UNIVERSITY OF GOTHENBURG
SCHOOL OF BUSINESS, ECONOMICS AND LAW

A study of diffusion of Augmented Reality in the Swedish construction industry

A Master's Degree Project in Innovation and Industrial Management

Author: David Mijatovic

Supervisor: Rick Middel

Graduate School

Abstract

Innovations and technologies have proven to be a crucial step for organizations to gain competitive advantage. Construction companies are often known to lack innovative processes. However, studies have lately showed that the construction industry is starting to jump on the bandwagon, adopting new and innovative methods and technologies. A crucial part of this innovative gain can be derived to the digital development. This qualitative study will further on, aim to understand a part of this digital development, by evaluating augmented reality (AR) in large Swedish construction companies.

The goal with this study is not to provide best practice but to evaluate AR and its potential. The thesis is predominantly going to utilize a framework developed from past diffusion studies, i.e. Rogers's framework from his book Diffusion of Innovations, since it has proven to be beneficial to evaluate innovations. Rogers's diffusion theory mainly emphasizes the innovation as the best mean to evaluate the diffusion. However, every industry is special and therefore construction specific theory and research have been included to complement the diffusion framework.

This research will include which impact AR has had so far and which factors that have enabled and hindered the adaptation of AR. The results in this study indicate that the lacking properties of AR i.e. being expensive and providing insufficient results, are some of the reasons why AR has not diffused to a greater extent. There are also intangible reasons why AR has not diffused yet. The cultural resistance has, according the findings of this study, proven to be one of the major obstacles for adopting AR.

The findings of this study also indicate revealing indications how AR is used, which differentiates from the theoretical findings. The theoretical findings that explain how AR is used momentarily, has proven to be overrated, meaning that AR has not diffused to all fields, e.g. product design, training, quality management, maintenance and safety, as researchers suggest. This study could only find quality managing and product design, to some extent, being used in reality.

Keywords: AR, augmented reality, construction industry, diffusion study, diffusion of innovations.

Acknowledgements

I would first like to express my gratitude to my thesis supervisor, Rick Middel, for supporting and guiding me, during the process of the thesis. I would also express my gratitude for the interviewees for participating in the study. Without your help, time and knowledge shared, this thesis could not have been possible to conduct.

Table of Contents

1 Introduction

This sector will shortly introduce the construction industry and augmented reality, which is the research field of this study. It will further present limitations and gaps with contemporary studies. Also, the purpose and research questions will be presented, together with the research limitations.

1.1 Background Augmented Reality

Innovations in the construction industry can provide positive long-term effects for construction companies (Slaughter 2000) and higher levels of innovation implies having a higher chance of increasing the economic growth (Blayse & Manley 2004). Innovation is also important for other various reasons. Gambatese and Hallowell (2011) mention that innovation is important for achieving positive long-term performance. If managed properly, projects will: meet goals, decrease costs and improve in quality. Gambatese and Hallowell (2011) even argue that it is even essential to enable innovation, in order to stay competitive. Ling (2003) has complied studies that found evidence that having promising innovation results and high goals, increases the overall engagement of the organization. Recently, the demands for buildings have increased, in terms of functionality and aesthetics (Barrett, Sexton & Lee 2008). This have pressured firms to improve and update existing technology and be more innovative to please the increased demands (Barrett, Sexton & Lee 2008).

The mentioning factors behind some of the industry's ongoing innovativeness are usually connected to information technology e.g. computer aided design (CAD) (Feng 2006) and building information models (BIM) (Jeanclos, Sharif, Li, Kwiatek & Haas 2018). CAD was invented around 1960 by scientists and engineers working at MIT (Allen 2016) and is typically only used for blueprints. BIM provides a more extensive presentation about the information regarding the construction design in 3D and specifications about design on an object level. In addition to that, BIM provides information, which is shared on a project level (Turkan, Bosche, Haas & Haas 2012). BIM also provides communication and coordination among involved parties (Jeanclos et al. 2018). One way to meliorate CAD and BIM is to utilize AR (Harty 2008).

AR as an idea or technology is not new, and Wagner and Schmalstieg (2009) state that the first application of AR, used on a mobile phone, was created in 2003. Ivan Sutherland build the first see-through head-mounted display in 1965. The early potential areas where to use AR were medicine, machine maintenance and personal information systems (Poupyrev et al. 2002). However, it is not until recently that AR applications have diffused, e.g. Pokémon Go which was the first AR mobile game that was the most downloaded mobile game (Rauschnabel, Rossmann & tom Dieck 2017).

AR combined with BIM is a way to illustrate 3D objects, superimposing objects into the reality (Wang, Truijens, Hou, Wang & Zhou 2014). This should in theory result in giving clearer visual understanding for the users of the design (Jeanclos et al. 2018). 3D visualization can even further improve communication and present design, since it is a tool that can trace and check errors (Wang et al. 2014). Combined with BIM, AR can provide a full 3D interactive solid model of the design, giving the user a visual understanding of the design, in real-world scenarios (Jeanclos et al. 2018). AR is the type of technology that is predicted to translate and delineate BIM efficiently, when being used within the construction site (Wang et al. 2014). The technology, both from a software and hardware perspective is still being developed, but there already exist functional prototypes e.g. Microsoft HoloLens (Wang et al. 2014).

1.2 Background construction industry

The construction industry is one of the oldest industries according to Downing (1968). Construction is defined by Oxford English Dictionary, (OED) (2019) as "*The action of framing, devising, or forming, by the putting together of parts; erection, building.*" (OED 2019). Construction is however not as simple as just building constructions, since it also comprises repair and maintenance work, peripatetic building and immobile manufacturing. It also involves complicated processes i.e. often being project-based and embracing both public authorities and private actors (Andersson & Widén 2005). Since construction is a project-based industry, it is often coping with not providing enough customer focus and service, not investing enough in research and development (R&D) and having bad intra-organizational communication (Barrett, Sexton & Lee 2008).

Innovation in the construction industry has not been at the helm, but rather on the bottom of the ladder (Ozorhon, Abbott, Aouad & Powell 2010). The construction industry is essential for a nation's growth and development, and the construction sector employs more workers than any other sector in Europe (Izkara, Pérez, Basogain & Borro 2007). During 2014, Sweden's construction industry employed about 311000 people and the value of all the combined real estate value, accounted for about half of the national wealth (Sveriges Byggindustrier 2015).

In 2007, when the European Union (EU) had 27 members, the construction industry accounted for more than 11% of the gross domestic product (GDP) and employed more than 8% (Pellicer, Correa, Yepes & Alarcón 2012). Blayse and Manley (2004) calculated that the average national product of the construction industry including related industries e.g. designers and property managers, stands for nearly 15%. The value created by project-based firms in the construction industry can not only be measured to their economic contribution to the GDP (Gann & Salter 2000). Project-based firms create prerequisites that takes care of and facilitate social and economic activities. A poorly constructed or maintained building has a strong negative correlation with social and financial activities. To achieve a higher level of demand and meliorate the design e.g. construction engineering and indoor environment, organizations are enforced to improve their technical capabilities (Gann & Salter 2000).

As stated by Ozorhon et al. (2010), recent decades have been poor in terms of new output from construction companies. Since the level of innovation is low, contractors have not much to gain, due to the possibility of jeopardizing their own processes (Barrett, Sexton & Lee 2008). This can also be seen in the rapport by Dale (2007), where 66.25% of the asked companies felt that they did not invest enough in R&D. The European Committee of the Regions (CoR) (n.d.) implemented the Lisbon strategy in 2000 to make EU "The most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion." (CoR) (n.d.). In 2005, EU revised the strategy, where one of the key pillars was knowledge and innovation (CoR) (n.d.). The goal was that the R&D spending should be 3% of the GDP (Pellicer et al. 2012). However, in 2006, the members of EU did not meet the target, spending only 1.77% of GDP and the construction industry invested even less (Pellicer et al. 2012). Although construction has been a well-known sector for its lack of innovation and productivity (Dale 2007), productiveness has started to increase, and the construction sector had the biggest growth of all sectors in 2014 (European Commission 2014). An example of the construction industry utilizing innovative methods, are modularization and prefabrication (Jeanclos et al. 2018) which dates from the 1600s (Smith 2009). Modularization is a clear example how to cut cost, but foremost, improve quality, which other industries use as well (Jeanclos et al. 2018).

Although construction industry is a part of the architecture, engineering and construction industry (Chi, Kang & Wang 2013), the AEC terminology will henceforth be defined as and aggregated to the construction industry, mainly due to the construction phase being the main core of this thesis.

1.3 Problem discussion

Rogers (1995) advocates that the dominance of studies, research the attributes of the adopter and not characteristics of the innovation itself i.e. properties of innovation affecting diffusion rates. Meanwhile, Harty (2008) states that "Construction often presents a terrain with no single or coherent driving force behind implementation in which innovation must be grounded" (Harty 2008 pp. 1030). Gao, Li and Tan (2013) also state that few studies that have analyzed the diffusion of innovations in the construction industry, have considered which types of driving and hindering factors affects their results.

Even though construction has a vital function influencing a company's or a country's wealth (Izkara et al. 2007), few scholars have researched about the differences between how innovation is managed in the construction industry versus the manufacturing industry, where manufacturing is being the more investigated one (Gao, Li & Tan 2013). Gao, Li and Tan (2013) further argue that generally, few researchers have researched how innovation diffuse in the construction settings. In addition to Gao, Li and Tan's (2013) findings, how innovations diffuse in organizations is also rarely studied by researchers (Rogers 1995). Rogers (1995) states that only a dozen reports have conducted studies about intra-organizational diffusion processes (Rogers 1995).

Conducting science about innovations in the construction industry differs from other industries e.g. manufacturing, since the production within the construction industry is fragmented and project-oriented with many actors being combined into one project. It is more challenging to achieve innovativeness when the production is spread among different locations (Pellicer, Yepes, Correa & Alarcón 2017). Andersson and Widén (2005) also state that the most theories describe a point of view that depict a standardized manufacturing industry, and not a project-oriented industry i.e. construction.

Scholars also write about ideas how AR could be used. However, not many of them state what actual practical applications companies are using AR for (Li et al. 2018). Although studies demonstrate fields and potential areas where and how to use AR applications, not many of them mention the lack of the technical development and which bottlenecks that are dragging AR down, not letting AR flourish (Martínez, Skournetou, Hyppölä, Laukkanen & Heikkilä 2014).

1.4 Purpose and research question

Little research has been conducted about how innovations diffuses in organizations (Rogers 1995) and how companies are using AR (Li et al. 2018). The purpose with this study is to map the extensive matureness of AR, by investigate how diffused AR is in large Swedish construction companies. This will be done by using Rogers's (1995) four key elements for innovation diffusion. The research question for this study is defined as:

To what extent has the applications of AR, for large construction companies in Sweden been diffused?

Sub research questions

Which factors enable the diffusion of AR in large Swedish construction companies?

Which factors hinder the diffusion of AR in large Swedish construction companies?

By doing so, one should get insights about why AR is diffused and to what extent AR is diffused. This can be valuable when implementing AR for contemporary and future purposes, since the study will provide indications on what the future potential for AR will look like. The objective with this study is to identify the underlying drivers that affect the adoption of AR. The overall focus will not be to examine how a company's innovation management is managed and how it has impacted the adoption of AR. External influences e.g. a company's innovation management, will only be included if it turns out to impede the result in a significant way. The overall focus will be to examine AR from its technical boundlessness and limitations.

1.5 Limitations of the report

The main purpose of this report is to investigate the reasons why and if companies have implemented AR, among large construction companies in Sweden. Thus, the entire span of the construction spectrum will be not be investigated. Factors relating to how a company's innovation management makes decisions, how they arrive at them and how they move on with the implementation process, will not to a greater extent be dealt with in this report. Factors that can influence their decision, mainly from a technical point of view, will be the basis for this report.

Andersson and Widén (2005) mention that the standardization in the construction industry is lacking, compared to the manufacturing industry. This combined with the construction industry being a project-oriented industry, are reasons why innovation in the construction industry is lagging other industries. These are also the reasons why not all types of innovation research can be comparable and translated to fit the construction industry. Thus, making the construction industry unique and not compatible for all type of innovation research (Andersson & Widén 2005). Although the construction industry is an industry with traditional measures, it does not mean that the industry is not innovative. A lot of the innovation that happen in the construction industry, are in fact hidden, since it occurs on project level, sometimes developed with other firms (Ozorhon et al. 2010). This could limit the results deriving from the empirical findings.

Problems may also arise, since measuring innovation is a complex activity (Ozorhon et al. 2010). In reality, companies, laymen and scientists often measure innovation by investigating how much companies spend on R&D expenditures, patents and trademark applications. Since the construction industry is project-based, a lot of the innovation is hidden and spread between the companies in projects. These traditional ratios do not give a representative picture, and thus, a gap exists between the real and the foreseen world (Ozorhon et al. 2010). A lot of the innovation are also neither reliant on patents and trademarks, which usually is very important in other industries (Slaughter 1993). Since innovation is difficult to measure, it could further limit the outcome of this report.

2 Methodology

Simons (2014) argues that a study can only be defined as research if the outcome generates new knowledge to the public. This is the predefined condition what makes a study a research. To conduct a research however, one must acknowledge the methods how to conduct a research. The first step is designing a research strategy. This and information about the research design will further on be explained in this paragraph.

2.1 Research strategy and approach

This thesis will utilize a qualitative approach, which will hereinafter be used, interchangeable with qualitative research and qualitative method. Qualitative research can be characterized as collecting rather unstructured data in natural settings, as well as focusing on the verbal data instead of numerical data (Bryman & Bell 2015). Packer (2010) presents multiple authors that states qualitative data as soft, messy data or as the good stuff of social science. One of the reasons why they call the data messy or the good stuff of social science is because the qualitative researchers study the real world, rather than processes occurring in clinical conditions (Hammersley & Campbell 2012). Since qualitative research is often unstructured, it allows interviewees and participations to use their own terminology which allows the researcher to understand their perspectives (Hammersley & Campbell 2012).

Another attribute of qualitative research that Hammersley and Campbell (2012) mention is that qualitative research examines natural settings, which Hammersley and Campbell (2012) explain as where e.g. people live and work. By contrast, standardized methods create settings e.g. laboratories and other settings, that are solely designed to suit the purpose of the report. Surveys and structured interviews are often used as means to collect data in those studies.

Hammersley and Campbell (2012) state that qualitative work, is often characterized by having a smaller number of cases studied. Survey research must however, have several sources of cases to collect data, since generalizing the outcome is often the goal with survey studies. This because survey studies must provide data from more cases to provide a reliable comparative analysis. By comparison with the antagonism, qualitative studies core is to examine the complexity of a case, thus imposing using fewer cases (Hammersley & Campbell 2012). A qualitative approach does not constrain the researcher only using verbal data, but it is the most referred method to collect data, since the role of qualitative research is to thoroughly discover the factors of an event of some kind (Hammersley & Campbell 2012).

Although, this is not by close a complete definition what the qualitative approach covers, since the qualitative approach is an immense phenomenon (Hammersley & Campbell 2012). Packer (2010) further states that it may be easier to understand qualitative research by taking a closer look of what sets qualitative research apart from other methods and why it will fit the purpose. Other research methods, i.e. quantitative research, will however in some degree cover areas where the qualitative approach is not sufficient enough, i.e. quantifying the results. Quantitative work is often hypothesis driven and target numerical data collecting (Hammersley & Campbell 2012). Quantitative work has to be objective since their work methods must be standardized, and they often use big samples which facilitates generalizations. Controlling variables statistically is also an essential process in quantitative research (Hammersley & Campbell 2012). However, the goal with this thesis is not to quantify the findings, but rather to provide and try to understand why and how AR is diffused in

Swedish construction companies. To fulfill this objective, a qualitative method will be used for this report.

It does however exist criticisms against qualitative methods. Packer (2010) maintains that people have always been told that clinical trials is the gold standard and observational and descriptive researches as scoria - scoria is defined by OED (2019) as "the dross remaining after the smelting out of a metal from its ore". This because observational and descriptive researches are only good for achieving axioms but not possible to test them (Packer 2010).

The objective with this study is to understand the profoundly processes underlying how construction companies in Sweden empower a radical innovation e.g. AR. Due to the definition of the research question and since the thesis's goal is to provide descriptive insights and not entirely testing predefined hypothesis, a flexible research design will be used, which is optimal in qualitative research (Hammersley & Campbell 2012).

As noted before, the report will have a flexible research design, however, since diffusion and adoption theories are already well explored, the research will utilize insights and frameworks from the theory when the research design is developed. Diffusion theory provides a clear framework how to forcible collect data, which has proven to efficiently measure diffusion of innovations.

Ideally, the report would follow an inductive approach, which can be explained as when researchers start with collecting the data and then developing a theory that explains the patterns in the data (Bryman & Bell 2015). However, the way that this thesis is structured is to utilize well-known frameworks before conducting the interviews, since existing diffusion theories are well established and approved by researchers. This approach corresponds more with a deductive approach, where researchers begin with reviewing the theory, then proceed to collect and analyze the data, and finally adopt or reject the hypotheses based on the outcome (Bryman & Bell 2015).

Since both methods are going to be used, an abductive approach will be used hereinafter. This approach will let scholars review research, preparatory to data collecting and enable researchers annex theories during the research process (Bryman & Bell 2015). The abductive approach will further be used for the report, since diffusion studies main purpose is to predict how effectively an innovation will diffuse in a future setting. Present theory regarding explaining the diffusion of AR in the construction industry is limited, only providing relevant insights to some extent. Knowing to what extent and whether a company will adopt an innovation as AR, by only reviewing existing diffusion theories, is more or less almost impossible to predict. This is also relevant for this thesis. Commonly, diffusion theory is based on testing common factors that have proven to have a high significant in vast fields. In this thesis, it was however discovered that some important factors affecting the diffusion of AR were not presented extensively in prior reports. These factors were further examined. This is where the more abductive approach will settle in. If empirical phenomena emerge that existing theories cannot explain, an abductive approach will again be a suitable substitute (Bryman & Bell 2015).

2.2 Research design

Bryman and Bell (2015) state that the research strategy is the first decision to take when conducting and establishing a research. The second step is to assess how the research is going to be conducted. That is the purpose with the research design, giving the readers a chance to understand how the study will be performed (Yin 2010).

Bryman and Bell (2015) state that the research design is often confused with the research method. The differences between research method and research design can be explained as, that the research design contributes to the framework, whereas the research method is the technique used to collect data (Bryman & Bell 2015). For this report, a case study will be used as research design.

2.2.1 Case study

Case study is a widespread method among researchers, especially in business research. The purpose of a case study is to get detailed information about a case (Bryman & Bell 2015). Simons (2014) argues that case study is an excellent way of working when evaluating complex processes and understanding complex outcomes. Simons (2014) further explains case study as the way of getting profound results from several perceptions in real-life contexts. Case study is suitable to explain changed processes and especially explain research that focus on the underlying reasons why and how things happens (Simons 2014).

Since case study is all about singularity and providing the researcher a flexible way of working, case study does not need a standardized way of writing and collecting the data. Different formats to summarize the data and write the case can be used, to meet the interviewees or researchers needs (Simons 2014). Since case studies are personal, they enable a more natural language, which inevitably invites the interviewees engaging more in the research (Simons 2014).

Case studies have received critique since detractors argue that one sample cannot be compared with studies that accumulate multiple and large samples, in terms of providing a valid research (Simons 2014). Simons (2014) further explains that understanding a case thoroughly and profoundly does not work efficiently as an argument. Detractors that have preconceived thoughts against case studies, will have a difficult time listen since it is comparable to ideological preferences. Other disadvantages that some researchers face when conducting qualitative research is e.g. finding the truth when people are in exposed positions. However, Simons (2014) says that most of these problems can be solved by using other methodologies and that many of the problems are "intrinsic to the nature and strength of qualitative case study research" (Simons 2014, pp. 7).

Simons (2014) and Bryman and Bell (2015) refer to Stake (1995) to explain different types of case studies. Intrinsic case studies focus on thoroughly reviewing one case, and the findings applies to the case in question. Instrumental case studies are used to get a broader sense, where the cases work as an instrument explaining other processes or even enabling generalizations. A collective case study comprises multiple cases. However, Bryman and Bell (2015) noted that the boundaries between these three types of case studies are blur, thus being the reason only the differences are presented and not the details.

2.2.2 Selection of research cases

Bryman and Bell (2015) write that the selection of cases should be based on which cases the researchers think will be most useful for their findings. Yin (2010) defines purposive sampling as choosing candidates that can provide relevant data. However, this was a challenge in this report since the cases, i.e. companies used for collecting data, are large construction companies with headquarters in Sweden, which are limited to some extent. In large companies, it can be more cumbersome to find the candidates that can provide the most relevant data.

Large companies in this report are defined based on the recommendation of the European Commission (2003). The European Commission (2003) defines small and medium-sized enterprises, as companies having no more than 250 employees and having a maximum annual turnover up to 50 million EUR. Large companies can thus be regarded, by using the process of elimination, as companies with more than 250 employees and an annual turnover of more than 50 million EUR (European Commission 2003).

To get the information needed about Swedish construction companies that meet these requirements, data from Sveriges Byggindustrier (2018), i.e. Sweden's construction industry, were used. Sveriges Byggindustrier is an industry and employer association that annually compile a list of Sweden's 30 largest construction companies based on turnover. By margin, all of the 30 companies listed had a turnover of more than 50 million EUR during 2016, but not all of them had more than 250 employees. Having that said, the top ten companies meet the requirements and were selected and requested to take part as candidates in this report. The top ten companies had all more than 250 employees globally. Of those companies, two firms had their headquarters in Norway and were thus removed from the list. The majority of the companies answered, when being questioned to take part as candidates in this study. However, after interviewing four companies, i.e. using four cases, it was believed that all the variation that could be met was achieved. Thus, no further case was added to the report. This statement is strengthened by Bryman and Bell (2015). An overview of the case companies used in this report are presented in Table 1.

Table 1: Overview of case companies

Organization	Global turnover	Global number of employees
A	<10 billion SEK	<1500
B	<5 billion SEK	<700
C	<50 billion SEK	<15000
D	<50 billion SEK	<15000

2.3 Data collection method

Since this study is adopting a flexible research design, it is reflected on the collection of data. There are different methods of collecting data. The numerical data collecting method i.e. primary quantitative work, usually uses surveys of some kind to collects its data (Bryman & Bell 2015). A qualitative approach on the other hand, and especially a case study, uses interviews and observation as its main source of data collection. This report will however only exploit interviews as a source for data and no observations will be used, due to how the research question is written.

2.3.1 Semi-structured interviews

This study is going to use semi-structured interviews. The advantage with semi-structured interviews is that it facilitates a comparability among the participations, giving the respondents enough space to answer questions openly (Bryman & Bell 2015). To keep track which topics had to be included in the interviews, an interview guide was created and used as recommended by Yin (2010). Using an interview guide is typically used for semi-structured interviews (Bryman & Bell 2015), which also was the case in this study. The guide was used as a tool where the interviewees would steer the conversations that they thought was is important, but at the same time, stay within the topic of this report. New factors were mentioned during the interviews, which initially were not considered having any significance, which means that new data was found thanks to the interview guide.

Three of the interviews were conducted face-to-face and one was conducted by phone as seen in Table 2. It is debatable if conducting interviews by phone is good or bad. Some advantages mentioned by Bryman and Bell (2015) are that they are easier to supervise and that the interviewer's personal characteristics do not impact the interview negatively. There exists critique against phone interviews as well. Bryman and Bell (2015) argue that phone interviews tend to be shorter, having a higher risk not covering sensitive data and that the overall quality, compared with face-to-face interviews, is lower. These are the reasons why face-to-face interviews are preferred.

The respondents were selected by their skills and knowledge about AR in their company, mainly by snowball sampling (Bryman & Bell 2015). All the employees had intrinsic knowledge about AR and worked more or less with AR. Interviewing respondents that can provide relevant data, increase the validity (Yin 2010).

