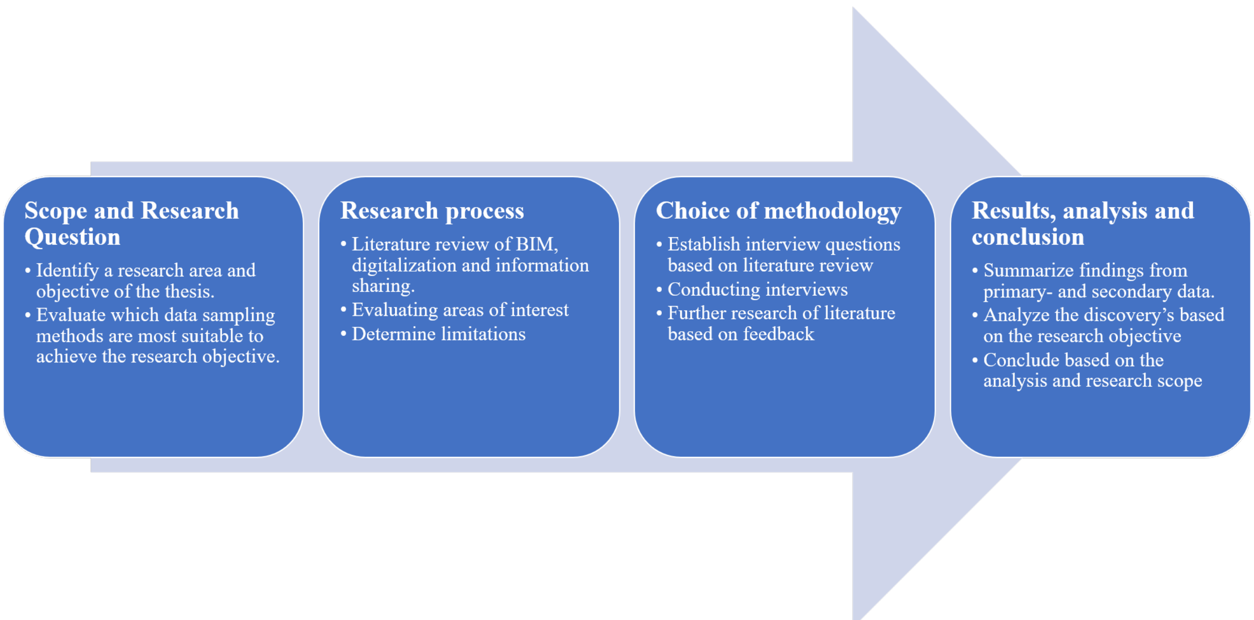

Figure 5: Research process

3 Theoretical framework

This section describes the theoretical framework for this thesis. It is divided into three subsections. Presented firstly, in subsection 3.1, is a short introduction to digitalization. Subsection 3.2 provides the main part of the theoretical background and starts with an introduction to Building Information Modeling, various definitions and historical development. Following is an explanation of different delivery methods, along with BIM dimensions and maturity stages. Concluding this subsection is a review of the advantages and challenges for the technology in conjunction with an introduction to OpenBIM. The final subsection, 3.3, displays relevant theory regarding information sharing in supply chains. This section will serve as a point of comparison for the results obtained from the interviews.

3.1 Industrial revolution 4.0

Klaus Schwab defines a revolution as an abrupt and radical change. He argues that revolutions have occurred throughout history as new technologies have emerged. There have been three distinct industrial revolutions, and a fourth one is now ongoing [Schwab, 2016]. These four revolutions are depicted in figure 6.

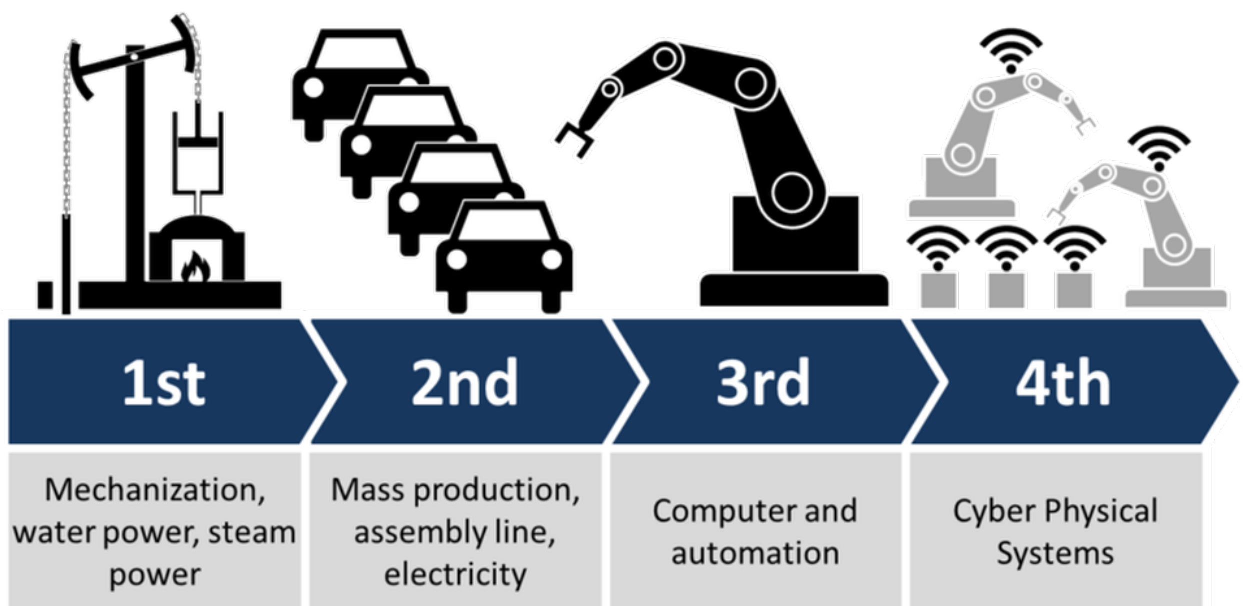

Figure 6: The 4 Industrial Revolutions [Roser, 2016]

The first revolution was between 1760 and 1840, when mechanical production was introduced and developed. Railroads were built, and steam engines became more prevalent in the production processes [Schwab, 2016].

The second industrial revolution started in the 19^{th} century and lasted until the early 20^{th} century. Mass production, defined by electrification and division of labor, was now a possibility [Marr, 2016] [Schwab, 2016].

The third industrial revolution was the digital revolution. Advanced electronics and information technology made strides in the further development of production process automation [Marr, 2018].

A fourth industrial revolution, which began at the turn of this century, is now in progress. This revolution is defined by the predicted progression in technology, in terms of digital innovation, and how it affects manufacturing. It is predicted that it will involve a combination of cyber-physical systems, the Internet of Things, and the Internet of Systems. The creation of smart factories will also be feasible, where the machines are interconnected and augmented to a point where they can visualize the production chain and make decisions without the need for human interactions [Marr, 2016]. This ongoing revolution takes the adoption of computers and automation, which was part of the third revolution, and enhances it by implementing smart and autonomous systems, which is enabled by data and machine learning [Marr, 2018].

A broad range of concepts can define Industry 4.0. Digitalization, networking, miniaturization are some of the concepts included in Industry 4.0. Research and innovation, standardization, and security of networked systems are some of the essential elements for implementing the Industry 4.0 framework.

The fourth industrial revolution is not limited to smart and connected machines and systems. The scope of this revolution is much broader and includes breakthroughs in areas such as from gene sequencing to nanotechnology, and from renewables to quantum computing. The fusion between all of these technologies along with the interactions across both the physical, digital, and biological domains are what fundamentally differentiates this fourth industrial revolution from the previous revolutions [Roser, 2016].

A remaining question is how long will it take for the revolution to be globally widespread. In 2016 17% of the world had not fully experienced the second revolution, and about 50% had not experienced the third revolution. Even the first industrial revolution took almost 120 years to take hold outside of Europe. The extent to which society is able and willing to embrace these technological innovations is, therefore, an important aspect to the progression of the fourth revolution [Roser, 2016].

3.1.1 Digital

A multitude of definitions for the word digital exists, especially when referring to digital transformation [Schallmo and Williams, 2018]. McKinsey has established a definition that considers the way companies manage their business rather than consider one specific process. Three key focal points can summarize this definition [Dörner and Edelman, 2015]:

- Developing value within the new aspects of the business world.
- Enhancing the operations that have a direct effect on the client or consumer experience.
- Create a basis of competencies and capabilities that strengthen the entire business actions.

Implementing digital technologies in itself is considered to be useless without the proper evaluation of how it can create value for the firm [Schallmo and Williams, 2018].

3.1.2 Digital transformation

A definition of digital transformation created by [Schallmo and Williams, 2018] says that it is *"a sustainable, company-level transformation via revised or newly created business operations and business models achieved through value-added digitization initiatives, ultimately resulting in improved profitability"* [Schallmo and Williams, 2018, Page 4].

Digital transformation is an essential term that all businesses and industries have to take seriously. According to Caudron and Peteghem, the development of digital transformation are described as moving in waves, as seen in figure 7 [Caudron and Van Peteghem, 2014].

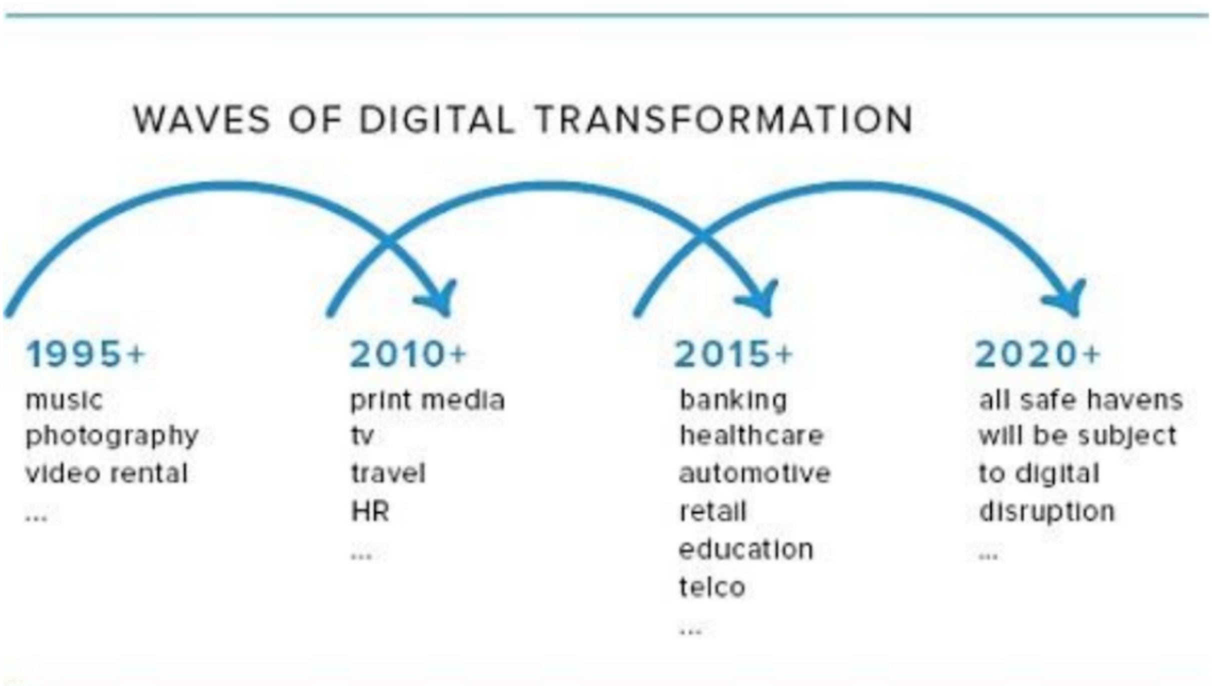

Figure 7: Digital transformation waves [Caudron and Van Peteghem, 2014]

There are plenty of examples of how disruptive the digitalization can be for industries. TV, Newsmedia, Recruitment, and Travel industries are affected by newer applications such as Netflix, LinkedIn, Uber, and

Airbnb. This is an indication of an ongoing wave of digital transformation [Caudron and Van Peteghem, 2014].

Eastman Kodak serves as an example of why it is crucial to keep up with the emerging digitalization. They were the leading photography company which revolutionized the industry for over a century. Kodak failed to prepare for the digitalization of the camera industry, even though they invented the digital camera in 1975. They knew that this invention would disrupt their photographic film business and chose to hide their invention for almost 20 years. This resulted in them going bankrupt in 2012, which is a dramatic fall from being one of the leaders in the industry [Caudron and Van Peteghem, 2014].

The Kodak example goes to show that the digitalization process moves fast, and not everyone is able to predict how it will change the industries. It shows that there is a need for innovative thinking and an ability to adapt and change rather than to stick to what has always worked. If it happened to Kodak, then it can happen to anybody else. It is vital to keep up to date with emerging technologies and prepare to change, even if it disrupts the current market. As mentioned above, there are already many industries that have been revolutionized the past 5-10 years, and who knows what new changes will happen the next 5-10 years again? [Caudron and Van Peteghem, 2014].

A survey, conducted by SCM (Supply-Chain Management) World, included 1415 respondents and their beliefs about how disruptive various technologies would be for supply chain strategies[O'Marah, 2016]. This survey is illustrated in figure 8.

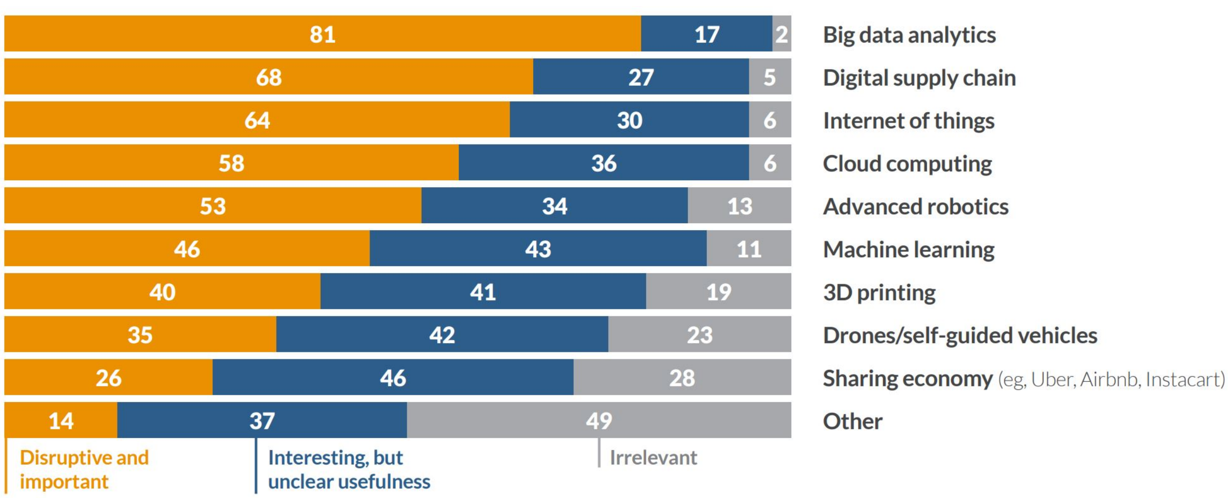

Figure 8: Beliefs of disruptive technologies [O'Marah, 2016]

3.1.3 Digitalization in oil and gas industry

According to Ståle Tungesvik, the oil industry has a lot to learn from the bank and finance industry. He envisions an opportunity for the oil industry to share data on applications where everyone can communicate and understand each other. Only then is it possible for the industry to fully take advantage of the opportunities that Big Data and artificial intelligence offers [Oljedirektoratet, 2018].

Several challenges have to be dealt with in order for the industry to take advantage of the digitalization. The competence that is required to take advantage of the opportunities has to be acquired, and they have to be able to understand which challenges that the industry needs help with [Oljedirektoratet, 2018].

3.2 Building Information Modeling

A Building Information Model (BIM) contains specifications about a project in a virtual environment. It is a simulation of the project objective containing all the relevant information needed to complete the end product. The model contains input from several stakeholders, such as owners, engineers, suppliers, architects, contractors, and subcontractors. It is an application in which everyone involved with the project can introduce, alter, or extract data. Figure 9 shows examples of an architectural (left), structural (middle), and plumbing (right) model [Azhar, 2011].

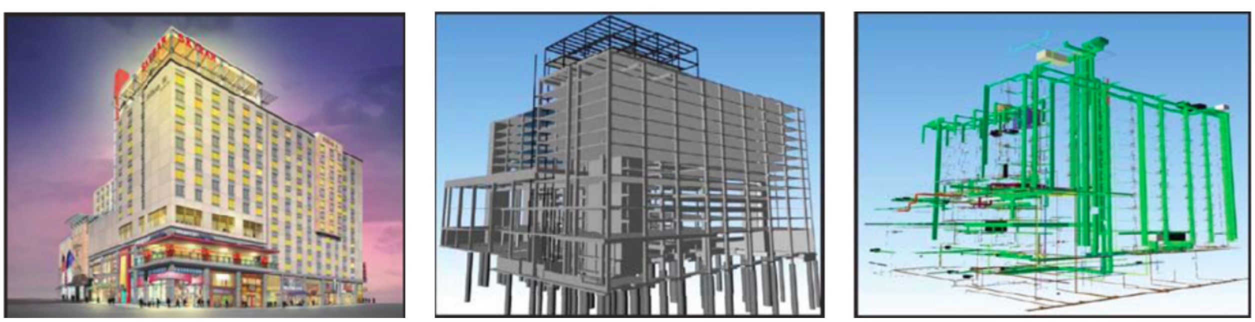

Figure 9: Different BIM models [Azhar, 2011, Page 244]

During the entire project life cycle, the model can be updated by team members. Adjustments and fine tuning by various stakeholders, in order to fully satisfy the requirements set by the owner, are instantly updated in the model. This assures that the virtual representation of the finished product is as precise as feasible before construction commences [Azhar, 2011].

By centralizing the information, in a single and complete model of the objective, BIM allows for easier cooperation and intercommunication amid stakeholders. Once the model is completed, the information incorporated in the model aids in all project phases, from design, through procurement and fabrication, to the actual completion of the physical building. Also, the model can be utilized by facility management teams after the conclusion of the construction project [Azhar, 2011].

Traditionally, the Architecture Engineering and Construction (AEC) industry has employed two- and three-dimensional drawings of sections, plans, and elevations in order to characterize and depict a building. Should one of the views be edited in any way, connected drawings could also require editing in order for the model to remain coherent. However, the necessitated changes in connected drawings do not occur automatically and must be done by hand. This requires a significant amount of effort in order to implement a potentially small change to one of the drawings in the model [Fakhimi et al., 2017]. The process of updating and checking all the other views after an update is a source of poor documentation and is an extremely error-prone procedure [Azhar et al., 2008].

The conventional drawings of the end product are merely a graphical representation of different boundaries, curves, rectangles, circles et cetera. A BIM model is far more complex and semantic, as shapes are described by walls, columns, and other structural elements. This adds a new dimension of information which is far more detailed than traditional 3D Constructive Solid Geometry CAD models [Fakhimi et al., 2017].

A critical point is that BIM is way more than a 3D modeling tool. The model incorporates construction/design-related information such as spatial relationships, geometry, building element characteristics, and volumes. It is enriched with data essential for the project manager(s) and the owner(s) such as cost estimates, schedules and material lists. On top of this, drawings and documentation specifying details regarding acquisition, submission, or other stipulations can be added. Azhar et al. (2008) highlight the example of an Air Conditioning unit, which in BIM contains documentation such as procedures for maintenance and operations, and supplier information. This an example of documentation incorporated in the BIM model, which is not found in more traditional 3D modeling software [Azhar et al., 2008]. Figures 10 and 11 illustrate the difference between pre-BIM and post-BIM processes. In the post-BIM process, all relevant information needed for construction is integrated in the model.

