Master's thesis ACEX30

Increasing implementation of digital tools on the construction site

Master's thesis in the master's program Design and Construction Project Management

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CHALMERS UNIVERSITY OF TECHNOLOGY

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Abstract

In recent years there has been an increasing digitalization of the Swedish construction industry. However, the digitalization has mainly been aimed at the design phase, even though there are digital tools well suited for the construction phase. Research has shown that the increase in productivity within the construction industry has decreased, and that there likely is a correlation between low productivity and low digitalization. Furthermore, there is a great potential for reducing costs, increasing client and coworker satisfaction, and increasing the quality in the production phase while using digital tools. This thesis is therefore aimed at investigating how the implementation of digital tools at the construction site can increase. This is done by semi-structured interviews with professionals at various positions connected to digitalization of the constructions site, both at a studied company and some similar companies, to get an industry context. Different organizational and managerial aspects are identified and researched to give an understanding of how the organization can promote innovations such as digital tools to the construction site. Furthermore, the construction phase and its prerequisites are researched and related to knowledge about change, innovation, and implementation to get an understanding of the setting where the digitalization is taking place. One specific digital tool, Dalux, is further investigated since it is the tools currently under implementation at the studied company. It is evident from the study that in order to successfully increase the digitalization of the construction process it is important to not only consider the project teams and the technical capabilities of specific tools, but to also consider human aspects through the management and culture of the wider organization. There are great potential benefits to gain from utilizing digital tools in the production phase. Short-term benefits are found in aspects such as improved production management, enhanced quality, increased documentation, and modernized communication. Moreover, there are long-term benefits from generating data which can be used for improved work processes and taking more informed decision regarding future projects. Being in the forefront of the increasing digitalization will also attract more competencies in the area, contributing to the long-term growth of knowledge and competence within the organizations. This study argues that the studied company is among the forefront companies digitalizing the Swedish construction industry in general and the production phase in specific. However, to enable increased utilization of the digital tools and to remain a prominent digital construction company in the increasing pace of digitalization, more efforts are needed. To increase the usability of collected data and increase the organizational learning there is a need for common frameworks and guidelines regarding digital tools in production. The support regarding these tools, and digitalization within the organization at large, must also be improved to be better structured. To align efforts towards digitalization, both in the projects and in the wider organization, there is a need for clearly defined goals and visions for the digitalization. Finally, the digitalization is not a project with a start and an end, rather it is a continuous effort towards improved productivity and quality within the construction industry and should therefore be a part of the core activities of construction companies. Future studies could be aimed at researching the monetary value of using digital tools in production, to convince the individuals recalcitrant towards digitalization, as this has been identified as a hindrance.

Keywords: Change management, Digitalization, Digital construction, Digital strategy, Implementation, Innovation, Lean construction, Production management, Productivity, Site BIM

Sammanfattning

Under de senaste åren har digitaliseringen ökat i den svenska byggbranschen. Digitaliseringen har dock främst riktats mot designfasen, även om det finns digitala verktyg som är väl lämpade för byggfasen. Forskning har visat att produktivitetsökningen inom byggbranschen har minskat och att det verkar finnas ett samband mellan låg produktivitet och låg digitalisering. Dessutom finns det en stor potential i att minska kostnaderna, öka kund och medarbetarnöjdheten samt öka kvaliteten under produktionsfasen genom att utnyttja digitala verktyg. Denna studie syftar därför till att undersöka hur implementeringen av digitala verktyg på byggplatsen kan öka. Detta görs genom semistrukturerade intervjuer med yrkesverksamma på olika positioner kopplade till digitalisering av produktionsfasen, både hos ett studerat företag och några liknande företag för att få en branschkontext. Olika organisatoriska aspekter och ledarskapsaspekter identifieras och utforskas för att ge förståelse för hur organisationen kan främja innovationer som digitala verktyg på byggarbetsplatsen. Dessutom undersöks produktionsfasen och dess förutsättningar för att relateras till kunskap om förändring, innovation och implementering vilket ger en förståelse för miljön där digitaliseringen sker. Ett specifikt digitalt verktyg, Dalux, undersöks ytterligare eftersom det är de verktyg som för närvarande implementeras på det studerade företaget. Det framgår av studien att för att framgångsrikt öka digitaliseringen av byggprocessen är det viktigt att inte bara ta hänsyn till projektgrupperna och den tekniska kapaciteten hos specifika verktyg, utan också att ta hänsyn till mänskliga aspekter genom organisationens ledning och kultur. Det finns stora potentiella fördelar med att använda digitala verktyg i produktionsfasen. Kortsiktiga fördelar finns i bland annat förbättrad produktionshantering, förbättrad kvalitet, ökad dokumentation och moderniserad kommunikation. Dessutom finns det långsiktiga fördelar med att generera data som kan användas till förbättrade arbetsprocesser och för att fatta mer informerade beslut om framtida projekt. Att vara i framkant för den ökande digitaliseringen kommer också att locka till sig kompetenser inom området, vilket bidrar till en långsiktig tillväxt av kunskap och kompetens inom organisationen. Denna studie argumenterar för att det studerade företaget är bland de främsta företagen som digitaliserar den svenska byggproduktionen. För att möjliggöra ett ökat utnyttjande av de digitala verktygen och att förbli ett framträdande digitalt byggföretag i den ökande digitaliseringstakten krävs dock fler ansträngningar. För att öka användbarheten hos insamlade data och öka det organisatoriska lärandet finns det behov av gemensamma ramverk och riktlinjer för digitala verktyg i produktionen. Stödet för dessa verktyg och digitaliseringen inom organisationen i stort måste också förbättras och bli mer välstrukturerade. För att förbättra ansträngningarna mot digitalisering, både i projekten och i den bredare organisationen, finns det behov av tydligt definierade mål och visioner för digitaliseringen. Slutligen är digitaliseringen inte ett projekt med start och slut, utan snarare en kontinuerlig process för förbättrad produktivitet och kvalitet inom byggbranschen och bör därför vara en del av byggföretagens kärnverksamhet. Framtida studier kan vara inriktade mot att undersöka det monetära värdet av att använda digitala verktyg i produktionen, för att övertyga individer som är motsträviga till digitalisering.

Nyckelord: *Digital byggproduktion, Digital strategi, Digitalisering, Förändringsledning, Implementering, Innovation, Lean bygg, Plats BIM, Produktionsledning, Produktivitet*

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List of Abbreviations

AEC – Architecture, Engineering and Construction

API – Application Programming Interface

AR – Augmented Reality

BIM – Building Information Management/Model/Modelling

CDE – Common Data Environment

CEO – Chief Executive Officer

IFC – Industry Foundation Classes

ICE – Integrated Concurrent Engineering

ICT – Information and Communications Technology

LPS – Last Planner System

QEHS – Quality, Health, Safety, and Environment

Q&A – Question and Answer

TFV – Transformation Flow Value

VDC – Virtual Design and Construction

English – Swedish Dictionary

Block manager – Blockchef

Change and modification, Contract change, Change – Ändring, Tilläg och Avgående arbeten

Construction document – Bygghandling

Construction engineer – Entreprenadingenjör

Construction journal – Byggdagbok

Deviation – Störning eller avvikelse

Deviation report – Avvikelserapport

Inspection plan – Kontrollplan

Interference – Störning eller avvikelse

QEHS (Quality, Health, Safety, and Environment) – KMA (Kvalitet, Miljö, Arbetsmiljö), används även synonymt med HMS (Hälsa, Miljö, Säkerhet)

Quantify – Mängda

Self-inspection – Egenkontroll

Supervisor – Arbetsledare

Site – Arbetsplatsområde

Site manager – Platschef

Site office – Arbetsplatskontor

Work plan – Arbetsberedning

Preface

This thesis is the product of one semester investigating different aspects of the digitalization in the production phase of construction. We have come to many conclusions and insights giving us a drive and passion to get out into the industry and contribute to the reshaping of one if the most important industries in society. However, it is important to note that we would not have come nearly as far if was it not for all great minds and personalities supporting us, believing in us and giving us valuable feedback. Therefore, we would like to express our deepest gratitude's to:

- Our supervisor at Chalmers, Mikael Johansson
- Our supervisors at the studied company
- All interviewees from different organizations
- The student opponent, Albin Karlsson, providing continuous feedback
- Family and friends providing support and encouragement

Thank you!