Table 2: Overview of interviews

Interviewee	Organization	Length	Form	Date
A	A	50 min	Face-to-face	2018-12-05
B	B	70 min	Face-to-face	2018-12-11
C	C	40 min	Skype	2018-12-12
D	D	70 min	Face-to-face	2019-01-11

An effective way of collecting data is to use audio- and video recording (Hammersley & Campbell 2012). This report solely used audio recordings. Two devices were used to record the interviews, since technical problems are described by Bryman and Bell (2015) as a possible major problem. Hammersley and Campbell (2012) propose that transcripts should be produced continuously during the recordings, which was also the case for this report. Right after the interviews were finish, the transcripts were completed, by listing on the interview recordings, in order to replicate the empirical data in an accurate way.

2.4 Data analysis

Since this thesis is adopting a flexible design, this should also be reflected in the stage of analyzing data (Hammersley & Campbell 2012). Hammersley and Campbell (2012) state that data should be categorized in categories and not in prearranged departments. These categories should be open-ended (Hammersley & Campbell 2012), but this assumption has to be questioned since the abductive approach has inevitably provided some efficient ways of managing and assorting the way to collect and present data, which may to some extent be contradictory to the flexible approach.

Memos were used during the process of collecting data and analyzing the data. Memos are an efficient way of conceptualizing the data (Yin 2014). These memos can provide insights that further provide analytical abilities and patterns (Yin 2014). Since the analysis and theory develops back and forth, the analysis in this report will follow similar headlines that appears in the theoretical framework. These headlines have evolved together with the categories from the empirical findings.

2.5 Research quality

Bryman and Bell (2015) state there are three factors when evaluating the quality of a research. These factors are reliability, replication and validity. Replication will however not be further investigated, since it does not affect the outcome nor quality of the report, and due to its similarities with reliability.

2.5.1 Reliability

Reliability deals with the problems if the research is repeatable or not, i.e. are the results consistent or not (Bryman & Bell 2015). However, Bryman and Bell (2015) further state that reliability is a more crucial problem in quantitative research, due to if the results fluctuates if doing the same research again, it is considered to be an unreliable report. However, since time is a crucial variable when conducting diffusion studies, it is impossible to recreate the same settings that this study had for future studies. It is further redundant to investigate historical events, since the chance that the diffusion of AR will change over time, is regarded to be high.

Yin (2014) mentions that studies should be constructed to lessen errors and researchers' biases. To get a high reliability, a researcher should construct their report in an easy matter, in order to make it easy to follow (Yin 2014). These findings were taken into consideration when construction the report. Since semi-structured interviews were used, which makes it more difficult to replicate the research, getting the same conditions. Due to that the interviews were partly open, there is a risk that the interviewees' insights will not be covered, if recreating the study.

2.5.2 Validity

Validity is possibly the most important factor when evaluating the quality of a study according to Bryman and Bell (2015). Validity can be described as the accuracy of the findings generated in the study (Bryman & Bell 2015).

Yin (2014) states that some people are critical how qualitative studies are affected by subjective influence. Hammersley and Campbell (2012) also state that reactionists claim that the data collected must be objective, and that the research methods should be standardized without any personal indication, since it could threaten the validity of the thesis (Hammersley & Campbell 2012). Simons (2012) states however that subjectivity is the nature of qualitative work, which is validated by this study. Instead of counter it, subjectivity should be embraced and seen as an intelligence to understand the involvement of the interviewees. Hammersley and Campbell (2012) have established that it is impossible to decontaminate the data from subjectivity, which may lead to errors. This can also be seen in Rogers's (1995) framework, that will be presented in the theoretical framework. Rogers's (1995) framework emphasizes the perceived advantage of a technology and not the objective advantage. Diffusion studies using Rogers's (1995) framework, are evaluating their results partly on subjective data.

Generalization may be a problem for case studies, but Yin (2010) states that it concerns all types of studies. However, generalization is not the primary advantage with a case study, nor is it either the goal of this report. Simons (2014) quotes Stake (1995) which cites that "The real business of case study is particularization, not generalization". (Simons 2014, pp. 20). These types of validity issues are therefore not as noticeable in this case.

Validity also deals with how well the conclusions avoids confounding (Bryman & Bell 2015), i.e. the confusion between cause and effect variables. Many factors studied in diffusion studies are indistinct factors e.g. size. Explanatory case studies have to deal with these problems. This logic is however not applicable in descriptive and exploratory case study (Bryman & Bell 2015), which this study mainly is.

Yin (2014) also provides approaches to increase the validity. One approach for achieving high validity is to use multiple sources of evidence. In this report however, it was not possible for practical reasons, because it was challenging to find other people who had just as good knowledge of AR as the interviewees had. However, multiple different case companies were used in this study, which increases the validity (Yin 2010). The data given by the interviewees were similar, which reckoned to have increased the validity. The interviews were also recorded, which decreases the need of using different sources (Yin 2010).

3 Theoretical framework

This chapter will examine the diffusion process and the four elements that defines the diffusion process, i.e. innovation, communication channels, time and social systems. Additional to diffusion theory, construction specific factors affecting innovation will also be presented. This chapter will also explain what AR is and examine its potential applications.

3.1 The difference between innovation, invention and technology

In order to get a wider understanding how innovation is connected with diffusion theory, it is important to understand what innovation is and that there exist different types of innovation. An easy description is presented by Ozorhon et al. (2010), that divide innovation in two parts, one technological part and one non-technical part. The differences are that technological innovation focuses on new products i.e. radical innovation, or improvements on already existing products, i.e. incremental innovation. Whereas non-technical innovation is restricted to organizational and marketing innovation (Ozorhon et al. 2010). Slaughter (1998) complies, on the other hand innovation into five topics, namely: incremental, modular, architectural, system and radical innovation, where incremental and radical innovation can be seen as technological innovation, and architectural and system innovation can be seen as non-technical innovation. Modular innovation can be seen both as a technical and non-technical innovation, depending on the context.

What all these frameworks have in common, are that they distinguish technical innovation, e.g. radical and incremental, from the rest. Incremental innovation can further be defined as "a small improvement…minimal impacts on other components" (Slaughter 2000, pp. 3) and radical innovation as "a new concept or approach which often renders previous solutions obsolete" (Slaughter 2000, pp. 3). The technological part, which in this case can be both incremental and radical innovation, will be the focus in this thesis. If AR is an incremental or radical innovation will not further be discussed, because it will not add value to the report and is not included in the scope of this report. It is however highly plausible that implementing new technologies changes how companies work i.e. organizational innovation, which will be taken into consideration.

It is also important to know that an invention, is not always an innovation, which often is the basis of researchers' studies. Slaughter (1998) for example, defines an innovation as "the actual use of a non-trivial change and improvement in a process, product, or system that is novel to the institution developing the change" (Slaughter 1998, pp. 226), whereas Gambatese and Hallowell (2011) define innovation as a "positive change in a process, product or system" (Gambatese & Hallowell 2011, pp. 560). However, Gambatese and Hallowell (2011) further define that the difference between an innovation and an invention, is that an invention is a novel process or device, and that an innovation is an invention with a usefulness. They further state that an innovation includes three parts, namely: opportunities, generation of ideas and diffusion (Gambatese & Hallowell 2011). Martínez et al. (2014) state that the transformation from an invention to an innovation usually emerges as a jump, whereas diffusion emerges as a somewhat slow and constant process. Hence, diffusion is often regarded to be an influential factor that affects economic growth and the usage of an innovation (Martínez et al. 2014).

Other researches, e.g. Pellicer et al. (2012), state that the outcome of an innovation involves four factors, i.e. "improving competitiveness of the company, increasing its technical capacity by being able to solve organizational problems, offering incentives for employee learning and succeeding in transferring the solutions to subsequent projects" (Pellicer et al. 2012, pp. 41). Using Pellicer et al.'s (2012) logic, AR needs to support these four factors in order to be seen as an innovation, otherwise it could be implied that AR is not an innovation. The same logic can be applied to Gambatese and Hallowell's (2011) definition. Rogers (1995) distinguish innovation and invention apart in an even simpler matter, namely by defining invention as the process where new ideas are created, and innovation as the process when new ideas are being adopted. The differences can further be explained by Andersson and Widén (2005), as that an innovation is an invention with a development and with an implementation/adoption. The boundaries between invention and innovation are thus clear. Although researches define innovation differently, the terminology of innovation have a common thread and emphasize the same factors.

Rogers (2003) argues that most reports studies technological innovations, and therefore are technology and innovation often regarded as synonyms. Rogers (2003) defines a technology as "a design for instrumental action that reduces the uncertainty in the cause-effect relationships involved in achieving a desired outcome" (Rogers 2003, pp. 13). Rogers (1995) further says that the social perception mostly views a technology as a physical component or as a machinery. This conception can be argued against, since a technology usually covers both a hardware section and a software section (Rogers 1995). It is even possible that a technology is widely comprised by a software part, which basically is the information base for a technology. Rogers (1995) states that political philosophy e.g. Marxism, can also be regarded as a technology.

However, since most innovations in diffusion research have been technologies, i.e. Rogers's research, innovation and technology will be used as interchangeable synonyms in this report.

3.2 Measuring innovation

After establishing what an innovation is, it is further important to understand where and how an innovation diffuse. To understand where and how an innovation diffusion, one must acknowledge how to measure the outcome of an innovation. Organisation for Economic Co-operation and Development (OECD) (2018) has dedicated an entire manual, i.e. the Oslo Manual, to explain what innovation is and guidelines on how to collect, report and use the data regarding innovation (OECD 2018). However, there exists skepticism if it is possible to measure innovation, since the traditional innovation indicators, e.g. patents and R&D have weaknesses in showing how innovative a company really is (OECD 2018). The bottom line is that some aspects of measuring innovation are cumbersome, and it can appear troublesome when using the concepts based on manufacturing industries for service-based industries, which the construction industry is to some extent (Ozorhon et al. 2010).

The non-technical aspects of innovation can also be challenging to measure. It is uncertain if any survey can grasp some of the aspects, e.g. organizational change (Smith 2005). R&D and patent inputs are also uncertain when using surveys. Although surveys provide decent details of generality, they have flaws in measuring depth. One way to reduce the uneven balance is to combine the data with case studies, which provides individualized and definite results at the expense of providing general results (Smith 2005).

Studies presented by Egbu (2001) and Tucker (2004) in Gambatese and Hallowell's (2011) report suggests measuring innovation by using the following factors as indicators, which are: the percentage rate of profit/sales coming from an innovation, numbers of innovation introduced, numbers of innovative generated ideas, numbers of man-spent hours derived to an innovation and numbers of filed patents. Other researchers in Gambatese and Hallowell's (2011) report have also added an organization's objective, resources and governmental incentives as means to measure innovation. Despite that, quantitative studies coping with these measurements are lacking in providing positive correlations between tested metrics and predicted outcomes (Gambatese & Hallowell 2011).

According to studies presented by Ozorhon et al. (2010), one can observe innovation in three different stages, i.e. sector, business and project stage. Innovation in the sector stage is the easiest to review and innovation on project level is the most difficult one, since some of the innovation is hidden. However, since construction companies mainly work by using a project-based approach, thus the majority of innovation is derived to the project level.

Ozorhon et al. (2010) state that understanding the project stage, is the most important, but researchers tend to focus on the firm level. However, firm and sector levels have to be taken into consideration when measuring innovation (Ozorhon et al. 2010). Ozorhon et al. (2010) also present that construction is a mix between manufacturing and service, i.e. it contains both manufacturing and service-based parts. As one could expect, characteristics of innovation in manufacturing and service-based companies do not correlate. Therefore, Ozorhon et al.'s (2010) conclusions are that measuring traditional innovation indicators, e.g. R&D inputs and patents or/and trademark outputs, are not efficient, due to innovation being unrelated to those traditional innovation indicators. Project-based innovation are often hidden, and process innovations are seldomly patented nor trademarked (Ozorhon et al. 2010).

An easier way to measure and understand innovation is to compare the contemporary state with the past state (Gambatese & Hallowell 2011). Doing this, one could analyze if positive change has occurred. Positive change is the result of integrating new ideas that are non-trivial, which have added some type of value. Gambatese and Hallowell (2011) further state that change could be identified as when new ideas are being generated, tested or implemented or the speed it takes for an innovation to diffuse for a single company or an industry and if a company must train and educate their employees due to changing settings. Gambatese and Hallowell (2011) also mention other indicators and to which extent they change, e.g. profit, cost, schedule, safety, quality, market share and competitiveness. If positive changes occur, it could be regarded as a result of an innovation. Then, comparing an earlier stage with a contemporary stage, you should be able to see the differences and make it possible to measure the outcome of a new innovation (Gambatese & Hallowell 2011). Since positive change and value can be derived to the diffusion of the innovation according to Gambatese and Hallowell (2011), their statement validates that the diffusion approach, presented by Rogers (1995), is a legit method measuring innovation.

3.3 Where and how innovation occurs

Before understanding which attributes of e.g. an innovation or an organization that affect diffusion theory and the diffusion rate of an innovation, one needs to understand where and how an innovation in the construction industry emerges. Pellicer et al. (2012) start stating that an innovation emerges from three different types of settings, partly: "technological problems at the construction site, demands from clients, and stimuli from upper management" (Pellicer et al. 2012, pp. 45). Technological problems at the construction site seems to be the most important factor where the main ideas are established, standing for high 80% (Pellicer et al. 2012). Problems solved at construction sites leads, more often than not, to new improved products or processes (Pellicer et al. 2012). Studies have also shown that innovation related to products, have a higher possibility being adopted than a process innovation (Gambatese & Hallowell 2011).

Harty (2008) has a different view where the interest of an innovation emerges. Harty (2008) reports that the two settings where the starting point or interest in innovation arises can be explained by external factors, e.g. clients asks and higher demands for better and new building-technology. An example of what new and smarter buildings are, is when the design and the environmental performance is improved (Harty 2008). The other sight where innovation emerge from, is that innovation come from somewhere else (Harty 2008; Weidman, Young-Corbett, Koebel, Fiori & Montague 2011), e.g. suppliers that improve building materials (Harty 2008). Harty (2008) furthermore argues that these two settings cannot enfold all activities regarding innovation. Factors such as e.g. knowledge used for problem-solving, can further drive innovation (Harty 2008).

Ozorhon et al. (2010) further validate the statement by stating that a substantial part of the construction innovation can be derived to manufacturing firms, since their R&D spending are much higher than contractors, ultimately ending in having a higher chance of innovating new products and processes. Pries and Janszen (1995) further argue for the statement that the influence from other industries are vast. 50% of products used in construction industry can be derived to other industrial industries. Ozorhon et al. (2010) disclose manufacturing firms as significant inspiration for the construction industry. Pries and Janszen (1995) also emphasize the chemical industry as an important source of innovation. Electrical engineering, machinery and metal industries are other important sources of inspiration. Pries and Janszen's (1995) conclusion are that the construction industry is heavily dependent on other industries. Since the construction industry is heavily dependent on other industries (Pellicer et al. 2012), it has resulted in the construction industry becoming better at copying and integrating new processes and products. Having that said, contractors operating in project-based companies always stand to some extent for new innovations, since projects are often unique (Ozorhon et al. 2010).

Research by Van De Ven (1991) showed that innovation often occurs in cumbersome and bumpy ways, as a result of organizations being impatient, unwilling to do a proper evaluation of the innovation's core functions, thus leapfrogging into new technologies. Doing so, paradoxically organizations need to spend even more time to develop and understand peripheral tasks, often ending in postponing the adoption (Van De Ven 1991). Van De Ven (1991) further explains that not all organizations are equal, thus, innovation has to be managed contrastively. Innovations that are radical, that possibly could eradicate mature and creating unfamiliar and newfangled settings, seem to suit organizations that remunerates individuals, whereas incremental innovations may suit collectivistic organizations better. While this may be true, an overall evaluation of different innovation types has proven that simple technically innovation was better arranged than complex technically innovation (Van De Ven 1991).

3.4 Diffusion of innovation

One of the most famous authors in the field of innovation diffusion is Everett Rogers, as he published his book *Diffusion of Innovations* in 1962. Diffusion regarded by Rogers (1995) can be defined as a process where innovations arises, where the innovation itself, communication channels, time and the social system affects the outcome (Rogers 1995). Rogers (1995) states that these four elements could be found in every case. Yet, the diffusion process is always including some degree of uncertainty. Although Rogers's framework will hereinafter work as the base for the theoretical framework, being the used model in this report, it has to be slightly modified to suit the purpose of this thesis. The model is influential when used in settings regarding individuals, but it does not manage all the complex fields observed in settings when organizations are the main focus (Van De Ven 1991). Yet, Rogers (1995) presents evidence that the correlation between how innovation diffuses in individual versus organizational settings is high (Rogers 1995).

Rogers (1995) has created a model, explaining the process of the diffusion of innovations. Rogers's models capture more or less all the important aspects needed to understand innovation diffusion (Van De Ven 1991). Most researchers have conducted their studies within the field of diffusion, from the perspective of individuals and not from the perspective of inter-and intra-organizational organizations (Van De Ven 1991). The latter have proven to be much more challenging and sophisticated, since it involves social, political, and bureaucratic complexities of large organizations (Van De Ven 1991).

Contemporary researchers and practitioners are still using models based on individuals to evaluate organizations. Given that situation, the majority of researches, studying organizations adopting innovations fail. To their defense, it is well-known that organizations that seems to be similar, have dissimilar outcomes when adopting same innovations (Van De Ven 1991). Rogers (1995) supports the statement that the innovation process is much more complex in companies than it is for individuals. Organizations are generally adopting innovations in a more slowly pace, due to, when more people are involved in the innovation decision, it is more likely that the adoption rate is going to be slower, according to Rogers (1995).

3.5 The first element: Innovation

Innovation is the first element in Rogers's (1995) framework. Rogers (1995) defines innovation as a new idea being adopted. Innovation will be the key element of this thesis, since it handles the research questions in the most natural way. What an individual perceives as a new idea may differ from different systems, industries and companies (Rogers 1995).

3.5.1 Rogers's factors affecting the rate of adoption

Some innovations are more likely to have a faster spread e.g. smartphones or VCRs, whereas some innovations may have a slower rate of diffusion and may never be adopted entirely e.g. the metric system in the United States. Prior researchers have assumed all innovations as corresponding entities, a statement which Rogers (1995) reasons as dangerous in diffusion research.

Rogers (2003) mentions that which type of innovation-decision a unit takes, how communication channels are involved in the innovation-decision process, the role of the social system, and the role of change agents' part in the diffusion process are some of the variables affecting the rate of adopting. These variables will be explained more in detail later on. The most important factor is however the perceived attributes of an innovation. Perceived attributes of an innovation are one of the most significant factors, usually explaining the variance in adoption rates by 49 to 87 percent (Rogers 1995). Rogers (1995) has developed five indicators i.e. factors included in the perceived attributes of an innovation, that explain the rate of adoption of an innovation, maximizing generalization and conciseness as a group.

Rogers's (2003) five factor are derived for old studies and can be used to predict future adoption rates. Case studies presented by Rogers (2003) showed that 27 percent of the variance in the rate of adoption were explained by twenty-five factors, where Rogers's five factors were included. When only regarding Rogers's five factors individually, it explained the variance by 26 percent in the same case. The remaining 20 factors were thus only explaining the variance by 1 percent. The difference between the five factors versus the twenty-five factors are that the latter came from interviewees' own frame of reference. It is concluded that Rogers's five factors alone, are enough to explain the attributes of an innovation. However, every innovation is unique, and it is impossible to predict that these five factors are important for every adopter (Rogers 1995).

3.5.1.1 Relative advantage

The first indicator is Relative advantage, which Rogers (1995) explains as if an innovation is perceived to have an advantage over an innovation it substitutes. A higher rate is beneficial to a faster adoption. However, Rogers (1995) emphasizes that the perceived advantage is not based on the objective advantage, the only important factor that affects the relative advantage is the subjective advantage. How individuals perceive an advantage is not determined by a fixed framework, but rather indicators as users perceive useful e.g. adding or improving financial conditions, gaining social status and convenience and satisfaction values. The relative advantage can change with an increased number of end-users as well (Rogers 1995).

Researchers have found that the relative advantage seems to be the strongest factor predicting the rate of innovation adoption (Rogers 2003). The sub factors that showed to have the largest impacts were having a positive profitability, low start-up costs, increased pleasure, increase social prestige, witness direct gain and decreasing the time and effort. These subfactors are not in the advantage of preventive innovations i.e. opposite to incremental innovations which value is present. Preventive innovations have a slower adoption rate and are more difficult for change agents to promote, because the value does not exist now, and it does maybe never occur. The relative advantage is seen to be highly uncertain for preventive innovations (Rogers 2003). Rogers (2003) further states that innovations that impose risks have a higher possibility not being diffused. The perceived effectiveness of innovations has proven to be stronger for incremental innovations than for radical innovations (Van De Ven 1991).

3.5.1.2 Compatibility

Compatibility is the next indicator, which explains how consistent the innovation is perceived by users to work with existing values, cultural settings and present and past settings. If the innovation is not compatible with current social systems i.e. values and norms, the rate of adoption will not be as fast (Rogers 1995). Cultural values can totally block innovations to diffuse, if it is not suitable for the users' need. The same issue is concerning change agents. If the units are not willing to adopt an innovation, there is nothing the change agents can do to promote the innovation (Rogers 2003).

How compatible an innovation is can also be derived to how units perceive the innovation work with existing ideas and innovations, because adoption units use old ideas to evaluate new innovations. Compatibility can lead to over-adoption or mis-adoption, if the adopters do not have right experience maintaining the innovation (Rogers 2003). It is also important to notice the idea or the innovation that a new innovation supersedes. Sometimes innovations have no relationships towards other innovations, sometimes they do. If the relationship is high, it may force the adopter to adopt another innovation that suits their ecosystem. If adopters must change their behavior to adopt an innovation, the chance that the new innovation will diffuse is reduced. Some studies have empirically found that relative advantage and compatibility are similar, even though they are not similar, theoretical speaking (Rogers 2003).

3.5.1.3 Complexity

The third indicator is Complexity, which explains how difficult or easy it is to understand an innovation. The easier the innovation is to understand; the faster the rate of adoption will be. The importance of complexity differs from various innovations. Home computers had a major problem to overcome in the beginning, because the complexity was a huge threshold. Regular people did not have the knowhow to use a computer, compatible with engineers and scientists that were regarded as early adopters, because computers were not regarded as complex.

Relative advantage combined with compatibility and complexity can be found in other models like Technology Acceptance Model, (TAM) (Martínez et al. 2014). TAM discloses an aspect about an individual's attitude to use an innovation, comparable with compatibility, which consecutively is fractionated by an individual's perceived usefulness and perceived ease to use of an innovation (Martínez et al. 2014). Martínez et al. (2014) further disclose that perceived usefulness is when an individual believes that an innovation will improve the performance, which resembles relative advantage. The perceived ease of use occurs when an individual believes that slight effort is needed to use the innovation, which resembles complexity (Martínez et al. 2014).

3.5.1.4 Trialability

Trialability explains how capable an innovation is of being tested in cases or experiments e.g. settings on a limited basis/budget and learning by doing. Dividable innovations that can be implemented at one time have a higher chance being implemented (Rogers 1995).

Pries and Janszen (1995) state that trialability overall, in the construction industry is low because companies avoid new and stick to old proven methods and innovations.

3.5.1.5 Observability

The last indicator is Observability, which means how noticeable the results are of an innovation to others. Innovations that emerge in settings that are less likely to be noticeable, have a smaller chance to diffuse. Innovations that a greater number of users, that have experienced the innovation, have a higher chance to diffuse (Rogers 1995). Software is not so apparent and innovations that empathize software have a slower adoption rate. Some studies have shown evidence that an economic aspect i.e. relative advantage is the most important factor describing the adoption rate, whereas other studies found that a combination of cost-effectiveness and observability were the most important factors shaping the adoption rate (Rogers 1995).