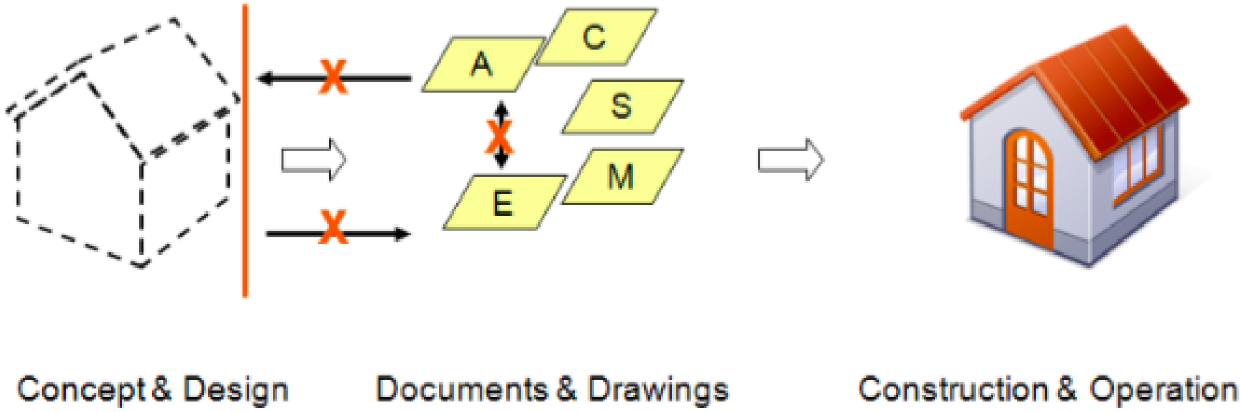

Figure 10: Pre-BIM process [Azhar et al., 2008, Page 437]

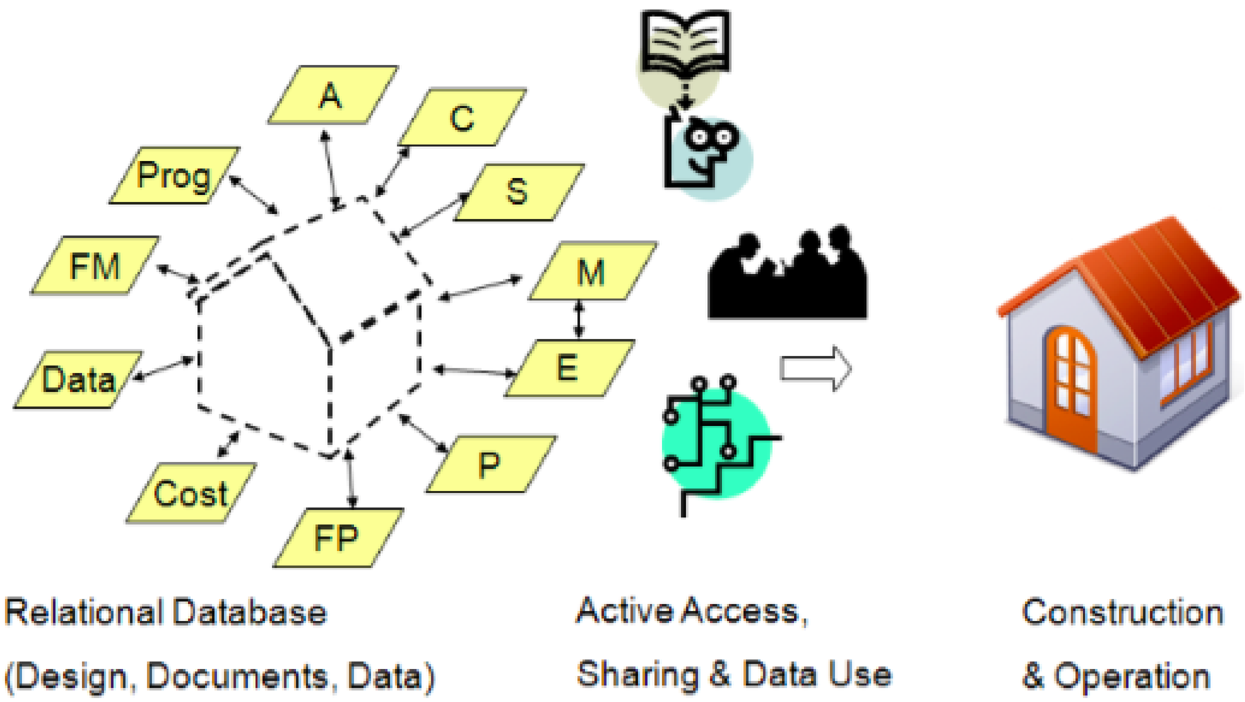

Figure 11: Post-BIM process [Azhar et al., 2008, Page 438]

BIM can be defined both widely and narrowly, depending on the usage area of the technology. Therefore, a single, clear definition is hard to come by [Volk et al., 2014]. Some definitions include:

Already in 1999 professor Charles M. Eastman, one of the pioneers within research and development of computer-aided design, stated that *"A building product model is a digital information structure of the objects making up a building, capturing the form, behavior and relations of the parts and assemblies within the building"* [Eastman, 1999, Preface]. Hardin and McCool (2015) refer to the book published by Eastman in 1999 when they introduce a definition of BIM [Hardin and McCool, 2015].

The National Institute of Building Sciences (NIBS) presents another definition: *"Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition"* [NationalInstituteOfBuildingSciences, 2019].

Eastman et al. (2011) use the following definition in their book: *"a modeling technology and associated set of processes to produce, communicate and analyze building models"* [Eastman et al., 2011, Page 16].

Azhar et al. refer to BIM as *"A Building Information Model, is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analyzed to generate information that can be used to make decisions and to improve the process of delivering the facility"* [Azhar et al., 2008, Page 436].

The acronym BIM is used to describe three independent but connected functions [Rogers et al., 2015]:

- Building Information Modeling: A business process easing the origination and application of data to design, build, and operate a building throughout the lifetime of both the construction project and the completed building.
- Building Information Model: A digital representation of the real-life building compromising both physical and operative building properties. It acts as a shareable hub of data from which information regarding all phases of the building can be withdrawn.
- Building Information Management: Refers to the organization and control of the before-mentioned business process through collaboration amongst project team members with the help of the shared digital prototype.

3.2.1 History

BIM is the result of several decades of 3D technology research, eventually evolving into the parametric modeling use today. It started in the 1960s, with intended usage areas such as design, motion pictures, and games. The movie Tron (released in 1987) became the first movie to employ computer graphics as a result of extensive research into the representation of polyhedral shapes on a computer [Eastman et al., 2011]. Oxford Dictionaries defines a polyhedron as *"A solid figure with many plane faces, typically more than six"* [OxfordDictionaries, 2019]. The technology utilized for making Tron was relatively limited as only a narrow spectrum of scalable shapes could be modeled. Therefore, it was insufficient for designing, as this requires the ability to create more complex shapes. What today is known as solid modeling, entails the ability to both generate and change three-dimensional solids. This first came into light in 1973 and soon led to the first 3D modeling tools [Eastman et al., 2011].

Initial 3D modeling tools saw two distinctive modeling forms competing for superiority; the Boundary representation approach (B-rep) and Constructive Solid Geometry (CSG) [Eastman et al., 2011].

The B-rep approach had a set of predefined computational functions, which allowed the user to create different geometric shapes such as rectangles, spheres, and pyramids. Also, the user could revolve 2D shapes around a set axis, and extrude 2D shapes into a three-dimensional space. Boolean operations such as intersection, subtraction, and spatial union ensured the combination of the individual parts. The shapes created through these functions had to fulfill a set of volume-enclosing criteria and were represented in the program as *"a closed, oriented set of bounded surfaces"* [Eastman et al., 2011, Page 33]. Figure 12 depicts a B-rep representation of a mechanical part [Eastman et al., 2011].

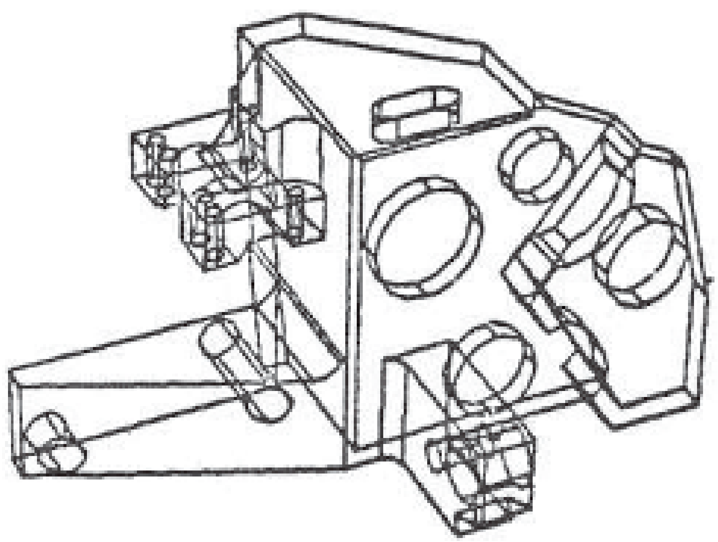

Figure 12: Boundary representation approach [Eastman et al., 2011, Page 34]

CSG was the other form of 3D modeling at the time. This type of modeling described primitive polyhedral shapes (such as blocks, planes, or spheres) by functions. These primitive shapes had a set of coordinates in relation to an origin. The different polyhedral could be combined using algebraic expressions or Boolean operations. For example, a house could be described as a block (the outer perimeter) minus the inside space, door, and two roof-planes, as depicted in figure 13 [Eastman et al., 2011].

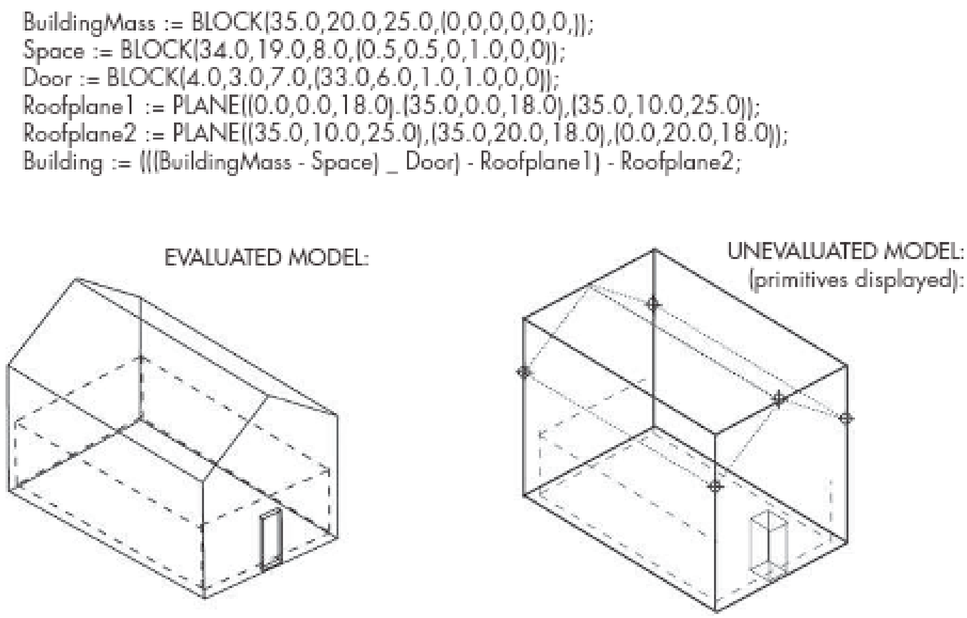

Figure 13: Constructive solid geometry [Eastman et al., 2011, Page 35]

The two approaches both had their advantages. As elements in CSG were described by text strings with coordinates and formulae (as shown in figure 13), they could be easily modified whenever desired. However, given the computing power available at the time, the shape could take quite some time to compute. According to Eastman et al. (2011), elements modeled in a program deploying the B-rep approach were *"excellent for direct interaction, for computing mass properties, rendering and animation, and for checking spatial conflicts"* [Eastman et al., 2011, Page 36]. Considering the two rivaling methods both had considerable benefits, it did not take long before a combination was proposed. The fusion retained the advantages of each approach, resulting in more complete software. Before long, it was realized that material properties could be assigned to these polyhedral objects. This unwrapped a broad spectrum of functions for the modeling programs such as structural analyses and volume determination [Eastman et al., 2011].

The first example of building modeling was developed in the late 1970s and early 1980s, based on 3D solid modeling. These were called Computer-Aided Design (CAD) systems. Alavala's (2008) proposed definition of CAD is as follows *"CAD may be defined as a design process using sophisticated computer graphics techniques, backed by computer software packages, to aid in the analytic, development costing, and ergonomic problems associated with design work"* [Alavala, 2008, Page 4]. At the time, these systems were often too powerful for the computing power available. Despite the system being functionally formidable, the CAD solid modeling software were an unknown concept for several designers, who preferred the 2D systems to which they were accustomed [Eastman et al., 2011].

Despite the shortcomings of CAD systems, many manufacturing companies worked with CAD software producers towards improving them. The reason being that they saw many potential benefits of employing a system such as CAD. The 3D modeling programs could help the industry move towards total automation in addition to reducing errors and improving analysis capabilities. Most of the construction industry was not as convinced about the advantages of CAD and worked more towards improving their 2D designing software [Eastman et al., 2011].

Allowing numerous profiles to share parameters was another step towards the realization of full parametric modeling. Instead of the individual shapes being defined in relation to a global origin, they were partially defined according to the shapes connected to them. This meant that a wall could be defined with respect to the connected walls, floor, and ceiling. The resulting connectivity of parts led to object-generating functions, which made it possible to design, for example, a flight of stairs solely based on parameters. Instead of being designed from scratch, the set of stairs could be modeled based on parameters such as location, stair riser, width, and thread. This resulted in a considerable amount of modeling hours saved for the designer [Eastman et al., 2011].

Building Information Modeling software today uses an improved and modernized version of the before-mentioned parameter-sharing technology. The user can redefine the existing shapes on demand. Updates have been made in order to reduce the computing power needed to make changes. After these modifications, only parts of the object associated with the change are updated [Eastman et al., 2011].

3.2.2 Delivery methods

The three most widely-used delivery methods in the construction industry today are Design-Bid-Build (DBB), Design-Build (DB) and Construction Management at Risk (CM@R). An illustration of these methods is presented in figure 14. Both Eastman et al. (2011) and Hardin and McCool (2015) also introduce integrated project delivery (IPD) as the fourth, more state-of-the-art delivery method [Eastman et al., 2011] [Hardin and McCool, 2015].

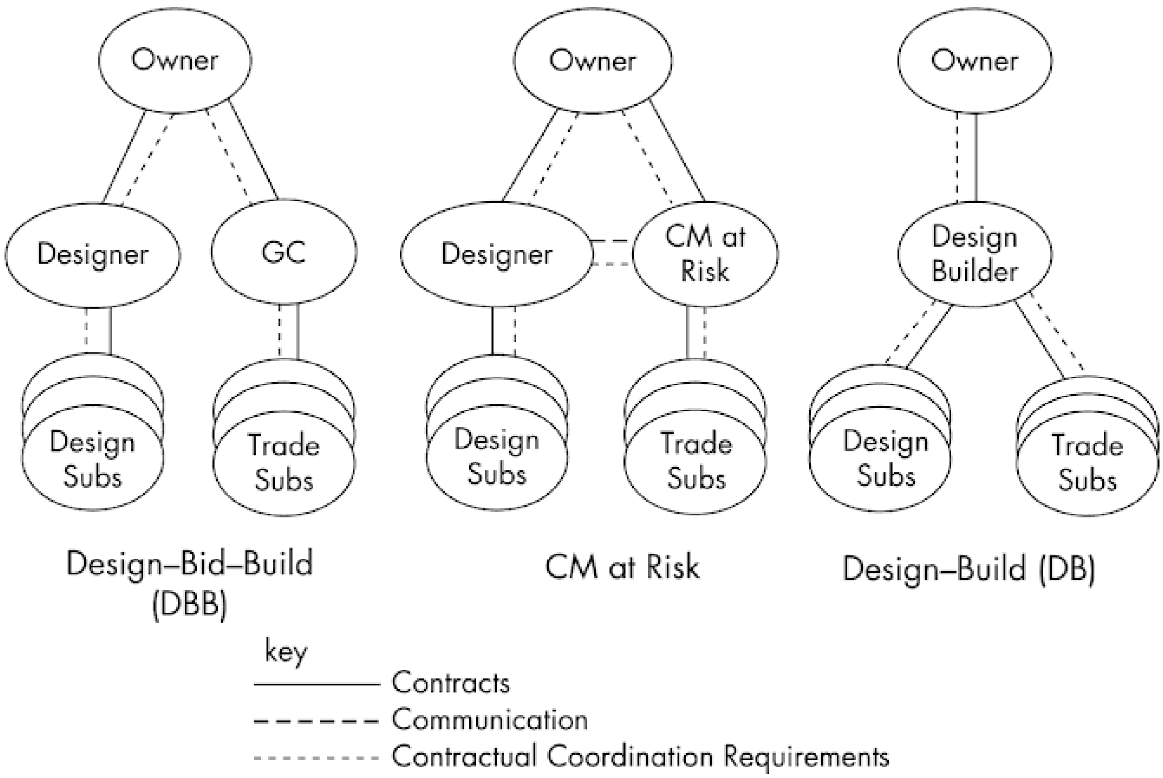

Figure 14: Various delivery methods [Eastman et al., 2011, Page 4]

3.2.2.1 Design-Bid-Build

This practice is the most traditional of the three delivery methods and is based on a linear process [Hardin and McCool, 2015]. In the United States, this method is used in 90% and 40% of public and private buildings, respectively [Eastman et al., 2011].

The owner (also called client) of the project hires an architect which firstly forms a requirement list for the building, along with design objectives for the project. Once these have been completed, the architect undergoes a series of design and contractual phases. Normally, plumbing, structural, HVAC (Heating, Ventilation and Air Conditioning) and piping parts of the design are done in cooperation with consultants hired by the architect. All of the designs are kept in plan or elevation drawings or as 3D visualizations. Once all of the drawings and documents are completed, they must be comprehensive and detailed enough for the bidding process to start [Eastman et al., 2011].

The General Contractor (GC) must compile a bid for the project. Firstly, different scopes of work are defined in cooperation with the subcontractors used in the project. Once the scopes are defined, subcontractors will give the GC an estimate of the cost for them to undertake their part [Hardin and McCool, 2015]. Once all cost estimates are in place, the general contractor can compile a bid for the project.

The bid is based on the estimates from the subcontractors and an independent quantity survey. This survey is composed by the GC based on the drawings sent from the architect. Typically, the lowest bid for the project wins the project contract [Eastman et al., 2011].

In many cases, the GC must create general arrangement drawings. This includes redesigning parts of the architects' sketches, in order for them to adequately express both the labor phases and the building proceedings. The subcontractors must undergo the same process to produce their shop drawings, which better reflects their exact part of the project, for example, the plumbing or pipe layout [Eastman et al., 2011].

A considerable source of error leading to both time and cost overruns in such projects is the presence of incorrect, fragmentary drawings at any stage. Most disastrous for the project is the case where the architectural drawings are lacking in quality, as all the drawings are based on these. As a result of the potential problems arising from inaccurate drawings, most of the fabrication is undertaken on the construction site. This is the only way to make sure that the circumstances are accurate [Eastman et al., 2011]. Not uncommonly, this type of delivery method drives a wedge between the general contractor and the architect. This is seen most commonly in projects where the architectural drawings are lacking in detail [Hardin and McCool, 2015].

The process of handling change in a DBB project is comprehensive. The architect, or another appropriate party, must answer a Request for Information (RFI), before a CO (Change Order) is issued to all parties to which the change will have an impact. This is undertaken not only to determine the appropriate handling of the change but also to resolve the source of the change, who is responsible, along with potential cost or schedule impacts [Eastman et al., 2011].

For the client, the Design-Bid-Build has a couple of significant advantages. Firstly, there is no political pressure to chose any given contractor, meaning that they can choose whichever contractor they prefer. Also, the bidding process is sufficiently competitive in order for relatively low bids to be feasible, saving capital for the owner [Eastman et al., 2011].

3.2.2.2 Design-Build

Envisioned by several as the solution to BIM integration, the Design-Build approach encourages more collaboration than the DBB approach. A higher level of amalgamation of project phases is also feasible by employing the DB method. There are two types of DB projects depending on who is the lead of the project: Design-led, where the architect is lead or Contractor-led, where the contractor is the lead [Hardin and McCool, 2015].

Using this delivery method, the client utilizes one entity which undertakes the role of both architect and contractor. This party is called the design-build contractor, or simply the design-builder [Hardin and McCool, 2015]. The design-builder gives the owner an estimate, for both construction and design, of time and cost. The two parties (owner and design-builder) then sort out any potential changes required from either part and establishes a final project budget. The design-build contractor is responsible for the hiring of any subcontractors needed to complete the project objective. From this point on, the owner is no longer responsible for potential changes, oversights, or errors. All of these burdens fall on the DB contractor [Eastman et al., 2011].

A considerable advantage of employing a DB method is the streamlining of tasks such as construction, design, and permits. Since a single entity is responsible for all of these efforts, it is profitable for them to make the process as smooth and effective as possible [Hardin and McCool, 2015]. As mentioned earlier, DBB projects can see a wedge being driven between contractor and architect due to incomplete documentation. This is far less present in DB projects. In addition, it is unnecessary for the DB contractor to properly finalize all drawings before construction can commence. This also helps the project move faster. As a result of these streamlining advantages, DB projects are typically completed faster than DBB projects. Another advantage is that the DB approach makes design modifications feasible at an earlier phase in the project, saving both time and project capital [Eastman et al., 2011].

3.2.2.3 Construction Management at Risk

CM-at-risk can be thought of as relatively similar to the DBB delivery method. As mentioned earlier, in the DBB approach, the owner hires an architect to do the design before hiring a general contractor to undertake the construction. When employing a CM-at-risk delivery method, the Construction Manager (CM) is hired by the owner at the same time as the architect [Eastman et al., 2011]. The CM acts as a consultant in the pre-construction phases and can, therefore, get his/her inputs for the design heard [Hardin and McCool, 2015].

The reason for the name construction management at risk is that the CM needs to ensure a guaranteed maximum price (GMP) for the project. This acts as an incentive for the construction manager to realize the project in the most cost- and time-effective manner possible. Should the project overrun the GMP, the contractor would experience a loss in profit through a cutback in their fee [Hardin and McCool, 2015].

For the owner of a CM-at-risk project, there is a risk of CM using his role as a contractor to change design aspects in order for the building to be easier to build. Should the owner want an aesthetically appealing and picturesque product, these wants may be trumped by the contractor having apprehensions regarding costs and constructability. The answer to such worries is the owner being reasonably involved, especially in pre-construction phases, making sure both his aesthetic and cost requirements are being upheld [Hardin and McCool, 2015].

Including inputs from the CM in early project phases have certain advantages. The construction manager has a somewhat different view from the architects regarding what is constructible and what is not. The CM will also be able to consult the designers regarding which type of documentation will be needed to complete the building [Hardin and McCool, 2015]. In addition, it acts as a cost guarantee for the owner, transferring some of the risk of cost overruns from the owner to the general contractor [Eastman et al., 2011].

3.2.2.4 Integrated project delivery

IPD, or Integrated Project Delivery, is somewhat of a new procurement process concept rapidly increasing in popularity in the AEC industry with the development and elevated use of BIM. There are multitudinous approaches to undertake a project using this delivery method. A reason for this is that it has quite recently been developed [Eastman et al., 2011].

What hallmarks all IPD projects is a potent intercommunication, from start to finish, among all project participants. There are constant tradeoffs in a project, between for example time, cost, constructability, and functionality. A key to successfully undertaking a project with an IPD delivery method is for the owner to be involved in all phases, either in person or by trusting a representative to act in their place [Eastman et al., 2011].

3.2.2.5 What is suitable for BIM?

The implementation and success of BIM integration in the AEC industry can hinge on the delivery methods utilized. Depending on the process employed, it could either acts as a handicap or as a catalyst [Eastman et al., 2011].

The Design-Bid-Build method demonstrates a challenge for BIM usage. Being a linearly based method, it excludes the contractor from the design phase. Thus, a new model of the building, with inputs from the general contractor, is often required before construction can commence. Generally, all delivery methods where collaboration between different entities working in the project will only moderately experience the benefits BIM can provide [Eastman et al., 2011].