Alexander Zimmerman

Rasmus Pettersson

1.Introduction

The CEO - *Chief Executive Officer* of the studied company stated that the company can cut costs in their projects by 30%, in connection with the appointment as CEO (Company A, 2019c). The CEO has previously shown bold character and issued similar statements. Even though being a bit bold, others have made similar statements, one example being another large contacting firm arguing that in just a few years' time digitalization have the potential to decrease construction time by 25% and costs by 20% (Snow, 2019). The think tock McKinsey & Company (2016) is also one of those urging for a change in operations, which they argue could lower construction costs with 20-30%. The production phase is one of the major areas where savings and efficiency improvements should take place, according to the CEO of the studied company (Company A, 2019c). Furthermore, the studied company recently issued a statement recognizing that the digitalization now has taken up speed, starting to catch up with other industries (Company A, 2020a). One of the key concepts in the company's cultural values is involvement. To reach this goal it is important to investigate how all disciplines on the worksite can partake, contribute, and benefit from the digitalization now taking place. There is also a Swedish innovation initiative called Smart Built Environment where private, governmental, and academic actors work together with the aim to increase digitalization and streamlining in the Swedish construction industry (Jongeling et al., 2016). Showing that digitalization has an industry-wide focus in Sweden. Given that this is a priority issue at the studied company, and the industry at large, this study addresses opportunities and difficulties of digitalizing the production process at the studied company.

1.1 Background

The construction industry has been along almost as long as human settlements and societies, last century Cox and Goodman (1956) summed the erection of a building up as *follows "The physical substance of a house is a pile of materials assembled from widely scattered sources. They undergo different kinds and degrees of processing in large numbers of places, require many types of handling over periods that vary greatly in length, and use the services of a multitude of people organized into many different sorts of business entity. For any given house, the parts of the process must be well enough performed and coordinated so that in the end all the separate pieces come together*" (Cox & Goodman, 1956, p. 36). The complexity of construction projects is likely even higher in today's industry than it was when the quote above was written some 64 years ago. The industry is to a greater extent finding answers to increase the performance and coordination of production in the digitalization reforming the industry (Hautala, Järvenpää, & Pulkkinen, 2017).

Andersson and Lessing (2017) describe digitalization as the single most important change factor for construction, arguing that digitalization will allow for an integrated and continuous exchange of information throughout the construction process. In addition, Hautala et al. (2017) argue that it is in the construction phase and operations stage that the most significant benefits are going to emerge, and that the digitalization is accelerating in these phases. Further, explaining that the digitalization is changing the business structure and ways of working in these stages. Considering the Swedish market, plenty of actors have stated that they are beginning to implement new digital applications to the Swedish construction sector (Moscati & Engström, 2019). However, there is a substantial difference between the levels of digitalization, as well as the goals for the digitalization, among these various Swedish actors.

A report by Barbosa et al. (2017) stated that the global increase in productivity within the construction industry has stalled in the past decades. Moreover, Remes et al. (2018) showed in their report on

productivity and digitalization that in Europe, the construction industry by 2018 was the least digitalized industry. Remes et al. (2018) also argue that there is an interconnection between degree of digitalization and productivity growth within industries. In Sweden, digitalization and industrialization of the construction industry are seen as crucial goals in the government's agenda (Moscati & Engström, 2019). Aiming towards, among other things, streamlining the construction process. However, Cidik (2019) argue that the construction industry has been going through a digitalization phase in the last decades, but despite these efforts the productivity increase in construction is still low. Cidik (2019) believe that an organizational perspective is the key to increase productivity through digitalization, meaning that simply introducing innovation at a specific task is not enough, the whole system must be considered to aggregate increased productivity. In support to this, Strind (2018) argue that the biggest economic advantages gained from digitalization is reached when the companies develop their business models and work processes in accordance with the digitalization. Connected to this, Talamo and Bonanomi (2020) state that a lack of understanding of the organizational changes and integration process connected to digitalization is one reason behind the lack of beneficial effects from the digitalization already undertaken.

In another aspect, Hautala et al. (2017) explain that when introducing technological advances, it is vital to develop optimized user interfaces for the intended users. Furthermore, that technological applications must be easily accessible and provide accurate data for each user. Moscati and Engström (2019) also emphasizes the importance of handling human matters connected to the changes needed when implementing new technology. Showing the importance of ensuring usability of technologies, considering the user perspective. Sattineni and Schmidt (2015) argue that mobile devices are increasingly used on construction sites and that their great ability to enhance productivity and communication will cement them on the building site of the future. Large global software suppliers such as Autodesk continuously work with enhancing their offer of mobile compatible software (Sattineni & Schmidt, 2015).

Whilst the promises of digitalization is clear, Davies and Harty (2013) argue that predictions of future implementation historically have been too optimistic. Even so, the digital development is happening. However, the digitalization has mainly been focused on the design phase (Koseoglu & Nurtan-Gunes, 2018). As for the site management, Davies and Harty (2013) argue that the paper is still a very real reality, both in forms of obtaining information but also in the form of notes for capturing information. A lot of the existing research have focused on the digital applications for design and office applications (Davies & Harty, 2013). Hautala et al. (2017) argue that the whole construction process can benefit from digitalization and point out on-site surveying as an example of where digitalization could be better utilized. This study therefore aims towards examining how the digitalization can increase at the construction site.

1.1.1 Digitalization in numbers

As a pre-study for this thesis the top 10 biggest construction companies in Sweden was identified, from the annual compilation of Sweden's biggest companies published by Byggföretagen (2019). Through the annual reports from either 2018 or 2019 depending on what was available, it was investigated how these companies mention digitalization. The investigation presented in appendix 4, showed that digitalization is regarded as important from the major contractors and developers. And that they see the increased value that digitalization can bring. However, it is also clear that it is mentioned but not given a major focus, indicating that none of the companies see digitalization as a part of the business model.

A lot of research point out that BIM - *Building Information Modelling/Management* increases overall construction performance (Azhar, 2011; Nguyen et al., 2018). However, despite a clear consensus very few has managed to point out just how much. Sattineni and Schmidt (2015) argue that a high utility of mobile devices enhances the efficiency in terms of saving time and money, and more efficient communication. This will result in a positive competitive advantage in comparison with competitors. However, it is difficult to establish a consensus in the research on what can be saved where, mainly it seems to be a lack of large quantities of coherent data. Noruwa, Merschbrock, Arewa, and Agyekum-Mensah (2018) argues that a hinder in the implementation of greater tools for communication in construction is that a lot of practitioners present a skeptical view on whether the cost of the adoptions can be justified. However, some research present interesting numbers in relation to different aspects of digitalization of the production phase.

A study by Jongeling (2008) argued that contractor cost of contract changes in the production phase could be lowered by 50% when moving from 2D drawings to BIM. The same study found that the overall costs of the building project would be at least 4% lower. In a more recent study by Koch, Hansen, and Jacobsen (2018) the potential cost reduction from efficient digital communication in building processes in Sweden was found to be somewhere in the range of 15-25% of the building sum. Whilst Hwang, Thomas, Haas, and Caldas (2009) find that poor interpretation of design documents and drawings result in direct costs of 5% of the total construction cost. Furthermore, a recently presented study on productivity in the Swedish construction industry by Koch, Shayboun, Manès, and Nordlund (2020) present a lot of interesting findings, the main one being that the construction productivity in the Swedish construction industry turned from negative development to an increase of around a percent per year. It is found that BIM projects save at least 10% compared to non-BIM projects, ascribing the positive development in the industry to the digitalization. For some projects, especially those with low cost of construction per square meter, an even bigger increase of up to 30% is found. In the same study it was found that even though the average lead time increased the relative time of production of a square meter decreased. Further, Koch et al. (2020) found that around 50% of the Swedish contractors and 33% of the clients utilized BIM, in relation to this they argued that BIM is now at an important crossroad where the industry either will have more BIM implemented and adapted for production management, or BIM will continue to mainly be a tool for planning. Adding that if BIM usage is increased in production management, it is likely that this will have a clear effect on the construction process. Connected to this, in Gustafsson, Gluch, Gunnemark, Heinke, and Engström (2015) survey research on one of the largest contracting firms in Sweden, a large portion of the responders claimed that VDC - *Virtual Design and Construction* was used in the production phase to some extent today. However, over 75% of the responders stated that VDC should be used to a high or very high extent in the future. Alarcon, Mandujano, and Mourgues (2013) found that despite a high interest in VDC few had succeeded with full implementation, this was due to comprehensive VDC

implementation guidelines, cultural barriers, lack of interoperability, issues with software and hardware, contractual and legal aspects, lack of training, lack of commitment and a lack in demand derived from clients not requesting VDC.