3.5.2 How organizational attributes affect the diffusion of innovations

A major reason to how an innovation diffuses can be derived to the organizational attributes. The first step of evaluating an organization's attributes starts with the decision step, which usually contains one of four different types mentioned by (Rogers 1995). These four different types are:

Optional innovation-decision, Collective innovation-decision, Authority innovation-decision and Contingent innovation-decision (Rogers 1995). Optional innovation-decision can be described as when individuals in a system make the call to either adopt or reject an innovation independent from the other members in the system. Collective innovation-decision is when an entire system collectively makes the call whether to adopt or reject an innovation. Authority innovation-decision occurs when few individuals within the system with technical knowhow and influence decide whether the system is going to adopt or reject an innovation. Finally, contingent innovation-decision makes it possible for an individual in a system to adopt an innovation, but only after a prior innovation decision has been made. A contingent innovation-decision approach is usually a collective innovation-decision, followed by an optional innovation-decision (Rogers 1995).

Which one of these methods companies are devoted to depends to a certain degree to the organizational structure (Rogers 1995). Rogers (1995) further advocates that the structure can be obtained by observing five aspects i.e. Predetermined goals, Prescribed roles, Authority structure, Rules and regulations and Informal patterns. However, how these aspects affect the adoption of innovations cannot be derived from the properties of the innovation itself, which is the scope of this thesis. Having that said, independent variables have to be regarded since a non-negligible part can be derived from those variables.

Rogers (1995) states that a lot of the characteristics of individuals are interactable with organizations. Individuals with a high social status or having the funds to invest in innovations are characterized as being more innovative. These individuals are interchangeably with large organizations who also are more innovative than their counterparts. There exist however aspects that are not mutual between individuals and organizations. Individuals do not have as much bureaucratic burdens as organizations do. Organizations are however more likely to have characteristics i.e. system openness, which Rogers (1995) defines as an open system exchanging and gaining information outside the borders of the social system, which indeed is not as likely for individuals.

Implementing innovations may affect the organization, since the innovations could possibly demand the organization to change structure to utilize the innovation efficiently (Rogers 1995). Innovation is important for companies, even one of the most important processes taking place, as reported by Rogers (1995). However, Rogers (1995) further expresses that the desire to break old habits is low and organizations may oppose hinders.

Size is a clear aspect that have shown to be related to innovativeness where larger organizations tend to be more innovative. Size is also an indistinct factor because it joints variables as e.g. resources, expertise, structure into one variable. Which variables that are aggregated into size and how they affect innovativeness is still not clearly understood by researchers i.e. do big organizations get big because they innovate, or do they innovate because they are big? (Rogers 1995). Van De Ven (1991) has showed that small organizations may have a smoother process adopting innovations, whereas larger organizations have more resources enabling them to invest means to keep the innovation efficient (Van De Ven 1991).

Pries and Janszen (1995) also state that larger construction companies tend to be involved in product innovation to a greater extent than small construction companies, but that small construction companies tend to be more involved in process innovation than large construction companies. Larger organizations enable a sturdier basis, making them more likely to support and reinvent innovations (Van De Ven 1991). Studies from Pries and Janszen (1995) have on the contrary, proven that the majority (75 %) of innovation emerges in small companies and not in large companies. Pries and Janszen (1995) state that their findings correlate with opinions from Best (1990) and Wijnberg (1990). Different results have thus been presented from different authors.

Large organizations also tend to gravitate towards a more bureaucratic system, making adopting innovation more unfavorable and disadvantageous (Blayse & Manley 2004). According to Blayse and Manley (2004) a spacious share of the construction industry is dictated by small players that do not have the strength to innovate.

Organizational structure e.g. centralization or decentralization is also a relevant variable. Centralized organizations have often had a negative correlation with innovativeness (Rogers 1995). One reason is that top management that makes the decisions in centralized organizations have poor knowledge to identify problems and find innovations that suit the entire organization's need. Decentralized organizations tend to be better in the initial stage, adopting new innovations, whereas centralized organizations have showed to be more effective in the implementation process. Conclusively, Rogers (1995) states that hundreds of studies show that independent variables e.g. size and structure, have low correlation with an organization's innovativeness and that the noticed relationships between the variables are further low.

3.5.3 Construction industry specific factors that affect innovation

The construction industry is often seen as a slow industry following behind other industries, not only regarding innovation, but also in terms of finding more efficient ways of working. The automotive industry is a great example of an industry doing a lot right by being capable of adopting innovation from other industries, but also efficiently developing their own technologies (Harty 2008). It might be plausible that the construction industry could adopt their approach to more successfully implementing innovative technologies (Harty 2008). Harty (2008) further states that innovation is changing the way firms works, forcing companies to implement innovations across an inter-organization site. It has been declared that a further need to understand the characteristics of the construction industry is required (Harty 2008). Harty (2008) further states that the view that innovation management is bases on, is not adjusted to work in construction contexts.

To fully understand the innovation systems and development of the construction industry or any industry at all, one has to be aware about the characteristics, both the internal and external driving forces and influences (Andersson & Widén 2005). Harty (2008) mentions that researchers have not efficiently depicted the characteristics of the construction industry yet. Furthermore, studies that have been accomplished among others e.g. Ling (2003), states that construction is quite different from the manufacturing industry. This is also supported by Gao, Li and Tan (2013) that argue that few researchers have done an investigation on which problems and special needs that could arise in the construction industry and that few researchers have constructed a model suiting the construction industry. The manufacturing industry is often more individual-driven and emphasizes buy-sell relationships (Ling 2003). Whereas construction puts a different emphasis on relationships, being more project-based and having a shared interest in technical competencies and capabilities. Projects are sorely founded on customers' demands, which is not always the case with consumer-goods industries (Ling 2003). Another reason, argued by Blayse and Manley (2004) why the manufacturing industry tends to be more innovate, is because manufacturing markets tend to be more standardized and steadier, thus enabling them having a better basis for R&D programs. These programs are unlike for the construction industry, the main driver for innovations (Blayse & Manley 2004)

Gann and Salter (2000) do not see construction industry as an industry, but as a construction process. One of the reasons behind this conception is because construction deals with complex products and systems. Every project is unique and involves many organizations, hence the view as construction being a process (Gann & Salter 2000). Gann and Salter (2000) define a sector or a firm as a project-based industry if: "their design and production processes are organized around projects; they usually produce one-off, or at least highly customized, products and services; and they operate in diffuse coalitions of companies along the supplier–customer chain." (Gann & Salter 2000, pp. 959).

3.5.4 Driving forces that impact innovation for construction companies

Blayse and Manley (2004) argue that there exist six focal factors that impacts the degree of innovativeness for construction companies, namely: "clients and manufacturers, the structure of production, relationships between individuals and firms within the industry and between the industry and external parties, procurement systems, regulations and standards, and the nature and quality of organizational resources." (Blayse & Manley 2004, pp. 144). Blayse and Manley (2004) do however acknowledge that the relationships between the factors themselves and also that the relationships between the factors and business strategies are still not crystal clear.

3.5.4.1 Procurement

The procurement process is when the constructor or the client that are responsible for the building, additionally with other parties involved, determine which types of working methods and techniques get diffused (Vinnova 2012). Without these settlements between clients and contractors, innovations that only cuts costs will be implemented (Vinnova 2012). Having committed key actors have shown to have a strong and positive correlation to the adoption and diffusion of innovations (Vinnova 2012). This approach is especially important for project-based industries. Service providers should involve their customers in specific and long-term relationships (Gambatese & Hallowell 2011). Momentary, the physical product is only a part of the final product that construction companies provide. Services and means that adds value in form of supporting the customer e.g. running and maintaining the building is clearly more emphasized in modern papers, erasing the typical boundaries separating manufacturing and service sectors. Companies with this approach could gain competitive advantage (Gann & Salter 2000).

3.5.4.2 Clients and manufactures

The most important factor that drives innovation in the construction industry according to Gann and Salter (2000) is fundamentally new types of houses and buildings. For past decades, information and communication technology (ICT) combined with new manufacturing methods have generated the demand. Globalization and new markets in eastern Asia have forced some segments of the industry to be more innovative (Gann & Salter 2000). What has been requested by customers, is that complex projects should be done on tight timetables and reaching all the other goals e.g. budget and quality (Gann & Salter 2000). The demand from customers forces innovation development, which pushes the industry to find new ways to produce new products (Ozorhon et al. 2010). Parallel to this progress, the demand for services seems to increase as well (Gann & Salter

2000). Gambatese and Hallowell (2011) have also presented studies on what contractors could do to successfully increase the usage of new technologies. Some important factors have shown to be, having the needed technical capability for a project and involving clients.

Blayse and Manley (2004) further expand the statement that customers and manufacturing firms are powerful factors, enabling the innovation the most. Blayse and Manley (2004) advocate that customers have a vast impact how companies cultivate innovation and that this conception is accepted among many researchers as a fact. Blayse and Manley (2004) argue that customers can strengthen a company's innovativeness, either by forcing the developer, but also suppliers and operators to build a facility that has specific innovative requirements e.g. improved facility performance. The clients can force the project being more flexible and hence force companies to introduce new standards.

3.5.4.3 Industry relationships

Gann and Salter (2000) argue that since construction is a project-based process, companies are required to collaborate and manage their network with other firms. Thus, one firm cannot be responsible to perform if the entire network does not co-exist and collaborate together. These networks are mutually dependent on each other to functionate (Gann & Salter 2000). The companies are thus to a greater degree dependent on technical support e.g. institutions and organizations that can support learning between companies and projects. This should force companies to abandon internal technology strategies, since technologies need to overlap with the internal projects to be managed properly and to work efficiently, which is in line with many other complex project-based industries e.g. oil-platforms and aviation (Gann & Salter 2000).

Theory that states that companies should collaborate with other various firms, is validated by Gambatese and Hallowell (2011). Sharing resources i.e. capacity and competencies, combined with having common goals are key factors to achieve innovational success. Blayse and Manley (2004) also validate the statement that universities, institutions and researchers can assist knowledge to companies and also means to support partnership between companies and the innovation brokers. Blayse and Manley (2004) further present studies that show that innovation brokers are possibly even more important in the construction industry, because technology watch is limited and often not feasible, due to companies rarely design or develop innovations themselves. Many of the companies are small and the industry is seldom high-tech (Blayse & Manley 2004).

3.5.4.4 Production structure

The type of project and its context that the members create, which companies base their decisions on regarding innovation management, plays a crucial role in how successful innovation will be implemented in project-based industry (Gambatese & Hallowell 2011). Managers and senior managers often play a key role, how and when an innovation is going to be implemented (Ling 2003). Gambatese and Hallowell (2011) state that the characteristics of project managers and supervisors is one of the most important attributes impacting innovation within companies and organizations. Van De Ven (1991) states that managers should find flexible solutions, spend the time needed not taking shortcuts, foster technical competence and listen on those how are implementing and using the technology. All these factors have proven to be critical for the innovational success in large organizations (Van De Ven 1991).

However, project-based companies may differ from other manufacturing companies since team members' commitment plays a significant role, if an innovation is received with open arms or not on a project level. Older studies presented in Ling's (2003) report, demonstrates findings that team members also must show readiness and opportunity to embosom alternative approaches that they are not used by. Ling (2003) means that the team member's interest is the most important factor if an innovation is going to be valuable or not, given that the company and employers have the technical capability and skills. Having an interest in an innovation implies and often causes being committed. Ling (2003) further argues that this statement is in line with other conclusions from other scholars i.e. Funke (1988) and Slaughter (2000), which state that management plays an important role, investing and committing wherewithal for the implementation of an innovation. Their commitment must be total in providing enough means until a definitive success and not an arm's length commitment (Ling 2003). If not, further steps have to be taken to stimulate involved actors. Studies published in Gambatese and Hallowell's (2011) article reports that project groups must involve clients and have technical capabilities, if contractors successfully want to get acquaint with new technologies.

3.5.4.5 The nature and quality of organizational resources

Some of an organization's resources are tangible and some intangible. Some of the tangible attributes i.e. size has already been discussed previously in the sector *How organizational attributes affect the diffusion of innovations*. The intangible attributes are often linked to the culture of the company. To enable a positive sight on innovation, a company should not punish new ways of workings that have not succeeded (Blayse & Manley 2004). People in the organization should also be able to question present ways of working without being penalized and workers in the company should strive to understand the goals set by other individuals in the organization (Blayse & Manley 2004). If an organization is going to develop and learn, it requires that the people working in the organization are open towards new ideas and that they are contributing to an ongoing dialogue (Blayse & Manley 2004).

Having innovations champions have also been concluded to have a vital role, if innovations in the organizations are going to flourish (Blayse & Manley 2004). Blayse and Manley (2004) present that innovations require people to have the technical competence to help the organization to overcome uncertainty and to carry the idea to mobilize the rest of the company (Blayse & Manley 2004).

Branding and reputation are another important factor, if a construction company will successfully perform well or not (Gann & Salter 2000). The way that branding and reputation is connected to innovation is the companies need of being recognized for its technical capabilities to the public knowledge. Utilizing reputation to win new contracts is a well-known strategy and simultaneously, the company gains more expertise. Although it may be costly to maintain a high position, it could be the means to improving a company's long-term competitiveness (Gann & Salter 2000). Maintaining a technical reputation is seen as a key element to show the customers an ability to handle and solve complex challenges that might occur during the manufacturing process (Gann & Salter 2000). A way of showing competence is to publish journals and articles, which works as an indication to other companies operating in the sector, how innovative and professional they are (Gann & Salter 2000). This statement is closely comparable to Rogers's statement that social status is a legit reason why individuals adopts innovations (Rogers 1995).

3.5.4.6 Regulations and standards

Governments can also introduce incentives to boost non-private but also private investments of R&D through e.g. tax benefits and standardization. This has happened in Spain, where the government has initiated tax benefits on income tax, but also adopted a bundle of standards that standardizes the innovation processes (Pellicer et al. 2012). Regulation and policies have an important role impacting the technological change. These regulations and policies usually come from the government, international agencies, and organizations, which create frameworks which organizations must adapt (Gann & Salter 2000). However, these frameworks can be as much as hinders as drivers, which the paragraph *Hindrance for innovation* will cope. The technological regulations on quality are tangible in the construction industry, both in social housing and civil engineering (Pries & Janszen 1995). Financial and technical regulation is just one way to influence the outcome. The government also influences "competition, business licensing conditions, procurement and working conditions" (Pries & Janszen 1995, pp. 45). Having that said, governmental decisions and regulations may be the fastest way to affect the adoption (Rogers 1995). Security innovations e.g. automotive seat belts are one example when authorities have force companies to implement new innovations (Rogers 1995).

3.5.5 Hindrance for innovation

A lot of theories that have been presented hitherto supports and advocates innovation. However, the construction industry is exclusive and has limitations that other industries do not have (Blayse & Manley 2004). Meanwhile, many metrics have been mentioned by researchers, which they argue to impede and enabling innovation. However, factors like those have not to a great extent been widely validated (Gambatese & Hallowell 2011).

3.5.5.1 Industry relationships

Although Gann and Salter (2000) and Gambatese and Hallowell (2011) state that companies should collaborate with other firms, the reality looks different. Even though there exists a need to cooperate in integrating networks, firms in the construction industry tend to do the opposite (Gann & Salter 2000). Firms adheres to information inside their own circle of control and they do not spread the knowledge outside their own circle, not even to momentary partnerships (Gann & Salter 2000). The consequences that are persecuting the firms are higher costs and complexity. However, this results that companies get a broader know-how in these fields, as they need to spend more time and resources. This could be proven by looking on academic journals published by construction firms, which demonstrates an increased number of papers published in fields, not merely associated with civil engineering and construction, but also in fields e.g. mathematics and chemistry materials (Gann & Salter 2000).

One reason why you cannot compare the construction industry with a highly innovative industry e.g. the manufacturing industry, is that the construction industry does not only incorporate material and machineries, but it also incorporates services (Ozorhon et al. 2010). There also exist intricate processes which can complicate the innovational processes since innovation hardly ever occurs in isolation, but commonly with other organizations e.g. firms and universities. Firms and universities are in turn affected by regulations and laws, which enable systems to commercialize innovations (Ozorhon et al. 2010).

That innovation does not generally happen in isolation, but in relationships with other organizations and firms e.g. government agencies, universities, suppliers and customers, are supported by Edquist (2010). Strong inter-organizational relationships are an important way to enable innovation in the construction industry, which is widely recognized among researchers (Blayse & Manley 2004). Blayse and Manley (2004) argue that if the opportunity for innovation is going to arise, the industry's relationships must be stronger. However, construction companies suffer from partially exchanging vital information with actors involved in common projects, which leads to reworking parts and disputes (Harty, 2008). In these environments, where companies do not change information, implementations tend to be bounded and cannot always be controlled if they go beyond the individual or a single company (Harty 2008).

Blayse and Manley (2004) argue however that temporary forms of partnerships may occur during project phases, but then dissolve when projects have to come to an end. These temporary forms can inspire to innovation, to the extent that the projects can be seen as experimental workshops using innovation to solve quirks or unique demands specifically tied to a project. However, it belongs to the rarity (Blayse & Manley 2004).

3.5.5.2 Regulation

What enables innovation can also hinder innovation i.e. regulation might be as much a driver as it is a hindrance of innovation (Edquist 2010), since it influences the framework how companies use innovations (Gann & Salter 2000).

3.5.5.3 Production structure

Taking the decision to integrate new technology e.g. full-scale prototypes, is not ideal conditions to test new technologies in the construction industry (Gann & Salter 2000). Thus, making development, planning and simulation extra important. Gann and Salter (2000) further claim that in order to successfully accomplish these types of tasks, firms are forced to transfer knowledge within these complex networks, since it usually includes multiple specialists (Gann & Salter 2000).

Customization is also needed for some projects since clients have different needs and demands and these environments may not be optimal for extending innovation from one project to another (Gambatese & Hallowell 2011). This statement is also defended by Pries and Janszen (1995). Pries and Janszen (1995) argue that since the contractor might have final selecting decision e.g. suppliers and design depending on how the contract is written and who the customer is, every project becomes unique, making it unnecessary to invest in innovation that does not improve their own process (Pries & Janszen 1995). Since the buildings are costly, bounded to one location and expected to have a long-life span and with a high required quality, proven construction methods are selected with the purpose not to jeopardize quality and take risks. Radical innovation is deprecated. Economies of scale and learning effects do not usually arise in these construction settings, partly because they are project-based (Pries & Janszen 1995). Similar ideas can be found by Blayse and Manley (2004).

Some other disadvantages with project-based processes is that the framework does not support routines to the same extent as non-project-based industries do. When being project-based, the opportunity to experience systematic repetition is reduced, thus the chance to experience economies of scale, standardization and process improvement reduces as well (Gann & Salter 2000). Internal project financing could also affect the outcome, possibly influencing the utilization of the new technologies (Gann & Salter 2000). Environmental protection is included in the process chain, introducing conditions which companies must handle and deal with (Gann & Salter 2000). Project-based industries also tend to have a more difficult time creating and maintaining knowledge bases and a harder time achieving virtuous cycles regarding learning, mainly because projects are irregular (Blayse & Manley 2004).

3.5.5.4 Clients and manufacturing

Blayse and Manley (2004) argue that companies do not have incentives to innovate and that companies or project-teams usually have different solutions for similar problems, hindering organizational learning. Blayse and Manley (2004) also argue that since facilities are expected to have a great lifespan, well-known techniques are preferred over new and unpredictable methods and techniques (Blayse & Manley 2004). Since risks can be devastating for construction-companies, one way they are dealing with risks is to pass them further down the supply chain to their suppliers. This in turn, forces subcontractors to use well documented tactics (Blayse & Manley 2004).

The construction industry also has complex systems. Introducing new or changing existing systems can create domino effects that can be difficult to anticipate, if companies do not use a systematic approach and identifies the factors that can decrease the risks (Slaughter 2000). One method mentioned by Slaughter (2000) to lower these risks, is to use the cycle of implementation stages. Nevertheless, if you want to change a process, large parts of the remaining supply chain must usually undergo the same changes, because the construction process is coordinated between many different actors (Harty 2008). Blayse and Manley (2004) also present data that having multiple number of actors involved in a project have a negative conjunction. The reasons behind this conception is that different actors are liable for diverse elements. Communication between these parties have often struggled to be effective, and the improvement of the communication among themselves usually occurs at the expense of not being able to introduce innovations (Blayse & Manley 2004).

3.5.5.5 Procurement systems

Blayse and Manley (2004) also advocate that procurements systems intimidates companies taking risks adopting innovation. Not trying to update their processes or products is the biggest harmfulness against new innovations (Blayse & Manley 2004). Procurements systems that are present now, emphasize price or speed. Ling (2003) also presents other reasons as e.g. complex contracts, inadequate connection between contractors and consultants, high R&D costs and the lack of finding financial gains from innovations can lower the innovativeness (Ling 2003). However, innovations must and are often implemented before knowing the full potential, making it even more difficult to access the innovation potential (Vinnova 2012).

3.5.5.6 The nature and quality of organizational resources

Vinnova (2012) presents studies from Freeman and Soete (2009) that established that organizational and social settings often are regarded as the largest obstacle hindering innovation. Internally and externally, cultural resistance is one example of these problems (Vinnova 2012). The nature of having a hierarchical management that does not give managers sovereignty and flexibility has also proven to affect innovation negatively (Blayse & Manley 2004).

3.6 The second element: Communication channels

Communication channels are quite intuitive since the terminology is descriptive, explaining what communication channels means (Rogers 1995). The most basic idea behind the diffusion process is that it involves an innovation, an adopter with knowledge about the innovation, a unit with no knowledge about the innovation. The communication that may occur between these two parties is defined as the communication channels. Communication channels between two individuals is the most effective way to persuade other individuals to adopt an innovation, partly since they occur face-to-face (Rogers 1995). Mass media channels are however the fastest and the most effective way to inform individuals about new innovations (Rogers 1995). Although communication channels as explained by Rogers (1995), are an important factor explaining the adoption rates, it concerns mainly communication between individuals and not the communication between companies. Communication is challenging to measure, and researchers often get ambiguous results (Rogers 1995). Communication channels are outside the scope of this thesis, since communication channels as explained by Rogers (1995), are more focused on individuals and not on an organizational level. However, communication channels as a topic explained by other researchers was brought up during the interviews with the case companies in this study. This data is presented in the paragraphs concerning innovation in the analysis.

3.7 The third element: Time

Time is usually disregarded in science, but in diffusion research it is looked upon as a strength, although being difficult to measure (Rogers 1995). Time brings gradations into diffusion research, in sense as a variable measuring the time needed for a unit in a social system to get the initial knowledge about an innovation to finally adopting the innovation. This process can be called the innovation-decision process (Rogers 1995). Rogers (1995) further conceptualizes the innovation-decision process in five parts. Knowledge is the initial step, where a decision-making unit obtains the necessary know-how about an innovation. Persuasion occurs when a unit decides a positive or negative attitude against an innovation. Decision is the process when a unit actively decides to adopt or reject an innovation. Implementation occurs when a unit actually uses the innovation, and finally Confirmation, which is the time until a unit decides to proceed or finalize with the usage of an innovation (Rogers 1995). However, the process may have a different direction, where decision comes before persuasion (Rogers 2003). Rogers (2003) further states that it is difficult to measure where in the process a unit is located and that the boundaries overlap.

Further explained, the decision stage involves adoption, as Rogers (1995) defines as the full use of an innovation, at the best course available. Trial utilization of an innovation is an excellent way to detect uncertainties (Rogers 1995). Trial application of an innovation is regarded, according to Rogers (1995), as a part of the decision stage. If the innovation has an influential degree of relative advantage, a unit can proceed to the implementation stage, if the unit desires to progress with the innovation. The essence of the innovation-decision process is either to adopt the innovation or to reject the innovation (Rogers 1995).

In a similar way, Van De Ven (1991) describes that an adoption of innovation usually starts with a trial implementation of an innovation i.e. an experimental implementation. Based on these tests, decisions are made to either adopt or reject the innovation. This assumption has proven to have empirical support when individuals make the decision. Organizations however, have obtained mixed results using this strategy (Van De Ven 1991), since they have different structures and features that affects the behavior of adapting innovations. Size, complexity of organizations and bureaucratic procedures are examples that may restrict positive innovation behavior (Van De Ven 1991). Admittedly so, Rogers (1995) also mentions that many decisions are made by organizations rather than by individuals. Decisions made by a system are even more complex (Rogers 1995). The implementation stage stresses the behavioral change of an adopter and even more for organizations, since decision makers are usually not the people that implements the innovation (Rogers 1995).