Both the Design-Build approach and Construction Management at Risk are relatively suitable for BIM usage. They allow collaboration among designer and contractor from early phases of the project, which benefits BIM [Eastman et al., 2011].

3.2.3 BIM dimensions

It is usual to refer to the different features in BIM as dimensions. There are five main dimensions in BIM; 2D - 5D. Kensek (2014) also refers to a further two dimensions; 6D and 7D, which are less used and have various definitions [Kensek, 2014].

3.2.3.1 BIM 2D: CAD, space planning and specifications

Even though Building Information Modeling is mainly a 3D modeling program, there are still integrated 2D elements. In the project commencement phase, 2D can be utilized efficiently as the earliest plans are often no more than square footage assigned to different areas. Three criteria which can help in determining whether 2D is more appropriate than 3D are [Kensek, 2014]:

- **Appropriateness,** does modeling the object in 3D add any information a 2D model could not display? Unnecessary 3D models substantially scale up the file sizes needed. If there is no distinct advantage to adding the third dimension, a 2D model could be as effective as the corresponding 3D model.
- **Time and effort to complete the task,** is the effort of modeling the objective in three dimensions worth the effort compared to a simpler 2D model?
- **File consistency,** adding a 2D file in a 3D model might not always be easy to discover for the subsequent person working on the same area. If the 3D model is updated, the connected 2D model might not be, which can be confusing.

3.2.3.2 BIM 3D: Virtual design and construction

An important usage area for the three-dimensional BIM models is for visualization. The 3D views eases the envisioning of the actual environment within the model objective, allowing for an improved understanding of the finished product. This visualization can be employed, for example, in meetings with clients and for promoting intentions [Kensek, 2014].

A relatively common occurrence in the construction industry is the designing of two or more objects at the same point in the model. Another significant aspect of the 3D models obtained through BIM is what is referred to as clash detection. The interference programs check for both within and across disciplinary design conflicts. Running clash detection in BIM is relatively straightforward and allows architects, engineers, and constructors/contractors to resolve the discovered clashes before the construction phase commences [Kensek, 2014].

In practice, several 3D models of the same objective are created with differing detailing and complexity levels and different intentions. However, a single model could easily incorporate the totality of the project scope. By utilizing the 3D models created in BIM, clash detection and code checking, among other things, can be accomplished. When using the BIM model for prognostic performance and simulations, the accuracy depends mainly on the completeness and level of detail in the model. Some simulations are more advanced than others, and the level of detail needed for the different simulations depends on which type it is. For example, wind analysis and shadow studies needs a relatively low detailing level (building form/mass, position and location context). More advanced simulations such as energy modeling requires a far higher degree of accuracy (material properties, ventilation, heating, AC systems, inner zoning, tenancy agendas, etc.) [Kensek, 2014].

3.2.3.3 BIM 4D: Time

The fourth dimension in BIM is time and is utilized for two main purposes, construction sequencing and animation [Kensek, 2014]. Kensek (2014) refers to an animation as *"a series of rendered views taken from the 3D model"* [Kensek, 2014, Page 25].

Some examples of animations achievable in BIM are solar and walkthrough animations. In a solar animation, shadows both within and without the objective can be simulated for a particular perspective, position, and time interval. The walkthrough is a simulation of what an individual walking through the end product would experience. More precocious simulations can be generated by importing the BIM model into more sophisticated simulation software [Kensek, 2014].

The amount of phases in an arbitrary project fluctuates depending on several variables such as complexity and magnitude. The creation of project phases corresponding to construction sequences is a function in BIM which allows the user to compare actual progress with what is scheduled in the virtual model. Even though the application itself is somewhat uncomplicated, it can at times require a great deal of insight and knowledge [Kensek, 2014].

3.2.3.4 BIM 5D: Cost

The fifth BIM dimension is cost, or more specifically cost estimation, which is pivotal, especially during the designing and building phases. An on-the-spot cost appraisal can be extracted at any point in the project. The exactness of the value assessment is not only reliant on the quality and content of the model, but also on the precision of the cost databases utilized to make the valuation. The cost estimation functions in the models can be both simple and fairly sophisticated. A simple estimate would take into account the prices of objects such as doors and windows and the material costs associated with the construction. A more advanced simulation also considers the end prices of similar construction projects conducted in the past [Kensek, 2014].

BIM eases the possibility for the designers or architects to undertake a "what if" analysis. Numerous design alternatives with an associated cost can be considered and presented to the decision makers. The beforementioned analysis aids a more well-informed and cost-effective final design [Kensek, 2014].

3.2.3.5 BIM 6D and 7D: Life cycle management

With the 6th dimension, Kensek (2014) refers to the inclusion of energy managing, life cycle, and facilities. The 7th dimension is referred to as the introduction of life safety concerns internally in the construction. These dimensions depend on an information-rich model and can introduce knowledge regarding both computerized maintenance and building management systems, among other things [Kensek, 2014].

3.2.4 BIM Maturity

BIM maturity refers to the level of understanding of Building Information Modeling and its uses within an industry or organization [Fakhimi et al., 2017]. It can be defined as *"the quality, repeatability, and degree of excellence within a BIM capability"* [Fakhimi et al., 2017, Page 1065]. Succar (2009) defines three stages of BIM maturity in addition to the pre-BIM stage as well as the long-term goal of BIM implementation [Succar, 2009]. The stages are illustrated in figure 15.

Figure 15: BIM implementation stages [Succar, 2009, Page 363]

- PRE-BIM
- Stage 1: Object-based modeling
- Stage 2: Model-based collaboration
- Stage 3: Network-based integration
- Integrated Project Deliver

3.2.4.1 PRE-BIM

Traditionally, the construction industry has largely based itself on employing 2D drawings in order to describe the three-dimensional relationships occurring in the field. Some 3D visualizations are used. However, they are based on 2D documentation, leaving them incoherent and confusing. Underinvestment in technology yielded limited synchronization among different stakeholders leaving workflows nonsynchronous and linear [Succar, 2009].

3.2.4.2 Stage 1: Object-based modeling

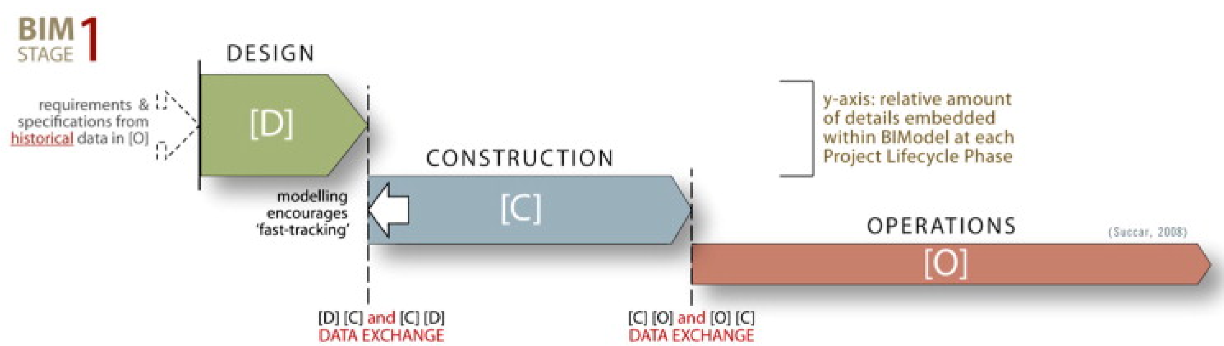

Figure 16: BIM stage 1 [Succar, 2009, Page 366]

A result of the increased utilization of 3D technology is fast-tracking. Even though the projects are mainly executed in a linear and phased fashion (see figure 16), design and building efforts can be somewhat overlaid, allowing time-saving. In spite of producing three-dimensional models, project associative efforts are not too dissimilar to the previous stage as most of the intercommunication among team members is still limited. Low interoperability among models created in heterogeneous project phases and disciplines acts as barriers for the communication efforts among disciplines [Succar, 2009]. Interoperability is defined by Eastman et al. (2011) as *"the ability to exchange data between applications, which smoothes workflows and sometimes facilitates their automation"* [Eastman et al., 2011, Page 99].

Succar (2009) argues that the modeling implemented in this stage incentivizes evolving to the next stage of BIM maturity, as users start to see possible gains from employing other actors having analogous modeling competencies [Succar, 2009].

3.2.4.3 Stage 2: Model-based collaboration

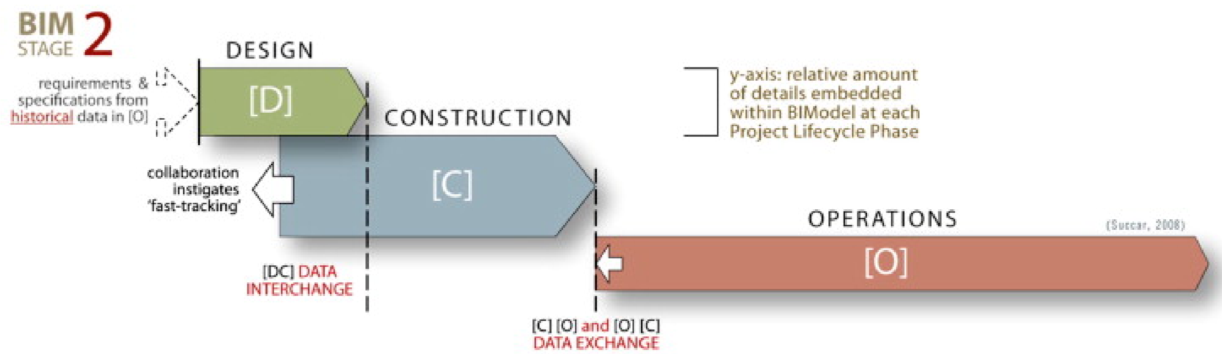

Figure 17: BIM stage 2 [Succar, 2009, Page 366]

The pre-BIM role-, discipline- and lifecycle-separating lines are disappearing progressively as cross-disciplinary inter-communication and collaboration are gradually advanced. This is achieved through either entire models or model parts being traded through interoperable formats, either between different actors in the same project phase (e.g. Construction-Construction or Design-Design) or between phases (e.g. Design-Construction or Construction-Operations). The exchanges can be traded proprietarily between two different software of the same producer or non-proprietarily between two heterogeneous producers. Some contractual reforms are starting to become imminent as the exchanges of models facilitate the supplanting of the traditional paper-based workflow [Succar, 2009].

As displayed in figure 17 above there is an overlap of the design and construction phases. This overlap is a result of actors in both phases (Construction and Design) initiating increasingly cross-disciplinary services. For example, a construction company presenting designing services or a designing company incorporating construction and acquisition data in their models [Succar, 2009].

3.2.4.4 Stage 3: Network-based integration

Keys to a successful stage 3 implementation includes a substantial revision of risk-allocation models and contractual relations, among other things. Essential for this transformation is appropriate, well-understood technology allowing all stakeholders to access and make changes in an inter-disciplinarily shared model. The model and document sharing allow project phases to seamlessly overlap into a process where phases are nonexistent, as depicted in figure 18 [Succar, 2009].

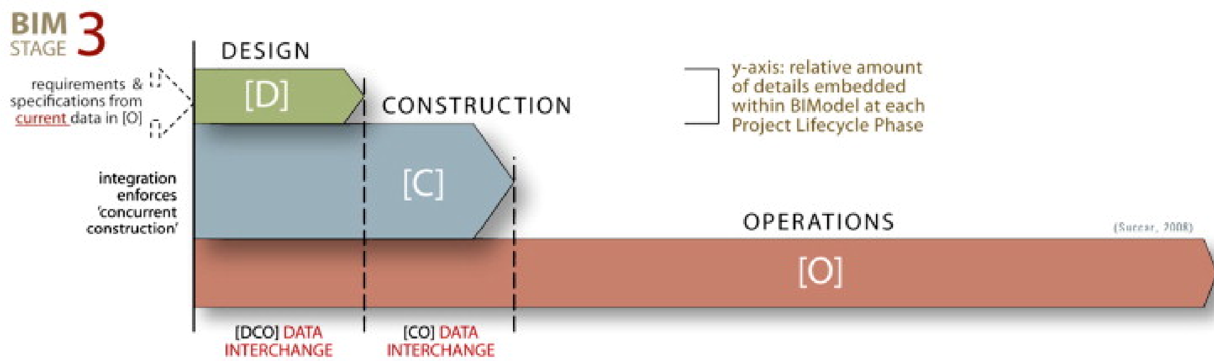

Figure 18: BIM stage 3 [Succar, 2009, Page 367]

In the phase-less project process now attained, semantically rich models are conceived, updated and interchanged collectively by the project stakeholders both proprietarily and non-proprietarily. According to Succar (2009), there are three key enablers to the extensively shared model; model server technology, single integrated/distributed federated databases and SaaS solutions. The three concepts are briefly explained below [Succar, 2009].

- Model server technology enables stakeholders to centrally store the models created through BIM, in order to work together more effectively [Beetz et al., 2010].
- A federated database system (FDBS) allows for both sharing and transferring of information by virtually mapping numerous databases into one centralized database [Kim and Moon, 2018].
- Software as a Service, or SaaS, is a type of cloud computing in which a singular application delivers a certain service to several customers through a browser. This is achieved using multitenant architecture, in other words, allowing several tenants to run the same service through one application [Knorr and Gruman, 2008].

At this stage, advanced analyses and simulations are made possible through the cross-disciplinary collaboration of the unified models. This again results in the easing of cost estimation, lean construction and business intelligence [Succar, 2009].

3.2.4.5 Integrated project delivery

The term integrated project delivery is relatively loosely defined but is described by Succar (2009) as the long-term goal for Building Information Modeling. It is achieved through the combination of technology, policies and practices [Succar, 2009]. Eastman et al. (2011) provide a different view of integrated project delivery, describing it as a project in which owner, contractor(s) and designer(s) all communicate and collaborate effectively throughout all project phases [Eastman et al., 2011].

3.2.5 Advantages

There are considerable advantages to employing BIM, the literature highlights the following as the main profits of BIM introduction:

3.2.5.1 Visualization

The models created through BIM can be directly produced instead of being created through several 2D views, allowing for an in-house generated 3D visualization needing less effort than traditional ones [Azhar, 2011] [Eastman et al., 2011]. Traditional 3D visualizations can be both time-consuming and expensive, therefore, one generated through BIM can help free project capital. In addition, the visualization created in BIM is in a format readable for all project members. Traditional efforts were often made to different detailing standards, in different project phases and by many different project stakeholders. Due to a lack of standardization in software, sharing of the visualizations were hard [BuildingSMART, 2019h].

The visualization works to the advantage of designers, owners and builders, among others. It helps them obtain a better and more accurate picture of room placement and improves the understanding of relations and distances between rooms. Also, it can serve as a tool for visual inspections of constructability [BuildingSMART, 2019h]. The improved perception of the end product that can be provided for clients through BIM visualizations also helps make the customer more satisfied with the firm's customer service [Azhar et al., 2008].

The 4$^{\text{th}}$ dimension in BIM, time, can help obtain a superior understanding of potential problems, or opportunities for improvements. By synchronizing the model to a proposed schedule, a simulation is facilitated which can mirror what the end objective will look like at any point in the project timeframe. This visualization effort is made feasible through BIM usage, as it is information non-obtainable from paper documents. The details provided can help the project team coordinate the arrival and departure of equipment such as cranes and scaffolding, among other things [BuildingSMART, 2019h].

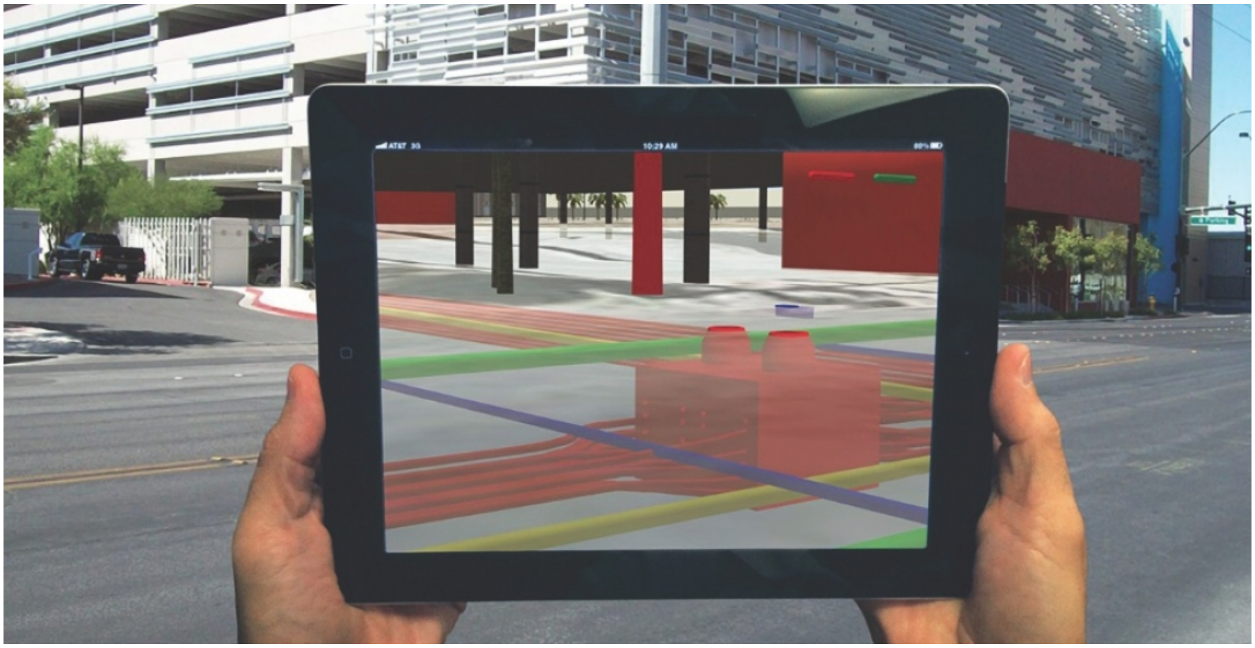

Figure 19: Example of Augmented Reality use [Barista, 2013]

Even though it is not widely implemented at present in the AEC industry, BIM has the possibility to integrate augmented reality (AR) in its visualization techniques [Wang et al., 2014]. Furht (2011) defines AR as *"a real-time direct or indirect view of a physical real-world environment that has been enhanced/augmented by adding virtual computer-generated information to it"* [Furht, 2011, Page 3]. Augmented reality creates a bridge between the physical and the virtual world (an example is shown in figure 19). Both real and virtual environments coexist, creating a superior visualization of among other things, spatial relationships [Wu et al., 2013]. Wang et al. (2013) refer to AR as an aggregator of data which can both gather and strengthen information from sources such as a Building Information Model [Wang et al., 2013]. By making real-time visualizations feasible, augmented reality can aid in making BIM an even more effective tool for decision making and communication [Wang et al., 2014].

3.2.5.2 Cost estimates

Designing a project in BIM allows the user to select material types for the different components in the design. The model creates an overview of material quantities which is automatically updated when any changes are made [Azhar, 2011]. This overview can be extracted at any time in the design process. The model also incorporates prices from available databases or given directly from the producer, allowing the creation of a project cost estimate. The cost estimates generated eliminates the calculation errors common in many projects not using BIM. However, it is reliant on the model being provided with accurate price and quantity information [BuildingSMART, 2019c].

At the early design phase, the cost estimate is very rough. As the design becomes progressively more detailed, the cost estimate obtained will automatically update to become increasingly accurate. One advantage of an accurate cost estimate is more well-informed decision making with regards to the cost of the project [Eastman et al., 2011]. Another major advantage is the "what if" analyses attainable through BIM usage. As the cost estimations are easily retrieved from the model, a designer can present several different sketching options with the affiliated cost estimations. Enabling the decision makers to weigh the various options both based on the designing solution and the cost associated [Kensek, 2014].

3.2.5.3 Collision detection

A lack of collision detection has long been a major source of delays, extra costs and deteriorating building quality. Collision detection refers to quality control across construction disciplines checking for geometric crashes. An effective collision control detects for instance; twice modeled objects, colliding objects both within and across disciplines (shown in figure 20) and whether object margins and tolerances are sufficient [BuildingSMART, 2019b]. According to Kensek (2014), the design clashes can add cost overruns estimated to be up to 10% of the project cost [Kensek, 2014].

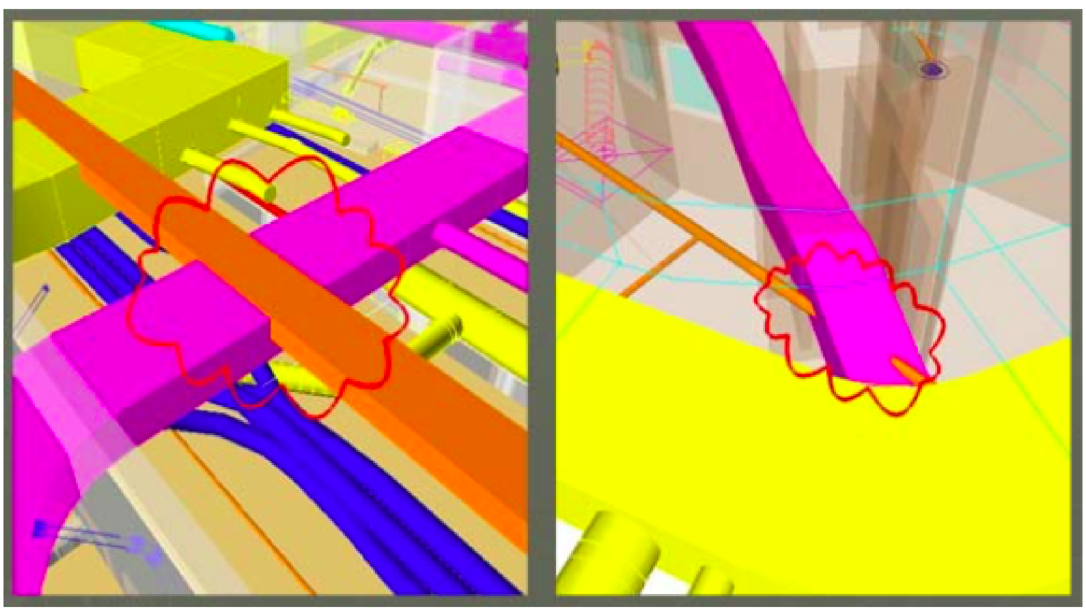

Figure 20: Collision detection [Azhar et al., 2008, Page 439]

Collision detection, which is mostly done pre-construction, has been made possible through BIM as the model created contains data from all relevant disciplines such as designers, electricians and plumbers. The amalgamation of information from these different sources in one model allows the program to systematically analyze design clashes [BuildingSMART, 2019b]. The constructability glitches and cross-disciplinary conflicts are discovered pre-construction rather than during construction. The early detection of such problems aids in cost reduction, speeds up construction and diminishes possibilities of legal disagreements. Overall, the entire production process from design to construction is smoothed [Eastman et al., 2011]. An example of such a control would be to check if the piping system in a building collides with walls, ducts, electrical systems, mainstays or other beams [Azhar, 2011].