According to a report by Nguyen et al. (2018), digital production tools can enhance effective work quality management and save time through assisting in cooperation, reducing mistakes, and management of work information. Furthermore, the report claims that a studied project saved 2,5 hours per day, due to simplified working processes. In another study, Götborg and Olsson (2016) recognized a 20% error deduction in the production phase during the BIM project at Rörforsbron in Sweden, ascribed to BIM visualizations. This due to the fact that the workers got a common vision. Although the effectivity increased, Nguyen et al. (2018) reported some difficulties regarding adaptation to new work methods using digital tools, it took some employees approximately one month to properly learn and adapt to the new technology. There might therefore be a need for more education regarding digital tools to shorten the adaption period. Two recently performed studies where data was collected through surveys showed that a high amount of the production teams wanted to have more education in digital production tools. Banka, Frugård, and Jensen (2019) found in their research that 97% of the respondents requested for more education and research by Brantitsa and Nordberg (2018) found that 87% of the respondents requested education. Even if the demand for digitalization and the long-term benefits are significant, the construction industry has not yet fully taken advantage of the new digital technologies available (Koseoglu & Nurtan-Gunes, 2018). Alarcon et al. (2013) found that in order for an organization to successfully implement VDC it will need a strategy to do so, and further an implementation plan, the challenge was identified to formalize the implementation guidelines and apply them throughout the projects. This study therefore aims towards examining how the utilization of digitalization can be increased at the construction site.

1.2 Aim

The study aims to study and analyze different production units at various locations in the studied company's geographical area of operation in order to identify important aspects for implementation of digital tools into the production process. In addition, a brief study is done at one affiliated and some competing companies to evaluate what common issues or thoughts there are, and to get a broader perspective from the industry. Furthermore, the study evaluates how far the studied company has come in their efforts towards implementing digital tools in the construction process. Tools that are of interest are the production-related tools such as tools for work planning, work management, quality control, among others. However, the study mainly focusses on Dalux since it is the digital production-related tool currently under implementation at the studied company. To ensure that the reader understand why implementation of these tools is crucial, a short background on the production managements requirements and challenges will be clarified in relation to the production which is the value creating activities in a complex process of activities leading up to a built product.

The study also aims to research how digital construction management tools implementation can be increased to enhance streamlining, efficiency, and digitalization of the production-related tasks. Furthermore, to study what support is available or needed for the production teams to properly adopt digital tools at the construction site. Since the implementation of new ways of working progresses quickly, new roles and organizational structures needed to endorse the implementation will also be examined. The structures on all levels in the company will be examined and evaluated in relation to how well they function in for example, delivering operational support or supporting change and innovation management.

The role of this thesis is to contribute to a broader knowledge about production aspects and applications. The conclusion and implications of this study will be a set of recommendations and statements that aim to describe how the company and industry stand today, and how to act to continue improving and meeting the future of digitalization.

1.3 Research questions

The thesis will aim to answer the following research questions:

- What support does the organization and projects need in order to better implement digital tools in the construction phase?
- What is the current state regarding digitalization of the worksites within the studied company?
- How can the organizational structure affect the usage of digital processes?

1.4 Limitations

The study was done in cooperation with a studied company which is currently undertaking a digital development. Therefore, the study was focused on the situation at the studied company. The study focusses on the Swedish market, specifically business regions South and West within the studied company. However, an interview in with a representative from the Norwegian part of the studied company is also included to compare different country-regions within the organization.

The Covid19 virus tearing through the world during the spring 2020 proved to limit this study lightly. When the pandemic reached Europe and Sweden at large, the study where in the late part of the interview study. The implications where that some interesting projects and roles across organizations could not be visited, and thus not observed and some professionals not interviewed. However, the belief is that the empirical data incorporated in the study will prove to be comprehensive and sufficient for some interesting conclusions.

1.5 Delimitations

Delimitations in the project is to mainly focus on the construction phase, the planning stage is described briefly to put the study into context. The study focuses on the building construction department at the studied company, not researching the industry-, civil engineering- and property development departments. Furthermore, there are several competing digital production management tools, but Dalux is the digital production tool currently being implemented at the studied company, therefore detailed question regarding specific tools is limited to Dalux. Interviews and observations conducted at some competitive companies and one affiliated company is also used in the study to briefly compare their situation with the studied company. Interviews and observations at other companies was limited to companies and projects that also use Dalux, to better be able to compare the different companies.

1.6 Structure of Thesis

The thesis adheres to the following structure.

- Chapter 2: The methodology used to conduct the study is explained.
- Chapter 3: The theoretical framework based on a literature study is presented. Containing information regarding organizational factors, the construction industry, innovation, and digital tools with focus on Dalux.
- Chapter 4: Results of the conducted interviews and observations are revealed. Existing guidelines regarding digital tools in the studied company are also presented. Finally, the interviews and observations are analyzed and compared to the theoretical framework from an objective standpoint.
- Chapter 5: Discussion about the results from the interviews and observations, as well as the theoretical framework is disclosed. Furthermore, implications and suggestions for the studied company are presented.
- Chapter 6: Conclusion of the research conducted, with answers to the research questions and suggestions for improvement regarding implementation of digital tools. Finally, suggestions for further research are presented.

2.Method

The civil engineering industry is under an increasing pressure to digitalize and is slowly picking up phase. Especially the production phase has been found to lag in comparison with other industries. From the perspective of the authors, the education reflecting upon various aspects of this has not been given enough focus. As a cause of this, part of the study will be of an explanatory nature identifying important aspects and views, trying to define for example the prerequisites of production management or how implementation and change is carried out in a managed way.

Saunders, Lewis, and Thornhill (2016) state that research projects can have different nature, some views are, purely or mixed exploratory, descriptive, explanatory, or evaluative. The research questions of this thesis are clearly evaluative and the road leading to those evaluations takes the reader through an exploratory literature and interview study accompanied by observations and an inventory of current internal guidelines and supporting documents.

2.1 How data was collected

The empirical research of this thesis consists of semi-structured interviews conducted during the winter and spring of 2020. The interviews were conducted with 23 professionals active in contracting companies, of whom 15 were working at Company A, which is the studied company for this thesis. In the table under Chapter 4.1 these individuals and their organizational roles are displayed in detail. Most of the interviews were conducted face to face in the daily workplace of the interviewees, both on sites and at offices. Two of the interviews were however interviewed online with a video communication tool.

2.2 Theory of used methods

The study was based on a qualitative approach which according do Silverman (2011) gives room for different sub-methods, namely, observation, text and document analysis, and interviews, to name a few. The text and document analysis part of the thesis was based on a literature study which describe digital tools used in the construction process, mainly focused on Dalux since it is the tool being implemented at the studied company. Furthermore, the literature study describes organization management and change management aspects needed to implement the change toward a more digitalized work process. Some potential benefits from digital processes, both economical and efficiency focused, are also described. Following an initial literature study, an interview study was conducted in a semi-structured manner. A semi-structured interview allowed for prepared questions with the opportunity to ask supplementary questions and the interviewee to speak more freely on each subject (Lantz, 2013). Alongside the empirical interview study, the literature study continued with further research on what was discussed during the interviews through an abductive research approach. This allowed for the theory to be expanded and adapted to information found in the empirical study and ensure that the theory and the empirical information are well suited for the study (Gadde & Dubois, 2014). Hallin and Helin (2018) argues that the semi-structured interview is suitable for abductive research approaches.

When performing a study, the question of how to collect data and information arises. There are typically some philosophical ways of seeing this, the deductive approach takes off from a theoretical knowledge and then moves towards the collection of data. The opposite being the inductive form of collection where data is gathered, and then theoretical knowledge is collected in relation to the empirical findings (Saunders et al., 2016). For this thesis, the mix of the two was used, namely the abductive approach, this

is due to the limited period when the study took place. Alongside a quite extensive gathering of empirical data the literature study was performed parallel. Alvehus (2018) describe that the abductive approach is suitable for the explorative approach where the goal is to find out what the accepted assumptions is and then question them. In *figure 1* Bryman and Bell (2015) present the iterative process making up for the abductive method, where insights in the interpretation of data may lead to needs to go back and find more knowledge from the literature.