The five parts of the innovation-decision process that is mentioned above, mainly declares factors explaining the situation of one unit's progress. If you want to compare a unit's progress with other members in the system, adoption categories have been developed to present these results. Rogers (1995) defines adoption categories in five parts, based on the individual's adoption rate relatively to other members in the system. The classifications in order, with the fastest adopter first and the slowest last are: Innovators, Early adopters, Early majority, Late majority and Laggards. Rogers (1995) prefers adoption categories instead of calling individuals less innovative than average, because it is clearer to understand and more effective to put them in static categories. All these groups have a lot in common, however, there are some great differences as well. Innovators do for instance, actively seek information about new innovations, using interorganizational networks, whereas the late majority does not use media channels as effectivity (Rogers 1995).

The phenomenon using relative time with relation to adoption rates, has Rogers (1995) defined as the rate of adoption. Adoption rates plotted on cumulative basis will follow a s-shaped curve. The s-shaped curve only occurs for successful innovations in a social system. E.g. idiosyncratic reasons are reasons why not all innovations diffuse. However, when a rate of 10-20 percent of the individuals in a system have adopted an innovation, it is almost impossible to stop the diffusion. Therefore, this part of the diffusion curve has been referred to as the heart of the diffusion process (Rogers 1995).

The actual adoption rate is diverse for different innovations, making the lifespan unique for every innovation, even if the innovation is the same technology but adopted in different socials systems (Rogers 1995). Hence, making diffusion research more difficult to execute by only looking at one individual's aspects (Rogers 1995). The phenomenon when the adoption rate has reached a 10-20 % adoption rate in a social system can be defined as the critical mass. Some innovations require a strong network effect to reach the critical mass. An example that Rogers (1995) mentions is email. Such innovation has an overwhelming disadvantage for the first user since the first adopter has no one to communicate with. The innovation will have an impractical benefit for the first users until substantial users have adopted the innovation i.e. when the critical mass is reached.

Although Harty (2008) argues that standards may not be an actuatable factor for driving innovation forward, it could be important to establish a stronger network effect, since interrelationship among technologies are higher in today's economy (Martínez et al. 2014). The network effect is strengthened when the value of the technology grows with an increased number of users in a social system (Martínez et al. 2014). Network effects may occur either directly or indirectly. When the value increases with a higher number of users, it is a typically an example of a direct network effect. A practical example is introducing AR in settings where content is available. That should likely lead to an increased number of users, which in turn should drive the development further, increasing and evolving new settings and applications for AR (Martínez et al. 2014).

The time aspect is according to Adner and Kapoor (2016) an important factor that people have insufficient knowing about. Adner and Kapoor (2016) argue that researchers have provided smart tools and that people are well-equipped to judge whether a technology imposes restrictions or not. Yet, firms seem to have a bad comprehension understanding when the diffusion will happen. Some innovations diffuse rapidly e.g. social networks, but some innovations need decades to diffuse e.g. high definition televisions, HDTV (Adner & Kapoor 2016). Adner and Kapoor (2016) further explain that the biggest fear companies have is to miss an innovation that can lead to an evolution. Being too early does not seem to be as alarming for companies, but Adner and Kapoor (2016) state that being too early should be their second biggest fear.

3.7.1 Ecosystems

One way to figure out if an innovation is going to diffuse rapidly or not, according to Adner and Kapoor (2016) is to analyze the innovation itself, but also the ecosystem that enables the technology. This statement is supported by Harty (2008), that states that some authors argue that the change of technology is not driven by the innovation, but merely by how users accept or reject an innovation and how it suits their existing products that are available. Thus, the characteristics of an innovation and how it could fit the purpose of an industry is important to understand (Harty 2008). Harty (2008) states that an organization's need is important to understand and that different users in the construction industry have different needs and restrictions, thus needing personalized and not standardized technological solutions. Innovations are most often not invented with predetermined attributes, but rather to work with existing innovations (Harty 2008).

The ecosystem itself is a profound reason contributing to if the technology is going to be successful or not. Adner and Kapoor (2016) further argue that it is rather a flight between new and old ecosystems and not between technologies (Adner & Kapoor 2016). Analyzing ecosystems provides a perspective that helps organizations make more intelligence decisions, whether risks or openings exist. Noticeable elements that cover ecosystems are: standards, regulations, services and technologies (Adner & Kapoor 2016).

However, Adner and Kapoor (2016) write that the most basic reason whether an innovation has potential or not, is if it provides any form of value to the organization. This can be decided by using Rogers's five indicators as mentioned before, but also using factors as e.g. if the innovation is price-competitive or not. If the outcome is positive, one could assume that an adoption of the innovation should be self-explanatory. However, Adner and Kapoor (2016) argue that this reasoning is only true if an innovation's dependence on other innovations is low. Adner and Kapoor (2016) mention that plug and play technologies, e.g. new light bulbs that fit to existing sockets, can provide great results, while other innovations, e.g. HDTV, depends on other technologies, e.g. standards, to emerge, which are needed to support the ecosystem. The HDTVs were invented in the 80's, but they did not gain much popularity during the first 30 years, due to the limited broadcast standards. This can partly be explained by that HD cameras had not emerged and became commercial yet (Adner & Kapoor 2016).

Lightbulbs is an example of innovations that have a low dependency on other technologies and HDTV as a technology with a high dependency on other technologies (Adner and Kapoor 2016). Yet, some innovations seem to overcome the hurdles not being play-and-plug compatible and still being successfully adopted (Adner & Kapoor 2016). It is an ongoing battle between old and new ecosystems, whether to introduce an innovation in a new ecosystem or trying to improve the existing ecosystem by improving an old technology. Adner and Kapoor (2016) mention that barcodes started out as a technology with limited use, eventually evolving to provide more information than only price. However, barcodes are not an efficient technology since barcodes only store information in a horizontal direction, whereas QR codes provides information in two dimensions (Cata, Patel & Sakaguchi 2013).

Adner and Kapoor (2016) claim that if a new technology is going to be successful, the users must see the potential of the innovation, meaning being adequately developed and having the complements of providing needed services that are derived from the innovation. Old technologies have the possibility to remain as an incumbent technology if it has the competitiveness to enable improvement. The essence is that the relationship between a new technology versus an old technology, is about the pace of substitution. Adner and Kapoor (2016) have constructed a model showing four interactions between old and new technology, which they have defined as: creative destruction, robust resilience, robust coexistence, and illusion of resilience. The figure can be seen in Right Tech, Wrong Time (Adner & Kapoor 2016, pp. 66)

Creative destruction is the first and the best quadrant, where new technologies have the biggest chance to emerge and when technology is expected to override old technology, because the obstacles for the new technology are low and the opportunities to prolong the old technology are low (Adner & Kapoor 2016). Robust coexistence is located in the second quadrant, where old technologies have a high opportunity to continue being used and developed, but new technologies also have a high change to diffuse, thus having a longer period of coexistence. The illusion of resilience is the opposite reality of robust coexistence, which makes new technologies having a harder chance to emerge and old technologies having a reduced risk to be improved. Unlike robust coexistence, where new and old technologies do coexist to a greater extent, the exchange will happen more quickly in the illusion of resilience (Adner & Kapoor 2016).

Robust resilience is the fourth quadrant where new technology has the hardest time to diffuse i.e. new technologies have a small chance to diffuse, whereas old technologies still have opportunities to improve. Adner and Kapoor (2016) define robust resilience as the reality when technologies seem to be revolutionary but being overhyped when analyzed in hindsight. Being in this quadrant does not make it impossible for new innovation to emerge, but innovations in this quadrant usually need decades to emerge to the public. Hence, creating settings where being a decade too early can be costlier than missing the emergence of the technology entirely (Adner & Kapoor 2016). Adner and Kapoor (2016) suggest that the full value of an innovation will only be perceived if there are no bottlenecks left in the ecosystem, thus, it could be advantageously to focus on solving these problems first.

Adner and Kapoor (2016) propose that users should firstly figure out which quadrant their industry is in. As with Rogers's framework and with much other diffusion research, these models do not provide any usefulness if applied in retrospect and hence, making this a question of an individual's discretion (Rogers 1995). The other part deals with which type of strategy a start-up versus an incumbent company should have when approaching new innovations (Adner & Kapoor 2016).

3.8 The fourth element: Social systems

Rogers (1995) defines a social system when units, whom are distinguishable from e.g. individuals and organizations that are involved in projects, use problem solving to achieve similar goals (Rogers

1995). Rogers refers to Katz (1961) that argues that it is impossible to conduct a study about diffusion without knowledge about social systems. Indeed, social systems creates and affects boundaries, norms, roles of leaders and innovation decisions (Rogers 1995). Social systems are vast, with units not having identical behaviors. It does however exist a structure that provides regularity and stability in terms of information which individuals should follow (Rogers 1995). An example of this hierarchy is government agencies, which are the top dogs, giving information e.g. executing regulations, which they expect units to follow.

Norms can cope everything from cultural norms to religious norms. These norms can be found on all levels i.e. national, organizational or individual levels (Rogers 1995). The social system of an organization is however the most important level (Van De Ven 1991), since it is mostly the direct source to develop and foster innovations, in terms of material and financial means. Gambatese and Hallowell (2011) write that research about attributes affecting the innovative capacities of organizations are extensive. Gambatese and Hallowell (2011) present multiple studies that highlight different influencing factors just regarding managers e.g. senior managers' position, industry experience, age, gender, education, willingness and ability to manage conflicts and willingness to share control. More general factors that Gambatese and Hallowell (2011) mention that can affect innovation are political, social, technical and environmental dynamics.

Blayse and Manley (2004) argue that culture of innovation falls under organizational resources. They further argue that this intangible attribute promotes innovation if the organization does not castigate negative attempts trying new ways of working, if the employees share their opinions and tries to understand each other's goals and that the company maintain an openness.

The research about social systems is immense and almost ungraspable due to its size. Since social systems includes both internal and external influences, most of these attributes are difficult to distinguish from the factors mentioned in the paragraph *Construction industry specific factors that affect innovation*, therefore, no special emphasis will be placed on social systems per se, but more general attributes of the organization that have influenced innovation.

Although social systems are crucial in order to understand diffusion-theory, Rogers (1995) has stated that only few studies that have been conducted about social systems, have actually obtained results how communication and social structures impact the adoption of innovations since they are challenging to realign and measure.

3.9 Augmented reality

AR as a technology is not a new invention, yet it is not until recent days that research on how to further develop the technology has emerged (Izkara et al. 2007). The first idea to use AR in the construction industry derives back to 1996 (Wang 2009).

AR successfulness depends on powerful processors that can manage tasks processing and rendering pictures and videos, which prior to lately has not been possible (Martínez et al. 2014). This since the majority of AR applications require a mobile device and not desktop computers (Izkara et al. 2007). However, the background behind why AR has become a buzzword can be derived to the shift from traditional 2D (two dimensions)–drawings to 3D-models (Johansson et al. 2015). The shift from 2D to 3D has increased the information about the facility in question. Along with the digital models of the facilities, information about product planning, energy analysis and cost analysis can be supported with the digital models. The umbrella term used for these models is usually called Building Information Models (BIM). When time, costs for modelling and sharing costs are supplied to the project team, this type of BIM is called 5D BIM (Smith 2016). BIM models often provide information of resources, which is divided and shared with the stakeholders involved in a project (Johansson et al. 2015).

A descriptive explanation of what AR is, is that the AR system starts with a video camera that collects data from the real world (Izkara et al. 2007). This data is used to determine a user's position with every movement made. With this data, augmented objects are made and combined with the real-world data, which works as the background. This scene is then projected to a display, thus presenting an augmented reality (Izkara et al. 2007).

Fenais, Smilovsky, Ariaratnam and Ayer (2008) state that Omar and Nehdi (2016) claim that AR as a technology is extremely promising, suitable for all types of project types and sizes. Chi, Kang and Wang (2013) present studies that predicted that approximately 30 % of the construction workers in 2014, would use some type of AR technology. 2014 was also regarded to be the year when the public commercialization would occur. Chi, Kang and Wang (2013) further state that it is generally believed that a wide part of the construction industry will adopt AR technology within a decade. Rankohi and Waugh (2013) wrote however an article in 2013, stating that the benefits with AR is not yet experienced. As a result, companies tend to pilot AR on few projects and not adopt AR in the entire company.

Martínez et al. (2014) have applied AR to Rogers's theory. However, not specially for the construction industry, but to a broader spectrum, analyzing several industries. Martínez et al.'s (2014) conclusions are that AR does offer new types of relative advantage e.g. visualization. Compatibility is only seen as an issue in some fields due to privacy issues. Martínez et al. (2014) further state that AR is easy to use, thus not affecting Complexity. Trialability issues are slim to none, because Martínez et al. (2014) state that AR is easy to use and that several fields and applications are accessible, if users have hardware and software available. The benefit with AR, seen from the perspective of observability is not clear for some of the users, according to Martínez et al. (2014).

3.9.1 The components of augmented reality - the ecosystem

AR is a tool, based on digital design or drawings, usually deriving from BIM models (Harty 2008). Digitalization and integration with blueprints and software can be used together to virtually produce an augmented environment, with every possibly detail needed (Harty 2008). Usually this data contains information about the construction that the user does not have or cannot detect (Izkara et al. 2007). This augmented information is presented on displays, where the users get their information (Izkara et al. 2007).

Rogers (1995) explains a technology, often as a combination of hardware and software, which is also the case with AR. Traditionally, AR needs three components to work (Martínez et al. 2014). Izkara et al. (2007) define these three elements as the processing device, the visualization device and the positioning device. Martínez et al. (2014) also describe the AR with three similar elements, which they conclude as; AR needs to utilize a component that collects data, which usually is a camera. GPS devices can in some cases be used and equipped as well or being utilized combined with the camera. Other hardware sensors that can be included in the system are e.g. gyroscopes and accelerometers (Martínez et al. 2014).

The second component that has to be included is a device that can translate and process the information from the camera and the sensors, which is a computer or a processor of some kind (Martínez et al. 2014). The third major component that has to be implemented is a screen i.e. a display. Head mounted displays, usually provides see-through displays, which means that the displays are transparent. Phones are video-through which means that they have no transparent screens (Izkara et al. 2007). Today's smartphones usually have the hardware needed to project augmented objects and can thus be used to utilize AR technology (Martínez et al. 2014). Nevertheless, there exists purpose made technology made purely to fulfill the constraints and giving the best experience possible, which goes under the umbrella term Head Mounted Displays (HMD) (Martínez et al. 2014).

The software aspect of AR is heavily based on digital design/models, which is the prerequisite for AR. Digital designs are the basics of AR, but digital drawings are currently used mostly as a tool to improve the modeling process, which reduces the cost of buying physical printings and having uniform drawings reduces the coordination problems (Harty 2008). Digital drawings were said to be a radical step and a more well-organized way of working. The reasons behind the introduction were considered to be: "construction clients seeking for ways to improve cost-effectiveness, software vendors who want to sell new products, construction organizations seeking to improve profits." (Harty 2008, pp. 1034). However, Harty (2008) further states that it exists challenges with implementing new technologies, such as CAD-based technology.

3.9.2 Augmented reality and its tracking system

A major problem with AR technology is to find the reference position of the user by tracking markers. It exists different ways to track and detect markers and different methods may suit other industries differently. Since the technology is superimposing virtual objects into the real scene, the data that this technology is built on, must use data generated from the real world (Gomes et al. 2017). The technology must seize the real world's settings precisely in order for the technology to be useful (Gomes et al. 2017). A commonly used method to track markers in the construction industry is to use visual tracking, which is a method based on natural features (Gomes et al. 2017). The way that a natural feature work, is that the system uses elements that exist in the real-world scene without any preprogrammed markers and then compares with pictures that the cameras collects with preprogrammed pictures that are already stored (Gomes et al. 2017). In construction-related settings, the AR-tracking system can use equipment (Gomes et al. 2017) or physical attributes e.g. a wall or a corner of a building to calculate where the user is positioned and what the user should see related to the direction of the user i.e. the camera. For the system to work, the features that the camera collects must be previously registered so that the computer can compare factual objects with the collected data to figure out which objects should be superimposed (Gomes et al. 2017).

Gomes et al. (2017) further explain that tracking and referencing the users is the most critical task for AR, especially in outdoor contexts. Detecting objects is fundamental in AR technology and it is necessary to track and create augmented environments. Although AR may be conceived as a novelty in the construction industry, it is not new as a technology and Gomes et al. (2017) present that not many new ideas regarding visualizing data in such manner have emerged.

However, there exists other ways to detect markers visually. Rodrigo et al. (2017) argue that artificial markers can be an attractive alternative to natural markers since artificial or fiducial markers are easier to detect and less error-prone. By having artificial markers, the system can track artificial markers instead of needing to compare factual pictures with preprogrammed images to calculate and localized the position of the user. These artificial markers are placed in a scene where the system uses the markers as a way of reference (Rodrigo et al. 2017). Li, Chen, Lu, Ma and Q. (2012) state that the most AR systems use artificial markers, since it meets the requirements of giving sturdy and fast results.

3.9.3 The potential usage of augmented reality

AR seems to have the potential to benefit the architecture, engineering and construction-industry since every project is unique and because every working site is a new place (Izkara et al. 2007). Chi, Kang and Wang (2013) state that some of the most critical problems in the construction industry are that field operators do not have access to the information needed, that planned solutions do not always correlate with practical implementations and that the communication between project actors is insufficient. AR has the potential to solve these gaps (Chi, Kang & Wang 2013).

Martínez et al. (2014) state that there are five key drivers of AR. The first factor is to reduce costs e.g. in manufacturing processes or by reducing errors. Fast learning curves are important because the technology is user-friendly. People's curiosity should also not be underestimated, as explained by Martínez et al. (2014). Visualizing 3D content to the real life also offers value. Finally, Martínez et al. (2014) state that AR is fun to use, especially in education (Martínez et al. 2014).

Rankohi and Waugh (2013) state that AR can be utilized in three ways i.e. visualization, information retrieval and interaction. Rankohi and Waugh (2013) further present studies that have proposed AR systems, being implemented in the whole project life cycle. Other studies that are presented in the same article have presented AR models to automate some of the processes e.g. monitoring and collecting data and communication. The possible applications for using AR mentioned in the article continues, covering all the important processes in the construction stage (Rankohi & Waugh 2013). Various researchers have proposed similar potential fields where AR could be implemented, same as in the subjects mentioned above by e.g. Martínez et al. (2014).

Guo, Yu and Skitmore (2017) have also presented studies about AR being used for security, where they define three sub branches, namely: hazard identification, safety training and education and safety inspection and instruction. Jeanclos et al. (2018) have also found applications using 3D imaging for less costly repairs while tracking manufacturing processes. Nevertheless, the common denominator or the biggest driving force is to reduce costs (Martínez et al. 2014). The basic concept behind this idea is that AR could work as a tool for learning and guiding tasks e.g. maintenance. This should lead to a faster learning and reducing errors, which in return reduces the cost by increasing time savings and having safer production processes (Martínez et al. 2014). The essence is that AR seems to have a great potential and that it can be utilized in different fields. Next paragraphs will describe these applications more in detail.

3.9.3.1 Product design

Martínez et al. (2014) present four applications for the manufacturing industry and military, where one of the fields is product design. Product design includes physical prototypes, which enables designers to create prototypes without manufacturing a physical device and see how it would be presented in a real scenario (Martínez et al. 2014). It gives the designers the ability to detect errors and reduce costs. On common denominator for the majority of the applications is its ability to reduce cost (Martínez et al. 2014). However, the most important factor in this field could be that the designers could see how the prototype would interact with surrounding objects, testing different colors and textures (Martínez et al. 2014).

3.9.3.2 Training

Martínez et al. (2014) state that AR, in small studies have proven to be more beneficial than psychomotor learning regarding manufacturing and assembling in the training phase. This could result in lowering costs and reducing training time since the accuracy increases and the errors reduce (Martínez et al. 2014). The beneficial attraction that AR has is that it is interesting to use, and it is well-suited for fast learning. It is also appropriate to suit many fields and AR is also capable for guiding e.g. maintenance tasks. AR has proven to have the potential capacity to make procedures safer (Martínez et al. 2014). Rankohi and Waugh (2013) also present studies that have explored the possibility to use AR-based applications when training heavy equipment operators.

3.9.3.3 Reducing production and quality errors

AR has also been proven to be successful in the physical production stage, reducing the risk to not having to rework and repair components by tracking the process (Jeanclos et al. 2018). Rankohi and Waugh, (2013) mention studies that integrates AR with BIM models to detect potential defects. Jeanclos et al. (2018) present studies that shows that the U.S. pipe manufacturing industry is worth 45 billion USD. Of the total construction costs, up to 10 percent of the construction costs is due to rework, since the methods to detect errors in time are inadequate. 50 percent of these faults is caused by human errors. Thus, having potential savings of 2 billion USD, if having means to detect errors in time, which AR could possibly provide (Jeanclos et al. 2018).

3.9.3.4 Maintenance

Operations and Maintenance (O&M) and Facilities Management Service (FM) comprise maintenance, which is the process that provides means to prevent material failure as stated by Lee and Akin (2011). Lee and Akin (2011) further state that the spending of Operations and Maintenance stands for 85% of the total spending. Although maintenance has proven to be important, 50% of construction questioned in a study did not acknowledge the importance of AR.

Lee and Akin (2011) state that it is possible to utilize AR technology to provide the user with information what is integrated in the models. This approach could shorten the time, otherwise needed to get the information.

3.9.3.5 Safety

Li, Yi, Chi, Wang & Chan (2018) present studies that show that visualization technology i.e. AR and VR, have the potential to efficiently reduce the risk of preventing accidents and improving the safety training and detecting job hazards. Ahmed (2018) states that AR technology has been used for construction safety and worker training for years. The construction industry suffers from a high rate of accidents (Jeanclos et al. 2018) and have the worst rate of health and safety records (Izkara et al. 2007). The total cost of accidents in Europe stands for approximately for 2% of the sector's GDP, which is equivalent to 16 billion Euro. This mainly because construction projects are large in size and the workplaces are densely populated (Wang et al. 2014). Creating a more secure working place, is one of the biggest challenges in Europe (Izkara et al. 2007). One way to make the construction sites safer is to provide the workers with updated information about the changes and activities happening on the construction sites. Mobile computing solutions can work as a tool to provide this information, not compromising the health and safety (Izkara et al. 2007).

However, Li et al. (2018) show some objection by criticizing the lack of research done, i.e. how these technologies are going to be used factually. To critically report AR and its potential applications regarding security as Li et al. (2018) did but, also more in general is not that common in academia yet. The majority of scholars focus only on future aspects and not many of them focus on which problems that may occur implementing AR now. Meanwhile Li et al. (2018) mean that scholars and the industry are aware of factual gaps and boundaries that AR poses.

3.9.4 Hindrance for augmented reality

Although the possibilities seem to be immense for AR, the technology is still lacking behind the fulfilled needs and the potential benefits researchers are talking about. Some of these bottlenecks have a technical aspect and some a managerial aspect (Martínez et al. 2014).

Some of the non-technical standpoints that is hindering the adoption of AR are implications that there exist no standards for AR (Martínez et al. 2014). Finding a standard suiting all types of industries does not seem realistic. Making sector-specific standards could be a better way of managing the task, which the tourism sector to some extent already has done. Yet, industries are still on a prototype level and it still exists inconsistency, making industries still having hurdles to overcome (Martínez et al. 2014).

Other technological hurdles that are relatively linked to both software and hardware are that AR is lacking accuracy, especially in bright conditions. This statement, according to Martínez el al. (2014) affect the alignment of the augmented objects. Another bottleneck is that some of the processes are too time consuming "which may be an important bottleneck in some devices with limited computational power" (Martínez et al. 2014, pp. 35). These constraints are still not met. AR has not been socially accepted in all industries, which indeed is an obstacle to overcome. Gomes et al. (2017) also write that for the last 20 years, there has been few to none new ideas regarding visualization processes. Natural features, which is the most commonly used method in the construction industry, is not without hurdles. Li et al. (2012) stated that methods using natural features are still not adequate since "availability and distinctiveness limit their broader use" (Li et al. 2012, pp. 1413).