3.2.5.4 Lean construction

Alarcón (2014) highlights that the primary goal of lean production is *"to avoid waste of time, money, equipment etc."* [Alarcón, 2014, Page 11]. In the construction industry, similar principles are applied to achieve lean construction. Among other things, lean construction techniques ensure, by proper intercommunication and coordination, that all resources needed to accomplish a job are available on-site for contractor or subcontractor [Eastman et al., 2011]. The Just-In-Time (JIT) principle (also known as the Toyota Production System, or TPS), a Japanese management philosophy, also highlights the importance of having the right amount of quality goods in place at the right moment. Appropriate utilization of the JIT principle has reported a surge in productiveness, information flow, capability and product quality along with both cost and waste decay [Cheng and Podolsky, 1996].

Through BIM, delivery schedules for construction elements, material and fabrication efforts are all superiorly harmonized compared to traditional methods [Azhar, 2011]. Building Information Modeling offers the possibility of what is called the 4^{th} BIM-dimension, time. By centralizing the planning tools, which traditionally often were heterogeneous, into one application, the intercommunication among the project team is improved, resulting in eased implementation of the Just-In-Time philosophy [BuildingSMART, 2019f].

By means of the enhanced coordination, job site collaboration is improved, unnecessary efforts are diminished and the need for field-level material lists are considerably lessened [Eastman et al., 2011]. We see these advantages especially in projects where the order of assembly is important. As a result of these benefits, BIM is nearly always involved in lean construction [BuildingSMART, 2019f].

3.2.5.5 Fabrication

Employing complex computerized techniques is nothing new for fabricators. They have been utilizing sophisticated methods for the production of sketches as well as computerized fabrication efforts for several years. BIM allows for a smoother information transfer between designers and fabricators for both simple and complex objects, but especially for the intricate ones, advancing their affordability [Kensek, 2014].

In steel production, it is today common procedure that pre-defined 3D models of parts are autonomously fabricated through the use of diverse mechanical equipment. Specialized components in need of fabrication are defined in the model, along with their ties to the rest of the building. For the fabricators, this results in improved insight regarding intended usage area and where fabricated parts fit in the big picture. These advantages can result in both cost and time reduction for the project. Adding to this, the most complicated components, which are often made using 2D drawings, can obtain a higher quality thanks to the greater accuracy of the BIM-produced 3D designs [Eastman et al., 2011].

3.2.5.6 Collaboration

Traditional AEC projects have a tendency of nearly completing the design phase before engineers or the facility management team gets to add their input. Engineering evaluations, for example, are traditionally applied after the significant designing solutions are applied. Implementing BIM in a project allows for earlier cross-disciplinary collaboration and facilitates a shorter design timeframe and reduces the number of errors occurring in this phase. This is a result of the various disciplines working together in one centralized model, with inputs from all different stakeholders [Eastman et al., 2011].

3.2.5.7 Change management

The analysis of a virtual building can improve change management in construction substantially, as it is considerably less costly to analyze and implement changes in the model than on the construction site [Hardin and McCool, 2015]. Once imposed changes are incorporated in the model, the connected objects which are affected by the change are automatically updated, along with cost estimates and material quantities. In addition, clash detection can be run again after the imposed change in order to check if it is feasible. Should the change pass all the tests and be implemented, the effects of the change can be visualized in three dimensions to owners and other essential stakeholders. This is undertaken in order for them to fully comprehend the potential effects the change could have on the rest of the building. Imposing changes by utilizing traditional paper-based methods can be terribly susceptible to errors [Eastman et al., 2011].

3.2.5.8 Post-construction benefits

As the model is continuously updated and maintained with accurate information by the project team, it serves as a practical square one for the facility management (FM) teams. It also serves as a source of intelligence for all systems employed in the structure once it is finished. In BIM, maintenance and material data are linked to all objects modeled in the building. Once the structure is ready to be handed over to the owner, after construction, all of this information is available for the owner and the facility management crew. Also, the model can act as a control check for the owner to ensure that the design he approved is the same as what has been completed by the construction crew [Eastman et al., 2011].

3.2.6 Challenges

No technology can be implemented seamlessly, following are highlighted challenges for BIM implementation mentioned in the literature.

3.2.6.1 Technology

A consistent mention with regards to future challenges of Building Information Modeling is the technological perspective. Talebi (2014) highlights the importance of solving the remaining problems of interoperability in order for all project participants to be able to indulge in the same information. Interoperability among software is not always achieved, as many BIM suppliers offer compatibility amid own products but not with each other [Talebi et al., 2014]. The problem is also highlighted by Azhar (2011), pointing to better-defined models for transactional construction processes as the solution [Azhar, 2011].

Mehran (2016) points to several other technological challenges in addition to interoperability, such as compatability of software and unsatisfactory detection and visualization of clashes among designs [Mehran, 2016]. Through following a project employing BIM, Jupp (2013) found that even though much of the technology to manage a building from design through operation stages is out there, it is not always available for the project team to utilize. Adding to this, several of the project team members found it difficult to adjust to the new type of software, especially since there was limited prior experience with the technology within the company. This may apply to all companies employing BIM, especially in the first projects operating with the software [Jupp, 2013].

Software appropriate for members in all phases of the project to utilize is not yet widespread. BIM-software for facility management and production efforts are not particularly prevalent at this time. This causes the project phases to become disjointed and some members are kept 'out of the loop'. Since BIM software for designers is way more prevalent in the market today, it creates a divide between the design phase and the other phases [Talebi et al., 2014].

3.2.6.2 Collaboration

Although a full BIM implementation probably results in improved collaboration among project team members, in the early phases of BIM adoption into an industry it could pose a challenge. One collaboration aspect which could prove difficult is possible problems relating to maintaining effective project teams. The sharing of models created by different team members among the project team could prove to be a significant speed bump in the project flow. Eastman et al. (2011) point to an example where an architect has not yet utilized BIM models and applies more conventional methods like paper-based drawings. For the BIM to be enriched by the architectural drawings, an alternative team member would have to incorporate the drawings into the model. The resulting model derived from the architectural drawings may not be adequately intricate to be adopted. In addition, it could entertain incomplete object definitions making it impossible to derive the needed construction quantities. Consequently, a new model must be generated for construction purposes, which violates parts of the reason for employing BIM [Eastman et al., 2011].

A prosperous and accurate BIM model relies heavily on the sharing and updating of data among several project team members. However, many firms are not too open to sharing their datasets as they are viewed as one of their sources of competitive advantage and their intellectual property. This is a major hindrance for a successful BIM implementation, as a model created by firms who are reluctant to share their data is unlikely to be successful [Smith, 2014]. The collaboration efforts are especially exacerbated in certain projects, where one or more of the parties need to share proprietary data [Talebi et al., 2014].

Smith (2014) discusses potential faults related to a lack of trust in the information displayed in the BIM model, as the data is both relatively complex and submitted by a wide array of differing participants. The validity, preciseness and completeness of the data displayed in the model are pivotal to utilizing BIM to its fullest capacity [Smith, 2014]. A potential cause of the data distrust is inadequate validation procedures, which can cause confusion among the team. Several team members in the study conducted by Jupp (2013) found the lack of verification of what had been installed extremely troublesome. Even once the model had been finished and construction had begun, this distrust was present. As a result of the miscommunication, the three-dimensional model created in the project was insufficiently maintained. Also, facility management staff was unsure about the quality of asset data [Jupp, 2013].

3.2.6.3 Legal issues

Both Eastman et al. (2011) and Ghaffarianhoseini (2017) highlight that certain legal issues could arise from working with BIM. It derives a manifold of datasets with diverse constructions, designs, fabrications and analyses. A consequent dispute is regarding who is liable for their preciseness and what amount each party involved in the project should pay [Eastman et al., 2011] [Ghaffarianhoseini et al., 2017].

Talebi (2014) adds further legal concerns with regards to who has access to simulation results and design entry data in addition to the BIM model itself [Talebi et al., 2014]. A large project will involve a magnitude of participants, which all rely on the validity and accuracy of the same data. Numerous efforts to fix this problem has been initiated, but none have, as yet, derived a fault-free model for dividing the responsibilities [Smith, 2014].

In addition to legal concerns regarding payments and preciseness of the information shared, trouble can also arise when determining the partition of potential economic benefits obtained from employing BIM. Monetary incentives are essential in order to conceive the groundwork for BIM adoption. Thus, generating a mutually advantageous case for all project stakeholders must be a top priority in any industry [Talebi et al., 2014].

3.2.6.4 Security

As running a project with BIM involves sharing and storing potentially sensitive and proprietary data, there is a significant concern with regards to the security of this information. Especially as this data is openly available to all project members, it opens up the firms participating in the project to the risk of being hacked. Cybersecurity is, therefore, a priority in order to protect the participating firms from copyright infringement and unsanctioned access [Ghaffarianhoseini et al., 2017].

3.2.6.5 Management

Even though management of a company has been convinced of the economic benefits of employing software such as BIM in their operations, some work may still be necessary in order to convince the other employees of the same. Misconceptions regarding what BIM can achieve for the company will serve as a hindrance for its successful implementation [Talebi et al., 2014].

One of the main goals of employing BIM is obtaining a competitive advantage. However, it could turn out to be a real headache for management. This is true, especially in low-profit margin markets with an intense competition. Here, an investment in BIM could prove to be the downfall of a company, due to the amount of capital needed. One of the reasons BIM implementation can prove relatively burdensome is that its business impact could prove substantial [Smith, 2014]. It requires the firm to re-assess their current business models in addition to the associated BIM-employment costs [Fakhimi et al., 2017]. Talebi (2014) argues that one of the reasons BIM implementation has been relatively slow in some cases is that predicting the effect resulting from it is troublesome. However, they are imperative in order to reap the full gain of Building Information Modeling [Talebi et al., 2014].

Another inconvenience for executives is the dilemma of how to modify the business culture and mindset of employees in order for the company to grasp and mature with the new technology. Many firms see the staff inability to adapt and change as one of the significant obstacles for change [Smith, 2014].

3.2.6.6 Attitude and awareness

A factor which is significantly holding back BIM is the attitude towards it. This attitude includes the general interest and awareness of what BIM is, in addition to how willing members are to employ the software and learn how to use the it. Some confusion can also arise from the differing perceptions of what BIM is. Some may think of it as another CAD program and be unaware of its potential economic benefits [Mehran, 2016].

In order to increase the awareness of BIM, Smith (2014) argues that a universal education of the software should be incorporated at tertiary level. This could propel both the implementation and the evolution of BIM. Educating young, BIM-trained, and knowledgeable students will be a massive milestone for its successful implementation in AEC industries [Smith, 2014].

In addition to educating the younger generation, there is a need for existing building owners, facility managers, among others, to obtain a better understanding of the technology. These groups relatively scarcely utilize BIM. A better understanding would increase the likelihood of them employing BIM in their operations [Volk et al., 2014].

3.2.6.7 Culture

Talebi et al. (2004) argue that in addition to new processes and technology, BIM is also a fusion of the two with the business culture [Talebi et al., 2014]. Culture can be defined as the way people *"think and do things around here"* [Weippert and Kajewski, 2004, Page 4]. In general, the AEC industry has a culture which is reluctant to change, unless they see a need for it. Weippert and Kajewski (2004) claim that it is easy for players in the industry to be blinded by the way things have always been done in the company, which could act as an impediment towards change. However, if appropriately used, both culture and technology can help improve the company's position in the market. Comprehending the role in which culture interplays with project teams and organizations is a critical aspect in making them more productive and competent [Weippert and Kajewski, 2004].

The recent development of BIM worldwide has led several governments to incentivize the use of BIM, forcing an increasing amount of firms to grasp the importance of employing it. They must now either adapt to the new technology and embrace it or get left behind. The welcoming of new technology can prove a threat to senior, experienced personnel. Smith (2014) assert that senior employees are, in general, more reluctant to change than younger, more inexperienced ones [Smith, 2014].

As mentioned, a general attitude which is prevalent in the AEC industry is one that is reluctant to change and adapt to new technologies. It is often called the 'wait and see' attitude, and is holding back the technological development of the companies. Being the pioneer within a particular technology is risky. In many cases it can also prove costly, as the pioneering firm often ends up losing money. Competitors can learn from implementation strategy failures or successes within other companies. Subsequently, they can tailor an improved approach. Thereby they are allowing the pioneer to attain part of the risk involved with the technology adaptation. As everyone wants to be second, but no one wants to be first, technology is very slowly adapted. This has been true for technologies in the past and is also true for the adoption of BIM [Smith, 2014].

3.2.6.8 Cost

Exploring the adaption of BIM in the United Arab Emirates, Mehran (2016) highlights that *"BIM does not come cheap"* [Mehran, 2016, Page 1114]. It requires a high implementation cost in addition to the original investment for the software [Mehran, 2016]. Adapting a firm to the full implementation of BIM goes way beyond purchasing the software, it is a comprehensive and time-consuming process. Besides the cost of the software itself, proper hardware is a necessity in order to operate the programs efficiently. Once both software and hardware is readily available, an extensive and company-widespread training program in order to operate them appropriately is needed. The training programs are both costly and time-consuming [Talebi et al., 2014].

An associated cost which is prevalent at a time where BIM software is still not universally embraced is if the in-house architect is utilizing other methods for design. The BIM model will then have to be outsourced by the general contractor incurring a loss of both time and project capital. Also, it is possible that the drawings supplied by the architect are insufficiently detailed, resulting in an even higher cost [Talebi et al., 2014].

3.2.7 OpenBIM

To effectively use BIM, it is vital that the model is shareable among the project team. This is achievable in two ways. Either the entire team needs to work in the same application, or a standardized file format which is easily shared amid the project participants needs to be used [BuildingSMART, 2019d]. The first option is relatively intricate. For the most part, designers, engineers and other members of the project prefer heterogeneous software to produce their contributions. Therefore, developing a standardized format for seamless interchange of data is a significant priority for the industry [Grilo and Jardim-Goncalves, 2010].

BuildingSMART (originally established International Alliance for Interoperability) is an international non-profit organization formed in 1996 (renamed January 2008). Their vision is, within the global built environment sector, to ensure engagement, community, and quality for open BIM [BuildingSMART, 2019a]. OpenBIM is a result of an initiative from buildSMART in collaboration with other software vendors. According to buildSMART themselves, openBIM *"is a universal approach to the collaborative design, realization and operation of buildings based on open standards and workflows"* [BuildingSMART, 2019g].

BuildingSMART describes five basic methodology standards, explained in table 3.

Name	What it does	Description
IDM	Process Standard	Through an Information Delivery Model (IDM), a comprehensive description regarding what information is required to be produced by a specific project individual is provided.
IFC	Data Standard	By developing a standardized data schema called Industry Foundation Class (IFC), the possibility of data interchange amongst heterogeneous software applications is achievable. The IFC standard is an attempt from buildingSMART to achieve interoperability. The utilization of IFC allows project members involved in different project phases to share information despite using contrasting software applications.
BCF	Change Coordination	Though not yet released, the BIM Collaboration Format (BCF) is set to become a specification for buildingSMART. They describe it as *"a 'simplified' open standard XML schema that encodes messages to enable workflow communication between different BIM (Building Information Modeling) software tools"* [BuildingSMART, 2019e].
IFD	Mapping of Terms	The International Framework for Dictionaries (IFD) is tailored towards solving problems of misconceptions and interoperability by making sure everyone uses the same terminology.
MVD	Process Translation	The Model View Definition (MVD) is a guide for implementing of IFC. It provides the industry with a specification of conditions for the software utilized to satisfy the requirements needed in order for an exchange of information to be possible.

Table 3: Description of BuildingSMART standards [BuildingSMART, 2019e]

3.3 Information Sharing

Successful and effective sharing of information has been well proven to boast several benefits for effective Supply Chain Management (SCM) [Li and Lin, 2006]. Multitudinous definitions coexist in an effort to define what the Supply Chain (SC) is. Mentzer et al. (2001) define the supply chain as *"a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer"* [Mentzer et al., 2001, Page 4]. The SC, in other words, consists of several firms in both upstream and downstream positions in the market, in addition to the end user [Mentzer et al., 2001].

Differing complexities of the SC exist, depending on the number of “links”, or ”joints” in the chain. The least complex, direct supply chain (figure 21), involves a supplier, an organization (or company), and an end user (or customer) [Mentzer et al., 2001].

Figure 21: Direct supply chain [Mentzer et al., 2001, Page 5]

The more complicated extended SC (figure 22) also involves the supplier’s supplier and the customer’s customer [Mentzer et al., 2001].

Figure 22: Extended supply chain [Mentzer et al., 2001, Page 5]

The ultimate supply chain (figure 23) reaches out to the ultimate supplier and the ultimate customer. A financial provider may in this ultimate supply chain assume some of the risks [Mentzer et al., 2001].

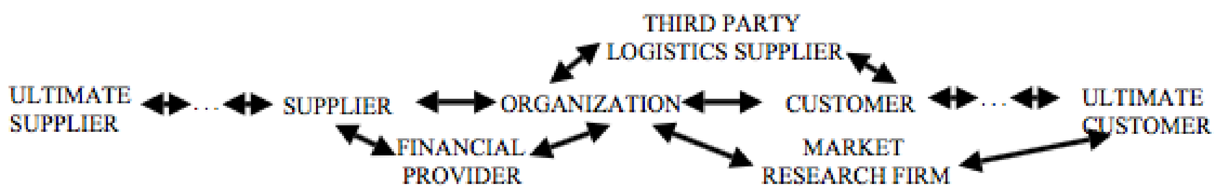

Figure 23: Ultimate supply chain [Mentzer et al., 2001, Page 5]

Effectively and competently managing the supply chains serves as a source of competitive advantage both for the supply chain itself and for all the incorporated firms. How this advantage is achieved is through augmenting both satisfaction and value for the customer. Mentzer et al. (2001) argue that this further leads to inflated profitability [Mentzer et al., 2001].

Among other things, competition increasing on a global scale is described as part of the reason for the recent focus on improved supply chain management. Marinagi et al. (2015) point out the importance of combining new technology with people, as well as tailoring technology for each contributing firm, in order for all to respond as rapidly as possible to customer needs [Marinagi et al., 2015].

Information Sharing (IS) plays a significant role in achieving a successful supply chain management. A product of free-flowing information is escalated collaboration and coordination among SC member firms. Culminating from this is the facilitation of a smoothed material flow in addition to trimmed inventory costs. By making it easier for firms to speed up the flow of products to the market, IS affects the performance of the supply chain positively. It does this by respectively increasing and decreasing customer satisfaction and total costs [Li and Lin, 2006].

The role in which information sharing plays with the performance of the supply chain is a well-studied area. Modernized, ergonomic Information Technology (IT) is a crucial tool for improving the sharing of data throughout the supply chain. If deployed correctly, these technologies could substantially strengthen process coordination among member firms, acting as a lubricant to smooth the performance of the SC. Non-ergonomically designed information technologies may act as an encumbrance for the shareability of data among firms [Marinagi et al., 2015].

Information Quality (IQ) is called a multidimensional concept [Borek et al., 2013]. The multitude of dimensions to IQ makes the term relatively hard to define. Interpretability, completeness, timeliness, verifiability, and accuracy are some of the dimensions highlighted by various researchers (see figure 24) [Marinagi et al., 2015].

Figure 24: Information Quality dimensions [Borek et al., 2013, Page 12]

Marinagi et al. (2015) refer to a constantly updated definition provided by the United States Patent and Trademark Office (USPTO), defining quality as *"an encompassing term comprising objectivity, utility and integrity"* [USPTO, 2019]. The three terms are briefly defined below [USPTO, 2019]:

- **Objectivity** consists of two factors, substance and presentation. The first factor, substance, refers to the information not being biased, and that it is dependable and accurate. How this information is presented, in exhaustive, precise, and non-partisan fashion is the second factor.
- **Utility** means that the information is useful for the intended users.
- Information which has **Integrity** is one which is secure and protected from non-intentional consumers.

The quality of the information shared within the SC is of extreme importance. Naumann (2001) points out information quality to be *"the response time of the Web age"* [Naumann, 2001, Page 247]. Firms within the supply chain sharing incomplete or distorted information is pointed out by a multitude of articles on supply chain management as a significant barrier for productivity. This low-quality data is shared in fear of leaking potentially proprietary and confidential information [Marinagi et al., 2015] [Li and Lin, 2006] [Kembro et al., 2017] [Wu et al., 2014].

Many firms have a built-in reserve for sharing quality information within the supply chain. This is not only apparent when sharing with competitors but perhaps more surprisingly, also when customers or suppliers are the intended receiver of information. Sharing proprietary data, in particular, can feel like a loss of power for certain SC contributors. Firms may purposefully distort information in order to avoid the aforementioned power loss [Li and Lin, 2006].

Li and Lin (2006) point out a set of factors affecting the willingness of firms within the supply chain to share quality information [Li and Lin, 2006]. These factors are depicted in figure 25.