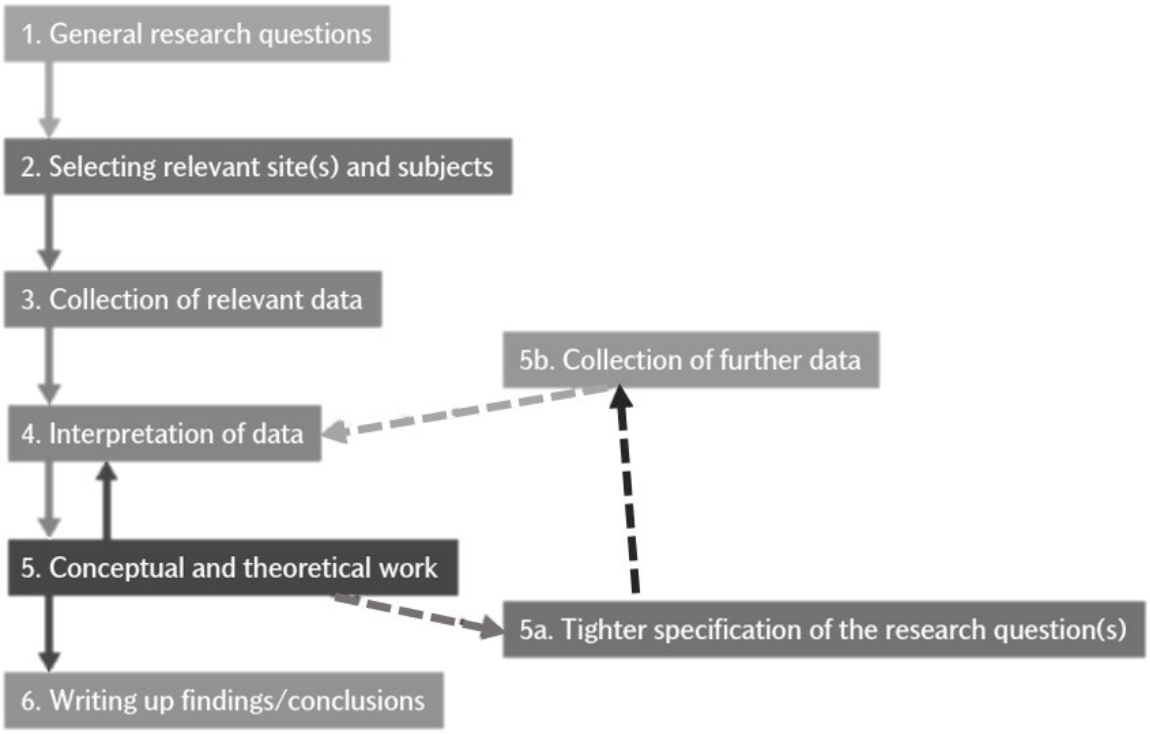

Figure 1 – methodology of an abductive, qualitative interview study (Bryman & Bell, 2015).

2.2.1 Interviews

In the interview theory some important characteristics is important to bring along. Kvale and Brinkmann (2017) rules out the basics as consisting of epistemology and ontology, some different goals of the interview can be defined. The interview research can be focused around the phenomenon that is to investigate how the interviewee perceive the world. Another aspect of the research can be in the hermeneutic direction, were the researcher tries to decode and understand the meaning of what is found in the interview which is a narrative understanding. Yet another approach is to focus in the discourse, were the language and the social interactions is in focus (Kvale & Brinkmann, 2017). Dalen (2015) argues that for a qualitative research approach, the investigation of how the interviewee perceive the world is central.

Saunders et al. (2016) describe three types of potential bias. The first being interviewer bias where the interviewer influence the respondent by different forms of verbal and non-verbal types of impact. The empirical material can also be affected by interviewee or response bias, which amongst others can be

triggered by the exploratory sensitive questions where the interviewee chooses to not reveal and discuss what he really thinks, but instead go for an answer that is more political.

The quality of the interview will affect the reliability of the analysis and the report. Kvale and Brinkmann (2017) present numerous criteria to succeed with a high interview quality. One practically applicable criterion for the interviewer is to make sure that the interview questions are short and that the answers to the questions are longer. It is also important to clarify what is unclear or not certainly understood in order to verify or decode the information during the actual interview. For the semi-structured interview Hallin and Helin (2018) prescribes preparing with an interview guide with interesting topics and generally broad questions. This allows for the interviewee to develop the question a little and the interviewer can ask follow-up questions in regard to interesting topics.

According to Hallin and Helin (2018) digital interviews with video communication provides for an as natural interview situation as possible if not physical encounter is applicable.

2.2.2 Observations

Hallin and Helin (2018) reflect that the study of some phenomena's is not suited for interview studies, and then it can be good to supplement with observations. A framework for observations to consider in connection to the study was prepared before the site visits.

2.2.3 Literature study

Reviewing the knowledge already attained in the industry is important to proceed and learn. The theoretical knowledge presented in this study originates from recognized electronical databases provided by Chalmers Technical University. Articles found through these databases in combination with printed books, previous thesis's lays the foundation for the literature review shaping the knowledge about the subjects. The main search engines used was Scopus, Chalmers Library, and Google Scholar.

As described in *figure 1* the abductive approach of this work gave the study the opportunity to bring in new theoretical knowledge along the entire process, when a new finding emerged, or an interesting discussion resulted in a deeper understanding of an empirical finding.

2.3 Presenting and analyzing the data

A central term when interpreting data is the validity, Dalen (2015) states that since the validity of the interview as a method lies in the words and stories of the interviewed it follows naturally that an interview that allows for the interviewer to ask relevant questions and the interviewed to respond comprehensively will have a better validity. The validity is a term to describe how well a chosen research method measures what is aimed at measuring (Bryman & Bell, 2015). The interviews conducted in this study was carried out semi-structured and predominantly without time limit or a generous one which ensures the validity.

The term reliability describes to what degree the study can be repeatable and once again by another researcher find the same result (Saunders et al., 2016). Bryman and Bell (2015) states that the reliability is important to affirm when studying for example, teamworking, employee motivation or organizational effectiveness, and the question being is the organization consistent.

2.4 Ethical aspects of research

The study was conducted in line with the guidelines and codex specified by Chalmers Technical University. Further, attention was given to the four main criteria's given by the Swedish Science Council (Vetenskapsrådet, Nd), namely:

- Information – all approached interviewees should be informed of the purpose of the encounter.
- Consent – all approached individuals should give their consent.
- Confidentiality – if needed both organizations and individuals should be offered confidentiality.
- Usage – the material and information attained through research should only be used for what was informed at the point of collection.

In relation to this Bryman and Bell (2015) describes ethical principles that should guide research where it is important to not harm the participants. This is secured by anonymizing the interviews and what company they belong to, the framework for this is explained in Chapter 4. Another ethical aspect described is the need of informed consent, this has been secured by incorporating this as a question in the interview manuscript. Further all interviewees were given a protocol summarizing the interview. They then had the opportunity to submit comments, and suggestions on parts that should be added, removed, corrected, or changed. Blomkvist and Hallin (2014) further reflects that the personal integrity is important, but that academical aspects such as correct and reliable referencing or fair and correct citation should also be a focus. Saunders et al. (2016) adds that a responsible analysis of data and reporting of findings is critical to withhold a high ethical level.

2.5 Ethical aspects of subject

Digitalization in the construction industry has some clear aims, one such is to increase the amount of data we can access. Increased data on the individual workers whereabouts and performance, may be an ethical question. The same reasoning is applicable for the broader perspective, if the main contractor or even the client get access to broad sources of data concerning, for example, efficiency or deviations this could put an unethical pressure on the "governed" or "surveyed" actor.

Increased efficiency, which is one of the hypotheses of this study, will likely decrease the resource usage in the industry. From a material resource perspective this is good, since one of the big tasks for the industry is to become more sustainable. However, there is a chance that increased efficiency will lead to fewer jobs for the individual workers. Hopefully, there will be a change in the industry where more people are instead involved in the improved safety and learning processes that these tools will enable.

2.6 Evaluation of chosen methods

To get a broader understanding on how the implementation of digital tools is undertaken in the studied company and in the industry at large, the study could have used a merge of a qualitative and quantitative approach, however time were limited and therefore interviews, and observations were considered the main key to explore the subject.