Social acceptability is a fairly new bottleneck. Martínez et al. (2014) are stating that social acceptance could be a problem since it concerns privacy. AR also deals with issues that users absorb too much information (Martínez et al. 2014). Gomes et al. (2017) are affirming the statements that contemporary methods are insufficient in detecting and tracking real world scenes and that the processing time i.e. the time to collect data and superimpose virtual objects is too long. Gomes et al. (2017) advocate that fiducial markers used in physical environments could reduce processing time. However, no method is without its problems. Markers like these are proven to be more successful and less costly than its antagonists but including non-natural markers in a real environment constitutes problems. The reason why they do not suit the construction industry is because the technology cannot work reliable if the markers are being destroyed. If the markers are moved, even just temporarily, the technology will not work in a correct way and even maybe compose hazards since everything gets offset (Gomes et al. 2017).

Gomes et al. (2017) present studies that concludes that, if digital visualization is going to be successful, it must have the aim to be the main method of presenting data, meaning that it must replace classical means e.g. textual and numeric data and information. Visualization must as well be easy to use, and the data must be presented in the most natural way in order to make AR possible to blossom (Gomes et al. 2017)

3.9.4.1 Software

BIMs that are the essential for making AR operating are primary made to give details about a facility, but these details can be difficult to utilize on a real-time basis (Johansson et al. 2015). Johansson et al. (2015) further argue that BIMs can be counteracting if not updated to a sufficiently level, since it would influence the navigation and orientation negatively. Since BIMs have such a huge impact on AR, it makes more sense to analyze the usage of BIM. However, Johansson et al. (2015) write that identifying the challenges with visualizing large BIMs in real-time settings have not yet been done properly.

Although it exists many platforms for AR e.g. AMIRE, ARVIKA, StudierStube, DWARF and DART (Izkara et al. 2007), Martínez et al. (2014) state that AR struggles with two main tasks that it must overcome, namely "recognition of the environment and the rendering of virtual content." (Martínez et al. 2014, pp. 28). Rendering pictures and videos does not need to be a struggle, since it is already managed for VR. Nevertheless, problems occur when comparing the systems with each other. VR is fully virtual, but AR is only partly visual. Therefore, one must be extra alert in order not to provide too much information, nor to little information, because it could engulf the user by having a too detailed model and distracting the user. A moderate amount of information should be presented (Martínez et al. 2014). Some problems may also occur when the system is required to spot and track human movements, which hitherto has revolutionized the system. These demands have led to the abandon of a marker tracking systems and embracing a more natural tracking system, which in return requires even more powerful processors, which turns the problem into a hardware problem (Martínez et al. 2014). Izkara et al. (2007) further add that the main problem with the AR technology is its inconsistency to precisely align augmented features into the real world.

3.9.4.2 Hardware

The technological aspects of the hardware are also dealing with problems. As explained before, GPS input can be used to localize the user's position and there exist models that use GPS signal as the main source. However, Gomes et al. (2017) write that GPS signals do not give the needed accuracy for using the technology in an efficient way since GPS localization give errors, "up to 7,8 meters with 95% of confidence." (Gomes et al. 2017, pp. 512).

Nonetheless, the first prototypes of Head Mounted Displays (HMD) have lacked the processor power needed and they have also been too heavy to use (Martínez et al. 2014). Mobile devices in general, which is the most prevalent device used, can only work as input and output for collecting and displaying the data, since they do not have the processor capacity (Izkara et al. 2007). Low processor power is on the other hand solved by using cloud services, which remotely enables the processing of the augmented objects (Izkara et al. 2007). Although cloud services could be an excellent solution, the disadvantage is that it requires a stable internet connection (Martínez et al. 2014), because AR creates a big flow of information, which is not always the case with the environments of construction sites (Izkara et al. 2007). Thus, using these mobile devices e.g. Personal Digital Assistants and smartphones, proposes problems due to hardware limitations (Izkara et al. 2007).

3.10 Recap

In the table below (Table 3), the most important findings from the theoretical framework are summarized. These factors are also presented in a similar figure at the beginning of the analysis. The figure starts with using Rogers's (1995) factors evaluating the innovation, which is followed by theory, explaining how AR can be used, forecasted diffusion rates, which factors affect the adoption of AR and how the attributes of the construction industry have affected the adoption of AR.

Table 3: Summary of theoretical framework

Theory	Summary of theory	Researcher
Rogers's (1995) five factors regarding the innovation, affecting the rate of adoption	Relative advantage • AR offers new advantages compared to VR	Martínez et al. (2014)
	Compatibility • AR may be not socially accepted	Martínez et al. (2014)
	Complexity • Easy to use, but AR require software and hardware	Martínez et al. (2014)
	Trialability • Easy to try, as there are many applications available	Martínez et al. (2014)
	Observability • Benefits may not be clear from some individuals' point of view	Martínez et al. (2014)
Potential adoption areas	Product design	Martínez et al. (2014)
	Training	Martínez et al. (2014), Rankohi & Waugh (2013)
	Reducing production and quality errors	Martínez et al. (2014), Rankohi & Waugh (2013), Jeanclos et al. (2018)
	Maintenance	Lee & Akin (2011)
	Safety	Li et al. (2018), Ahmed (2018)

AR diffusion rates	Extremely promising	Fenais et al. (2018)
	Circa 30 % of the workers in 2014 will use AR	Chi, Kang & Wang (2013)
	A widely part of the industry will adopt AR technology within a decade	Chi, Kang & Wang (2013)
Enabling factors	Reduced costs, errors etc.	Martínez et al. (2014), Harty (2008)
	Fast learning curve	Martínez et al. (2014)
	Curiosity	Martínez et al. (2014)
	3D visualization	Martínez et al. (2014), Harty (2008), Izkara et al. (2007), Chi, Kang & Wang (2013)
	Fun	Martínez et al. (2014)
	Branding & reputation	Gann & Salter (2000)
	Communication	Chi, Kang & Wang (2013), Rankohi & Waugh (2013)
Hindering factors	Limited processor power	Martínez et al. (2014)
	Reference and tracking issues	Gomes et al. (2017), Martínez et al. (2014)
	No standards	Martínez et al. (2014)
	Time consuming	Martínez et al. (2014)
Construction specific factors that affect innovation diffusion	Procurement	Vinnova (2012), Gambatese & Hallowell (2011), Blayse & Manley (2004), Ling (2003)
	Clients and manufactures	Gambatese & Hallowell (2011), Blayse & Manley (2004), Gann & Salter (2000), Ozorhon et al. (2010)
	Industry relationships	Gambatese & Hallowell (2011), Blayse & Manley (2004), Gann & Salter (2000), Edquist (2010), Harty (2008)
	Structure of production	Gambatese & Hallowell (2011), Blayse & Manley (2004), Gann & Salter (2000), Ling (2003), Pries & Janszen (1995), Van De Ven (1991)
	Organizational resources	Vinnova (2012), Blayse & Manley (2004), Gann & Salter (2000), Rogers (2003)

4 Empirical findings

The purpose of this chapter is to present the data from the interviews. After a short introduction of how every case company have worked with innovation, the empirical findings will be followed up by a detailed description of how Rogers's four elements have affected the outcome of the adoption of AR, among the case companies. Other construction specific factors, not explained by Rogers's framework, will also be presented. Ecosystems and how they affect AR, will finish the empirical findings. A presentation of the cases can further be found in the Appendix.

4.1 Innovation – Augmented reality

4.1.1 Organization A

4.1.1.1 Diffusion and current usage

Organization A is not using AR in any form at all. Thus, they do not have any innovation champions responsible for AR. They do however use Virtual Reality (VR) for marketing, where they present models of buildings to customers, by using smartphones and touchpads. Their main purpose with VR is to provide a wow factor to their customers, according to interviewee A. The interviewee mentions a couple of reasons why they have not implemented AR in their company yet. The main reason is because the organization is a young company. They have spent a lot of work, developing and trying to get traditional construction process in place, because it is their most prioritized need and they have not had the time needed to implement AR, i.e. spending time on product development.

It is further noted that the organization has not had the time to develop an innovation policy, and thus, not had the time, making someone in charge for this type of technology. The interviewee stated that this problem could be explained by the young age of the company, but more so on the managers and project leaders within the company, which may have negative attitudes toward change. The interviewee states that these contractors and projects leaders are usually older people with a long experience. These employees provide good results, thus making it more difficult to question their strategies and working methods.

Interviewee A explains that there is a shortage of experienced construction engineers in Sweden. The interviewee states that, if an organization forces the employees to adopt new ways of working which they are not comfortable with, there is a high risk that the employees will change employer and move to another company that let them work the way that they want. Interviewee A says however that it does exist an interest among some of the employees, and especially among the younger generation, to adopt new ways of working. An open and willing attitude toward change does exist in the company. When asking the interviewee about Rogers's five attributes, no in-depth thoughts were provided by the interviewee. The relative advantage was perceived to be high. However, the interviewee stated that these conclusions are merely based on thoughts of the interviewee's perceptions, and not real experience with AR. The reason why interviewee A perceived the relative advantage as high, was because the interviewee did not see any limitations nor obstacles with using AR. Thus, only advantages with AR were seen.

The compatibility was however seen as low since interviewee A stated that the construction industry is very slow as industry, needing more time than other industries to accept and get comfortable with new technology. Complexity was set to moderate-high, mostly because the interviewee did not have the knowledge needed, to understand AR as a technology. Interviewee A did however state, that a straight-out civil engineer would probably have different thoughts, not having as steep learning period as the interviewee would. Trialability was set to high, because the interviewee stated that the nature of their structure, i.e. being a project-based organization, would suit excellent for experimental trials. Observability was seen as low, but it was also seen as an unimportant factor affecting the adoption rates. The interviewee argued it could be a more important factor, when evaluating diffusion of innovations among individuals.

4.1.1.2 Future potential

One future potential application of AR could be to provide the customers, that already have bought an apartment, AR solutions how their kitchen could look like when designing and choosing different materials and colors (Interviewee A). Interviewee A states that this would be possible, because they already now build real modules how the kitchens could look. Today, organization A only provides VR solutions for these services, whereas interviewee A states that AR, would provide a more realistic reality.

The interviewee notes that these kinds of processes are especially important for an organization like them, because they are to some extent providing and selling apartments unseen, i.e. the customer does not buy a finished product. Interviewee A believes that marketing and sales, or factors that are related to service, will have the biggest future gain by using AR technology. However, interviewee A believes that these conclusions could be biased interpretations, because it is the only field where interviewee A has some type of extensive knowledge in. However, the interviewee sees a future where they are integrating AR into the construction phase. The interviewee states that they do however only see AR as a complement, not taking over other well-known techniques and methods of working. The interviewee thinks that the usage of AR will be superior to VR in the future.

Organization A speculates that their start-up time adopting AR should theoretically be fast, because they mostly have turn-key projects. Turn-key projects means that they order and build the construction, mainly with their own workers and use their management to plan and construct the building. Interviewee A sees this as an advantage, because they can use their own methods of working, and they do not need to adjust their methods of working with other companies involved in a project, which may occur when adopting a radical innovation. The interviewee does however recall that most ways they work by, correlates predominantly with the rest of the construction industry.

4.1.1.3 Critique

The interviewee does not have any major critique against AR, since they are not familiar with the technology. The interviewee does however see the need to jump on the bandwagon, adopting AR or at least being prepared adopting the technology. The interviewee reckons that it will be expensive for the company if they end up being behind other companies in the long run.

4.1.2 Organization B

4.1.2.1 Diffusion and current usage

Interviewee B said that they as a company, are innovative. They encourage employees to adopt innovative methods and products as means to improve their work. Since they are a decentralized organization, it gives individual projects more leeway, because their projects are not dependent on having common denominators, according to the interviewee. However, because they are a decentralized organization, they cannot push all projects to adopt new innovations according the interviewee. They can only force project groups to adopt new systems e.g. IT system, that are implemented for the entire company. This leads to some innovations only diffusing in some project groups, whereas some project groups wait as long as they can to adopt new innovations. This has also happened for AR, according to interviewee B.

The way that AR has diffused in organization B, is that Application Developers and VDC engineers follows trends regarding new innovations and report to the management. The developers and the VDC engineers drive the adaptation of AR, with instructions from the top-management, that ultimately make the call whether to test AR or not. Thus, the developers and the VDC engineers are the main responsible to cherish and foster AR. Their role is thus similar to an innovation champion. The interviewee further states that they do not want to be six months or a year behind new technology. Interviewee B says that they want to be involved and give feedback, e.g. what is working and what is not working, to the companies developing the AR systems. Further on, AR is not adopted to solve any existing problems, but merely to exploit the technology and then find areas to apply AR. The approach to adopt an innovation without having clear need, is according to interviewee B, the construction industry in a nutshell.

Interviewee B confess that they have not really found and exploited all applications of AR yet, since they are in the process trying to figure out "what is play and what is test?" (Organization B, interview, 11 December 2018). They are, as the other companies in this study, still in the evaluation stage and only using AR in tests, although having some concrete applications for AR. The organization has mainly tried implementing AR on the building side and not in infrastructure projects, due to it is worth spending more on residential constructions than it is on infrastructure projects. The explanation behind this conception is that there is no need developing complicated digital models for construction infrastructure, because e.g. roads are simpler in nature, according to the interviewee. Another reason why AR does not suit infrastructure projects, is that the contractor, who runs the project, never has all the information needed to execute a digital model in these settings, which is the basis of AR. The interviewee also states that these projects also change a lot during the construction phase and it is not worth developing models. They are not exciting enough, according to the interviewee.

Organization B has primary used AR for quality control. The interviewee stated that two weeks before the interview was conducted, a project team in Lund was willing to test AR. When they scanned a prefabricated wall, by using AR, they could see that one of the ventilation shafts were placed wrongly. The fault was so great, i.e. one decimeter, that you could discover it using AR glasses, according to the interviewee. Usually the sub-firms that are contracted to perform installations, which the company responsible for the project does not often perform themselves, are responsible for controlling that everything is right according to their blueprints. However, since construction projects take place according to a very clear order, e.g. due to some installations are dependent on other installations, many actors are affected if any unforeseen error occurs during the construction phase, according to the interviewee. The interviewee states that postponing installations adversely affects the general project time, and if projects are delayed, some type of contractual penalty is often paid to the customer. Furthermore, since organization's B employees detected the error themselves, weeks before the ventilation installer should perform their work, the company that delivered the prefabricated wall could fix their error before the ventilation installments were scheduled.

Organization B has exploited AR solutions for projects in Norway in addition to projects in Sweden. However, interviewee B says that they cannot use AR as the only tool to provide the basis for quality control. The results are not reliable enough according to the interviewee. The interviewee says that the supervisors do however see the benefits with AR, even if it is not reliable enough, and they see a future commercial spin-off.

Interviewee B mentions reasons why AR has not fully been implemented yet in their organization. The main reason is related to culture contextures according to the interviewee. The other reason that is mentioned is high costs. Seen from the organization's point of view, they would say that they are quite innovative, and that their culture germinates new ways of working when adopting innovation according to the interviewee. They have started testing AR in the production stage by using Microsoft HoloLens, 2-3 years ago. Now they mainly use HTC 2. They also work with VR in the planning and design stage. The interviewee stated that the first version of HoloLens was not adequate. Newer and better versions from other manufacturers have reached the market and the development is moving fast. In recent years, the interest in AR-based headsets have increased rapidly and the network that is interested in AR has increased, which the interviewee sees as a reason why AR-based headsets are developing at a rapid pace.

The reason why AR is difficult to implement in their company, according to interviewee B, is due to their types of projects. The majority of their projects involve three to five managers and engineers. Interviewee B states that other projects are already started before existing projects have ended. The interviewee states that since there is no breathing space between projects, employees do not really have the time to reflect upon new innovative methods to work.

The cost-aspect was also mentioned as an important factor. These glasses that organization B are using cost around 30000 to 40000 SEK. Interviewee B says that it may not be a high cost if the glasses or HMDs lasts a long time, but in real life situations, i.e. in the hands of builders, the lifespan is often quite short.

When asked about Rogers's five attributes about the usefulness of AR, interviewee B expressed that the answers are solely affected on the interest of the interviewee, answering the questions. For instance, VDC was a new concept ten years ago, but companies have recently started to employ VDC managers, responsible for this field. At the same time, the interviewee states that there are people working in the construction industry that still do not understand what VDC is.

However, the perceived relative advantage was set to limited in present time, mainly because AR is costly, and it does not provide any clear beneficial value. The interviewee did however state that AR as a technology makes the workers curious and interested. Compatibility was set to moderate, but seen to the entire industry, extremely low according to the interviewee. Complexity was set to low, because the learning period to understand and learn how AR works is fairly short. Trialability is high, because it suits experimental trials. Observability was set to low-moderate. Moderate seen from the interviewee's perspective, but low seen from other employees in the industry, according to the interviewee.

4.1.2.2 Future potential

Except quality controlling, interviewee B sees the possibilities to use AR as visualizing blueprints, as instruments when construction-builders are mounting and installing installations, which organization B is especially interested in. Another field where the interviewee sees a potential in, is marketing, e.g. taking pictures of how the view from a balcony will look. Although, interviewee B mentions that marketing may suit VR applications better. The interviewee thinks that the usefulness will be visible, seen to a five-year future. Partly because the glasses will be lighter and easier to use.

Maintenance is also an idea mentioned by the interviewee, but this is a topic that the customers must ask for and not a topic that they will push themselves, according the interviewee.

4.1.2.3 Critique

The interviewee states that some aspects of AR are not ideal. Firstly, interviewee B mentions that it exists a safety aspect, that existing AR technology may not consider. Before, the glasses were not approved to be integrable with a helmet, with which they are now. The biggest tangible issues related to AR is however reliable issues. AR systems have a challenging time, localizing the right coordination of the user. Different software provides different solutions, but it does not exist a software that does everything what is expected for a VDC engineer, according to the interviewee. The biggest problem overall, is the conservative attitude towards change. The interviewee stated that "in the best case, we are only ten years after other industries" (Organization B, interview, 11 December 2018).

4.1.3 Organization C

4.1.3.1 Diffusion and current usage

As with organization B, organization C's management are main responsible for trying to implement AR. Organization C is, in contrast to organization B, a more centralized organization. Interviewee C states that, although they are a centralized organization and have employees similar to innovation champions, they cannot micromanage all details how project managers run their projects. The interviewee mentions that they do not micromanage projects to use AR, neither do the micromanage other innovations. The reasons are mainly due to the resistance of paper users. The interviewee states that everyone is used to work with paper drawings in organization C. The interviewee argues that the client or customer that orders the project, or the company having the main responsibility projecting the construction, are responsible for pushing these topics, e.g. not using paper drawings. The interviewee states the all these steps are regulated in the contract. The contract is the result of the communication with the customers. This is also a reason why they do not micromanage new innovation, according the interviewee.

Interviewee C states that governmental or municipal clients may sometimes have higher standards, e.g. environmental, which enforces the entrepreneurs using more sustainable methods of working. A project that the customer has enforced using digital printings instead of paper-based printings is the project for Slussen, a traffic point project localized in Stockholm. This information has been validated by interviewee B and D as well, that also are included in the project. Digital printings have mainly been adopted since it is regarded to facilitate coordinating large and complex projects, but also having beneficial environmental impacts, according to interviewee C. AR has however not yet been requested from customers, in contrast to digital models, that enables a more environmentally friendly method of working, which is more in the interest of municipal or state clients, to lead by example. Digital printings or models do not necessary give the customer any benefits except being more environmentally friendly. The interviewee says this is also a reason why they do not micromanage individual projects, because it is better if other forces e.g. customers or competition, driving the development and the adaptation of new innovations.

Other similarities organization C have with organization B, is that they also have close relationships with companies providing AR software. In comparison with organization B, organization C have their own laboratories where they test new ideas regarding AR, but also other technologies. Organization C has however tried AR applications on real workplaces with uneven results. Infrastructural projects have proven to have the worst results, according to the interviewee. They have only used AR for visualizations, although the interviewee mentions that they have tested other AR applications. When starting to use AR headsets, HMD, HoloLens was the first choice. These headsets were however not good enough and it was not until they started using HTC Vive headsets, that the results improved. The interviewee does however states that touchpads are just as good or even better than using head-mounted displays, in some cases.

The interviewee argues that the organization is innovative and started experimenting with AR a couple of year ago. According to the interviewee, organization C sees AR as a substitute for paper drawings, as the interviewee states that paper drawings are not environmentally friendly. Large projects also require many blueprints and the costs to plot drawings are high. Interviewee C also states that is costly to spend time sorting drawings and making sure the drawings are in the right place. More often than not, drawings are updated during the construction phase and old drawings can be forgotten and remained with the new blueprints, which creates problems, according to the interviewee. Organization C already uses digital models to some extent, by using touchpads on the construction site. They would prefer to use HMDs to a greater extent, because the interviewee says that MHDs suits the organization's needs better.

The interviewee stated that one of the biggest advantages and disadvantages of using AR is cost. The interviewee stated that the advantage with using AR or digital solutions is the elimination of using paper blueprints, which is a high cost indeed i.e. up and above 50 000 SEK depending of the project size. However, implementing digital models and AR is costly as well, according the interviewee. A DAQRI Smart Helmet, which is a safety helmet constructed for construction settings with integrated AR, costs around 15 000 USD for one helmet. Organization C states that this is not a sustainable technology.

"As soon as you can make money, i.e. save money, changing to another technology, it is interesting, but until that moment has passed, it will be difficult."

(Organization C, interview, 12 December 2018).

Beyond cost, other critical factors that have proven to have some significance resistance according the interviewee are cultural divergence and old ecosystems. The interviewee states that it is very difficult to change anything in the construction industry because it is a conservative sector. The relative advantage that has evolved with the technology is momentarily low. Mainly because AR does not replace any existing technology. The interviewee stated that the technology is too early and not well developed to provide significant advantage. Compatibility is also low, according to the interviewee, mainly due to that the will to change is low if a new technology does not provide clear and quick results. Although AR as technology is straightforward, easy to learn and use, and the learning curve is fast, engineers have to spend more time preparing the models than what is acceptable, according the interviewee. Software are not bug-free, which reduces the overall grade. Complexity is therefore moderate according to the interviewee. Trialability is high, because it is relatively easy to use without needing to sacrifice any current structure. Observability is set to moderate, mainly due which employee you ask in the organization.

4.1.3.2 Future potential

Some of the future applications for AR, that the interviewee in organization C sees, is the possibility to examine if you have installed a part correctly. You could also add work process steps e.g. as how to mount a window. It is also possible to use the headset's camera to check off finished parts and thus facilitate the project process. The interviewee also sees a major field towards maintenance, although being a customer related application, which they momentarily do not push. The interviewee also sees the advantage with AR for providing fictitious x-ray, facilitating the inspection works with operation and service instructions.

Although the technology seems to have a great potential, the interviewee does not think the technology is ready to diffuse, even though interviewee C sees that the technology evolves to the better. The interviewee mentions that VR has existed for 20-30 years, but it is not until recently that the technology has started to diffuse. The factor that has a large responsibility for the slow diffusion rate can be derived to high costs, according to the interviewee. The interviewee stated that the cost to utilize the technology has gone from three million SEK to five to six thousand SEK, in recent decades.

4.1.3.3 Critique

The interviewee in organization C mentions other reasons, comparing to interviewee B, why AR has not diffused yet. According to interviewee C, digital drawings have not worked optimally because the technology acts up, lags and touchpads break easily, when used in construction sites. The interviewee also says that AR works better for subcontractors, i.e. installers that mounts ventilation, electricity and plumbing. In addition, the interviewee states that there are security standards and requirements, which so far may not correspond to Swedish regulation. An example the interviewee states is that no matter what, construction workers must be able to see their surrounding all the time e.g. when they are climbing ladders, which is doubtful that they do when using HMDs. The material used in HMDs must also be protected and classified, which may not be the case. The AR glasses are not sufficiently providing good results, according to the interviewee. Microsoft HoloLens has a too small surface where the augmented objects are displayed.