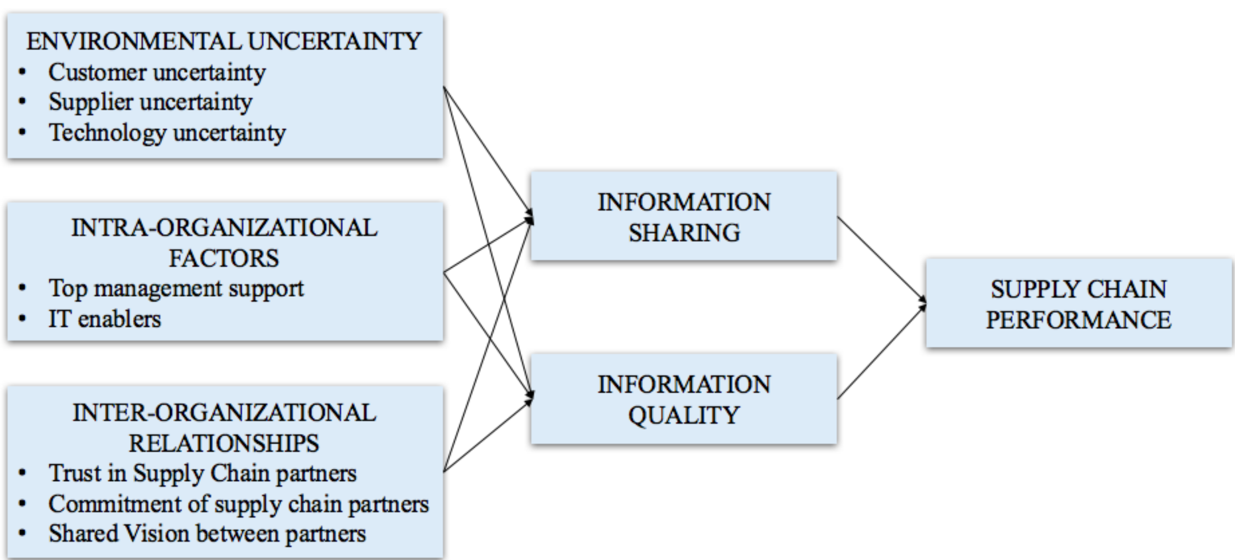

Figure 25: Quality information sharing factors (inspired by figure 1A [Li and Lin, 2006])

There are several critical aspects for allowing free-flowing, quality information within the supply chain. Encouragement, guidance, and vision are needed from senior management within each member firm. Advanced and well-understood information technology implemented within each SC contributor also plays a significant role in both the security and efficiency of information sharing. To conquer the fear of disclosing information within the chain, well-established trust among member firms is pivotal. The higher the degree of trust between the firms, the lower the fear of both information sharing, and the aforementioned power loss. Also, obtaining an inter-organizational vision and commitment towards a shared goal is a valuable tool.

A study involving data from 196 organizations performed by Li and Lin (2006) found inter-organizational relationships and supplier uncertainties to be the most critical factors for information sharing. Problems within these areas will thereby serve as a substantial obstacle for the quality and flow of information within the supply chain [Li and Lin, 2006].

4 Results and discussion

This section combines, for each research area, theoretical framework and results from interviews, tying them to the scope and research question asked at the beginning of this thesis.

Subsection 4.1 draws attention to initiatives for digitalization within both industries by analyzing relevant articles along with information obtained through interviews. A comparison of the two sectors is presented along with a summary. The following subsections, 4.2 and 4.3, starts with an outline of relevant theory and is further divided into three parts: Data from the construction and petroleum industries, comparison and summary. The first part summarizes the results obtained through interviews with firms from both industries. Part two, comparison, points out similarities and dissimilarities between the two industries and the theoretical framework introduced in section 3. The summary emphasizes the most critical aspects of each research area. The comparisons and summaries presented in this section serve as a foundation for the conclusions drawn in section 5.

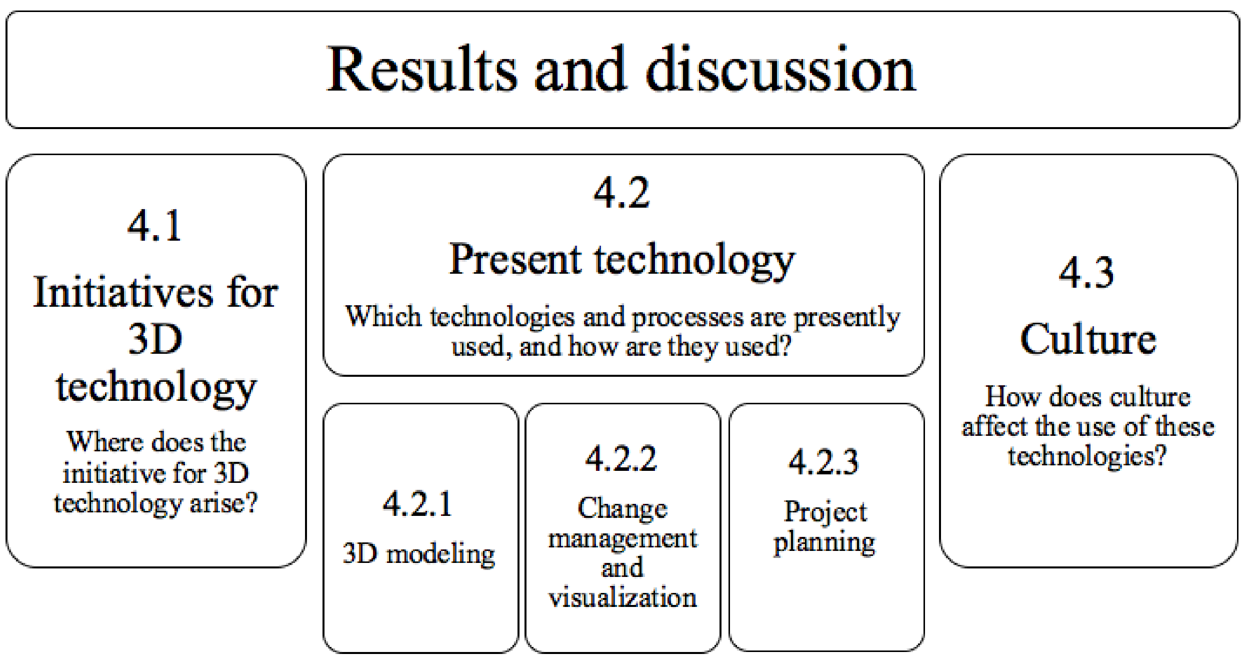

Figure 26: Results and discussion overview

4.1 Initiatives for 3D technology

This subsection aims to create an understanding of where the initiatives for 3D technology implementation arise. The UK has successfully implemented BIM and is regarded as the leading country when it comes to the use of this modeling tool. Where the initiatives for BIM introduction in Britain arose will be used as an example. The introduction of BIM, both in the UK and in Norway, will be analyzed through articles and interviews, respectively. Building on this, articles and interviews from the petroleum industry will create an understanding of where the initiative for 3D technology lies in the oil & gas sector.

The question answered by this subsection is:
Where does the initiative for 3D technology arise?

This subsection will serve as a background for 4.2 and 4.3, as it is useful to obtain an understanding of the factors which drive the use of 3D technologies before moving on to its usage and potential cultural obstacles.

4.1.1 Construction

Whenever a new technology is implemented, it is beneficial to take inspiration from those who have already adopted it with success. In the UK, BIM has been a high priority in recent years, and it has been successfully implemented on a wide scale. It is of interest to learn why and how the UK has taken advantage of BIM and its usage areas.

The government in the UK has made it mandatory to use BIM in construction projects, which forced the entire national construction industry to adopt this technology [BuildingInformationModelingTaskGroup, 2016]. The National BIM Report 2019, published by National Building Specification (NBS), shows the effectiveness of the government's intervention, forcing the use of BIM. The percentage of UK construction firms using BIM has risen from 13% in 2011 to 69% in 2019, as shown in figure 27 [NationalBuildingSpecification, 2019].

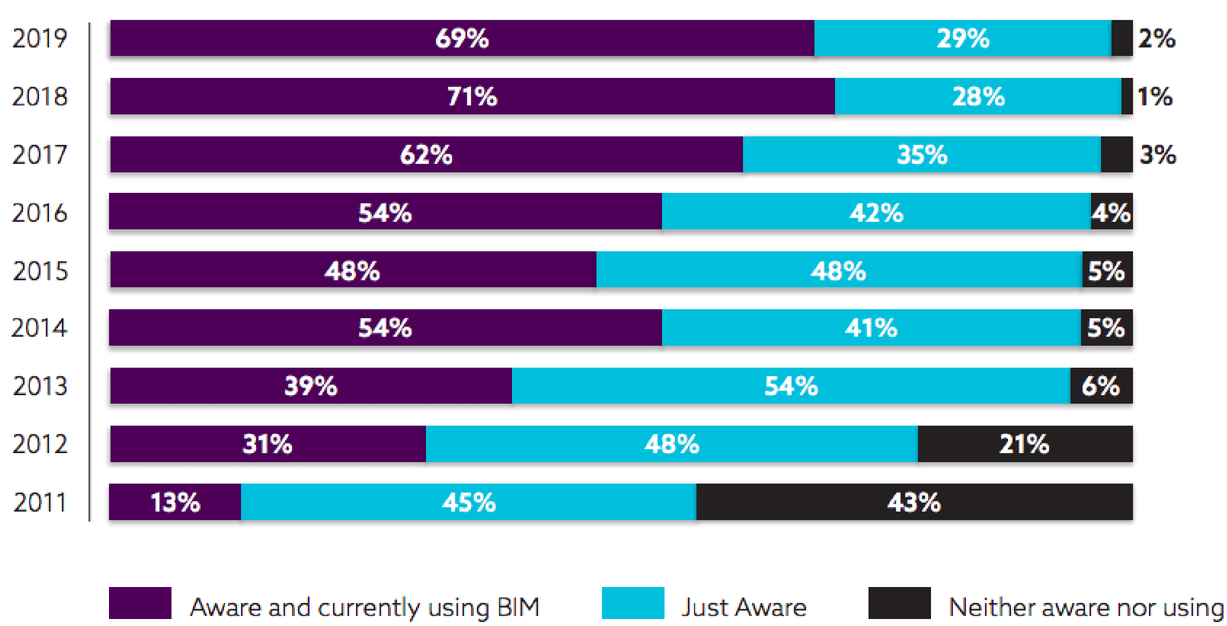

Figure 27: BIM use in the UK from 2011 to 2019 [NationalBuildingSpecification, 2019]

The BIM Industry Working Group was created in 2010 and is supported by OGC (Office of Government Commerce), Construction Sector Unit, and Electronic and IT Services Unit at BIS (The Departement for Business, Innovation and Skills). It includes representatives from the construction sector, their clients, and software suppliers. They developed a strategy called "Push-Pull" in 2011 for the implementation of BIM, and their objectives were [BIMIndustryWorkingGroup et al., 2011]:

- To determine measurable benefits and how they could be implemented to the construction and post-occupancy management through escalated use of BIM.
- To identify how the UK Government, as a client, could affect the widespread adoption of BIM in order to enhance project delivery and operational performance. Especially improvements within areas such as cost, value, and carbon performance.
- Investigate international performance and the US Federal Government's five-year program for encouraging BIM adoption.
- Review the potential benefit of Government policy on BIM to assist the UK consultancy and contractors to advance their solid standing in the international markets further.

BIM is seen as core to help the construction industry to improve both delivery and operational efficiency. The UK government looks at BIM as key to [BuildingInformationModelingTaskGroup, 2016]:

- Enhance collaboration across the supply chain.
- Increase quality.
- Deliver new, digitally built environment services.
- Be conscious regarding security in a digitally built environment.

The UK Government believes that BIM will boost collaboration between the construction sector and software industries, which in turn could lead to synergies for both industries [HMGovernment, 2012].

Britain has a strong position in the international construction market. They have a conservative estimate of £7,6 billion in global exports of construction services. The UK is, as mentioned, a leading nation when it comes to exploitation of BIM. However, it is reported that the benefits of BIM have been noticed internationally, with several nations looking to implement it in their construction market.

Technologies are developing at a relatively rapid pace, and 3D modeling software like BIM is no exception. It is believed that the continuation of BIM development and utilization is a key factor for the UK to retain its international position in the construction sector [HMGovernment, 2012].

It could be suggested that this focus on developing technologies and retaining their position in the market is driven by fear of losing their comparative advantage. The fall of Kodak, as described in section 3.1.2, is one example of how crucial it is to follow the development of new technology. For the UK, not to act and exploit BIM now is viewed as a considerable risk, and the development of BIM is seen as a race which they should not lose. Several factors drive the UK towards increased BIM utilization and development [HMGovernment, 2015]:

- Pressure on finite resources
- The demand for more capacity
- Provide less costly services
- Facilitate far better use of current and future built assets
- Commitment to maintaining their pole position on the global market

As mentioned in section 3.2.5.4, BIM is nearly always involved in lean construction as it improves collaboration and job-site coordination. BIM has dramatically contributed to cost savings in the UK with £840M in 2013-2014. Other nations, such as France and Germany, are trying to replicate similar BIM programs.

Britain has a goal of being one of the first countries to fully exploit the digital era, and they see BIM as a critical element to achieve that goal. A level 3 Strategy for the employment of BIM, described in section 3.2.4, is in focus and the slogan "Digital Built Britain" has been developed. A driver for the investment in BIM is the opportunity for Britain to exploit their ability to sell their technologies and expertise across the world. It is forecasted that the UK will have a share of $15 trillion in the global construction market by 2025 [HMGovernment, 2015].

One of the main advantages that the UK identify with BIM is that during the planning stage, it incentivizes designers, owners, and users to work together. This allows them to create the best design possible and gives them the ability to test them. In the operational stage, the customer has the opportunity to receive real-time information about available services. Also, facility management can obtain correct information regarding the conditions of assets [HMGovernment, 2015].

Many key measures will be used to measure the success of the implementation and development of BIM in Britain [HMGovernment, 2015]:

- Creation of new, international "Open Data" standards in continuation for easy sharing of data across the whole market.
- New contractual framework for projects to provide consistency, avert confusion, and strengthen open and collaborative working.
- Creation of an environment that is cooperative and pursue both learning and sharing.
- Training of the public sector client to implement BIM and aspects such as data requirements, operational methods, and contractual processes.
- Growth and development of jobs in technology and construction, both domestically and internationally.

As mentioned, BIM is highly regarded in the UK, and several countries look towards them for inspiration. Norway is among the countries which have recognized the advantages that follow a successful BIM implementation.

When there is a change in a business model or process, there is always someone or something that works as a catalyst for this transition. When asked about BIM, the interviewees pointed out that the big construction firms were among the first who took the initiative towards the adoption. They designed their contracts with conditions specifying the use of BIM in the project. This forced their contractors to work with BIM if they wished to secure the contract. The initiative from the bigger firms helped advance the technology's implementation from the top. The use of BIM, however, escalated from the bottom. Entrepreneurs and advisors sought solutions and tools that would be able to simplify, streamline, and enhance their work processes. Within the specific companies, it was pointed out that certain employees committed their own time to steer the company towards BIM.

As mentioned, pressure for the use of BIM in the Norwegian construction industry came both top-down and bottom-up. The advantages of this technology were apparent and understood throughout the industry. It was repeatedly expressed that BIM is extremely popular on the construction site, as it makes it easier for the construction workers to do their job. This pressure, both from the top and from the bottom, is a significant reason why BIM has been implemented extensively both nationally and internationally.

The theoretical background for this thesis explains that there are several different maturity stages when implementing BIM technology in a project or company. In the first stage, object-based modeling, the project phases remain linear, as in traditional methods. Meaning that the project first undergoes a design phase, before moving on to construction and eventually to operations. At stage two, the design and construction phases tend to overlap, thanks in part to enhanced collaboration. These maturity stages are explained more thoroughly in subsection 3.2.4.

When asked to point out any apparent change in project phases following the employment of BIM technology, none of the participants meant that this had occurred. Some overlaps are apparent, but mainly thanks to improved fast-tracking efforts, not because of the implementation of BIM. However, they did point out that an advantage obtained from BIM was that it forced designers and engineers to collaborate more effectively at an earlier stage in the project. This is indicative of the Norwegian construction industry being at a late BIM maturity stage 1 or early stage 2. Therefore, it still has a way to go to achieve the same level of BIM adoption as the UK, which is looking into stage 3.

4.1.2 Petroleum

Firstly, drivers for digitalization of the petroleum industry, in general, will be briefly highlighted, before specifying where the initiatives arise specifically for 3D modeling technologies.

World Economic Forum (WEF) undertook a study in 2016 investigating, among other things, what value a digital transformation could have for the petroleum industry. According to the study, a value of $1,6 trillion could be unlocked for the industry from undergoing a digital transformation. This number could further rise to $2,5 trillion, should certain constraints on operations and organizations be relaxed [WorldEconomicForum, 2017].

When discussing which factors could drive the industry towards this transformation, unlocking the profits, three main inter-organizational drivers were highlighted [WorldEconomicForum, 2017]:

- Commodity prices, supply and demand interruptions
- The fast advancement in technologies
- The shift in needs and expectations of customers

The volatility of hydrocarbon prices represents a shift in supply and demand, which is the first inter-organizational driver for digitalization mentioned by World Economic Forum. In the period before the drop in late 2014 (see figure 28), money was flowing in as a result of high oil prices. At this point, the industry had little or no incentives to undergo a digital transformation. However, in these recent times of lower hydrocarbon prices, digitalization has appeared as a part of the solution to lock in a better profit for the oil & gas companies. One of the drivers for a digital oil & gas sector is thus the recent drop in oil prices, which has forced the entire industry to consider investing in digital technologies [IQPCMiddleEast, 2018].

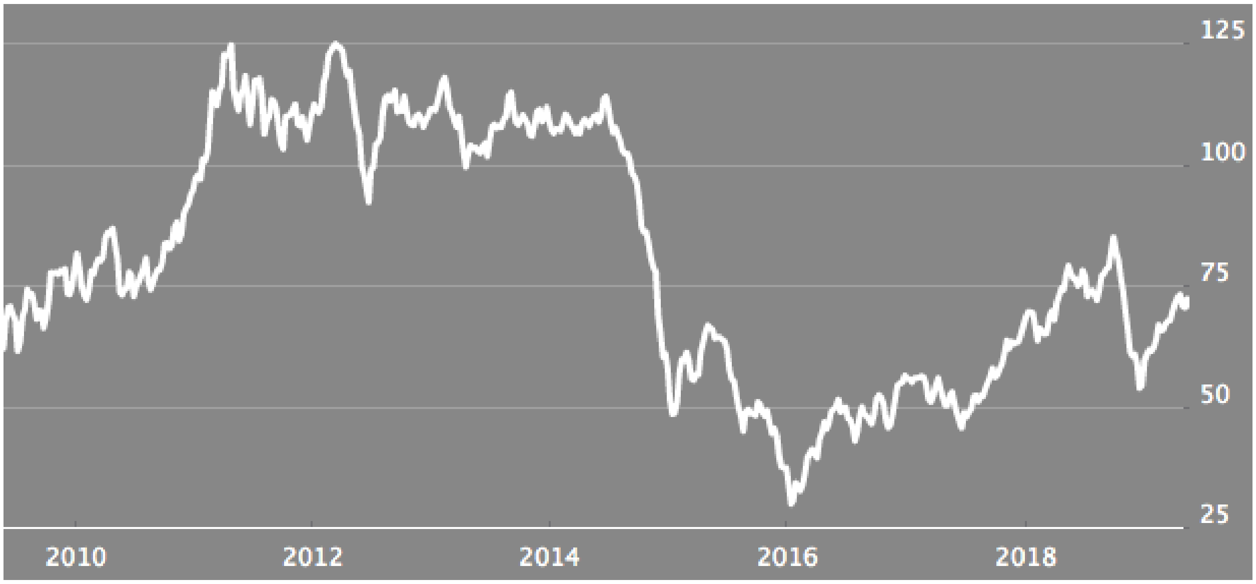

Figure 28: BRENT oil prices in the last ten years [E24Børs, 2019]

The second driver for digital transformation, mentioned above, is rapid advances in technology. Most efforts for digitalization at the time of higher oil prices produced relatively limited benefits. Also, the investment costs were extremely high. Given the marginal returns and high investment costs, it gave the petroleum industry even fewer incentives for investing to go more digital [IQPCMiddleEast, 2018]. Today, however, the recent additional advances in technology have, according to the study by WEF, the potential to unlock enormous profits for the industry [WorldEconomicForum, 2017].

In addition to the technology advances potentially producing huge profits, it also changes how the firms interact with the customers. Customer service expectations have changed with developing technologies. This, along with an increasing focus on green industry and sustainability issues, has also helped shift the focus towards digitalization [WorldEconomicForum, 2017].

Outdated regulatory frameworks can act as an obstacle for the digital transformation of the oil and gas industry. Governments and policymakers, in collaboration with broader society, should thereby, consider reforming these frameworks in order to help the industries on the path towards more digitalized businesses [WorldEconomicForum, 2017].

Moving on to incentives for 3D modeling specifically, it became apparent from interviews that corporate management often receives schooling of what technologies are available in the market, and which could soon become apparent. They are perceived to be well oriented regarding possibilities for driving the firm to adopt new digital tools, like 3D modeling. However, further down in the hierarchy, there is little schooling on this subject. Individuals taking the initiative and investing their time in learning new processes and technologies are aware of the possibilities. Within Equinor, these key characters, rather than management, were pointed out to be the main drivers for digitalization efforts, such as 3D technology. Through using their networks and holding presentations, they attempt to help the workforce realize the possibilities technologies like 3D modeling can bring.

Cutting costs is mentioned as one of the main drivers for digitalization of the petroleum industry. However, it was highlighted that when it comes to 3D modeling, this is not the highest priority. The main focus is on making operational management, change handling, and project planning more straightforward, through the use of virtual models. The main initiative for advancing 3D technologies within the company was, therefore, not because of cost-cutting. Instead, it was because of the enhanced understanding and communication efforts arising from using the 3D models in the processes mentioned above. This is partly a product of advancements in technologies, making it easier to communicate and visualize, the second driver mentioned by World Economic Forum. However, with regards to communication, there is still a problem of lacking interoperability between 3D modeling software in the petroleum industry. This concern will be examined in further detail in section 4.2.1.