Since the study was limited in both time and extent it could be argued that the reliability of findings would be low. However, it could be argued that the fact that interviews and observations were conducted at several companies, in several project environments and on different geographical locations, with the same overall results, the reliability is strengthened.

In terms of reliability it is likely that the interview proposal appealed more to individuals interested in digitalization and as such there might be a slight bias towards the optimistic and positive view. It was also noted during the interviews that interviewees had the perception that the interview would only concern Dalux, whilst the idea was to incorporate all digital tools, including Dalux. This had the implication that even though all interviewees where asked about digital tools in general and specifically about Dalux, some answers might have been influenced by this fact and biased towards the prerequisites and possibilities of Dalux.

A central term when identifying research area and formulating research questions is the concept of conformity. Alvehus (2018) describes conformity as being a threat towards the researchers free will of topic and focus. This is because strong authorities, norms, or a will to deliver something requested may force the study in a direction. To counter conformity, it is important that the researcher is given free will to render subject and problems. In relation to this it has to be mentioned that both the studied company and the department at Chalmers Technical University was unconditionally open minded and did not restrict any potential outcomes of this thesis.

As stated in the method theory, the best approach to gather empirical data is in person, however as the situation with the COVID-19 pandemic developed in the late spring of 2020 two of the interviews were conducted through an online medium as prescribed as doable in the theory of interviews. In respect to the other performed interviews the judgement is that the possibility to interact and the outcome where similar. Unfortunately, a visit to the Norwegian part of the studied company and a second visit with a more extensive interview at Company E was cancelled, due to the situation.

3.Theoretical Framework

The digitalization of the construction industry has led to the creation of several digital terms, such as VDC and BIM. BIM is often connected to digitalization within the construction industry (Moscati & Engström, 2019), and accordingly to Hassan, Taib, and Rahman (2018), VDC is synonymous with BIM-management, Foldager (2020) follows by describing VDC as taking action on BIM. Kunz and Fischer (2012), who introduced VDC in 2001, define VDC as: "*The use of integrated multi-disciplinary performance models of design-construction projects to support explicit and public business objectives*" (Kunz & Fischer, 2012, p. 1). While Hassan et al. (2018) argue that there is no consensus of what VDC entails, but that most agree that VDC is more than merely using a 3D model. Furthermore, studies argue that BIM is a process rather than a software, and that the understanding of BIM is both limited and differs between different stakeholders within the industry (Moscati & Engström, 2019). Meanwhile, Hautala et al. (2017) explain that information modeling has changed the construction industry processes and ways of working significantly, partly through new ways of communicating. Based on the confusion and unclarity regarding different digital terms, this study discusses digitalization in a wider context to include any tools that is connected to digitalization. Different terms such as BIM, VDC, ICT, digitalization, and digital tools, will be used depending on how it is referred to in the corresponding literature.

3.1 The construction industry

Compared with the overall economic productivity growth, the construction industry has fallen behind globally, in recent decades the productivity growth in construction have slowed down (Talamo & Bonanomi, 2020). In Sweden the construction industry along with the transportation sector lag the most in terms of digitalization (Anjou, 2019). Furthermore, Talamo and Bonanomi (2020) points out that research has found a positive correlation between digitalization and productivity growth, and globally the construction sector is ranked among the least digitalized sectors in the world. This is strengthened by the statistics given by Remes et al. (2018), where the relation between productivity growth and digitalization is established, it is found that the European construction industry is not only one of the least productive industries it is also the least digitalized.

The Swedish construction sector is one of the largest sectors in the country and has been described as fragmented (Callavik, Forsström, & Holmberg, 2019). In relation to this fragmentation the construction industry can be described as a project-based industry where there are tight couplings within each project while there are loose couplings between the projects and permanent network, which is hindering organizational wide innovation and learning, according to Bresnen, Goussevskaia, and Swan (2005); A. Dubois and Gadde (2002). The large amount of stakeholders with different characters, and the fact that the industry have tens of thousands of projects every year leads to the low speed of digitalization, another contributing factor is the distinct conservatism or traditional culture that prevails in the industry (Callavik et al., 2019).

Davies and Harty (2013) argues that the AEC - *Architecture, Engineering and Construction* industry for long have tried to implement digital production on the sites, with different kinds of software's and hardware's. Further they argue that since this have not been fully implemented, in the form of embracing digitalization as a way of working, points at the problem being of an institutional and organizational nature. In comparison to other industries Davies and Harty (2013) see a connection between low innovation and problems in productivity and quality. Hasan, Elmualim, Rameezdeen, Baroudi, and Marshall (2018) reflects that two of the reasons for the low productivity in the industry can be ascribed to the employment of

unskilled workers and that the adoption of ICT - *Information and Communications Technology* is to slow. This is strengthened by Noruwa et al. (2018) where it is described that one reason to the low labor productivity is that the industry has been to slow to adopt and institutionalize ICT. Hooper (2015) point out that since nobody owns the whole process in the construction industry, most optimization is done at individual or organizational level. This might be one reason why development in construction has fallen behind other industries.

The construction industry is one of the most institutionalized, as a cause of this, change and development is many times recalcitrant (Bosch & Gulch, 2017; Kadefors, 1995). One definition of what an institution consist of is given by Scott (2014, p. 56) *"Institutions comprise regulative, normative, and cultural-cognitive elements that, together with associated activities and resources, provide stability and meaning to social life".* What this implicates is that the institution control and constrain behavior and provide a guideline for acceptable and unacceptable behavior, by imposing restrictions in terms of legal, moral and cultural boundaries. A sound institutional environment will be a support and source of empowerment for activities and actors acting within it (Scott, 2014). The institution is argued to be made up of three pillars, namely the *regulative*, *normative*, and *cultural-cognitive* pillars. The *regulative* pillar is according to Scott (2014) the part of the institution that establish rules and make sure that the organization act in conformity with them, in an attempt to affect future behavior punishments and rewards may be sanctioned to those affected and create an environment of expedience. In relation to the explicit rules of the regulatory pillar, the *normative* pillar is found being more about values and norms. The values represent conceptions of preferred or desired behaviors, whilst the norms tell the actors how things should be done, in a way presenting how actors should pursue the values. Norms form the guidance or objectives for the actors in the organization and create an environment of social obligation. The last pillar of the institutional theory is the *cultural-cognitive* pillar, this pillar represent the social reality from which meaning is made and understood, and in a sense create values and norms that are mimetic and taken for granted. The cultural framework of the organization will, for those actors acting in line with it, create a feeling of competency and connection (Scott, 2014). Bosch-Sijtsema and Gluch (2019) argue that changing towards BIM is not only a matter of technological change on this a management aspect focusing on changing social norms and practices need to be applied. Lundberg, Engström, and Lidelöw (2019) finds a lack of research in the organizational and implementation aspects of the AEC industry where more focus needs to be given towards the meanings, practices, and institutional environments role in forming the industry.

3.1.1 Production management

The idea of production management was defined over a century ago by Taylor (1911, p. 39) *"Perhaps the most prominent single element in modern scientific management is the task idea. The work of every workman is fully planned out by the management at least one day in advance, and each man receives in most cases complete written instructions, describing in detail the task which he is to accomplish, as well as the means to be used in doing the work. And the work planned in advance in this way constitutes a task which is to be solved, as explained above, not by the workman alone, but in almost all cases by the joint effort of the workman and the management. This task specifies not only what is to be done but how it is to be done and the exact time allowed for doing it."* This description is in large valid still today as coming Chapters will describe, planning relates to for example efficient work, safety and quality. However, there may today be a larger focus on the individual skilled workers capacity to solve problems, even though many theories talk about standardizing the processes.

Byggföretagen (2020) presents statistics that show the average cost allocations for a housing project, during the production phase roughly 39% can be ascribed labor cost in the form of white collars, subcontractors and employed labor. Around 42% of the production costs is due to material costs and the lasting 19% is due to transports, machines and other expenses. Efficient management of the processes related to these costs is key for project success.

The construction industry has some characteristics that differentiates it from other production industries, one of the most noticeable may be the strong project-based organizations. This project-based approach to work is a way of handling the unique circumstances in terms of shifting locations and conditions, the different needs of the client in terms of what building is to be delivered, the high intensity of labor, the highly regulated market, and the nature of relations which is temporary or short-term (Hasan et al., 2018; Samuelson, 2010). The construction industry has also been described as a "complex systems industry" this description aims at mediate the diverse group of temporary project actors, consisting of actors and organizations, put together in a network to deliver a project (Davies & Harty, 2013).