The major problem according to the interviewee, which corresponds with all cases, is the lack of the reference and coordination system. The interviewee mentions that the margin of error has to be maximum 1 cm in order for AR to be used decently. The interviewee also states that it exists a lack of using other sensors i.e. GPS, which have a clear absence in today's AR glasses and HMDs. The reason behind this conclusion is that the AR glasses organization C uses, still needs input from the user where the user is located to be able to project right augmented objects. This is done by the user providing the system with information i.e. clicking where they are located on a blueprint. AR systems that do not support the system with the user's location are not beneficial according to the interviewee. This problem can be fixed by using GPS, which currently is not provided, as stated by the interviewee.

Further, the interviewee also states that the system is poor in terms of monitoring a user's movement, which may lead to that the system loses the user's position. Voice commands work poorly on construction sites, due to background noise but also due to wind. The interviewee express that HMD provides insufficiently contrasts, especially in bright sunlight. Battery and charging times are not sufficient enough. There are several different software programs, but none of them are ideal.

Network issues are also a major problem, which is crucial because models are updated frequently according to the interviewee. If you load models into the glasses' memory, there is no guarantee that you are using the latest version of the models. Then, you could have the same problems as you have now with paper drawings, not knowing if you are using the last version or not. Being connected through an internet network is a necessary precondition in order for the technology to work efficiently. However, network connections are still not sufficient in all cases, according to interviewee C. The reliability issue is however the most critical problem according to the interviewee. The interviewee's conclusions are that AR is not fitted for the construction industry yet, but merely as a consumer gadget.

4.1.4 Organization D

4.1.4.1 Diffusion and current usage

AR has in organization D diffused in a similar matter as AR has diffused in organization B and C. The upper management has initiated the opportunity to adopt AR. The organization has communication with universities and some communication with companies providing AR solutions, although if it is limited. As a part of the collaboration with universities, organization D has adopted some AR related software, according to interviewee D. Organization D is further a member and involved in industry associations, e.g. Bim Alliance, which organization B and organization C are also involved in. None of the organizations are members in any AR specific associations. Although AR is starting to take more place in some of the associations i.e. Bim Alliance. Bim Alliance fills a purpose, but they are not crucial for innovation adoption in organization D, according to interviewee D. Organization D's communication with customers regarding AR is more or less non-existent, because it has never been requested before, according to the interviewee's knowledge. As with organization B and C, organization D has tested AR in pilot projects but not substantially into real world projects.

The adoption of digital models has diffused to a greater extent than what AR has diffused, according to the interviewee. The interviewee does however states that they view AR and digital models as a necessary progress for companies to take to stay competitive. The value that they gain now from the AR technology is to be better prepared for the future when AR will provide value. Basically, organization D only experiments with AR to keep the organization updated, according to interviewee D. When the technology is ready, they interviewee argues that they will be ready to adopt the technology fast. Organization D is innovative, because the interviewee states that even old engineers and managers understand that digitalization is inevitable. The interviewee states however that some of the older workers have a larger fear of being redundant because they feel that the companies will no longer benefit from their competence. The interviewee states that this view is completely wrong.

The organization's current use of AR reaches only to pilot tests i.e. placing reinforcing bars. Digital models are used more or less in every project. It has despite that, not replaced traditional means of paper-based drawings. Projects that have only utilized digital models and touchpads have had different results according to the interviewee.

The main reason why to use digital models, according to the interviewee, is related to cost. The potential savings for some projects can be substantial when using digital models. The benefits with having digitized drawings are that it also increases quality, but above all, it reduces stress among the managers responsible keeping the blueprints up to date, according to the interviewee. However, as mature the technology is now, it is more a cost burden than benefit according to the interviewee. The hardware is still expensive. According to the interviewee, they bought a DAQRI helmet for approximately 150 000 SEK and it is only collecting dust.

When being asked why AR is not more diffused, the interviewee responses that the construction industry is slow, if you compare the industry with other industries and that they hurry slowly. No one wants or dares to abandon already proven methods with new potential innovation, even if the risk is small.

The relative advantage was set to low, mainly because it is not cost beneficial according to the interviewee. Compatibility was set to low-medium. The interviewee stated that the outcome depends on who you ask. This can be explained due to the structure. As with organization B, Organization D is a more decentralized company, or rather decentralized in some respects and centralized in other aspects, according to the interviewee. It is up to each project leader to make the decisions which methods and technologies should be used, if the contract allows them. The contract manages and controls everything. AR as an instrument is not complex, but the overall processes managing AR are too time-consuming, thus being the reason complexity being set to medium according to the interviewee. Trialability was argued to be a non-existent factor affecting the adoption rate, because it is fairly easy to implement in trials. The interviewee states however that buying an AR helmet for 150 000 SEK, is a cost that small construction companies cannot accept. Observability was also discussed to have no significant impact on the adoption rates, since the interviewee argues that all large construction companies have a good knowledge of new technology.

4.1.4.2 Future potential

The interviewee argues that AR, no matter which hardware or software that exist on the market, they all have the same problems, namely that none of the AR systems can reliably present augmented objects. It can however give a basic understanding how it should look and give information if e.g. a power line clashes with a plumbing line. If the technology fixes the reliability issues it will be of major investment, according to the interviewee.

Some practical applications and probably one of the most important fields for AR, that the interviewee sees, are maintenance and inspections. One way that it could be beneficial to the user is to provide the digital models with information, e.g. how to service heat pumps.

AR systems can provide a clear picture where e.g. electricity and water pipes are located according to the interviewee. This information could be beneficial when e.g. drilling. The interviewee states that organization D has no knowledge what they could use AR for in future events. Interviewee D does however think that the advertisement that some companies are publishing, will be obsolete and nonrealistic, within a near future.

4.1.4.3 Critique

To place the augmented objects correctly seems impossible with today's hardware and software according to the interviewee. The interviewee also discusses the time factor, which the interviewee says is a critical issue. The interviewee states that modeling and creating AR drawings for large projects e.g. hospitals can take months to fulfill. One construction had more 164 million polygons i.e. an umbrella term for plane figures with finite sides and corners, used as augmented objects. The interviewee states that it is a huge task creating and managing these polygons and getting them perfect.

As in organization C, the interviewee complains on the usefulness with AR when being used in bright conditions, because the models cannot be clearly seen. From a legal perspective, it is not illegal to track build worker, e.g. where they are and what they are doing, but the labor syndicates may oppose these settings, states the interviewee.

The most critical issue is however mutually shared among all cases previously, that has initiated an adaptation of AR. Interviewee D states that AR systems still have issues with locating the user and superimposing augmented objects insufficiently.

4.2 Ecosystems

When the interviewees were asked how the ecosystems has affected the adoption of AR, the answers were in unison. The answers from organization A differed to some extent from the other cases. Mainly because organization A stated that they are not so familiar with AR i.e. which factors in the ecosystem that can affect AR. The interviewee meant that organization A does not believe that the technique is too early, but it is more a question of a cultural matter.

"You have to have enough people who believe in the idea and get involved in AR, otherwise there will be no gain in AR regardless of how good the technology is".

(Organization A, interview, 5 December 2018)

The hardware and software are already sufficient for both VR and AR today, according to interviewee A. The major reason why AR has not diffused, is according to the interviewee, that organization A does not sees the construction industry abandon paper-based drawings within a near future. This statement is supported by all interviewees. Interviewee C mentions that:

"Everyone is used to working with drawings. The ecosystems are old and paper drawings are resilient. It is very hard to change anything in the construction industry since it is very conservative. It is always an uphill."

(Organization C, interview, 12 December 2018)

The interviewee in organization B states that the Swedish construction market is not global and that a low competition makes the industry react very slowly. The interviewee in organization B states that the time for the industry to mature is long. The interviewee is certain that the technology will be ready before the companies will be ready to use AR. This statement is based on using 3d pdf models. The interviewee stated that:

"We have shown that you can use a blueprint electronically, as a 3d pdf model on iPad successfully. But 58-year-old men who have been professional construction employees since they were 16, do not want it. Although they can receive an invoice of 50 000 SEK or paper-based drawings (1000 SEK per week), they do not want to use an iPad that may cost them one tenth. They are still not interested."

(Organization B, interview, 11 December 2018)

The interviewee from organization B further mentions that that some managers have tried digital blueprints and that they will never return to paper-based drawings. However, the standard is still to use paper drawings, even though they started implementing electronic drawings four to five years ago. So far, AR is more seen as a complement and they are still left in the analog system according to the interviewee B. Interviewee D states that AR will at the best only be a complement, and never a purely instrument used as the only way visualizing drawings.

The interviewee from organization D also mentions that the standardization regarding AR is low. The interviewee further states that is not necessarily the standardization that is the problem, but more that different software producers create software that does not include processes that the construction industry actually finds important. This statement is supported by interviewee in organization B, that states that software does not create consensus with that tasks that VDC engineers work with. The interviewee states that other areas are more prioritized. The interviewee in organization B does not however supports that standardization is redundant. The interviewee further states that issues that can occur when working with other companies, because they may not use the same types of digital formats, which can be derived to insufficient standardizations.

When asked to pinpoint where AR within the industry is located now in Adner and Kapoor's model, organization A, C, and D state that AR is in the second or fourth quadrant, whereas organization B set AR to the third quadrant.

5 Analysis

5.1 Summary of Analysis

Gomes et al. (2017) state that if visualizing blueprints digitally is a goal of an organization, it should be the main method of presenting data, meaning that it must replace classical means i.e. paper-based printings. This has not happened among the case organizations in this study, nor does it seem to be the goal within a distant future, although the case organizations aim to use digital models to a greater extent. If an organization wants to adopt an innovation successfully, the management should spend the time needed evaluating the innovation and not taking shortcuts and listen on those who are implementing and using the technology (Van De Ven 1991). Van De Ven (1991) further states that this factor has proven to be critical, if innovations are successfully adopted in large organizations, which cannot be said about the cases in this study. If the upper management would evaluate AR properly and listened on the users when evaluating AR, AR would not have been tried to be adopted so early. Ling (2003) also states that team member's interest in adopting a new technology is the most important factor if an innovation is going to be valuable or not, given that the company and the employers have the technical capabilities and skills. AR has however, according to the interviewees had a lot of resistance not being a desirable innovation to adopt.

In the figure presented below (Table 4), which follow a similar structure of the recap figure from the theoretical framework, the most important findings have been presented, explaining the reasons why AR has not diffused yet based on the case companies in this report. All reasons why AR has not diffused yet in this study can be derived to Rogers's (1995) five factors. Some forces why the case companies have tried to adopt AR e.g. branding, can however not be derived to Rogers's (1995) framework.

As seen in the findings presented in the empirical findings or in Table 4, the consensus between interviewees B, C and D is high, grading Rogers's (1995) factors affecting AR similarly. Interviewee A can to some extent be seen as an outlier, since the interviewee had no real experience with AR, as the other interviewees have. However, interviewee A views regarding relative advantage was the only category that substantially differed from the other interviewees. Compatibility, complexity, trialability and observability had a high correlation between all interviewees, which can to be seen as a high validity.

As mentioned by Rogers (1995), relative advantage is the most important factor describing the rate of diffusion. However, Rogers (1995) also presents findings that state that observability combined with cost-effectiveness is the most important factor affecting the diffusion rate. This finding deviated from the findings in this study. Observability may be an important factor affecting how innovations diffused among individuals, but it is not stated how important is it in other social systems that involves companies. Since it is not declared in Rogers's (1995) theory if observation of innovations is the same for both individuals and companies, the importance of observability as a factor will be discontinued. Mainly because it was regarded to have a low impact of the diffusion of AR among the interviewees, but also because existing theory from Martínez et al. (2014) that present this factor from an individual's perspective, thus it is not comparable with the findings from this study. Observability is thus not regarded to impact the diffusion of AR negatively or positively.

Trialability is a factor, that is regarded not to have affected AR negatively, since AR was considered from all interviewees to be easy to test and use. Trialability is thus a factor working in favor for AR. However, since trialability is an enabling factor, and because none of the organizations have adopted AR, trialability is not worth investigating more in depth, since there exist factors that are more critical. These critical factors are complexity, but mainly compatibility and relative advantage.

The learning curve is still regarded to be flat, which is presented by both Martínez et al. (2014) and the interviewees e.g. B, C and D. Although the surrounding processes e.g. time preparing AR models, makes the technology complex, according to interviewee C and D.

Relative advantage and compatibility had the biggest issues. These two factors are the most important factors in the thesis. Since Rogers's (1995) factors evaluate an innovation work together as an overall rating, thus, a chain is only as strong as its weakest link, which in this study are Relative advantage and Compatibility. These factors will be explained more during their respective sections in the analysis.

Table 4: Summary of empirical findings

Interviewees' answers regarding Rogers's (1995) five factors evaluating AR					
Interviewee	**Relative advantage**	**Compatibility**	**Complexity**	**Trialability**	**Observability**
A	High	Low	Moderate-high	High	Low/unimportant
B	Limited	Moderate	Low	High	Low-moderate
C	Low	Low	Moderate	High	Moderate
D	Low	Low-moderate	Medium	High	Unimportant

Current adopted areas					
Potential adoption areas	Product design	Training	Reducing production and quality errors	Maintenance	Safety
Interviewees	Yes, trial	No	Yes, trial	No	No

Diffusion of AR	
Interviewees	Nonexistent

Factors that hinder AR	
Interviewee	**Factors**
A	Conservative industry (resistance against change), fairly young company, not taking over other techniques and methods of working
B	Resistance (mostly older generation), not reliable results, high costs, easy to test but do not suit their projects (i.e. projects members do not have the possibilities to test new innovations), safety issues, long time finding markers, software does not suit VDC managers
C	Everyone is used to working with paper-based drawings in organization C (significant resistance), uneven results, high cost, lags, might not pass security standards, not sufficient results, voice commands are insufficient, bad contrasts, software not being ideal
D	Costly, slow industry, no one want to take risks, cannot reliably present augmented objects, takes time to prepare, inefficient in bright sunlight
Factors that enable AR	
Interviewee	**Factors**
A	Interest among younger people, only sees advantages with AR, future potential
B	Curious and interesting, real advantage (quality management), sees potential in future
C	Touchpads are just as good or even better than using HMD, replace paper-based printings, less time sorting drawings, easier to update, might save costs, future potential (although not soon)
D	Even old engineers and managers understand that digitalization is inevitable, might be cost-beneficial, future potential for some

An easier way to explain why AR has not diffused yet is because AR is basically not regarded or defined as an innovation yet. By checking Slaughter's (1998) definition, AR could be regarded as improving a process. The same could be argued with Gambatese and Hallowell's (2011) definition, since positive change can be argued to have occurred in a process, product or system. However, Gambatese and Hallowell (2011) further define that the difference between an innovation and an invention is that whereas an invention is a novel process or device, innovation is an invention with a usefulness. The relative advantage is however regarded to be low by the interviewees. Additionally, both Rogers (1995) and Andersson and Widén (2005) argue that an invention must be adopted to be defined as an innovation, which has not occurred yet. Just by looking on these definitions, the case companies in this report indicate that AR is not an innovation, and if it is not an innovation, diffusion theory does not hold, since it is based on innovations and not inventions.

Additionally, no of the companies have realized that being a decade too early with an innovation can be costlier than missing the emergence of the AR technology entirely (Adner & Kapoor 2016). Adner and Kapoor (2016) suggest that the full value of an innovation will only be perceived if there are no bottlenecks left in the ecosystem, thus it could be advantageously to focus on solving these problems first. This conception has been validated in the study. Organization D has for instance invested in a HMD-helmet for 15 000 USD and it has so far only collected dust. In a couple of years, this technology will be outdated, and they will have lost 15 000 USD for basically understanding that the technology is not ready yet. It is a balancing act between waiting and not waiting because innovations must, and are often implemented before knowing the full potential, making it even more difficult to access the innovation potential (Vinnova 2012). One must also not forget, that the construction industry does not provides ideal conditions to test new technologies (Gann & Salter 2000).

Why did the companies tried to adopt AR so early? It can be very well as the interviewees stated, that they are innovative organizations and that they do not want to be late, jumping on the bandwagon. Another reason that should not be underestimated, is their need for good reputation and publication, which have been validated when reading articles on some of the case companies' web pages.

The remaining part of this paragraph will provide a more detailed analysis.

5.2 The first element: Innovation

5.2.1 Innovation – where and how it occurs in reality

According to Ozorhon et al.'s (2010) definition, AR is regarded as a radical innovation. Slaughter's (2000) definition also makes AR a radical innovation, since it makes paper-based drawings obsolete, even though paper-based blueprints are preferable in some settings. Van De Ven (1991) states that innovations that are radical, e.g. AR, could possibly eradicate mature and create unfamiliar and newfangled settings. AR has not according to the interviewees in this study eradicated mature settings, it has however created newfangled settings. AR has not, by using Rogers's (1995) and Harty's (2008) theories, affected the organizations by forcing the them to change organizational structure to utilize the technology efficiently. This is a step that the case companies are not willing to take. As interviewee A states it; if their employees are not satisfied how the company manage them, e.g. if the company is forcing them to use new methods of working they do not like, the employees change employer.

As stated by Pellicer et al. (2012) innovations emerge from three different types of settings, namely "technological problems at the construction site, demands from clients, and stimuli from upper management" (Pellicer al. 2012, pp. 45). All cases in this research have only validated stimuli from upper management as the source for AR. The main reason why AR has only diffused from this setting can be described, according to interviewee B, because AR does not give any direct benefit to the customers. If clients do not see the benefit with an innovation, it is not likely that they will request it. Technological problems at the construction site is a setting that have not been found among the case companies. Although if 80 % of innovations emerge from technological problems at the construction site, according to Pellicer et al. (2012), interviewee B stated that it is quite normal that an innovation is stimulated from the upper management, without having any idea how the innovation is going to be used.

That customers are an important factor for driving the innovation process, is clear among researchers, yet it has not been shown to be clear for AR. Harty (2008) also mentions clients' demand for better and new building-technology as an external factor enabling innovation. No correlation between clients' demand for better building-technology has been found regarding AR. Digital models or AR can however be beneficial to the coordinator, which sometimes also is the customer, according to interviewee C.

The other setting where innovation emerges from, is that it comes from somewhere else. This is true, since AR were not first adopted in the construction industry. That the construction industry copies innovations from other industries is stated by Harty (2008), Ozorhon et al. (2010) and Pries and Janszen (1995). Ozorhon et al. (2010) state that companies operating in the construction industry have gotten better to copy and integrate new types of processes and products, originating from other industries. This statement can be validated by looking on other innovations, e.g. CAD, which was firstly adopted by IBM. That construction companies innovate by themselves (Ozorhon et al. 2010), can somewhat be proven with AR. Although no of the companies have researched or developed software and hardware regarding AR themselves, organization C has their own laboratories where they conduct own-initiated experiments and cases. Company D has closely related connections with universities, which has resulted in some software applications and company B has close connections with software companies developing AR systems.

The statement by Van De Ven (1991) that innovation, more often than not, occurs in a cumbersome and bumpy way is validated after collecting the interviewees' insights. None of the companies adopted AR with a clear idea how to use it. None of the companies did not really either do a proper evaluation of AR's core functions. This has led to leapfrogging into a new technology that the companies did not understand, which is validated by Van De Ven (1991). The effects of companies being impatient leads to that companies must postpone the adoption of new innovations, because the companies do not understand the main and lateral core functions of the innovation. This is the case with organization B, C and D, since they have still not found any beneficial applications of AR.

5.2.2 Rogers's five factors

When the interviewees were asked to mention factors affecting the adoption of AR, both negatively and positively, more or less all answers were included in Rogers's five factors. These findings correlate which other case studies done by Rogers (1995).

5.2.2.1 Relative advantage

The first factor that was examined was Relative advantage. As Rogers (1995) states, the relative advantage measures the perceived advantage, not the actual objective advantage. A majority of the interviewees had the same take as Rogers (1995) had, basically that an innovation has an advantage if it is better than another old innovation. However, if this definition would be the only definition used to catch the scope of relative advantage, it would be difficult to reach consensus. This mainly because all organizations saw some advantage with AR compared to existing technology, but to different degrees. Interviewee from organization C, saw some relative advantage with AR, but further stated that AR is never going to be the only way to present drawings, but merely a complement to existing solutions. Therefore, the interviewees were asked to mention all the factors about the relative advantage. Organization A differed from the other companies. The interviewee did not see any direct forms of disadvantages with AR, thus the conclusion was that AR has to have a relative advantage. The other companies were more limited to salute the advantages with AR.

Interviewee B stated that AR is still not cost beneficial. This statement was validated by interviewee C and D as well. Organization B was the only company mentioning an increased pleasure with using AR. Why the interviewees could not see any relevant advantages with AR now, could possibly be explained that the innovation is preventive. Although if interviewee A was positive that the technology is ready already now, interviewee B, C and D had complaints, criticizing the hardware not being as good as it potentially could be. Interviewee B, C and D all agreed that AR hardware has evolved exponentially during the last three to five years. They did however not see any of the subfactor e.g. having a positive profitability, low start-up costs, increased pleasure, increasing social prestige, witnessing a direct gain and decreasing the time and effort, for AR now. Rogers (1995) mentions that this view easily happens for innovations that do not tend to be incremental, but innovations that tend to be preventive and may have a future advantage. As Rogers (1995) explains it, preventive innovations have a slower adoption rate because they do not tend to have a value right now. This statement correlates with the interviewees' views. Rogers (2003) mentions that the relative advantage is highly uncertain for preventive innovation, which possibly could be the case in this report. Generally, Van De Ven (1991) states that radical innovations seem to have a less perceived effectiveness, in contrast to incremental innovations that seem to have an easier time convincing its users having a perceived usefulness, with may also be the case in this study.

Martínez et al. (2014) argue that AR does offer new types of relative advantage i.e. visualization. However, this advantage is not that distinct according to the interviewees.

5.2.2.2 Compatibility

All interviewees from the organizations that have tried to adopt AR, mentioned some disadvantages with AR. For example, interviewee C mentioned that AR does not work properly in bright light conditions, which Martínez el al. (2014) have validated. The biggest non-technical problem according interviewee D and the overall biggest problem according to interviewee B is however the cultural resistance. Studies by Vinnova (2012), that is referring to the study from Freeman and Soete (2009); Blayse and Manley (2004) and Rogers (1995) all state the importance with positive cultural values. Blayse and Manley (2004) state that cultural resistance is regarded as the largest hindrance preventing innovation, which is confirmed from interviewee B. Rogers (2003) shares the common ground that cultural values can totally block innovations to diffuse, if it does not suit the users' need. The users that imposes these changes are according to interviewee B, especially the older generation.

As Rogers (2003) states, if adopters must change their behavior to adopt an innovation, the chance that the new innovation will diffuse is reduced. This statement is clearly presented in this study by interviewee B, C and D. In addition, all cases mention that the construction industry generally is critically opposed to changes.

To promote positive culture values, Blayse and Manley (2004) argue that a company should: not punish negative attempts trying new ways of working, enable that the employees share the same opinions and that the employees tries to understand each other's goals. This is validated by interviewee A that stated that, if a new technology is going to have a wide spread, the employers and employees must believe in the idea and get involved in AR, otherwise there will be no gain in the technology regardless of how good the technology is. The interviewee states that this has not happened for AR yet. Gambatese and Hallowell (2011) also stated that the willingness to exploit new technologies is important if an organization successfully wants to adopt new innovations. However, Rogers (1995) further states that generally, the desire to break old habits is low and organizations may oppose hinders trying to change them, which is also the case for the case organizations in this research.

Compatibility issues is according to Martínez et al. (2014) were only seen in some fields, due to privacy issues. These findings were not found among the interviewee's answers.