Given the size of Equinor and the vast amount of different disciplines working within the company, not everyone will need to incorporate 3D technology in their work processes. However, they should still be aware of what technologies are available and used in the company. Information specifically regarding the benefits and usage areas of these 3D modeling tools does not need to reach all disciplines, only the relevant ones. In Equinor, the most appropriate uses for 3D were highlighted to be change handling, operational management, and project planning. 3D technology in Equinor is relatively advanced and could be used for the aforementioned processes. However, there is an inadequate awareness regarding how far the technology has advanced and for what it can be used. Employees working within change and operational management and project planning are mostly unaware of how the 3D models could potentially be used to improve their work processes. This could be as a result of lacking initiatives from both management and lower level workers, paired with insufficient information flow. Both insufficient awareness and lacking information flow will be examined more thoroughly in sections 4.3 and 4.2 respectively.

There is a lack of initiatives for implementing 3D technology further down the supply chain from Equinor. Contractors and subcontractors are often hired on contracts which allow them to log more hours, which in turn makes them able to quote a higher price for the project. This lack of initiative for cost and time cuts is one of the major obstacles for implementing new technologies or software for Equinor.

4.1.3 Comparison

It was pointed out that certain committed individuals within Equinor were the main drivers for increasing the use of 3D modeling software. This is recognizable from BIM implementation, where the same point was highlighted. Key individuals in the construction industry took the initiative for implementing BIM as they had realized its advantages and possibilities.

Part of the reason why BIM has been implemented on such a wide scale is that benefits from its introduction were apparent on all levels, from governments to entrepreneurs to contractors. The UK has been able to take advantage of BIM and the benefits that follow, which has lead to a pole position in the global construction market. It has, therefore incentivized the government to retain their position as it gives benefits to both the country and local construction firms. This is comparable to the situation in Norway, where it is economically beneficial to continue with oil production. It would be of value for the country as a whole to be able to take advantage of technologies that could give comparable benefits. Representatives from Equinor highlighted that the company is leading within 3D technology in the petroleum industry. Therefore, it could benefit Equinor to advance their competencies in the area further. Being in the pole position within 3D technology could reap benefits in the same way that the UK has seen profits from its leading position in the construction market.

Governmental influence in forcing industries towards a digital transformation is mentioned both in construction and petroleum. By changing policies and regulations, the government can ease the implementation of new technology. An example of this was apparent in BIM implementation, where the UK government forced construction companies to employ BIM. In the Norwegian petroleum industry, Equinor is a large company. The power that resides with them as a result of that can be used in the same way as the government did in the UK. Should Equinor demand the use of more advanced 3D technology, their contractors could be forced to follow their lead.

Even though Equinor is a large company in Norway, they are not as big on an international basis. To achieve international interoperability, many of the influential petroleum firms would need to cooperate in order for them to work in the same way as the government has in the UK.

A key point is that the petroleum industry is highly international, especially when it comes to the construction of platforms. 3D models can as mentioned, help make communication easier among project participants, through better visualization efforts. The resulting benefits will especially help when interacting over vast distances and often not in the participants' native language.

3D technology like BIM would largely benefit the contractors, which use the software for either design or engineering or both. Apparent from both theory and interviews regarding BIM implementation, is that the technology reduces wasted time and extra costs. This is achieved by ensuring that the foundation for construction is as good as possible. Clash detection software and visualization efforts are examples of BIM functions, which respectively reduce costs and improve communication.

For the contractors, things run more smoothly with the use of BIM technology. They reduce both the time and costs associated with their work and improve intra-organizational communication and collaboration. As a result of these cuts, they can offer a lower price than they could without BIM, in addition to being able to complete their part in a shorter amount of time. The savings propagate throughout the supply chain, up to the owners.

Savings from contractors could benefit Equinor in the same way that it benefits the owners in the construction industry. Even though cost cuts are not the main priority for Equinor's 3D modeling efforts, it is still one of the benefits. The reason being that the reduced costs for the contractors could result in them ultimately being able to undertake the project for a reduced price. Resulting from this could be reduced costs also for the companies above them. Therefore, with the power which Equinor has in the Norwegian petroleum market, there is little reason for them not to consider using it to a higher degree. However, mentioned in the interviews was that there is a potential problem with convincing contractors to streamline their processes. With the contract form customarily used, the more hours they spend, the more they get paid. Thereby, there is a lack of initiatives from the contractors to use more advanced time and cost saving technology.

4.1.4 Summary

The realization of potential benefits to be reaped from BIM implementation, increasing pressure to lower construction costs, finite resources, and capacity limitations drove the implementation of BIM both in the UK and in Norway. This lead to pressure both from high levels such as government and lower level individuals within each company. The perceived benefits acted as incentives for all levels of the supply chain to take the initiative towards the use of BIM. As a result of this widespread positivity towards 3D technology, it is now widely implemented and used in several nations around the world. In Norway, international pressure from countries like Britain also helped the firms take initiatives towards employing BIM technology. The main reason for employing more advanced 3D modeling software in the petroleum industry was highlighted to be the use of these models for improved change management, project planning, and operational management efforts. The widespread understanding of available technologies and their associated benefits, which helped BIM succeed is not apparent in Equinor. Many are still unaware of the advances of 3D technology within their firm, even though it could potentially help improve and increase efficiency in their work processes. Equinor could learn from the way BIM has become as extensively adopted in the construction industry by sufficient realization and information of what benefits accompany its implementation.

Within Equinor, it was pointed out that corporate management is informed regarding new technology advances, like 3D technology, and their associated benefits. This information is rarely passed down the hierarchy, resulting in a lack of awareness of these technologies in large parts of the company. It would be of great value to properly inform employees about the digital technologies implemented if they are to take advantage of them. Individuals taking the initiative towards adopting new technologies and processes is a massive part of what drives the companies towards digitalization. BIM in the construction industry and with 3D modeling in petroleum are examples of this. In that regard, they are pretty similar. Initiatives from these individuals do not seem to be sufficient in order to drive the company to go more digital. Thus, corporate management also needs to pass on the information they are given.

The petroleum industry can, as mentioned, look at the successfulness of BIM implementation as an example. All members of the supply chain embraced the technology. The lack of incentives for contractors to utilize new cost-saving technologies is an area which should be addressed. One of the significant reasons why BIM implementation was so successful, both in Norway and the UK, was that the pressure driving the companies towards BIM was coming both from the top and from the bottom. This is still lacking in the petroleum industry. Contractors are combating effectivization, through the utilization of more advanced 3D technologies, to be able to log as many working hours as possible.

In Norway, Equinor is a considerable part of the national petroleum industry. They possess a lot of the same power which the government in Britain used to incentivize BIM usage. This power can be used to help force the implementation of new technologies in the Norwegian petroleum industry. As oil & gas production is a considerable part of Norwegian GDP, the country could reap benefits from seeing Equinor's profits rise. The Norwegian government would benefit from making it as easy as possible for Norwegian oil companies to implement new technologies, like 3D modeling. No construction firm in Norway is as significant for the national construction industry as Equinor is for petroleum. They are in part reliant on the government, or a collaborative effort from national construction firms, to force through efforts like Building Information Modeling. However, given Equinor's influential position in Norway, they can act in the same way as the government does for many other industries. They should look at the benefits the UK government obtained through being leading within the use of BIM. Using their influential position in Norway, they could reap similar benefits from forcing their contractors to introduce potentially cost- and time-saving tools such as 3D technology.

4.2 Present technology

This subsection is split into three main research areas: 3D Modeling, Change Management and Visualization, and Project Planning. Relevant theory is first presented as an introduction to each research area before results from interviews with both the construction and the petroleum industry are analyzed. These results, in addition to the theory, will form the basis for the comparison. Finalizing this subsection is a summary of the most critical points highlighted in the comparisons from the three research areas.

This subsection will aim to answer the following question:
Which technologies and processes are presently used, and how are they used?

4.2.1 3D Modeling

Interoperability is a point mentioned as one of the challenges for BIM. Talebi (2014) argues that certain BIM software suppliers offer the possibility of information exchange between their products, but not with competing software suppliers. There are two possible solutions for achieving interoperability, according to the theory. The first is that everyone works in the same program. The second is having all project participants working in a shareable openBIM format such as IFC. BuildingSMART has developed a standard called Industry Foundation Class (IFC), in which heterogeneous applications can communicate. Also highlighted in the theoretical background for this thesis is that there could be a reluctance from certain firms to share proprietary data, as this is a source of their competitive advantage.

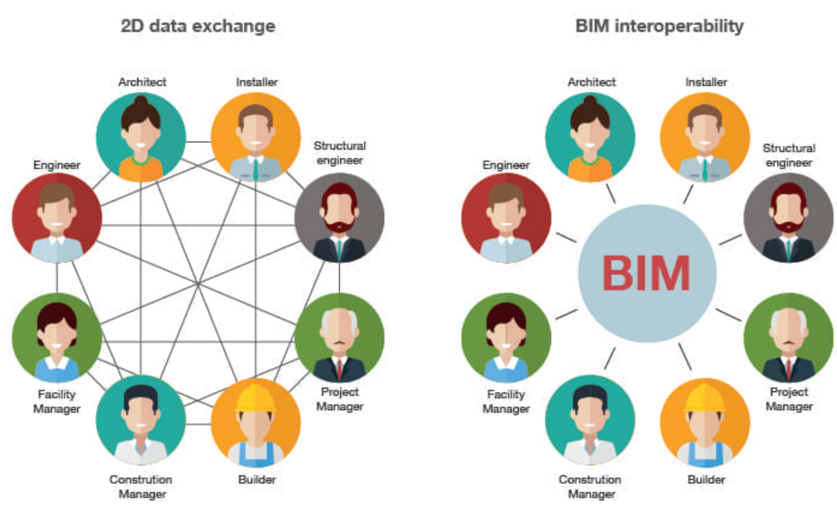

Figure 29: Interoperability [BibLus, 2017]

Improved quality of facility management through the FM teams obtaining a finished model of the building is mentioned as an advantage of BIM. The maintenance and material data can be incorporated in the model, easing the job for the FM team. This information is readily available once the operational management of the finished building commences. Also, when employing an Integrated Project Delivery (IPD) delivery method, facility management is involved in the design process. IPD is described as the long term goal for BIM implementation.

The sharing of information is an essential aspect of every phase of a project. Excellent flow of information within the supply chain, will, as explained in section 3.3, result in the SC running smoothly. Li and Lin (2006) pointed to several factors affecting the willingness for information sharing within the chain. Both intra-organizational (IT enablers and senior management support) and inter-organizational (trust, shared vision, and commitment) along with environmental (supplier, customer, and technological uncertainties) aspects affect the information flow. However, the quality of the information shared is even more important than the quantity. Many firms purposefully distort or share incomplete information, in fear of leaking proprietary data to competitors. Numerous researchers highlight this problem. BIM theory also mentions problems regarding the security of data shared among project members.

Ståle Tungesvik (2018) points out that the petroleum industry has to be able to share data on applications where everyone can communicate if they are to take full advantage of the opportunities that Big Data and Artificial Intelligence has to offer.

4.2.1.1 Results from interviews

4.2.1.1.1 Construction

It was highlighted in the interviews, that hired engineering and designing disciplines are required to communicate through an IFC-standard. The consultants can thereby use whichever program they so desire. In contrast to theory, there was no indication of any restrictions as to which BIM software products could communicate with each other. The reason for which being that a standard part of the employed contracts is that the modeling programs must be compatible with IFC. A possible reason for the contrast to the theoretical framework is that the firms interviewed operate solely in Scandinavia, whereas the theory internationally based.

There seemed to be no reluctance from any subcontractors hired by the interviewed firms to share data, and no mention of worries regarding the security of the data shared. A significant rise in the quality of services provided by contractors in the last years was mentioned. The respondents did not point to BIM as the primary cause of the recent quality surge. It is mostly a result of heightened general requirements for the models provided by the subcontractors. They need to be logical and coherent in three dimensions, which was not always the case when two-dimensional drawings were utilized. BIM technology has served as an essential tool to ease the process of making these higher quality models but is not the main reason for the improvement.

Even though using the model for facility management purposes is a possibility, and is highly recommended by BIM theory, it is not widely practiced. It was mentioned as a point in which the construction industry was lagging behind other industries. The owner of the project can require an "as built" model, along with requirements for what this model should include. However, many owners only request the model used for construction purposes and have no clear plan for how to use it. A few clients have stringent requirements for what information should be incorporated into the model. They have a detailed plan for how to use the data for facility management purposes. The degree to which the model is utilized for FM is therefore highly varied, and is not yet commonplace, as mentioned. Once the project is finished, the model is usually the property of the suppliers responsible for the design or engineering, unless specified otherwise in the contract. The entrepreneur keeps a copy of the model, but it is the property of the subcontractors.

4.2.1.1.2 Petroleum

In the petroleum industry, there are two software applications in which it is possible to design a platform. The two have split the market in half, and none of them are likely to be open to discuss a standardized format making it possible to work across the applications. This goes against what Ståle Tungesvik (2018) mentions about being able to share data with everyone in the industry and serves as a hindrance to take advantage of the technological developments fully. Highlighted in the interviews was the need for uniformity as a solution to the market split. However, there might be a need for government to intervene in order for this to happen. They have more power over the market than the companies themselves. The respondents also pointed out that the Norwegian companies are slightly more advanced when it comes to 3D modeling than most of their international counterparts. Standardization efforts are also somewhat impeded by the difference in 3D modeling technology progress within the industry.

The importance of the modeling application's capability to import and export IFC formats was pointed out. They could not make any offers on public contracts in the UK if they were not able to use this format. Without this requirement from the UK government, their application would not have been developed to import and export IFC. However, they cannot alter the imported IFC files. They are used purely for visualization purposes.

Concerns were expressed regarding the difficulty of getting their contractors to share information with them. These worries are especially apparent in subsea projects, where parts are highly specialized. Information sharing in these projects could lead to competitors obtaining the designs of critical parts and reverse engineer them. Increased market competition and more capital at stake have made the sharing of potentially proprietary data more difficult in the last years. It is harder to get contractors to share data today than it was 20 or 30 years ago, despite more advanced technology.

Petroleum operational management teams use the 3D models to plan efforts for change handling. In addition, they are used to organize precisely how this change should be managed. All platforms used in their operations have a virtual twin, even ones constructed decades ago. The quality of the models, however, varies. Equinor does not partake in the design process but performs the initial planning. When it comes to maintenance of the platforms, there has been a shift in recent years, from planned to condition-based maintenance. This means switching from replacing a component at certain time intervals, to replacing them when they are about to break, or is in poor condition. Condition-based maintenance is more cost-effective but can be viewed as riskier, as parts are not replaced until deemed to be unable to carry out its intended workload. The condition of the components on the platform is monitored by sensors, which continuously report variables such as temperature, pressure, and vibrations. However, at present, this information is not incorporated in the digital twin but will be, according to the respondent, in the not too distant future.

3D modeling is something that has been in the works for years in Equinor. However, they have only recently begun to put a real focus on the models and their, current and possible future, applications. It was stated that this is one of the first steps towards a digital transformation of the company. The technology available to create and use the oldest 3D models were both expensive and required vast amounts of computing power. The recent advances in the capacity of modern computers have made this problem less and less relevant. The digital twin of a platform can now be shown and used on hand-held devices such as phones or tablets. Also, the computers used to create the models are both cheaper and have far more computing power and storage. With the recent focus on the digitalization of all processes and areas, including 3D technology, it is predicted that the use and applications of the models will accelerate.

4.2.1.2 Comparison

The number of buildings constructed far exceeds the number of platforms. In general, platforms are far more complicated and incorporate more information than an average building. In addition to the platforms being very complex, they are often highly original. Requirements for different platforms can be radically diverse. Several original buildings are made as well, but in general, construction is more repetitive with regards to designs and solutions. An indication of the higher degree of complicatedness of the platforms serves the fact that there are only two software applications, available today, capable of modeling a platform. However, there are many capable of modeling a building. As mentioned before, these two applications have split the market in half and are content with their 50% market share. Any negotiations for a standardized, interoperable format is then highly likely to be shot down by these two duopolists. This is profoundly contrasting to the situation apparent in the construction industry of today. The IFC standard, which is now widespread, allows heterogeneous applications to intercommunicate effectively. It is so widely prevalent that it is a part of the standard contracts between entrepreneurial firms and their subcontractors. What the construction industry has achieved through IFC is in accordance with the theoretical section. A shareable and standardized format is referred to as the solution to solving problems of lacking interoperability. At present, the solution adopted by the petroleum industry only partially solves the problem. They can only communicate with the market half using the same software. This could prevent them from gaining the full benefits of 3D modeling technology.

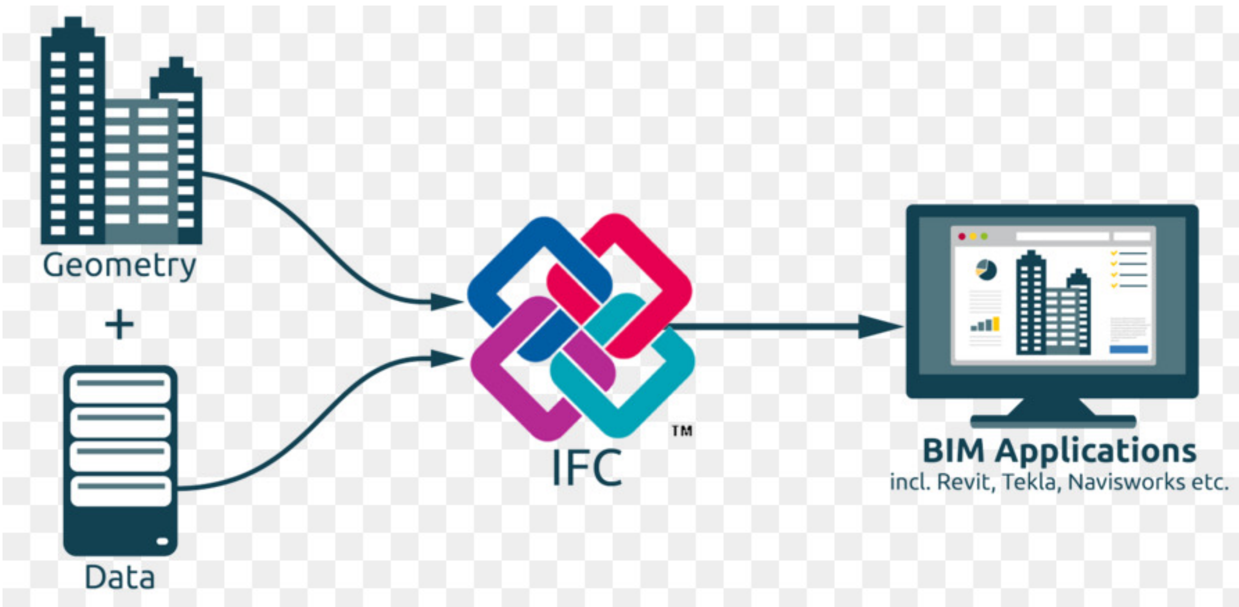

Figure 30: IFC standard [BIMcommunity, 2018]

The theory highlights that the sharing of potentially proprietary data between different firms involved in a project could serve as a hindrance for BIM. Also, having free-flowing quality information within the supply chain is pointed out in section 3.3 to boost productivity, coordination, and collaboration. Firms may feel a power loss resulting from the sharing of proprietary data, as it can result in a worsened position in the market. Mentioned earlier was that no difficulties with data sharing were pointed out from the interviewed construction firms. In the petroleum industry, there seems to be a prevalent problem of consultants not wanting to share data with the project owner. The reason being that many of the parts utilized, especially in subsea platforms, are highly specialized. There is more effort, technology, and proprietary data incorporated in a platform than in an average building. The fear of losing competitive advantage, through a potential leak of confidential data, seems to be prevalent in the industry. This is stopping the flow of quality information between the collaborating firms.

A part of the definition of IQ is that it needs to be presented exhaustively, meaning that all the data needs to be bestowed. This is the point in which information sharing in the petroleum industry seems to be lacking. Modeled parts are shared among the collaborators, but the information is not complete, as the technology incorporated in the parts is not shared. Simulations run by Equinor are thereby less accurate than what they could be. A reason for the problem is that there are no incentives for contractors to share this information. They do not profit from sending proprietary data to the operating companies; they only obtain more risk. The result is that they will not do it unless forced.

There is still much work to be done in terms of achieving full interoperability when it comes to the construction of platforms. The current duopoly in the market for software applications will be a hard nut to crack for the industry. Government influence, such as the one requiring the use of IFC in the British construction industry, might be the only feasible solution to the problem. However, as petroleum industry firms generally operate more internationally than construction firms, government influence might not have the same effect. Also, there is a lot of proprietary, sensitive data, which is not easily shared even if it is made possible by a standard format equivalent to IFC.

For operator companies, the more information made available for them by their subcontractors, the better insight they get. Simulations are also more trustworthy when the information inputs are as accurate as possible. As per today, Equinor chooses subcontractors who employ the same software as them, as effective communication with companies employing different applications is not easily achieved. Should the industry realize interoperability between their 3D modeling software, as construction has done, the operating companies would have more subcontractors from which to choose. As a result of the increased diversity, there could be a higher pressure on subcontractors to share sensitive data as the market competition increases.

Facility management should, according to BIM theory, be incorporated in the design process for optimum exploitation of the advantages which can be reaped from the modeling tool. Also, once the model is finished, it should be handed over to the FM team for them to utilize. This is, per now, not something which is widely practiced in the construction industry but does occur with some clients. As mentioned, it was a point in which the firms interviewed felt that the industry was underdeveloped.

In petroleum, however, operational management (equivalent to FM) uses the digital twins of the platforms to plan maintenance and necessitated changes. Equinor has a specific plan for how to utilize the 3D model after the project is finalized. This ranges from maintenance to handling changes to the platform. In the construction industry, this is not presently prevalent. They often keep a copy of the model but usually have no plan of how to use it after the building process is finished. The model can, according to theory, incorporate all material and maintenance data. Should facility management obtain a model of the building, it could serve as a stepping stone towards cost-saving condition-based maintenance, like the petroleum industry has started implementing.

The model created for the platform is kept by Equinor and works as a HUB which is updated once a day with the changes made by the contractors. This secures a model which is always up to date, ensuring that the information available for all project members is always correct. The theory highlights a potential problem with a lack of trust in the model, with project participants not knowing for sure if the information in their model is neither current nor precise. In the construction industry, this is normally solved by trusting team members and having excellent communication, but there is no way to know for sure. Employing the same HUB system as Equinor could remove some of the doubt reported. A model containing continuously renewed information is imperative for exploiting it in maintenance and change operations.