Projects typically start with a feasibility study, leading in to a brief and then planning and design with the goal to establish what to build and how to build it (Boverket, 2019b). When the planning and design stages of the construction cycle is finished the construction production begins. Révai (2012) argues that the project now faces reality on site with interference and disorders. Koch et al. (2020) finds that a majority of clients and site managers report interferences, where 35% of the site managers state that the interferences cost over 5 million SEK and an additional 25% state the cost being between 1-5 million SEK. These interferences can relate to internal and external circumstances. The external causes can be client change orders, weather, or other force majeure related issues. Internal interference can be issues with personnel, machines, equipment, tools, or material (Révai, 2012). The site management has the responsibility to manage and coordinate both the interferences and the issues arising with them, the best way to do so is through being proactive and work with plans and schedules. When planning is insufficient the site management must document the outcomes of errors and shortcomings. This puts requirements on access to computer which many times can be found at the site office, this often results in management doing documentation of tasks two times, once on site and then once again at the site office. It also result in a lot of transportation for the managers between the site and the office, which takes valuable time and is inefficient use of managerial resources (Svalestuen, Knotten, Lædre, Drevland, & Lohne, 2017). An emerging tool to improve the managerial productivity and efficiency in terms of site-monitoring, documentation, task management and real-time information sharing is the on-site use of smartphones enabling mobile tools (Kim, Park, Lim, & Kim, 2013).

Koseoglu and Nurtan-Gunes (2018) point out five categories, listed below, where mobile BIM can improve the production management.

- Design management – on site access to BIM models, enabling spontaneous revisions
- Information management – access to 2D drawings, access to work planning
- Quality control and assurance – site inspections and observations
- Resource management – crew tracking and jobsite planning
- Performance management – different types of reports, schedule tracking and production coordination

Ajayi et al. (2017) describes that the industry is increasingly looking to the site management to deliver the desired performance in an environment where both technical and administrative aspects are becoming increasingly complex, responsibilities aims at ensuring quality, time, costs, and safety, amongst other things. Mäki and Kerosuo (2015) describes the site manager as the key player on site, it is this person who takes the knowledge from the design stage and realizes information to a product. It is also the site manager who is responsible to make decisions and take action when insufficient or inaccurate information is provided from the design stage. Révai (2012) describes that most interferences on site can be managed, however, one critical interference is lack of supervision capacity. The first symptom is increased strain on the personnel on site which can be durable for shorter periods. Eventually a lack of supervision capacity will manifest in late or lagging decisions, wrong decisions, insufficient monitoring, and inadequate documentation. Berg (2009) reflects that one of the supervisor's greatest benefits of working digitally is that decisions can be made quicker. However, an increased digitalization also comes with the risk of focusing too much on the communication that this enable. The focus still needs to be on the propulsion of the construction and the traditional whereabouts of site management. Koch and Jonsson (2015) describes a sector where the main contractor more commonly rely on sub-contractors to do the majority of the site work. This will put increased managerial strains on the site management as it increases the importance of quality controls and documentation.

3.1.2 Monitoring, documentation, quality and planning

Metrics gathered on site does not only provide efficient ground for project related contract negotiations, schedule time, or cost growth. It can also provide later benefits such as knowledge and experience brought into the planning of new projects (Project Management, 2016). Belsvik, Lædre, and Hjelseth (2019) argues that metrics is a key for continuous improvement. Valuable metrics to gather could be the actual activity durations, measurements of productivity or labor hours (Project Management, 2016). Koch et al. (2020) reflects that it is likely that development in digitalization and big data will lead the industry to better tools for measuring productivity. Metrics that compare different construction parameters such as, output in relation to input, time, labor, or economy can be problematic to value between projects, however, Koch et al. (2020) argue that the solution is to measure a large amount of projects in a similar way, this will likely smooth out indifferences and in the end present a way of understanding productivity.

Whilst metrics is a way of monitoring productivity and performance, there is also a need for more hands on performance and quality measurement on site, part of this is ensured by performing self-inspections. Johnsson (2016) reflects that the literal meaning of the self-inspection indicates that this is an inspection performed by the individual worker. However, the situation today is often that a team leader or similar performs the self-inspections for the entire team. The idea is that the performed work is controlled to be in accordance with specifications, regulations and standards (Johnsson, 2016). The self-inspection is part of the quality management on site and are accompanied by site rounds, site reviews, deviation reports, which all are quality controls that is carried out continuously during the production. The basic idea from the contractors perspective is to have a quality system that enables detection of errors as soon as possible, as they are then more cost and time efficient to correct (Johnsson, 2016; Koch & Jonsson, 2015).

Besides being a tool for the contractor to monitor the quality and progress of the work, the self-inspections performed in the industry also aims at satisfying the regulations stated in the Swedish Planning and Building Act that states that all construction regulated by permits needs to be controlled. It is common that the developer and the inspections responsible set up the inspection plan, when this is in place the building committee will grant starting clearance. Part of this control can be satisfied by the self-

inspections (Boverket, 2016, 2019a). However, Koch and Jonsson (2015) finds that the relation between law and practice is weak and indistinct. This conclusion is based on a study in a few big contracting and consultancy firms on the Swedish market. In relation to this, it was also found that self-inspections were necessary because it is stipulated as mandatory in the control plan, rather than a necessity to ensure proper work and high quality for the actor himself. It is the site manager who is responsible to ensure that the subcontractors performs the quality documentation needed, which is deviation reports and self-inspections (Johnsson, 2016). According to the quality standard used in Sweden, the company should identify and plan to avoid deviations, in the cases where deviations occur the company should analyze what happened and prevent repeating of the deviation. The organization should also document and keep track of actions taken in relation to the deviation (Swedish institute for standards, 2015). In a study of how to increase the use of self-inspections Halme (2011) proposes that the communication of the company quality goals need to be strengthened and communicated down to the workers performing the inspections. A good way of doing this is to gather for an information session or site education where routines and procedures are discussed. Halme (2011) found that most workers see the self-inspections as a mean for someone higher in the organization to control them, when really the idea is to provide routines to increase quality. This is also reflected upon by Johnsson (2016) who argues that there is a loyalty amongst the workers not to control another's work. The self-inspection is a procedure done after finished work, in best case in connection with completion, and more often before leaving site.

There are also methods to document and control the work before the initiation. For the production phase Révai (2012) advice a more detailed instruction to be planned, the work planning is especially important for the activities that if not performed correct can interfere with time plan, QEHS - *Quality, Health, Safety, and Environment*, or economy. The work planning is commonly a document describing:

- When the activity is going to take place, with a start and end date
- What methods and procedures that is guiding the work
- Type of resources available, personnel, tools, machines and similar
- How the work is being coordinated with other building activities

The work plan is the foundation on which the workmanship will be carried out. The purpose of the plan is to satisfy the requirements from the society and the client (Gylldorff, Schlyter, & Sveriges Byggindustrier, 2012). It is advisable that the responsible supervisor sets up the work plan, however the dialogue with the skilled workers and other expertise in the planning stage is important to cater for bringing in valuable experience and knowledge. An involving dialogue may also spread knowledge amongst the team and create a culture of a learning organization (Johnsson, 2016). One way of bringing this knowledge in to the planning is one of the essentials of the process, namely, evaluating and documenting already performed works (Révai, 2012). As displayed in *figure 2*, a work planning will enable a smoother and safer production. When everything is prepared and thought out in advance fewer interferences and interruptions will occur making the production more efficient (Gylldorff et al., 2012).