5.2.2.3 Complexity

AR was only regarded as complex by interviewee A, mainly because they did not have sufficient knowledge about AR. The other cases ranked AR to be easy to moderate to use. According to Rogers (1995), knowledge is the first step in the adoption process for an organization, whether they will later on adopt or reject an innovation. The knowledge step can further be regarded by Rogers (1995) as the initial step when a decision-making unit obtains necessary know-how about an innovation. Organization A is not even in the first step. When asking why the organization does not have any knowledge about AR, the interviewee stated that they do not have a policy favoring AR and that the managers responsible did not have the time needed to evaluate AR. Having knowledge, experience, resources and policies that enable innovation have proven to be factors promoting innovation, according to Gambatese and Hallowell (2011). Organization A do not have any of these factors, regarding AR. Harty (2008) also states that knowledge is one of the most important factors fertilizing innovation. One reason why some organizations tend to lack the knowledge is because the industry is project-based. This topic will to some extent be further discussed in the sectors *Industry relationships* and *Clients and manufactures.*

Interviewee C stated that the technology itself is not difficult to understand, but that the surrounding steps to prepare AR to work, could be somewhat complex. That AR is not complex is further stated by Martínez et al. (2014) that states that AR is easy to use, thus not making it a complex technology to use.

5.2.2.4 Trialability

Rogers (1995) explains trialability as how capable an innovation is of being tested on trials. No objections against trialability were raised by any of the interviewees. Thus, consensuses among the case interviewees were achieved. The trialability was set to high or having no negative impact, regarding how one defines the range. Trialability related issues are, according to Martínez et al. (2014) almost non-existing because it exists several fields to apply AR and it is easy to use. It is however mentioned that a company testing the technology must often implement new hardware and software, which is quite self-explanatory (Martínez et al. 2014). All companies argued that AR is suitable for their type of industry, since the construction industry is already divided into projects. Interviewee D wanted to raise a note of caution, since some of the products they use i.e. a DAQURI smart helmet, cost around 150 000 SEK, which may be a high cost for smaller companies to invest in.

Martínez et al. (2014) argue that trialability issues are almost absent, because AR is easy to use and that there exist several fields.

5.2.2.5 Observability

Observability is the fifth factor stated by Rogers (1995), that Rogers (1995) defines as to which extent the innovation is visible to others. Observability can impel or prevent the spread of adaptation, as the other factors can do as well. Is was not that clear for some of the interviewees how observability would affect the adaptation in their organizations. Interviewee A and D argued that observability is not that relevant for the settings that construction companies operate in. Interviewee A further argues that it may be a more important subject when evaluate individuals. However, Rogers (1995) did not discuss particularly how observability differs from individuals and organizations, although discussing how important observability is to address the adoption. Further on, Martínez et al. (2014) state that observability is not clear for some of the users, thus not having any positive impacts. The overall impact of AR, deriving from observability among the organizations, were seen to be low-moderate.

5.2.3 Construction specific factors that have affected AR

Since none of the companies have actually adopted AR, it is impossible to see how their adaptation process has been so far. This conclusion correlates for almost all organizational findings. Which attributes of the companies that have affected the adaptation of AR becomes redundant since there are no characteristics to analyze, since none of the companies have actually adopted AR. The ground that this thesis will hereinafter bring, regarding AR, will mostly be based on hypothetical thoughts. It does however exist factors e.g. culture, which are clear to have affected the adaptation of AR. These factors are thus none hypothetical.

Blayse and Manley (2004) have stated that there exist six factors or fields that impact a company's innovativeness and adoption of new innovations, namely: clients and manufacturers, the structure of production, relationships between individuals and firms within the industry and between the industry and external parties, procurement systems, regulations and standards, and the nature and quality of organizational resources. All of these factors have been investigated to a varying extent. The factors will be presented in the same way as the theory, although some of the fields will overlap with each other.

5.2.3.1 Procurement systems

Vinnova (2012) argues that the procurement process determines which type of working methods and techniques get diffused. If one defines this as the process of constructing the contract, this statement is supported, mainly from the answers from interviewee C, but also interviewee D. Vinnova (2012) further states that without the settlements between clients and contractors, innovations that only cut costs will be implemented. That customers and contractors prefer innovation and technology that are financially beneficial is straightforward according to the interviewees, however interviewee C states that it is entirely up to the customer or coordinator to decide which methods or technologies should be used and if the company has competence to manage it. These findings are in parallel with the statement from Vinnova (2012).

Interviewee C states that regional and municipal clients usually push construction companies more than private clients. This could possibly correlate with Vinnova (2012) statement if regional and municipal clients are seen as key actors, which they state have a strong and positive correlation to the adoption and diffusion of innovations in the construction industry. The problem with the diffusion processes are that they are usually based on two reasons, price or speed. Risks are negotiated away and intimidating companies taking risks which, according to Blayse and Manley (2004) is one biggest harmfulness for innovation to diffuse. This statement is supported by interviewee D. The interviewee states that one of the reasons why AR has not diffused yet, is because no one wants or dares to abandon already proven processes i.e. paper-based printings, even if the risk is small. This is one of the reasons, according to interviewee C, why the industry is so traditional and conservative.

5.2.3.2 Clients and manufactures

The most important factor that drives innovation in the construction industry is, according to Gann and Salter (2000), customers demanding new types of houses and buildings. Although AR is not adopted among the case companies, the interviewees have a different take on this statement. Interviewee B stated that BIM for instance, is used for all types of projects they coordinate e.g. small, large, non-complex and complex projects. When and if AR is going to be adequate, it should be used in the same types of projects, according to interviewee B. Interviewee D had a different opinion. Interviewee D could only see a future for AR being used in large projects. Interviewee D stated that AR will never be financially beneficial in small projects. However, interviewee B stated that BIMs, that are used in small projects, are not as detailed as they are in larger projects, therefore they are not that costly to produce. No detailed theory was found whether AR could be efficiently used on all types of different projects, but Omar and Nehdi (2016) claim that AR, as a technology is very promising suiting for all types of project types and sizes.

Gann and Salter (2000) and Blayse and Manley (2004) further express the need, deriving from customers forcing innovation development, which pushes the industry to find new ways to produce new products. However, AR does not seem to be one of these innovations, derived from the findings in this report, since AR has not showed any clear benefits yet, according to the interviewees.

Parallel to the theoretical findings that customers' demand is important for companies to become more innovative, the demand for services seems to increase as well (Gann & Salter 2000). Barrett, Sexton and Lee (2008) argue that since the construction industry is a project-based industry, it is often coping with not providing enough customer focus and service. Interviewee A and D where especially objecting to this statement. Interviewee A states that providing the customers service is extremely important and that technologies i.e. VR has only been implemented to delight their customers' needs. That the construction industry has become a more serviced-based industry correlates with Ozorhon et al. (2010,) that present that the construction industry is a mix between manufacturing and service.

Gann and Salter (2000) argue that services and means that adds value to customer e.g. maintaining the buildings, are more emphasized by contemporary researches. That companies with this approach could gain competitive advantage is also stated by Gambatese and Hallowell (2011), that present that service providers should involve their customer in specific and long-term relationships. This is can be true for organization A, because they more or less only initiate their own projects with their own management, without having any ready and potential buyers. As interviewee A states it, if they do not have satisfied customers, they will not complete the purchase.

The other companies i.e. B, C and D focus on all types of projects and not only on residential constructions. They do often initiate projects from orders and public procurements and contracting. How private versus how public procurements affect the adoption of innovation was not included in this thesis, however there is a clear difference between organization A and B, C and D in how they work with services. Company A provides services to attract customers, while company B, C and D only include services if it is arranged in the contracts. Organization B, C and D also explain that they do not provide any services to their customer regarding AR, because the customers have not requested it, but they all mention using AR for maintenance as an attractive field. Interviewee D oppose Barrett, Sexton and Lee's (2008) statement that the construction industry does not provides enough customer focus and service, but they have never initiated and tested how AR could be used for maintenance, although admitting that maintenance will be a huge and important field for AR. This contradicts to some extend what the interviewee says from an AR perspective.

Blayse and Manley (2004) argue that since the lifespan for facilities is expected be too high, it is thus forcing companies to use well-known techniques. These methods are preferred over new and unpredictable methods and techniques (Blayse & Manley 2004). This statement is mainly supported by interviewee D. One way, according to Blayse and Manley (2004) is to pass the risks further down the supply chain. In return, this tactic forces subcontractors also using well documented tactics (Blayse & Manley 2004), which makes innovation harder to flourish. This could possibly be a problem because interviewee C stated that AR suits subcontractors better than it suits large construction companies.

5.2.3.3 Industry relationships

Gann and Salter (2000) argue that since construction is a project-based process, companies are required to collaborate and manage their network with other firms. When asking the interviewees about how their communication and collaboration with other firms is affecting AR or other innovations, the answers were unambiguous. As explained before by the interviewees, everything is regulated within the contracts. If the subcontractor is not comfortable with using new methods or technologies, they will not take on the project. If they want to sign the deal, subcontractors must have the competence that the contractor requests. In reality, this is not the most common problem according to interviewee B, because the construction industry is very slow and new technologies do not emerge over a night. Since the industry is slow, the industry evolves in coexistence, although it might be some spread on individual level, according to interviewee B.

Gann and Salter (2000) and Edquist (2010) further write that one firm can thus not be responsible to adopt new technologies, if the entire network does not co-exist and collaborate, which interviewee B validates. Gann and Salter (2000) further states that the construction companies are to a great degree dependent on technical support from institutions and organizations that can support learning between different companies and projects. To which extent the case organizations are dependent on technical support from institutions will be unspoken, however organization B, C and D are all members in Bim Alliance, which is a sector-driven non-profit association. How important the association actually is, was only briefly mentioned during the interviews, mainly by interviewee D. Although that interviewee D specially said that associations have not been critical for the adoption of AR, the interviewees still seemed to enjoy these associations.

However, Bim Alliance is not an AR-based association, although a Bim-based association and no data where presented that indicated that the case companies are involved in exclusively AR-based associations. The case companies have however relationships with universities, which Blayse and Manley (2004) validate being important. Interviewee D states that their cooperation with universities has been successful, which has ended up with software being used for AR applications.

Blayse and Manley (2004) also state that universities and institutions could assist means to support partnership between companies and the innovation brokers. Blayse and Manley (2004) further state that innovation brokers are possibly more important in the construction industry than they are in any other industry. However, innovation brokers' role was not mentioned by any of the companies, having influenced their knowledge or adoption of AR. Nor did any of the construction companies have any partnerships, regarding AR with other construction companies, although interviewee B stated that they do give feedback to software developers. Blayse and Manley (2004) state that their reasoning is based on that technology watch is limited and often not feasible in the construction industry and that many of the companies are small and that the industry is seldom high tech (Blayse & Manley 2004). That the construction industry actually does not collaborate with other firms and tend to do the opposite is validated by Gann and Salter (2000).

When asking the interviewees if network effects possibly could have affected the adoption of AR, ambiguous answers were given. No clear differences between AR from other technologies were mentioned.

5.2.3.4 Structure of production

All interviewees regard themselves as innovative, compared with other smaller construction companies. However, this statement can be discussed, because it exists disagreements among present studies. If the organizations that have assisted this report with the findings, compare themselves with smaller construction firms, they state that they may be more innovative which is validated by Rogers (1995). One of the attributes that have shown to be significant how innovative companies are, according to Rogers (1995) and Van De Ven (1991) is size, where they argue that larger companies tend to be more innovative.

Pries and Janszen (1995) do however state the contrary, that innovation diffuse more rather in smaller companies. Furthermore, if the companies included in this report are actually more innovative than their smaller counterparts, is without the scope of this thesis. It is very plausible that it is like interviewee D stated it, that the larger organizations can afford the high cost experimenting with new technology, which smaller companies cannot afford. This conception is confirmed by Rogers (1995) that states that individuals and organizations with a higher social status or having the financial means to invest in new innovation are characterized as being more innovative. These findings correlate with the paradox; does big organizations get big because they innovate, or do they innovate because they are big? Rogers (1995).

Maybe can the solution, if larger construction companies are better or worse than smaller companies to adopt innovation, be derived from which type of innovation is. Although large companies tend to be better than small companies to adopt product innovations, small construction companies tend to be better to adopt process innovations (Pries & Janszen 1995). It can further be discussed if AR is a product innovation, process innovation or maybe both.

The findings related to size, has thus far not proven that size have any influence on the adaptation regarding AR. Larger construction companies have however showed the interest in AR and proven to have the financial means to invest in AR. If these attributes are solely connected to size or not, will further not be discussed, since prophesying will not bring any value to the report, because small businesses have not been investigated in this report. Since small companies have not been included in this report, due to how the research question is written, benchmarking and comparing results between small and large companies is impossible to do. Although there might be some evidence that larger construction companies are well prepared to adopt new technology, it is not disproved that smaller companies are worse adopting innovation. For that reason, size is probably an indistinct factor based on the findings in this report, which is supported by Rogers (1995).

Multiple variables that may be hidden might be embedded into size. Which these variables are and how do they affect innovation is still not obviously understood by researchers (Rogers 1995) nor was it clear in this study. One of the variables that might be included into size is structure (Rogers 1995).

Rogers (1995) presented four different types of structure approaches, merely Optional innovation-decision, Collective innovation-decision, Authority innovation-decision and Contingent innovation-decision. Which type of approach that the companies have adopted depends on how one defines a system. If a company is regarded as one part of the system i.e. the entire construction industry, optional innovation-decision seems to be the approach companies has adopted based on the statements from the interviewees. However, if the system is regarded as one company and the employees regarded as individuals, one could argue for another outcome. Optional innovation-decision can be regarded as a more decentralized approach, since individuals make the calls themselves, whereas authority innovation-decision can be regarded as a more centralized approach.

How different types of approaches affect the diffusion of innovation, is not expend by Rogers (1995) although it does however give insights about a company's structure. Rogers (1995) has further presented five factors that explains an organization's structure, namely Predetermined goals, Prescribed roles, Authority structure, Rules and regulations and Informal patterns. How these factors influenced the adaptation of AR and new innovation in general, were questioned during the interviews, however no further differences between the companies could be noticed. Or rather, the differences between the companies could be achieved, but their impact in reality seemed negligible.

One finding is the difference or similarity between decentralized versus centralized organizations. Rogers (1995) argued that decentralized organizations seem to test innovations in a faster rate than centralized organizations do, whereas when centralized organizations have made the call to actually adopt an innovation, the implementation process seems to be shorter and more effective than it is for decentralized organizations. This statement could not be proved in this research, since organization B, C and D all begun testing and evaluating AR at the same time and they have all come as far as each other to utilize AR.

Rogers (1995) further states that centralized organizations have shown to be less innovative. The reason behind this reasoning is that the management, that makes the decisions in centralized organizations, has poor knowledge to identify problems and find innovations that suit the entire organization's need. Rogers (1995) does not mention that this conception holds for decentralized organizations as well. When conducting the interviews however, all organizations state that the top-management ultimately make the call whether to adopt or reject AR. The only difference in this report was that organization B, that defines themselves as a decentralized organization, took more input from the engineers and managers that actually works with the technology. If this is something that characterizes decentralized organizations or not, is not further researched in study. Since centralized organizations i.e. organization C states that they do not, nor can micromanage AR into their projects. The same was presented from interviewee B. The differences between how a centralized organization i.e. organization C and a decentralized organization i.e. organization B, manage innovation have so far not been seen. The bottom line is that although the cases argue they have different types of organizational structure, the outcome is similar to how the structure has affected the diffusion process. One of the reasons explaining this phenomenon could, according to interviewee C be derived to customer and contracts, which previously have been explained in section Clients and manufactures.

Other attributes that are related to the industry's structure, according to Gambatese and Hallowell (2011), is the type of a project and how its members acknowledge the innovation management, which plays an important role in how successfully an innovation will be adopted. How different projects i.e. small, large, complex and noncomplex suit AR has not been investigated extensively by researchers in the literature review, used for this thesis. There are however a vast of studies that have researched which types of fields AR could be implemented to. These findings will eventually be presented in the paragraph the *Enabling factors*.

Ling (2003) argues that managers and senior managers play a key role, how to implement an innovation, but also when to do it. This statement has been validated by all interviewees. Ling (2003) further argues that if the management is going to play an important role, they must invest and commit resources for the implementation of the innovation. No of the interviewees have complained that they did not get the financial means and support from the upper management. Their commitment is however low, according to interviewee B. As interviewee B states, the management does things without a plan. Ling (2003) states that a management's commitment must be total and not an arm's length when working with new innovation, which was not found to be validated, reviewing the case companies' answers.

Gambatese and Hallowell (2011) and Ling (2003) further state that managers and supervisors on the project level, have one of the biggest impacts how a company will use an innovation. This is established in the thesis, since even if organizations have proven to be centralized, i.e. organization C and organization D to some extent, the management have not micromanaged AR. How AR is used among the case organizations, is determined on project level for the case companies that have tried AR. Ling (2003) also argues that project members must be committed, if an innovation is going to be successful or not. Ling (2003) further states that team members must be prepared and show wiliness to alternative approaches that they are not used to. This is a challenging statement for the construction industry, due to that a big part of the projects members in the construction industry avoid changes to all cost. This conclusion reached one, if not the strongest consensus among the interviewees.

Customization does also have a negative effect on the utilization of new technology and to some extent even AR, according to interviewee B. Since every project is unique and buildings are costly and since constructions are required to have a high quality, project members choose proven methods in order not to jeopardize the quality and take risks. Radical innovation does not suit these settings and are thus deprecated (Pries & Janszen 1995). Economies of scale and learning effects do not arise in these settings according to Pries and Janszen (1995) and Gambatese and Hallowell (2011). Interviewee B states that project members do not have the time to read on and test new methods. This has been the case with AR in some cases according to interviewee B. Interviewee B also states that it seems to be difficult to transfer knowledge between projects. This concept is also presented by Gann and Salter (2000) that state that opportunity to experience economies of scale, standardization and process improvement is reduced.

5.2.3.5 The nature and quality of organizational resources

One of the most tangible resources of an organization's attributes, is size (Rogers 1995), which previously has been analyzed in this analysis in the section Structure of production. Innovation champions have however not been discussed yet. That innovations champions have technical competence, helping innovations thrive, carrying the innovation and mobilizing the rest of the company is clearly stated by Blayse and Manley (2004). Although Blayse and Manley (2004) state that innovations champions have a vital role if an innovation is going to diffuse or not, it was challenging to analyze the answers from the case companies how innovation champions have affected the outcome of AR, since AR has not been adopted yet by the case companies.

The culture of a company is often regarded as the of the most important intangible attribute impacting innovation (Blayse & Manley 2004; Vinnova 2012), which also has been validated by interviewee B. Blayse and Manley (2004) state that companies should never penalize individuals using new methods or innovations even though if the outcome was bad. Although that no of the companies have mentioned that they penalize failed attempts working with new innovations, they did not either seem to do the opposite, namely encourage positive attempts. If the organizations are not willing to take risks or if AR has not proved its worth, could not be identified in this report based on the case companies and interviews.

Blayse and Manley (2004) also state that if a company is going to evolve, employees in the company should strive to understand common goals and that employees are open towards new ideas. Although that, all case organizations state that they are innovative, only a minority of their employees seem to share this view, namely being willing to change routines. When asking the interviewees why employees seems to avoid change e.g. using digital models, the general answer was that the construction industry is an exposed industry. An example mentioned by interviewee A, is that the employees seem to have a strong negotiating power due to the shortage of competent people. Interviewee B also stated that it is difficult to question employees' methods of working as long as they provide good results. Interviewee B further stated that getting their employees more open toward new suggestions is the toughest issue they are facing. Moreover, interviewee B was the only interviewee that stated that the AR will be sufficiently developed and completely free from problems before the industry will consider adopting the technology.

Branding and reputation are another factor, closely related to innovation. The correlation between innovation and branding and reputation may be low according to the findings in this report, but branding and reputation is an important factor explaining why some companies have tried to adopt AR. The reasons why branding and reputation is important, explained by Gann and Salter (2000) is that there is a need for companies being recognized for their technical capability to the public knowledge. Rogers (1995) states that getting a better social status it a legit reason why units adopt innovations. Gann and Salter (2000) state that reputation is an important factor for winning biddings-contracts. None of the case companies contradicted this theory, but none of them admitted that branding and reputation was a factor why they have initiated the adoption of AR. A way for companies to show their technical reputation is to publish journals and articles (Gann & Salter 2000). Publications and articles on some of the case companies web pages have shown how they use AR today, was the background for conducting a study in this topic. This study has however demonstrated that these articles are exaggerated, and they do not provide a real picture how far the companies actually are using AR on a daily basis.

5.2.3.6 Regulations

One way to boost companies' investments in R&D is to introduce governmental incentives e.g. tax benefits. None of the interviewees were familiar with tax benefits related to AR, therefore, this area was not examined more. Although regulation may have an important role impacting the technological change e.g. automotive seat belts that forced companies to implement a new innovation (Rogers 1995), these regulations can be as much as hinders as drivers (Edquist 2010). Pries and Janszen (1995) state that the regulations in the construction industry are tangible. This may be true in some fields, although not true for AR. The interviewees did however mention some shortcomings that may possess some lawful issues. Interviewee C stated that builder must under all conditions be able to see their surroundings, which is questionable according to the interviewee, since some of the HMD displays are cumbersome. Interviewee D also stated that even though it is legal to track builder's movement, labor syndicates may oppose these findings. These findings have thus far not had any lawfully consequences or implications yet. Regulations have therefore been considered to be an unimportant factor affecting the adoption of AR this far.

5.3 The second element: Communication

As explained by the theory, communication channels did not prove to have a great significance affecting the diffusion and adoption of AR in this case study from a technical perspective, nor from any other perspective as well seen from Rogers's (1995) standpoint. Therefore, further research about how communication channels affected the diffusion according to Rogers's theory was discontinued. However, communication between companies and customers are further explained in the *Innovation* paragraph above. The process of communication has affected the adaptation of AR to some extent, still not to a significant extent.

5.4 The third element: Time

The process when the company first hears about an innovation until the process when the company finalizes the innovation is by Rogers (1995) defined as the innovation-decision process. The cases shift from being at the beginning of the process i.e. company A, to be in the middle of the process i.e. company B, C & D. The determination where in the innovation-decision that the companies are localized, can however be discussed, since the boundaries of Rogers's (1995) framework may be somewhat unclear. However, to address if an innovation has diffused or not, the innovation must be adopted by a unit. Rogers (1995) defines adoption as full use of an innovation, as the best course available. However, all of the companies that have tested AR i.e. organization B, C and D, have only adopted AR on trial basis. Company A has passively rejected AR so far. AR can thus not be considered to be diffused based on the companies in this report.

Rogers (1995) states that if the innovation has proven having a relative advantage, units proceed with the implementation, given that they initially want to progress with the innovation. Since no of the case companies have moved further than trial utilization, no companies in this study can be regarded as adopters of AR, nor has the critical mass been reached in this social system. Studies have predicted otherwise. Chi, Kang and Wang (2013) predicted that approximately 30 % of the workers in 2014 would use some type of AR technology. This forecast can be questioned, looking on the results from the empirical findings by Chi, Kang and Wang (2013).

Chi, Kang and Wang (2013) further predict that a broad part of the construction industry will use AR within a decade i.e. year 2023. When asking the interviewees when they think AR will diffuse widely in their organization or in the construction industry, no definite answers where given. Interviewee A said the technology is already ready to diffuse now, but then, the interviewee had no really experience with AR technology.

Interviewee B, C and D all saw some limitations with the first models of HMD e.g. Microsoft HoloLens. Some of the problems were that the screen is too small and that the HMD is heavy. These issues are however becoming less visible and notable. Interviewee B, C and D all state that the AR hardware technology will be more or less free from bottlenecks within a couple of years. Interviewee B states however that everything takes a longer time than expected in the construction industry. Technologies that they adopted 10 years ago, still seem to be unknown for some companies and employees. Digital blueprints have been available for years, but it has still not reached consensus in the construction industry. As interviewee B said before, the technology will be ready years before they actually adopt AR. Therefore, does the year 2023, which Chi, Kang and Wang (2013) think AR will diffuse widely in the construction industry, maybe seem to be a realistic year for the hardware to be without bottlenecks. However, it is not realistically that majority of the construction industry will be adopted AR within 4 years.

There exists a correspondence between companies B, C and D, since they have all tried AR, but not adopted it. However, it does also exist a correspondence between all the case companies because classifications e.g. innovators, are based on an actual adaptation, which none of the companies have pass through. Thus, it is challenging to catheterize one case company as more innovative than another only based on AR adoptions. In fact, it is difficult to put any label for any of the case organizations, just based on the results from this research.