3D technology has, in recent years, become way more available than it was just a decade ago. Programs that traditionally would take a large, powerful computer to run can now be run on devices such as iPhones, Androids, and iPads. The availability increase of this technology is predicted to take the petroleum industry by storm on a large scale. The use of 3D will not be limited to having virtual twins but will spread to all different departments and disciplines throughout the firms. This is something already seen in the construction industry. BIM is used in most processes, from design and engineering to visualizing changes and cost estimation, among other things. There is a usage area for 3D technology in many parts of both construction and petroleum firms. Perhaps not directly, but indirectly through employees obtaining a better understanding of the size, complexity, and technological difficulties of the project.

4.2.2 Change management and Visualization

One of the advantages of BIM, highlighted by Hardin and McCool (2015) and Eastman et al. (2011), is improved change management. They point out that handling changes in the virtual model is far less costly than on the construction site. In addition, changes are updated instantly in the model, along with material quantities and cost estimates. Changes are also far more easily communicated to stakeholders through three-dimensional visualizations than with traditional methods. A remaining challenge highlighted by Smith (2014) is a potential lack of trust in the model, with participants fearing that the model they have is not up to date. Eastman et al. (2011) and Ghaffarianhoseini (2017) also point out that legal issues could potentially arise from disputes regarding who is responsible for the quality and accuracy of the model.

Visualization, according to the theory, is useful for way more than merely being a tool for handling change. One impact of improved visualization is creating a better understanding of what is to be built, both for the client and the project team. Augmented reality (AR) is a tool mentioned which could help boost visualization techniques. AR bridges the gap between the real world and the virtual one, combining these two environments into one.

Collaboration is highlighted in theory as both an advantage and a potential challenge for BIM. If employed with the correct project structure, where all stakeholders are collocated and can discuss solutions in an innovative environment, BIM can lead to improved collaboration. Eastman et al. (2011) explain how BIM can be at a disadvantage for collaboration as well. They point to an example where one of the project participants (e.g., the architect) does not employ BIM technology. The model would then need to be created based on two-dimensional models, possibly resulting in the model lacking in coherency and detailing.

4.2.2.1 Results from interviews

4.2.2.1.1 Construction

In total agreement with each other, respondents emphasized that BIM is not necessarily altering how change is handled in the project. They pointed to visualization as an essential tool for communicating and discussing changes. The ability to visualize the exact location, extent, and impact of the change in three dimensions is one of the significant advantages pointed out by the interviewees.

Answering the question of how they assured that the model was up to date, the respondents were quick to point to good and effective intercommunication within the project team. In addition to collaboration by proper communication, a fair degree of trust in the rest of the team is also needed. It was highlighted that a model maturity index was employed in order to get an overview of the quality of the model. When a part of the model is finished, it is signed by the person in charge of that section. This acts as a proof for the other participants that the part is completed. The legal issues regarding the responsibility of the quality of the model, pointed out in the theoretical background, were not mentioned as a problem.

When asked about the advantages of BIM employment, the interviewees highlighted visualization efforts. The main advantages they see of these efforts are improved ability to explain solutions and that they obtain a unified understanding of the end product. It was also explained how popular BIM was at the construction site because the relevant information is more accessible than previously. The improved understanding has also lead to savings in both time and costs. As mentioned earlier, the interviewees have pointed to visualization as a significant advantage of BIM. Augmented reality technology, like HoloLens, has been experimented with in the industry, but as yet it has not proved to provide sufficient advantages to merit further use. Limitations with regards to file sizes were mentioned as a drawback. However, it was viewed as an auspicious tool for the future, once the technology has further evolved.

The interviewees did not think of BIM as the main reason for improved collaboration. They thought of it as a tool to improve communication and teamwork within the project. The ability to show the different solutions in a three-dimensional perspective helps give all team members improved understanding of the scope of the project. By ensuring that everyone is on the same page, it uncomplicates project intercommunication. It was pointed out that at the level in which BIM has been implemented in the construction industry today, there are no remaining problems concerning consultants not using BIM. It is now a standard part of the contracts.

4.2.2.1.2 Petroleum

The digital twins of platforms in Equinor undergo constant changes. Even before construction begins, updates are done. Everyone working in the software can make changes to the model, and the changes are updated every day. The information is, therefore, accessible to all project members and can be used for visualization efforts. Also, 1- and 2-dimensional data, referring to specifications about parts and sections respectively, are available. The 3D model incorporates data about all the parts in the platform, for example, valves or pipes. In addition to obtaining information about the part, it is also possible to extract information like the pressure in the valves, what and how much flows in the pipes, what temperature it is and so on. This is thanks to sensors which continuously record and report the data.

The contractors deliver progress reports once a week during the construction phase. While the platform is in operation and producing oil, it might be necessary to shut it down, for modifications or maintenance temporarily. When this happens, the progress is updated every day.

The 3D designs of oil platforms are often used as a visualization tool for employees to familiarize themselves with the platform structure and placements of different components, even before they go offshore. In addition, visualization is often used by operational management to plan before making changes. The platforms are often modified both before and during their building process. Therefore, visualization is a valuable tool for ensuring that these operations run smoothly. A highlighted drawback of the visualization efforts is their inability to capture the real size of objects in the model. Augmented reality has recently been adopted in the petroleum industry, with the primary usage area being checks to see if the virtual model is indistinguishable from the physical platform. Also, it is used to monitor design changes and evaluate both the quality and progression of the design. Visualization is not mentioned as a tool used in the planning phase. This will be further explained in 4.2.3.

There seemed to be conflicting thoughts on the use of 3D models for visualizing changes. A representative from the 3D modeling department mentioned this as a significant advantage to 3D technology. Another representative expressed that in his department, the models were not used for visualization at all, even though it could prove an effective tool.

VO (Variation order) is a tool often used to request a change to a platform. Both Equinor and their subcontractors can issue a VO to request a change. If Equinor initiates a VO, they specify what they want to change and receives feedback about how much this would cost. They then decide whether they still want to make the change. If the contractor initiates a VO, it opens up a debate about whether or not the change is necessary, if it could have been foreseen, how much it would cost and who should cover the added costs. They try to prevent changes overall, due to the challenge of predicting its effect. Many potential changes might seem like a good idea to begin with but might have unforeseen negative effects. A mentioned point of improvement was to be better able to visualize and see the effect of a change. Especially in cases where the effects are challenging to interpret.

Changes are not a problem in themselves, as long it is possible to foresee their full effect. As of date, there is no clear way to make such predictions. If the changes are to be adequately visualized in order to increase understanding of their effect, they would have to be incorporated in the 3D model. The modeling of said changes would take many engineering hours, incurring a cost for Equinor. As a result of this, visualization is, per now, not utilized to show the effects of changes. The company would then, in some cases, be paying to visualize a change which might not be implemented.

4.2.2.2 Comparison

Visualization as a tool to communicate changes, in order for the full effects of the change to be understood, is used to a higher degree in the construction industry than in the petroleum industry. The visualization does not necessarily need to incorporate the change but can be used to show where the change is, and which sections could be affected. Using the models for this purpose seems to vary from department to department in Equinor. This demonstrates that even though the technology is present and available in the firm, it is not utilized to its fullest potential. Representatives from different departments do not seem to know what technology and solutions are utilized elsewhere in the company. This might be a result of lacking collaboration and intercommunication within the firm. It is in stark contrast to the construction industry, where BIM is highly implemented, and there is a common understanding throughout the firm of what BIM is, and the advantages it brings. There could be some learning available for Equinor here. They could benefit by better communicating advantages and availability of the technologies they possess. Visualization of changes could benefit several departments, and help to increase the use of technologies already implemented. Most technologies need considerable investment. The more they are used, the higher the return they get from this investment.

It is mentioned that, in construction, there can be a lack of trust in the model due to uncertainty about how updated it is. In order for the construction firms to be sure that a section is updated with correct information, it needs to be manually signed off. Unless this is done, there is no way to know for sure whether the section contains accurate data, without contacting the person in charge. This problem is also highlighted by Smith (2014) in theory. The petroleum industry has solved this with the HUB system, where the model is automatically updated every day. This has removed doubts regarding the accuracy and completeness of the model.

4.2.3 Project planning

Mentioned repeatedly, in the theoretical background, is the improved quality of the planning process, through advanced understanding of the end product before construction commences. The theoretical foundation also explains the 4$^{\text{th}}$ dimension in BIM, time. Among other things, the time dimension allows for simulations of what the building should look like at any given time in the project. Solar simulations and construction sequencing are also achievable through BIM. The fabrication of components directly from the 3D model is feasible. This improves the fabricators understanding of what their parts are used for, and where they are used. Potentially resulting from this is improved component quality.

Several delivery methods are explained in section 3.2.2. Design-Bid-Build, Design-Build, and Construction-Management at Risk were mentioned as the three most commonly used methods. In the DBB approach, design and engineering are done separately in a linear fashion, where the design is finished before the engineering is applied to the model. When employing a Design-Build delivery method, the firms doing the design and engineering are contacted as a single entity and gives an estimate of cost and time to undertake both tasks. Construction-Management at Risk entails that the construction manager is employed as a consultant, working with the rest of the team throughout the design and engineering phases. Having collocated designers and engineers eases the creation of a quality BIM model. Accordingly, the DB and CM-at-risk methods are highlighted to be the most suitable for the modeling software. Utilizing linearly based methods will, in general, abate the advantages BIM offers.

Among others, Azhar (2011), Eastman et al. (2011) and Kensek (2014) all point to the cost estimation feature as one of the significant advantages of BIM. With material quantities and unit prices being updated continuously, the cost estimate obtained through BIM becomes increasingly accurate as the model is formed.

Clash detection, or collision detection, is pointed out repeatedly in the theoretical part of this thesis. Objects modeled twice or in the wrong place are detected by the software, which checks the entirety of the model for both inter- and cross-disciplinary faults. Savings from this detection are not only costs and time, but also potential legal disputes and quarrels between different project team members.

4.2.3.1 Results from interviews

4.2.3.1.1 Construction

It was highlighted that BIM is utilized in a varying degree, and which phases it is most used in also varies. Some projects employ robotized production directly from the BIM model, in accordance with theory, while some only use BIM to generate 2D drawings. The main usage area for the model is generating drawings and visualizations more effectively. As a result of this, BIM is most commonly used in the planning phase. This is where the benefits of using the technology are most easily observed.

Even though there has been a considerable improvement in the planning process the previous years, there was skepticism among the respondents with regards to if this was by virtue of BIM technology. Justifying this skepticism, it was pointed out that the entire planning process has developed considerably, independently of BIM. As a result of intensified market competition, there is further pressure on the companies to plan more effectively and to achieve satisfactory results on the initial attempt. These new market conditions have challenged the entire industry to employ more time and cost effective planning solutions. It was mentioned that BIM, as a tool, was used for conceiving improved solutions within a shorter timeframe. The model acts as a tool to achieve the goal of a more streamlined planning process. It is used both as an effective communication tool and for producing cost estimates. In conclusion, it was highlighted that BIM is not the triggering factor for more effective planning processes, but acts as a catalyst for achieving it.

4D simulations were identified as the significant difference BIM had brought to the planning phase. It was pointed out to be a radically dissimilar way of visualizing, communicating, and following up the project plan. 4D simulations are on the rise, being employed at an accelerated rate in the projects undertaken. Previous planning efforts were made in the form of Gantt-diagrams, an outdated method which has been used unchanged for decades. It was highlighted that Gantt-diagrams are extremely difficult to communicate. Even workers with substantial experience sometimes struggle to understand them.

There were differing responses concerning cost estimation. As they needed a price quote relatively early in the project, they rarely use the cost estimation software in BIM. Instead, they rely on other appraisal methods more based on experience with similar projects. An area where the cost estimation software seemed to be used more, was for quality control of the cost estimates they developed earlier in the project. It was pointed out that it is only used in situations where the models are very accurate. The model is more commonly used to obtain an overview of the components and materials used in the building. By selecting a specific component, they get an overview of the amount produced, how much time has been used for production, and the provisional manufacturing cost.

Both respondents boasted about the collision detection feature in BIM and explained that it is a well-used aspect of BIM. The result of running these, in accordance with the theory, is a better foundation for construction with fewer faults and unplanned design changes.

Both the interviewees' firms utilize a DBB approach, briefly explained above. The general response was that this method did not lessen the benefits of BIM, as the theory explains. With the requirements set by the entrepreneur, the models obtained from both architects and engineering firms are usually of sufficient quality. Also, when they set these requirements, they know exactly what they want. This makes it easier for designers to produce the model. A collocated design and architect team was pointed out as a source of higher quality models. However, this would be too costly. Thus, hiring them, as consultants, is the easier option.

4.2.3.1.2 Petroleum

The planning of a platform happens over a multitude of stages. It often starts between five and ten years before the construction of the platform commences. The level of detailing in the early planning phase is relatively limited. These vague plans are delivered to the contractors responsible for the production of a more meticulously detailed and complete plan.

Over recent years, Equinor has improved its use of digital tools to follow up the plans made by the contractors. Traditionally, hundreds of PDF pages were printed each week in order to follow up on the planning phase. No indication was apparent as to which section of these massive documents was necessary for each department. Presently, PowerBI is a tool used to ease the follow-up, reducing the amount of paper and effort used for the process. As the documents are segregated by section, it is also possible for the reader to choose which part of the plan he/she would like to follow up. Rather than reading through a large PDF file, one can now click on tags and find the specific information that is required.

Earned value is normally the method used to measure the progress of a project, although it has its drawbacks. One of the flaws voiced was the lack of prioritization of tasks. Crucial and non-crucial tasks have the same effect on the outcome of the earned value analysis. As a result, a plan in which the critical tasks are delayed, and some of the non-critical ones are completed early, will appear to be on schedule. Significant delays may arise as a consequence of the method's failure to realize the difference in the impact of various tasks. Resulting from this is a lack of real understanding of the development of the project compared to the schedule.

Gantt diagrams are used in platform-building projects as well. One of the main challenges with this method was that it might not always be clear what each activity represents or who has the responsibility for it to be done. Each activity needs a specific name that indicates what it is and who is in charge. Another challenge was the length of the activities. It was suggested that many struggles to foresee things happening on a long timescale. Long-lasting activities are difficult to plan, when at the same time measuring their progress.

It was revealed that during the planning phase, there are conflicting interests in a project. The petroleum technology department might wish to produce as much oil as possible in a short amount of time, while oil platform workers often prefer functionality over production quantities. Another example is that some might want a drilling platform to be able to drill as efficiently as possible, regardless of what cost implications this may have. Meanwhile, those concerned with company finances have a completely different view of the situation. The expectations across different apartments are not always aligned, which results in arguments and discussions. However, this works as long as everyone can accept the final decisions that are made at the end.

In terms of costs, it made no difference, for Equinor, whether the whole project was outsourced to a contractor, or if the engineering and design phases were offered to two separate firms. Cost estimations for a platform are often based on historical data and experience, and Equinor has a department for it. The firm's system for calculating costs was pointed out to be very good, with the estimation in most cases being within 10% of the actual cost. Contractors often give offers that are less than Equinor's estimations, but during the lifetime of the project, this price tends to increase up towards Equinor's calculations.

According to the respondents, there are also some disadvantages to the system Equinor utilize for cost estimations. One of the main challenges mentioned was that it could be difficult only to use historical data to predict the future, as a result of market fluctuations. Therefore, they have tried to incorporate more qualitative data along with the quantitative data presently utilized. Notes regarding positives or negatives in each project are taken, in order to use it alongside the quantitative data. This is one way to make sure that new, inexperienced employees will have adequate information to make future estimations as exact as possible. Without this historical data, it would be difficult for Equinor to negotiate on prices with the contractors.

Clash detection is a feature Equinor's 3D modeling software has in common with BIM. This feature is used to help minimize errors in the building process by making sure the virtual model is as representative as possible of the physical platform. As the platforms are extremely complex, with a wide array of different parts, the clash detection can save the contractors unplanned schedule revisions and cost increases. Ultimately, these savings result in lessened costs for Equinor. As mentioned in subsection 4.2.1, the models work as HUBs where the contractors can make changes. Once these changes are updated in the model, the system will run collision detection, making sure the model is free of design flaws.

In the construction of platforms, Equinor utilizes a DB approach, where a single entity is contracted to do both the design and the engineering. In some cases, the construction is also done by the same entity. There are often many changes to the requirements initially set by Equinor. Having collocated teams, as is the case when utilizing a DB approach, helps improve collaboration among team members, according to theory. In turn, this makes the changes easier to handle.

4.2.3.2 Comparison

Gantt-diagrams are used as tools for obtaining an overview of the project schedule. The diagrams incorporate information regarding both start time and duration for each project task. An example of a Gantt-diagram is presented in figure 31. In construction, the 4D simulations available with BIM technology are being utilized at an accelerated rate. The previously used Gantt-diagrams, still very much deployed in the petroleum industry, have gone out of date. According to construction representatives, these diagrams were far too complicated and difficult to interpret. Even experienced workers would struggle to understand the diagrams, even the ones they made themselves. One of the dimensions of quality information mentioned in section 3.3, is interpretability. A diagram which cannot be interpreted by its creator seems to be lacking this dimension.

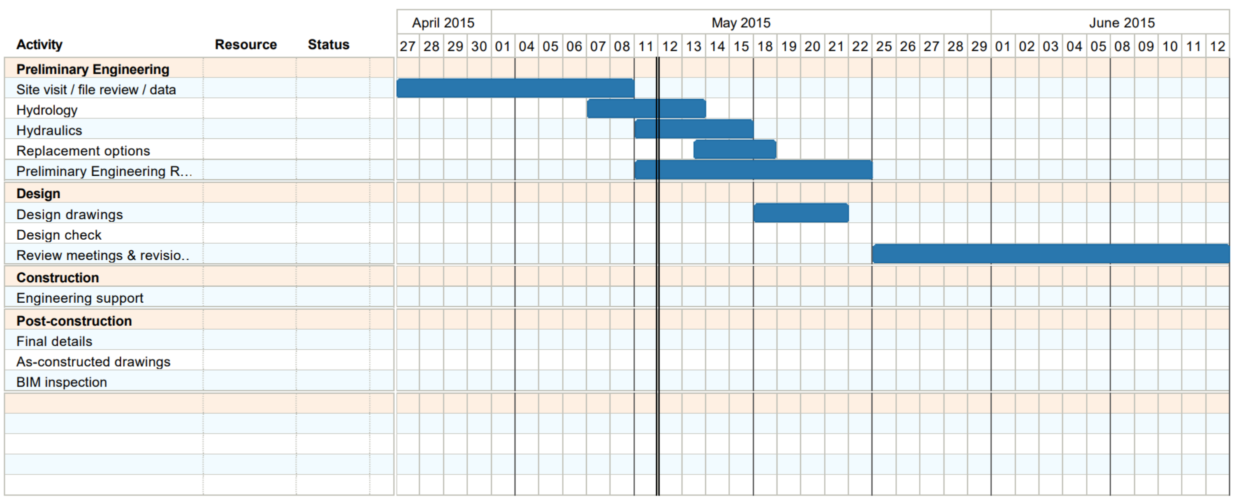

Figure 31: Example of a Gantt-diagram [Roseke, 2018]

The new 4D simulations, connecting the virtual model of the building to project schedule eased both understanding and communication within the project. In Equinor, they use a program called PowerBI to show these schedules, which is based on Gantt-diagrams and Earned Value analysis. The use of PowerBI is a step towards effectivizing the scheduling process of a project, through the use of digital technologies. They could still look towards BIM's 4D technology as an inspiration to further their advances towards improving the planning phase. This is one aspect of 3D modeling where construction has exploited the technological advances better than Equinor.

The two industries utilize different delivery methods, encouraging different levels of communication and collaboration. The DB approach utilized by the petroleum industry, according to theory, is better suited for collaboration. Designers and engineers are collocated and can discuss changes and modifications already in the planning phase. It is worth a mention that there is not as much design done in the construction of a platform as in a building, but way more engineering. There are many different engineering disciplines, which can communicate easier when they are collocated. The DBB approach utilized by the construction industry, is less suited for effective communication. Here, the design is completed before the engineering begins. Should the engineering team discover any faults with the design, this must often be communicated via the entrepreneur, to the designer. It was expressed that with minor changes, it was less costly to do the necessary changes to the model themselves, rather than sending it back to the designers. If the changes are rather significant however, the process of communicating and exchanging solutions with the designers is both time-consuming and costly. By employing the same delivery method as the one utilized in petroleum, the construction firms could save costs associated with design changes. The DB approach, along with CM-at-risk, is also mentioned in theory section 3.2.2.5 as one which is more suitable for BIM use than the DBB approach, which is used in construction today.

In both industries, cost estimation seemed to be based on historical data. BIM's cost estimation feature was used more like quality control in construction rather than a tool to achieve the estimate. However, the software does allow for an enhanced overview of components and materials. It can be linked to production in order to get an understanding of the amounts produced of each material, along with a cost estimate for that specific component. It seems as though the experience-based cost estimation techniques used in the petroleum industry is relatively accurate. It was expressed that their cost estimates, in most cases, hit the mark.

Collision control is another feature that is used in both BIM, in construction, and the 3D modeling application used by Equinor. This is a feature that is widely used and dramatically decreases delays and cost for both industries by reducing design errors. It also reduces the number of change management procedures both in the design and construction phase.

4.2.4 Summary

To conclude this subsection, it seems there is a cross-learning available between the two industries. In many ways, the petroleum industry is further evolved when it comes to 3D modeling, but introducing certain aspects of BIM could still prove to reap benefits. The introduction of IFC has made information sharing much easier in the construction industry. New software producers must make their applications compatible with the IFC format, or it is unlikely that it will be used. Introducing something similar could, as mentioned, be relatively tricky in the petroleum industry. However, there are potential benefits to be gained, such as the ability to effectively communicate with a higher percentage of the market. The HUB system used in the petroleum industry has proved beneficial as changes are quickly updated, removing remaining doubts regarding the preciseness of the model. This could potentially derive benefits for the construction industry.