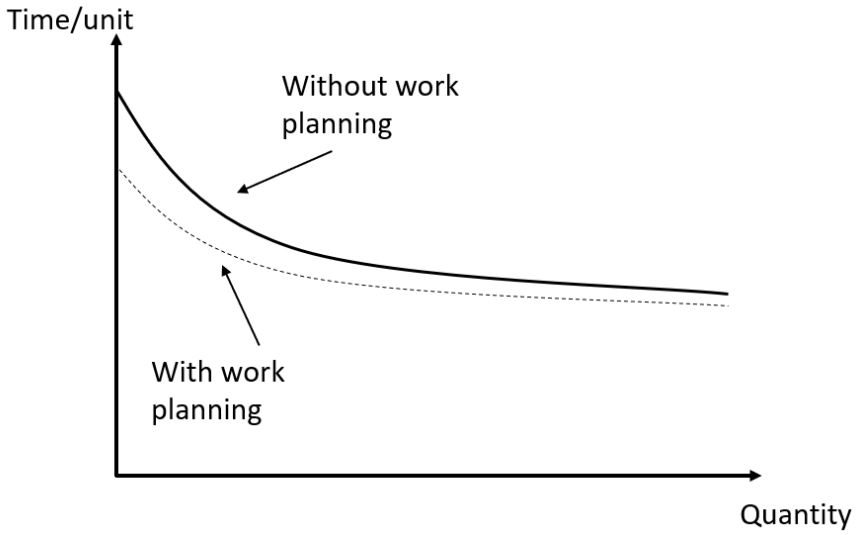

Figure 2 – How work planning make an activity more effective (Gylldorff et al., 2012).

3.1.3 The VDC engineer, the digital leader and the model engineer

Commonly found both in theory and practice is some kind of BIM-, VDC-, or Digital manager, this person is often involved in the entire process from planning to construction. The idea of this role is to maintain the knowledge and information from planning and design, and secure the utilization of the digital material and processes in the project (Bosch & Gulch, 2017). This can be described as a digital expertise, Addis, Boyd, and Raiden (2016) reflects upon this by stating that expertise is an attribute that is both collective and individual, and further connect with the knowledge, learning, thinking and action, in a way being an institutional attribute. In the conclusions of a thesis researching BIM in production Banka et al. (2019) suggest that more focus needs to be put on digital leaders in the production teams. In some literature the VDC role has been presented as somewhat synonymous with a BIM manager (Gustafsson et al., 2015), with an extension incorporating managerial aspects such as responsibilities for organizing, communication, and collaboration. As discussed by Gustafsson et al. (2015), there is no AEC industry consensus on how the VDC role should be defined, some argue that this should be a new profession, whilst others argue that it should be a responsibility incorporated in the already existing roles. Russell, Cho, and Cylwik (2013) argues that basic knowledge and skill in BIM and VDC are becoming inevitable for a managers in the industry. Gustafsson et al. (2015) found that a portion of the industry think that the VDC role is a temporary role until the rest of the professionals catch up, whilst other knowledgeable think that VDC is a profession here to stay. Something also attested by Bosch-Sijtsema and Gluch (2019) who find that the BIM roles might become less relevant in the future when the overall knowledge about BIM has been established amongst other actors. This is strengthened by Hardin and McCool (2015) who acknowledge that the BIM manager as a role is now transformed into BIM as a part of the entire project team. Another interesting aspect, around the denomination of the roles is the reflection made by Alvesson and Willmott (2002) where supervisor, foreman, or manager is interpret as something strict, a role to enforce, whilst a leader or a team leader instead is seen as less authoritarian and an amplifier. Even the title of the roles working with digitalization can thus be important to unconsciously communicate cultural values.

3.1.4 Swedish rules and regulations regarding BIM

In Sweden there has been some uncertainties regarding using computer models as construction documents, rather than traditional drawings. This is based on a lack of framework for handling BIM in a legal process, and because of a lack of standards that bridges new technologies and the old fashioned way with drawings (Thydell, 2017). BIM Alliance (2016) argue in their report that there is a need for a standardization of definitions, processes, and routines when working with BIM as construction documents in order to bring clarity into who is responsible in different aspects. Furthermore, that the general industry contracts, AB04, ABT06, and ABK09, needs to include regulations for information connected to BIM. From a governmental aspect to increase implementation of BIM, the government can demand models to be delivered in IFC - *Industry Foundation Classes* as a complement to drawings, which is the only legal construction documents, according to Thydell (2017). While the project Rörforsbron in Laxå was completed in 2013 with only computer models as construction documents, showing that it is possible to do construction projects in Sweden without 2D-drawings (Götborg & Olsson, 2016).

Efforts have been made to help organizations increase the digitalization within construction in Sweden, The Smart Building Environment is a long-term initiative which aims towards increasing digitalization and streamlining the Swedish construction industry (Jongeling et al., 2016). In a report for The Smart Building Environment, Jongeling et al. (2016) created guidelines directed towards helping the construction industry implement BIM. In connection to their report, a website was also created, with updated recommendations for standards and instructions concerning BIM that can be used in the Swedish construction industry. In both the report from BIM Alliance (2016) and from Jongeling et al. (2016) they conclude that there is a need for clarified rules, regulations and demands within the Swedish construction industry concerning BIM, in order to increase digitalization. Foldager (2020) reflects on the usage of digital tools in relation to legislative or mandatory requirements to use BIM across different countries, arguing that whilst regulations can support the procurement of software, it has likely little effect on the actual usage and implementation.

3.1.5 Communication

When describing communication, especially in this thesis, it is of value to differ between the communication which is conducted in projects and the communication that is conducted in the organizational network. The later can have many purposes, where the communication as an enabler for change is of certain interest. However, this section will mainly aim at describing the communication that digital tools can enable and is intended to make more efficient, this technology is commonly denominated ICT – *Information and Communications Technology*. The theoretical knowledge about communication as an enabler for change will be elaborated on in conjunction with the theories about change management.

Lack of, or ineffective communication have been found to be a major cause of poor performance and delays in the construction industry, a problem not isolated to the Swedish industry but occurring globally (Doloi, Sawhney, Iyer, & Rentala, 2012; Hasan et al., 2018; Olanrewaju, Tan, & Kwan, 2017; Sambasivan & Soon, 2007; Senaratne & Ruwanpura, 2016; Tsai, 2009). In relation to performance Johnsson (2016) concludes that most quality deficiencies can be related to poor communication and misunderstandings.

According to Chelson (2010), communication can be seen as a network of two way channels. If all actors in a project communicate directly with each other Chelson (2010), shows that a project with 50 actors have 435 different potential channels. Increasing the number of individuals in the project to 100 will instead result in a number of possible channels amounting to 4950 variations. The multitude of potential

channels create communication structures in a project that is complex. Normally the main contractor takes the role of reducing this complexity and a common method is to try to reduce the potential number of channels. This is mainly achieved by having all communication go through the contractor. Chelson (2010), further reflect that the contractor as a hub of information flow puts requirement on some kind of digital system to cope with the flows.

The construction industry is information intensive due to the large amount of information that need to be transferred in different forms and mediums between different stages of the construction process and between different collaborating actors inter- and intra-organizationally (Sattineni & Schmidt, 2015). Failing to communicate will negatively affect productivity (Xu & Luo, 2014). Communication and information are closely dependent on each other, when different stakeholders transmit information through an inefficient processes, there is a risk to fragment the information or create information islands (Xu & Luo, 2014). The problem is argued to be that the different actors on the production site do not necessarily have the same interests and sometimes even conflicting interests. This in combination with poor tools for communication such as paper drawings or verbal communication hinders efficient information transfer. An important aspect that will determine the quality and richness of information transmitted through communication is what media that is used to transmit. Alreshidi, Mourshed, and Rezgui (2017) argues that with increased project complexity the need of a collaborative environment for communication increase. Svalestuen et al. (2017) describes that an increased level of communication will be enabled through the ability of the media to handle multiple information cues simultaneously, the ability to transmit rapid feedback and the ability to establish a personal focus. The use of mobile devices on the construction site has greatly increased the ability to communicate feedback and information in the field (Hardin & McCool, 2015).

3.1.6 Lean Construction and Quality

Lean and BIM has been closely connected to digitalization and industrialization of the construction industry (Belsvik et al., 2019; Koseoglu & Nurtan-Gunes, 2018; Mandujano, Alarcon, Kunz, & Mourgues, 2015). This is also elaborated on by Alarcon et al. (2013) who finds that VDC is somewhat interconnected with Lean as the goal of the two doctrines aims at the same target, namely, eliminating waste, reducing cost, improving productivity, and create positive project results. Koseoglu and Nurtan-Gunes (2018) also argue that BIM can improve Lean practices and that together, BIM and Lean can transfer digitalization from the offices out to the construction site. Further it is found that that the philosophy and culture of both the Lean and VDC approach have mutual synergies where the big ideas of collaboration in design and construction, optimization of the whole system, participation and involvement of the end users all are synonym for both approaches (Alarcon et al., 2013).