5.4.1 Ecosystems

Another way to use time as a variable to evaluate new innovations is to evaluate new innovations based on existing ecosystems (Adner & Kapoor 2016). Adner and Kapoor (2016) state that the ecosystems are more important than the innovations itself to evaluate if the innovation is going to successful or not, given that the innovation provides some type of value to the organization. The old technology that AR mainly supersedes is paper-based blueprints or digital blueprints, since AR is a way of visualizing data, which both paper-based and digital blueprints do. When asking the interviewees to evaluate AR, organization A, C and D stated that it is somewhere between robust resilience and robust coexistence, where interviewee B placed AR into the illusion of resilience category. Given these results, the outlook for AR does not look great. Innovations categorized in robust resilience can take decades to diffuse, which innovations categorized as illusion of resilience also can e.g. HDTV. Robust coexistence is the probably the best categorization given by the interviewees, but interviewee D stated that AR will never be better than a complement to paper-based blueprints. However, it is questionable if the interviewees actually understood the gradation system, since robust resilience and robust coexistence impose that old technologies still have an opportunity to improve (Adner & Kapoor 2016). Thus, meaning that paper-based blueprints still can improve, which seems unlikely. Only interviewee B categorized AR as illusion of resilience which logically fit the majority of the interviewee's thoughts on AR e.g. interviewee D stating AR as a complemental innovation. Case organizations categorizing AR as robust resilience and still wanting to adopt AR is a challenging equation.

5.5 The fourth element: Social systems

As with communication, social systems have been presented and analyzed in the innovation paragraph since it suits the framework better. Norms and cultural implications for the construction industry have been presented previously and will thus not be mentioned again. In summary, resistance against breaking old habits is one of the most distinct intangible reasons why AR has not diffused yet.

5.6 AR

5.6.1 Hindering factors

Although most researches review AR from its potential, there exist research mentioning negative sides of AR. Some managerial issues mention by interviewee D, is that standards do not possess any hindrance against AR, which is opposed by researches (Martínez et al. 2014; Andersson & Widén 2005; Blayse & Manley 2004) and interviewee B as well. However, since AR has only been tested in internal projects among the case companies, the importance with a coexistent standardization in the construction industry has not been put into practice. A reason why there does not exist an industry standard can be explained by that the industry is still on a prototype level (Martínez et al. 2014), which is validated by the results in this thesis. Another hindering factor against AR is that it is time consuming to create AR models, which is validated both by interviewee C and Martínez et al. (2014).

5.6.1.1 Hardware

Researchers' theories used in the thesis have beyond the managerial part been divided in two parts, one part related to hardware and one part related to software. Since hardware evolves fast, research conducted a decade ago or even less, are more or less outdated. e.g. devices with low processor power (Izkara et al. 2007; Martínez et al. 2014). These articles were written 5-10 years ago, but these problems are not as big bottlenecks to the same extent today based on the interviewees. However, some of the possibilities that still exist now, related to the hardware was already mentioned by Izkara et al. in 2007 i.e. the potential to use cloud services to remotely process the data. The disadvantage with using network-based solutions is however that they require a stable connection to the Internet (Martínez et al. 2014) because AR creates a big flow of information. This is a legit problem according interviewee C. Whether this will be regarded as an issue, which low processor power was regarded 5-10 years ago, when the hardware will be free from bottlenecks, is remained to be seen. Using AR in bright conditions is further a problem both stated by interviewee C and Martínez et al. (2014); Gomes et al. (2017). No research was found whether it is a solvable problem or not. Interviewee C also requested integrating GPS into AR software. However, Gomes et al. (2017) write that GPS cannot accurately provide the coordinates since the errors are "up to 7,8 meters with 95% of confidence" (Gomes et al. 2017, pp. 512).

5.6.1.2 Software

One of the clearest reasons why AR has not diffused according to the interviewees, is that the AR technology has a hard time finding the right location of the user, thus not referencing adequate (Martínez et al. 2014) and its inconsistency to precisely align augmented features into the real world (Izkara et al. 2007). All these problems were validated by interviewee B, C and D.

There are however other ways to detect markers visually. Rodrigo et al. (2017) and Gomes et al. (2017) both argue that artificial markers can be an attractive alternative to natural markers, since artificial (or fiducial) markers are easier to detect, less error-prone and reduces the processing time. The reasons why artificial markers do not suit the construction industry are because AR cannot work reliable if the markers are being destroyed or moved. This theory was briefly validated by the interviewees.

5.6.2 Enabling factors

The enabling forces to use AR according to Martínez et al. (2014) are to reduce costs, reduce errors and have safer procedures. It also adds value in visualizing data in 3D and it is fun and easy to learn (Martínez et al. 2014). Indeed, AR has actually reduced errors in some cases, stated by the interviewee B. However, AR is still not financially sustainable. That the technology is fun and interesting to use has also been validated by interviewee B, although it seems to be an even greater opposition against AR. Thus, no clear relative values i.e. enabling forces, have been found in this report.

Of the five fields where AR can be used in, that scholars have presented, only two fields could be found among the case companies, namely Product design and Reducing production and quality errors. Some companies have used AR in the bidding and planning stage, although VR is more commonly used in these steps. Reducing production errors and visualizing blueprints at the construction site seem to be the most common field for utilizing AR, by the information given by the interviewees. Other fields e.g. maintenance has been mentioned by interviewee B, C and D. None of these firms have however pursued with this application, since it is being regarded as a topic customers should request. This is the wrong step according Gambatese and Hallowell (2011). They argue that companies should have customers included in long-term relationships, which maintenance is. Gann and Salter (2000) argue that companies could gain competitive advantage by supporting the customer services and means, by running and maintaining a building.

6 Conclusion

This paragraph is intended to answer the main research and the sub-research questions. It will further discuss the usefulness and the inferior approaches this research has taken, and how it has affected the outcome. Lastly, a suggestion of further research will be presented.

6.1 Revisiting the research questions

The primary goal with this thesis has been to conduct a diffusion study, evaluating augmented reality in large construction companies in Sweden. However, since augmented reality has not really diffused in this environment, an understanding of why augmented reality has not diffused yet, has become the main focus of this thesis. This has been done by adding two sub questions. These sub questions have studied the enabling and hindering forces.

What factors enable the diffusion of AR in large Swedish construction companies?

The theoretical framework used in this thesis, has presented various factors that could affect the adoption of AR. Out of Rogers's five factors used to evaluate AR, observability was seen as an unimportant factor explaining AR's diffusion rate. The reasons behind this conclusion was that the interviewees did not see observability being applicable for organizations, since organizations have different means and processes to observe innovation. Since it was not elaborated by researchers if observability is applicable on both individuals and organizational adopters, observability was discontinued as a topic in this thesis. A factor that was regarded to be important, seen from the interviewee's perspective, that enables the adoption of AR is trialability. Since the construction industry is a project-based industry, AR is easy to implement on an experimental basis. There also exist many applications that makes trialability a factor that enables the adoption of AR.

These also exists factors that enables AR, seen from the properties of AR. These reasons are mainly that AR, theoretically, could be a more efficient way of working, it can reduce cost and time, it can improve the quality and it can meliorate security issues. These factors have not reached a consensus between the case companies that have tried to adopt AR. The main reason why AR has not showed these advantages yet, is because the technology has provided reliable results. Since the organizations do not see any relative advantage with the technology, it is doubtful that the technology will diffuse based on the findings in this report, because the perceived advantage is the basis for an innovation to get adopted. However, the interviewees mentioned that there is a high change that AR will provide future potential, although it will not happen as fast the theoretical findings suggest.

Another reason that potentially can have affected the case organizations to adopt AR is branding and reputation. As researchers argue, reputation is an important aspect, especially for larger construction organizations, since being known for having high technical capabilities is beneficial when bidding on procurements and contracts. Although this subject was not that extensively discussed among the case organizations, the majority of the case companies have posted articles on their respective webpage how the use AR. Their usage of AR mentioned in these articles are somewhat exaggerated, which may indicate that the organizations want to create the impression to the public that they are more innovative than they actually are.

Rogers's five factors have a more negative, than positive, influence on AR. This because AR was conceived as being a relative complex technology. Having this said, the reasons why AR was perceived as complex is not because is it difficult to learn. On the contrary, the majority of the interviewees stated that the technology is quite easy to learn and use, which is also validated by researchers. The reason why AR was perceived as being moderately complex is because the technology demands preparations that are time consuming. It can also be derived to the software that AR needs, because the software used now, is not ideal from the interviewees' conceptions. Hence, making managers use multiple software when the managers inquire for one program that capsulize every process, e.g. time and cost calculations and blueprints.

The main two issuers are however that no relative advantage was seen in the case organizations, and the compatibility for AR to work in the construction industry is still low. The relative advantage was not seen because the results that AR systems provides, is still not adequate. AR has still a difficult time finding natural markers and having issues locating the user and showing augmented objects precisely. These reasons combined with that the technology is still costly and requires a lot of man hours, are reasons that the case interviewees mentioned. Issues regarding compatibility may be more severe than the relative advantage. Some interviewees described the cultural resistance as the main obstacle, why AR has not diffused yet. The industry's conservatism can be derived to many issues. Firstly, there seems to be a critical sight on change and the wiliness to change is further low. It is further noticed by the interviewees that not all employees are critical towards change. It is explained by the interviewees that is it mostly older people that oppose change. The reason why the case companies cannot reject older people's approaches, micromanage them and force them to change, are because that the employees have a high negotiation power. This because it exists a lack of competent engineers and managers in the construction industry. These are the reasons why organizations cannot micromanage employees adopting innovation but is must happen from the inside.

The old ecosystem that AR theoretically should supersede, is thus strong, because the willingness to change is low. There is however a great potential for AR to supersede paper-based blueprints, because paper-based blueprints do not have a great potential to get improved, which makes it easier for new technology to flourish.

Theoretically speaking, no deal breaking factors regarding AR as an innovation was found. It exists data that have proposed that some AR systems could have problems with reliability and not decently superimpose augmented objects. None of this research did however mention to what extent the technology fails. Other reasons mentioned by scholars were that AR hardware was lacking the processor power needed. These findings were however mainly presented in older studies and not in contemporary studies.

Of all reasons mentioned by the interviewees, four major issues were presented, namely: AR is still an expensive technology which demands to much time from employees, AR cannot reliable visualize the augmented objects within a margin of error that is required, AR imposes great cultural resistance, especially among older employees, and finally, AR does not really provide any relative advantage or value over existing technology, that AR theoretically is supposed to supersede. These findings are critical and until the bottlenecks have been resolved, it is not likely that AR will diffuse among the case organizations in this report.

To what extent has the applications of AR, for large construction companies in Sweden, been diffused?

As the result of this research, by interviewing four companies and using theoretical frameworks, it has been shown that AR has not diffused to the extent that scholars may propose. However, AR has been used on an experimental basis for three of the four companies involved in this study, as an instrument to control quality parameters, but also as a way to visualize blueprints. If there exist other construction companies that have adopted AR to a greater extent will be unsaid, but the majority of the interviewees were skeptical that AR will even diffuse within the next decade, regardless what researchers have proposed. The applications that AR is being used now differ quite extensively to what researchers propose, i.e. training, maintenance and safety. When asking the interviewees if these are areas that they have planned to utilize AR for, consensus was reached among the interviewees, that it is not realistic to use AR for these areas, at least not within a decade or two.

6.2 Recommendations for future research

AR and its diffusion as a topic is quite limited, since none of the case companies have actually adopted AR, not many other dimensions could have been taken regarding this subject. An approach that could have been taken, could be to conduct a scenario analysis of how AR will be used in future settings. However, present prognoses are overrated, and it can be challenging to get reliable results.

Another idea or technology that followed the interviews as a red thread, was the diffusion of BIM and digital blueprints. Doing the same study but about digital blueprints instead, can provide more interesting findings.

The goal with this thesis was not to generalize the outcome, but to get a deeper understanding why AR has not diffused to a greater extent in Swedish construction companies. Since there was a high consensus between the companies that had initiated an adaptation of AR, the profound data that was requested, to differentiate the cases apart, did not occur to the extent that was expected. A survey approach could in retrospect maybe study the topic better.

Rogers's five factors, and especially the relative advantage and compatibility were the factors having the most negative setbacks for AR to diffuse into the construction industry. Since one of the interviewees said that the construction industry is, at best course, 10 years after other industries, it is an indication that a more extensive research how compatibility and culture resistance is managed in the industry could be beneficial.

7 References

Ahmed, S. (2018). A Review on Using Opportunities of Augmented Reality and Virtual Reality in Construction Project Management. *Organization, technology & management in construction: an international journal*, *10*(1), pp. 1839-1852.

Allen, M. (2016). Representing Computer-Aided Design: Screenshots and the Interactive Computer circa 1960. *Perspectives on Science* 24(6), pp. 637-668.

Andersson, N. & Widén, K. (2005). Construction innovation systems-a sector approach. In *Proceeding of the Conference in Advancing Facilities management and Construction Through Innovation,* pp. 203-213.

Barrett, P., Sexton, M. & Lee, A. (2008). *Innovation in Small Construction Firms*. New York: Routledge.

Blayse, A. M. & Manley, K. (2004). Key influences on construction innovation. *Construction innovation*, *4*(3), pp. 143-154.

Bryman, A. & Bell, E. (2015). *Business Research Methods*. Oxford: Oxford University Press.

Cata, T., Patel, P. S. & Sakaguchi, T. (2013). QR code: A new opportunity for effective mobile marketing. *Journal of Mobile technologies, knowledge and society*, *2013*, 1.

Chi, H. L., Kang, S. C. & Wang, X. (2013). Research trends and opportunities of augmented reality applications in architecture, engineering, and construction. *Automation in construction*, *33*, pp. 116-122.

Dale, J. (2007). *Innovation in construction: Ideas are the currency of the future: Survey 2007*.

Downing, D. D. (1968). *Building block for wall construction*. US3391507A. 1968-07-09.

Edquist, C. (2010). Systems of innovation perspectives and challenges. *African Journal of Science, Technology, Innovation and Development, 2*(3), pp.14-45.

European Commission (2014). *Fact Sheet - World trends in R&D private investment. Facts and figures.* http://europa.eu/rapid/press-release_MEMO-14-2347_en.htm [2019-04-29].

European Commission (2003). *Small and medium-sized enterprises (SMEs).* https://ec.europa.eu/eurostat/web/structural-business-statistics/structural-business-statistics/sme [2019-04-29].

European Committee of the Regions (CoR) (n.d.). *The Lisbon Strategy in short.* https://portal.cor.europa.eu/europe2020/Profiles/Pages/TheLisbonStrategyinshort.aspx [2019-04-29].

Fenais, A., Smilovsky, N., Ariaratnam, S. T. & Ayer, S. K. (2018). A meta-analysis of augmented reality challenges in the underground utility construction industry. *Construction Research Congress 2018: Infrastructure and Facility Management*, pp. 80-89.

Feng, Y. (2006). Application of information technology in construction management. *International Symposium on Advancement of Construction Management and Real Estate, Beijing Jiaotong University, Beijing, 41*.

Gambatese, J. A. & Hallowell, M. (2011). Enabling and measuring innovation in the construction industry. *Construction Management and Economics*, *29*(6), pp. 553-567.

Gann, D. M. & Salter, A. J. (2000). Innovation in project-based, service-enhanced firms: the construction of complex products and systems. *Research policy*, *29*(7-8), pp. 955-972.

Gao, J., Li, M. & Tan, C. Y. (2013). A concept model for innovation diffusion in construction industry. *International Conference on Innovations in Engineering and Technology,* pp. 25-26.

Gomes, Jr. D., Reis, P., Paiva, A., Silva, A., Braz, Jr. G., Gattass, M. & Araujo, A. (2017). An Approach for Construction of Augmented Reality Systems using Natural Markers and Mobile Sensors in Industrial Fields. *International Journal of Computers Communications & Control*, *12*(4), pp. 466-478.

Guo, H., Yu, Y. & Skitmore, M. (2017). Visualization technology-based construction safety management: A review. *Automation in Construction, 73*, pp. 135-144.

Hammersley, M, & Campbell, J. L. (2012). *What is Qualitative Research?* Huntingdon: Bloomsbury Publishing.

Harty, C. (2008). Implementing innovation in construction: contexts, relative boundedness and actor-network theory. *Construction management and economics*, *26*(10), pp. 1029-1041.

Izkara, J. L., Pérez, J., Basogain, X. & Borro, D. (2007). Mobile augmented reality, an advanced tool for the construction sector. *Proceedings of the 24th W78 conference,* pp. 190-202.

Jeanclos, N., Sharif, M.-M., Li, S. K., Kwiatek, C. & Haas, C. (2018). Derivation of Minimum Required Model for Augmented Reality Based Stepwise Construction Assembly Control. *Workshop of the European Group for Intelligent Computing in Engineering*, pp. 336-358.

Lee, S. & Akin, Ö. (2011). Augmented reality-based computational fieldwork support for equipment operations and maintenance. *Automation in Construction*, *20*(4), pp. 338-352.

Li, X., Yi, W., Chi, H. L., Wang, X. & Chan, A. P. (2018). A critical review of virtual and augmented reality (VR/AR) applications in construction safety. *Automation in Construction*, *86*, pp. 150-162.

Li, Y., Chen, Y., Lu, R., Ma, D. & Li, Q. (2012). A novel marker system in augmented reality. In *Proceedings of 2012 2nd International Conference on Computer Science and Network Technology*, pp. 1413-1417.

Ling, F. Y. Y. (2003). Managing the implementation of construction innovations. *Construction management and economics*, *21*(6), pp. 635-649.

Martínez, H., Skournetou, D., Hyppölä, J., Laukkanen, S. & Heikkilä, A. (2014). Drivers and bottlenecks in the adoption of augmented reality applications. *Journal of Multimedia Theory and Application, 1,* pp. 27-44.

Organisation for Economic Co-operation and Development (OECD) (2018). Oslo Manual 2018: Guidelines for Collecting, Reporting and Using Data on Innovation. *The Measurement of Scientific, Technological and Innovation Activities*, Paris/Eurostat, Luxembourg: OECD Publishing.

Oxford English Dictionary Online (OED) (2019). Oxford: Oxford University Press.

Ozorhon, B., Abbott, C., Aouad, G. & Powell, J. (2010). Innovation in construction: A project life cycle approach. *Salford Centre for Research and Innovation in the Built Environment (SCRI) Research Report*, *4*, pp. 903-1012.

Packer, M. J. (2017). *The science of qualitative research*. New York: Cambridge University Press.

Pellicer, E., Correa, C. L., Yepes, V. & Alarcón, L. F. (2012). Organizational improvement through standardization of the innovation process in construction firms. *Engineering Management Journal*, *24*(2), pp. 40-53.

Pellicer, E., Yepes, V., Correa, C. L. & Alarcón, L. F. (2017). The Dilemma of Innovation in the Construction Company: A Decade of Lessons Learned. In *Project Management and Engineering Research*, pp. 21-33.

Poupyrev, I., Tan, D. S., Billinghurst, M., Kato, H., Regenbrecht, H. & Tetsutani, N. (2002). Developing a generic augmented-reality interface. *Computer*, *35*(3), pp. 44-50.

Pries, F. & Janszen, F. (1995). Innovation in the construction industry: the dominant role of the environment. *Construction management and economics*, *13*(1), pp. 43-51.

Rauschnabel, P. A., Rossmann, A. & tom Dieck, M. C. (2017). An adoption framework for mobile augmented reality games: The case of Pokémon Go. *Computers in Human Behavior*, *76*, pp. 276-286.

Rogers, E. M. (1995). *Diffusion of innovations*. New York: Free Press.

Rogers, E. M. (2003). *Diffusion of innovations*. New York: Free Press.

Simons, H. (2014). Case study research: In-depth understanding in context. In Leavy, P. (eds), *The Oxford handbook of qualitative research*. New York: Oxford University Press, pp. 455-470.

Slaughter, E. S. (1993). Builders as sources of construction innovation. *Journal of Construction Engineering and Management*, *119*(3), pp. 532-549.

Slaughter, E. S. (2000). Implementation of construction innovations. *Building research & information*, *28*(1), pp. 2-17.

Slaughter, E. S. (1998). Models of construction innovation. *Journal of Construction Engineering and management, 124*(3), pp. 226-231.

Smith, K. H. (2005). Measuring innovation. In Fagerberg, J., Mowery, D. C., & Richard R. Nelson, R. R. (eds.), *The Oxford Handbook of Innovation*. New York: Oxford University Press, pp. 148-177.

Smith, P. (2016). Project cost management with 5D BIM. *Procedia-Social and Behavioral Sciences*, *226*, pp. 193-200.

Smith, R. E. (2009). History of Prefabrication: A Cultural Survey. *Proceedings of the Third International Congress on Construction History.*

Sveriges Byggindustrier (2018). *30 största byggföretagen efter omsättning i Sverige.* Stockholm: Sveriges Byggindustrier. https://byggindustrin.se/sites/default/files/30_storsta_byggforetag_2018.pdf [2019-04-29].

Sveriges Byggindustrier (2015). *Fakta om byggandet 2015*. Stockholm: Sveriges Byggindustrier. https://publikationer.sverigesbyggindustrier.se/Userfiles/Info/491/FoB_2015.pdf [2019-04-29].

Stake, R. E. (1995). *The art of case study research*. London: Sage.

Turkan, Y., Bosche, F., Haas, C. T. & Haas, R. (2012). Automated progress tracking using 4D schedule and 3D sensing technologies. *Automation in construction*, *22*, pp. 414-421.

Van de Ven, A. H. (1991). *People and technology in the workplace*. Washington, D.C.: National Academy Press.

Wang, X. (2009). Augmented reality in architecture and design: potentials and challenges for application. *International Journal of Architectural Computing*, *7*(2), pp. 309-326.

Wang, X., Truijens, M., Hou, L., Wang, Y. & Zhou, Y. (2014). Integrating Augmented Reality with Building Information Modeling: Onsite construction process controlling for liquefied natural gas industry. *Automation in Construction*, *40*, pp. 96-105.

Wagner, D. & Schmalstieg, D. (2009). History and future of tracking for mobile phone augmented reality. *International Symposium on Ubiquitous Virtual Reality 2009*, pp. 7-10.

Weidman, J.E., Young-Corbett, D., Koebel, C.T., Fiori, C. & Montague, E.N. (2011). Prevention through design: use of the diffusion of innovation model to predict adoption. *International Council for Research and Innovation in Building and Construction Conference.*

Yin, R. K. (2014). *Case Study Research Design and Methods*. London: SAGE.

Yin, R. K. (2011). *Qualitative research from start to finish*. New York: Guilford Press.

Appendix

Presentation of cases

Since the data is processed confidentially, an anonymous presentation of the organizations is used.

Organization A

The first organization is a fairly new company and operates across northern Europe. The organization has specialized in creating residential buildings. The interviewee is a manager in digitalization and responsible for marketing and with insights of the production phase. The organization does not use AR for any platforms in the construction phase currently, but merely VR solutions for marketing and end customers. The company constructs mainly for themselves and capitalize by selling to the public.

Organization B

Organization B is an older company, with projects all over Scandinavia. They have both roads i.e. infrastructure projects and building projects. The interviewee is a technical Business Developer and a VDC engineer, responsible for infrastructure projects. The interviewee provided useful insights how AR is used in the entire company and especially for the building department, where experimental usage of AR is already implemented.

Organization C

Company C has projects across Europe and they manage all types of projects. The interviewee is a VDC engineer with vast knowledge in AR. The organization exploits AR on an experiential level, combined with a somewhat factual usage of AR in some projects.

Organization D

Organization D operates mainly in Scandinavia. As in organization C, they manage all types of projects. The interviewee has worked as a VDC manager for five years and is working in internal committees regarding BIM related processes. The organization tested first VR and later on, AR. Organization D is trying to have as many VDC managers as possible. The interviewee is responsible for construction projects and the interviewee has a close connection with VDC managers working in infrastructure projects. At the moment, the organization runs pilot tests, but they have plans to assign AR to future projects as the technology evolves.