One of the significant challenges in the petroleum industry is the lack of proprietary information sharing, such as highly specialized subsea parts in the 3D models. For Equinor, this inadequacy affects the accuracy of their simulations, as they do not have the full details of the parts in the process. The contractors do not have any incentives to share this type of information and fear to lose their competitive advantage if they share more than they have to. Equinor could benefit from obtaining more information, while the contractors receive more risk for no profit. For Equinor to acquire this information, incentives will have to be given to the contractors to balance their increased risk. Even though there is more quality information flow in the construction industry, the differences in integrated technology and complexity of parts used make it difficult to see any transferable learning between the two on this area.

Embracing the possibility of employing 3D technology on a broader scale within the company should be a focus for Equinor. Given the increase in computing power and the rise in availability, 3D modeling tools could play a consequential part in the digital transformation of the company. This was mentioned in the interviews, where it was highlighted that 3D technology would be the first step towards the digitalization of Equinor. When looking at how the construction industry is working with BIM, it became clear they use the 3D models for several different processes. It might not always be the reason why some processes are more effective today, but it is consistently mentioned as a tool to achieve more streamlined work processes. Equinor can view the company-wide embrace of BIM in the construction industry as a goal for them to achieve with their 3D technology efforts in the not too distant future.

There is an understanding of which relevant digital tools are available in the interviewed construction firms. This understanding is lacking in Equinor. Representatives from one department did not seem to know what technologies were used in other sections of the company, even though it could potentially improve their work processes. This could be as a consequence of inadequate information flow within the firm. However, it is worth a mention that Equinor is a much larger company than the construction firms interviewed. Obtaining an understanding of relevant technologies throughout the firm may, therefore, be significantly harder than in a smaller firm. Also, BIM has almost revolutionized how construction firms operate and has been adopted on a nation-wide scale. This makes a common understanding, both in the firm and in the industry, easier to come by. The usage areas of 3D modeling tools and its advantages needs to be communicated throughout Equinor in order for relevant disciplines to start using them. Through better communication of available technologies, like 3D, and their usage areas, Equinor can achieve the same understanding of available digital tools as in the construction industry. Also, advanced technologies require considerable investments. It would be beneficial for the firm to receive as much return in this investment as possible, by employees using the tools to a greater extent.

Through BIM, 3D modeling tools have become a part of the construction industry's backbone. The model is used more and more throughout every project, from early planning to construction. Both in change management and project planning processes, it was brought to light that the models are used as a tool for achieving effective intercommunication within the project. Better communication and collaboration both within the firm and with contractors through improved visualization efforts, was the point most frequently brought up by the respondents. Theory highlighted that sharing of quality information is crucial to an effective and productive supply chain. An essential dimension of quality information is that it must be easy to interpret. It seems the construction industry has found a way of communicating quality information easier through the use of 3D technology. This extensive use of 3D modeling has not yet spread to the petroleum industry, which seems to still cling to their old ways. As mentioned previously, the technology is available for them to utilize, but they are either not aware, or prefer to do things the way they have always been done.

Within the areas of both change management and project planning, the construction industry is utilizing 3D technology. Through 4D simulations used for planning, and visualization efforts used to create a superior understanding of changes, the industry has used the technology as a tool for improved collaboration. However, the delivery method currently employed is partially crippling the benefits reaped from using these tools. By shifting to either the DB approach often used in petroleum or CM-at-risk, which is also mentioned in theory, the construction firms could potentially see both inter- and intra-organizational collaboration rise to a new level.

4.3 Culture

This section will dig deeper into the culture and attitude prevalent in the two industries today, and this may act as either a catalyst or a hindrance towards implementing new technology.

The following question will be answered:
How does culture affect the use of these technologies?

The AEC industry has had, and still have today according to the theoretical background, a culture for resisting changes unless they see an aching need for it. The employees in the industry are often blinded by the way they have always done things, and are reluctant to opening up to new methods and processes. When it comes specifically to the inauguration of new technologies, the industry firms usually adopt a "wait and see" attitude. No one wants to be the first one to change, but no one wants to be far behind. High investment costs, as mentioned in theory as a challenge for BIM, is one of the factors which could leave some firms skeptical towards the implementation.

Non-informed managers were mentioned as a potential challenge for BIM adoption. This is because it is their responsibility to inform the staff further. The inability of staff to embrace and accept change is a considerable obstacle towards implementing any new technology. If employees do not see the benefits of advanced and contemporary digital improvements, such as BIM, difficulties can arise when asking them to learn new software or tools.

Theory identified the education of digitally adept, and BIM experienced students as a significant milestone towards the software being fully embraced and understood. Owners, consultants, and facility managers, among others, also need education within the art of BIM in order for the technology to be grounded in all hierarchical levels of the company. Inadequate staff awareness and attitude towards BIM can cause friction within the company when imposing a change.

4.3.1 Results from interviews

4.3.1.1 Construction

The respondents pointed out that there is a culture in the industry for doing things the way they have always been done. Asking the employees in the company to change their work process is, in general, not very popular. This attitude creates disunity within the company, often between management and other employees, and can act as an obstacle for change. With regards to BIM, it was pointed out that today, most employees see the advantages and need for change in order to keep up with the competition.

Participants were asked about a potential resistance towards the introduction of BIM in their respective companies. Several interesting aspects were mentioned. The first obstacle towards the adoption was figuring out if BIM was worth the substantial investment it took to employ it, which it was eventually found to be. Inadequate awareness of BIM benefits among employees was the second obstacle. Even though management was convinced of the economic benefits of BIM, it was not the inter-subjective opinion of the entire company. Many did not see why they should need to learn this new technology or did not feel like they had the time to acquaint themselves with it. This exact obstacle is also pointed out by Talebi (2014) in section 3.2.6.1.

Many who work in construction chose this particular industry because they are not overly fond of computers. In a way, the technology was not tailor-made for the workers, as they often prefer more conventional methods. This has created an alienation of people who are reluctant to change, which often have loads of experience, versus younger workers with better computer competencies. This estrangement of some experienced workers has, to some extent, caused friction within the company. Those who did not see the benefits of combining the expertise of older workers and younger computer handy ones were, and remain to this day skeptical of BIM.

Another obstacle pointed out was that even though employed in their company, several of their subcontractors were not as quick to embrace BIM. These subcontractors, often smaller and capital weak companies, could then either change or they would be replaced. The high investment costs mentioned earlier is one of the things leaving smaller companies behind. A study was done in 2013 by S&P Global (formerly McGraw Hill Financial) that supports this [S&PGlobal, 2013]. This can be seen in figure 32.

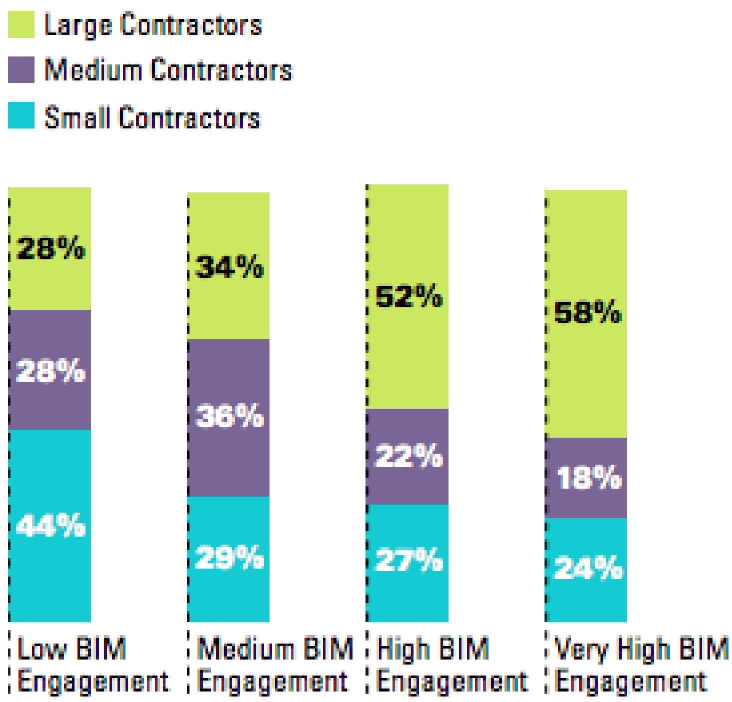

Figure 32: BIM engagement level according to firm size [S&PGlobal, 2013]

4.3.1.2 Petroleum

A significant piece of aging employees in Equinor is not very fond of new technologies such as 3D modeling tools. Even when the software is made available by the firm for them to utilize, they still persevere with more traditional methods. Even with 3D modeling tools becoming increasingly available in the company, several relevant disciplines still prefer to use two-dimensional drawings. These 2D drawings were highlighted to be extremely difficult to analyze for non-experienced employees. Expressed in the interview was how workers using two-dimensional drawings could visualize in their head how they would look in 3D. However, for employees not as experienced within that area, they can often look like complete chaos. These drawings are thus relatively hard to use for communication, as only a handful of people can understand them.

Those who already have multiple years of work experience in the industry have developed a particular way of working. They might be reluctant to change their well-used work processes. It was pointed out that newer employees, who had not yet been able to develop their work routines, were more susceptible to new methods.

Most employees are very positive towards constructing a highly automated and sophisticated platform, with new groundbreaking technologies and tools. Their attitude towards making an advanced platform is no issue, but rather their view of changing their work processes. Especially for elderly employees, this remains a problem for Equinor to this day. The paper-based, traditional methods which have been used for years are still prevalent within the company, despite recent efforts to increase the use of digital tools. An example was pointed to, involving a new program easing the process of an automatic transfer of data from one database to another. Even though this would save employees the time to put in all of this information manually, some choose not to use it. This serves as an example of unwillingness to adapt to and embrace time and cost saving software.

The increasing availability of information gives freedom to use it in new and different ways. A challenge with this exploration of technological opportunities is the possibility of some employees being reluctant if they think it will require more effort from them. A way to ease the challenge of implementing new technologies or processes is to inform and hold seminars to highlight the reasons for these advances. However, the seminars do not seem to be sufficient for employees to obtain a proper understanding of what benefits are associated with the new tools. The digital competence of employees was pointed to as a possible obstacle for new processes. Even though 3D modeling software has been made available, there is, as mentioned in previous subsections, a lack of an inter-subjective understanding among relevant disciplines of what the software can do. Also, perhaps more importantly, insufficient knowledge regarding how to use them. Even though the software is available, the importance of adequately educating employees of their intended usage and associated benefits have been partly overlooked.

Within a big company, conflicting interests with regards to what areas should receive what amount of funding can arise. A failure from some individuals to see the big picture was expressed in the interviews. Departments often want their tools to be highly advanced but are somewhat reluctant to realize that the cost is not worth the benefits obtained. Potential friction within the company can arise from such differences in interests.

As mentioned in theory, there are several different interpretations of what digitalization and digital transformation entail. With the worldwide focus on this area that exists today, this leads to many different solutions as to how to achieve the goal of a more digitalized company. This is also true within Equinor, where according to the interviewees, there seems to be a high focus on developing IT solutions rather than going through a real digital transformation as described in section 3.1.2. Some employees think that there is a lack of understanding within the company with regards to what digitalization is and which benefits could be derived. Notwithstanding that 3D technology is only a small part of the digitalization of Equinor, it is one of their main focuses. As mentioned earlier, it is viewed as one of the first steps into the company's digitalization era.

4.3.2 Comparison

There are many similarities between the petroleum and construction industry with regards to culture and how this affects the implementation of new technologies and processes. The difference in age groups and their corresponding attitude towards new digital tools and processes are mentioned. The older generation prefers to keep things as they have been, while the younger generation (who might not have developed a preference in work process yet) are more open to learning new techniques. This is in accordance with theory, as explained in section 3.2.6.7.

The petroleum industry has come relatively far when it comes to the use of technologies in general. It is an area where they excel compared to the construction industry. This can be reflected in the fact that most employees in Equinor were reported to be generally accepting of new technologies, as long as it did not affect their work process or create more work for them. Even though there is a considerable variation in the digital tools used, some employees still prefer paper-based, more "traditional" methods in both industries.

Within Equinor, it was expressed that many did not see the value in implementing new software and technologies. As a result, they did not feel the need to use them. This is comparable to how some smaller construction firms, often with limited capital, did not invest in BIM. They did not think the time and cost cuts they could achieve from the investment was worth the cost. Representatives from both industries reported problems with some employees not realizing the potential of newly introduced digital tools. Also, some might see what benefits can be obtained, but do not want to change their existing work processes.

Another comparable aspect between the construction and petroleum industries is the differences in opinion about whether or not certain new technologies and processes are necessary. Regardless, it is still a work in progress that has become a high priority within both industries. Both have their skeptics and their optimists, and with the heavy focus on digitalization that exists today, it could seem like the optimists are getting a stronger voice.

4.3.3 Summary

The strategic efforts for adopting new technologies, like 3D modeling tools, need to be paired with proper education and information. Highlighting possible benefits to a greater extent could ensure that the intended effects are realized. There is little use in investing in new software and applications if workers are not convinced of their advantages and refrain from using them. Today, employees in the construction industry are aware of BIM and what it can be used for, although a few still remain unconvinced of its advantages. However, in the petroleum industry inadequate informing of relevant disciplines, of 3D technology's usage areas and benefits, is apparent. The lack of information, paired with an employee attitude, which is negative towards new work processes, is hindering the implementation of technologies like 3D modeling tools. However, if they start educating their employees adequately regarding opportunities and their associated benefits, this attitude problem could be fixed.

Many employees in both industries, despite the investment in new technology, still swear to traditional methods. This culture of resisting changes to work processes is especially apparent in the older generation. Developing with experience and age is a particular technique for doing things, which is partly the reason for the heavier resistance from the older generation. Younger employees are less reluctant to change their work processes, as they are still developing their way of doing things. Representatives from both industries highlighted the difference in attitude towards changing work processes as a potential problem for technology implementation. It is also in accordance with the theoretical background.

5 Conclusion

The objective of this thesis was to elaborate on how BIM technology is used in the construction industry and how similar technologies are used in the petroleum sector. In section 4.2, a comparison of the two industries is presented, analyzing the use of these technologies. Through summaries, the most important aspects were emphasized. Also, section 4.1 and section 4.3 highlighted where the initiatives for 3D modeling software like BIM arise, and which role culture plays to affect the adoption of these new technologies.

The initiative for implementing BIM in the construction industry came both from the top of the supply chain and the bottom. Increasing pressure to cut time and costs paired with a growing realization of potential benefits from employing BIM started the industry's journey towards a digital transformation. Employees devoted to transforming their company, along with government influences, forced the industry to change. In petroleum, initiatives from devoted individuals also play a large role in implementing new technologies. In contrast to BIM adoption, 3D technology in the petroleum industry is not used with the main goal of saving costs. Instead, the main focus is on improving operational management, change handling, and project planning. There is a prevailing culture of sticking to traditional work process, both in the construction and the petroleum industry. A strategy for accelerating the digital development of the industry is to better inform employees regarding relevant technologies in order to counter the persisting culture of resisting changes in work processes. The lack of initiatives from contractors in the petroleum industry makes the top-down and bottom-up pressure, which was so effective in BIM adoption, hard to achieve. Learning from what the UK government did with BIM implementation, Equinor, with their influential position in the Norwegian petroleum market, could use this to force other petroleum companies to utilize 3D technology better. Also, Equinor is already at the forefront of 3D technology in the industry. Using this current position, in the same way as the UK is doing with BIM technology, could prove beneficial for the company.

3D technology in the construction industry has been widely accepted and is used throughout most projects, from early planning to construction. Through the IFC standard, both inter- and intra-organizational communication and collaboration has been significantly improved. By using the technology for various purposes like change management and project planning, the construction industry has found a way to increase the flow of quality information throughout the construction supply chain. Improved understanding through visualization efforts was the feature of BIM most frequently mentioned in the interviews. As mentioned, the petroleum industry is, in many ways, more advanced within the area of 3D technology. However, the persisting duopoly of modeling applications used for modeling oil platforms only allows for communication with 50% of the market. This, in addition to problems with the sharing of proprietary information among project participants, has crippled the flow of quality information within the industry. The IFC standards used in the construction industry could be used as a guideline to help oil and gas firms realize a higher level of quality information flow. However, the HUB system currently employed in petroleum, with constantly updated models, is something construction firms could look at for inspiration. The common understanding of what BIM is and its associated benefits is an area where construction excels compared to petroleum. Achieving this inter-subjective opinion throughout the firms of available technology should be a goal for the oil and gas sector. The successful and widespread implementation of BIM in construction should serve as learning for the petroleum industry on their road towards a fully interoperable 3D technology, potentially increasing the flow of quality information.

5.1 Further recommendations

This thesis is built on literary theory and interviews with entrepreneurs in the construction industry, as well as employees in Equinor company. It would be of interest to further expand this study to include all levels of the supply chain. A further investigation should dive deeper into suppliers and the suppliers' suppliers incentives for using 3D modeling tools and their culture for accepting new technologies and processes.

Of special interest would be the area of achieving higher quality information flow in the petroleum industry through developing standards and achieving a higher degree of proprietary information sharing. Analyzing economic incentives for sharing of information within the petroleum supply chain could potentially produce fascinating results. Another suggestion would be to investigate which methods are most effective for achieving an inter-subjective opinion of available technology within a company.

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Appendices

A Interview Guide Construction

Generelt Hvor utbredt er bruken av bygningsinformasjonsmodellering (BIM) i selskapet?

Var det stor motstand mot implementeringen, enten innad i selskapet eller fra underleverandører?

Forklar påvirkningen implementeringen har hatt på samarbeidet med underleverandører?

Har det oppstått noen endringer prosjektfasene etter BIM?

Ser dere noen forbedringer kontra tidligere metoder, i så fall på hvilke områder?

Når modeller overføres på IFC standard, sliter dere med veldig store filstørrelser?

Kan en gjøre endringer i en modell som en har blitt tilsendt, eller bare åpne den?

Vil du si at BIM er en viktig brikke i å oppnå såkalt "Lean Construction"?

Har dere, per nå, tatt i bruk Augmented Reality (AR) som et visualiseringsverktøy?

Hvilken leveringsmetode mener du er mest passende for bruk av BIM?

Er det andre leveringsmetoder som er mer optimaliserte for BIM?

Opplever dere noen gang at det blir konflikter mellom tekniske rådgivere og arkitekter?

Er det blitt noe vanskeligere eller lettere å få underleverandører til å dele informasjon?

Ca. hvor stor andel av delene brukt i byggene deres er standardiserte?

Når BIM først ble implementert, hva var grunnen til implementeringen? Var det press fra konkurrenter, myndigheter, eller så bransjen selv fordelene med teknologien?

Hvem tok initiativ til implementeringen av BIM i Norge? Tenker da på to ting:

Hvem tok initiativ innad i selskapet?

Hvem tok initiativ på landsbasis, eventuelt på internasjonal basis?

Blir modellen lagret i systemene deres etter bygget er ferdigstilt?

Hender det at dere blir kalt tilbake bil et ferdigstilt bygg for å gjøre endringer eller oppgraderinger?

3D-modellering

Hvilke endringer har oppstått på 3D modellerings-fronten etter BIM?

Bruker dere enda samme tegningsprogrammer som før?

Planlegging

Beskriv forskjellen i måten dere planlegger prosjekter på?

Har det vært en merkbar endring i kvalitet på planleggingsprosessen ved hjelp av BIM? i så fall, beskriv endringen?

Brukes tidsdimensjonen i BIM mye, hvilke metoder ble tidligere brukt for tidsplanlegging?

Kostnadsestimat

Kan du beskrive endringen i kvalitet eller tiden brukt på kostnadsestimatene deres etter BIM-implementeringen?

Forklar eventuelle forskjeller i anbudsprosessen?

Endringshåndtering

Hvordan har prosessen med å håndtere endringer forandret seg? Hvis så, har den endret seg positivt eller negativt?

Hvordan forsikrer dere dere om at BIM-modellen alltid er oppdatert?

Kultur

Brukes/bruktes det mye tid på å trene opp eldre ansatte til å forstå og omfavne BIM?

Hvordan opplever dere de nyutdannedes digitale kompetanse?

Vil du si at det er en felles forståelse gjennomgående i selskapet om hva BIM er og hvilke fordeler det innebærer?

Hvordan brukes erfaring i samarbeid med datakompetanse i selskapet?

Vil du si det er en generell kultur i bygge bransjen som er en motstander av endring?

Hadde kulturen i selskapet noen innvirkninger på implementasjonen av BIM?

B Interview Guide Petroleum

Planlegging

Kan du beskrive planleggingsprosessen dere opererer med?

Fordeler/ulemper?

Har dere noen programmer som simulerer fremdrift?

Kostnadsestimat

Beskriv prosessen med å gjennomføres kostnadsestimater?

Er det noen fordeler eller ulemper med denne metoden?

Hvilke mulige løsninger ser du på problemene med dagens metode?

Hvilke ting innen kostnadsestimering jobber dere med å forbedre?

Endringshåndtering

Kan du forklare endringshåndteringsprosessen dere har nå?

Ser du noen fordeler/ulemper med den nåværende metoden?

Hvilke fordeler tror du et verktøy som BIM vil tilføre til denne prosessen?

Kultur

Hva ser du på som de største motstandskildene mot implementering av ny teknologier eller arbeidsprosesser?

Kan du beskrive mulige måter å motvirke motstanden?

Hvordan vil du si kulturen i Equinor/petroleumsindustrien skiller seg ut fra andre industrier?

Hvordan vil du si samarbeidet innad i selskapet er?

3D-modellering

Hvilke typer prosjekter brukes 3D modellering mest, og hvordan brukes det?

Hva er den største utfordringen dere opplever med 3D modellering?

Er det ofte problemer med interoperabilitet blant de forskjellige programvarene dere utnytter i selskapet?

Hva med problemer med overføringer av modeller eller tegninger mellom dere og underleverandører?

Kan du beskrive prosessen med å følge opp arbeidet som har blitt utført av underleverandørene?

Brukes 3D modellene til noe etter konstruksjonen er ferdig?

Hvordan forsikrer dere dere om at 3D modellen alltid er oppdatert?

Kan du se for deg at BIM kan løse noen av de problemene dere opplever i dag?

I hvilke type prosjekter ser du for deg at BIM kan brukes mest?