The Lean philosophy was first developed by Toyota as a way of making automotive production more effective (Gao & Low, 2014b). At the turn of the millennium a lot of research pioneered in the field of Lean approaches to construction, one of examples was the theory presented by Lauri Koskela (2000) presenting the TFV-*Transformation-Flow-Value*-theory focusing on these three different topics to understand the prerequisites of construction. L Koskela, Ballard, Howell, and Tommelein (2002, p. 211) gives a concise definition of what Lean construction is *"Lean construction is a way to design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value"*. Bølviken, Rooke, and Koskela (2014) argue that the TFV-theory is the main theoretical foundation of Lean construction. The *transformation* aims at describing the reshaping of raw materials and parts into products. This is done utilizing machinery, energy, and labor, where waste in terms of transformation

would be to use more of these resources than needed. The *flow* perspective focus on time, in relation to time there can be waste in relation to workflow for example unnecessary movement, unnecessary work, inefficient work and waiting. The *flow* can also focus on the product where there may be waste in space not being worked in, materials not being processed and unnecessary transportation (Bølviken et al., 2014). The last foundation of Lean construction is *value*, where it is argued that all activities that does not create a measurable value must be eliminated (Lauri Koskela, 2000). There are also other approaches and methodologies, Gao and Low (2014a) describe that the other main interpretation of Lean is the *Last planner system – LPS,* which focus on the construction process. In the focus on construction process in LPS the main factors are to create reliable work flows by involving all actors, contractors and subcontractors alike, in the planning process. In this way Gao and Low (2014a) argues that the team jointly through a social interaction can find a plan that will decrease the waiting in the project, both workers waiting for work and work waiting for workers.

As previously described Lean construction principles are based on reducing waste and non-value adding activities and thereby maximizing value (Freire & Alarcon, 2002). Bølviken et al. (2014) argue that the relation between value and waste is that both are outputs of actions, whilst value is wanted output, waste is unwanted. Waste occur in construction as a cause of many reasons, for example by rework, unnecessary transports, delays, quality, inappropriate methods or equipment, and poor constructability. According to Anjou (2019) around half of the cost for production or a third of the total costs for the construction can be related to waste. These factors are often in some way related to insufficient information management (Svalestuen et al., 2017). Which is also strengthened by Ajayi et al. (2017), who studies ways of eliminating waste in construction, findings indicates that the one of the most important aspects is to build in accordance with drawings and design, related to this it is also identified that trying to reduce changes during the construction phase will limit the waste. Further, it is also important to communicate the changes done and to ensure that affected stakeholders work from the newest source of information. The solution to the problems is to continuously improve the work process, and always strive towards doing each part better (Tommelein, 2015). Lean construction works by planning for specified goals for the system to achieve, control the progress towards the set goals, and then evaluate and improve the system (Ballard & Howell, 2003). The idea is to keep improving the system even if it is working since there is always room for improvement. Tommelein (2015) explain that Lean thinking can help reduce unwanted complexity in construction systems and aid in keeping systems simple and effective. Since the system is analyzed continuously the system will not be outdated and unnecessary complexities will be removed.

Belsvik et al. (2019) address the fact that metrics is a key to enable continuous improvement, both in terms of VDC and Lean approaches, with the goal of streamlining processes. However, it is argued that few studies have established what metrics should be gathered, which can be challenging as some metrics may require more effort than the value they give, and as such produce waste. Freire and Alarcon (2002) describes that the lessons learned, and design mistakes attained in the production, many times take a long time to transfer back to the planning and design organization. Furthermore, arguing that the success of a construction project in terms of technical and economic aspects, many times lies in a successful planning (Freire & Alarcon, 2002). Connected to this, Anjou (2019) argues that the construction industry as a whole fail at delivering in accordance with the time plan and often with poor quality. Ajayi et al. (2017) find that most quality errors in the construction phase is due to insufficient understanding of design, drawings, and other documentation. Related to this, Ajayi et al. (2017) describe that in order to prevent waste in the construction phase it is important for the site management to attain knowledge about the

planned design and execution, however, for the designers to plan for decreased waste it is just as important that they get feedback and knowledge about ineffective and non-working site procedures. Connected to this, Bergman and Klefsjö (2012) argues that one of the most important aspects of quality improvement is the assembly of data and information. To make an improvement in an issue it is important to have information to support decisions in the matter. However, Bergman and Klefsjö (2012) continues by stating that data assembled without a goal or a clear picture of how to use it should be seen as waste.

(Koch & Jonsson, 2015) describes the skilled labor in terms of the Lean philosophy, where they argue that an enabler is that improvements and quality can be implemented in all levels of the construction hierarchy. A method to do the hands-on improvement work is the self-inspections implemented in the construction sector. However, it is found that the attitude from the skilled labor is that the quality is already implemented through the craft and that quality inspections unnecessarily. Connected to skilled professionals, Gao and Low (2014a) present the socio-technical approach to Lean construction, where it is argued that operational improvement is dependent on joint efforts of technical and human elements. Where the human aspects of Lean are described as focusing on problem-solving, team and creative thinking whilst the technical construction project-based focus on last planner, concurrent engineering, daily huddle meeting, quality management tools, and visual inspections. Mandujano et al. (2015) present another aspect in relation to waste, if the organization fails to address the competency of the employees, for example the knowledge and enthusiasm in BIM, this should be considered a waste.

Björnfot (2008) presents some critique against the Lean philosophy mainly because the diverse applications and research in the field have caused the term to be overexploited and thus losing some of the fundamental ideas. Gao and Low (2014a) find that one of the major problems with Lean is that it seems to be difficult for practitioners to adapt to the techniques and mindset. A study by Koch et al. (2020) found that a third of the Swedish contractors think they utilize Lean, the study also found that the some projects that actively use Lean had higher costs of production, however, some parameters connected to efficient processes for example less interferences and better time plan adherence improved. Hardin and McCool (2015) give account for numbers indicating that 86% of Lean approach users expects shortened schedules and 84% experienced higher quality in the overall project.

3.2 Implementing digital tools

Digital tools for production purposes, are used on a broad basis in the industry today, however research have shown that the utilization of digital tools on site offices and in mobile devices on site is not in accordance with the full potential (Koseoglu & Nurtan-Gunes, 2018; Sattineni & Schmidt, 2015). Companies would benefit from investing further in the implementation and follow up on new software. Doing so has the potential of increasing communication, quality, and innovation, in the long-term leading to increased profits (Sattineni & Schmidt, 2015).

It will be of value to try to define what a digital tool is, and if there are different levels of digitality. The consultant and thinktank firm Roland Berger try to define digitalization in the industry in a report from 2016. The report argues that the main ingredients for digitalization are (Schober, Hoff, & Nölling, 2016);

- ***Digital access***, mobile access to information networks such as internal or internet
- ***Connectivity***, increased connection and synchronization of previously separated activities
- ***Digital Data,*** collection and analysis of data
- ***Automation,*** increased use of self-organizing systems

Where a higher degree of fulfillment of each of the ingredients indicates a higher degree of digital capability. One term describing these capabilities is the ability to work in a CDE - *Common Data Environment,* where the goal is to store diverse data that then can be coordinated and accessed in a common environment (BIM Wiki, 2020; Radl & Kaiser, 2019).

Another report about digital transformation lists the biggest challenges of becoming more digital in the construction industry (EY, 2018);

- Need for higher integration between systems
- Training of personnel to be able to implement and operate technologies
- Adoption to new technologies
- A mentality where digitalization and technology are not suitable for construction
- Motivating costs of digitalization for client

Other hinders for higher implementation of digital tools was found by Hasan et al. (2018) who describes that a limiting factor of the improvement through digitalization or investments is the branch typical low-profit margins. And yet another hinder for implementing more digital tools has been found to consist of executives being skeptical about what business values new technologies can bring (Merschbrock & Munkvold, 2015).

Svensk Byggtjänst, a Swedish industry owned information and development company, presented a report 2017 about the digitalization of the construction industry. The report showed that 62% of the surveyed companies had a good idea of what digitalization is, and that the big companies all had a good idea of the concept (AB" & Byggtjänst", 2017). In the same report around 50% of the responding contracting firms think that they reached halfway in the journey towards digitalization, and 13% of the large contracting firms think that they are now fully digitalized and should now work with continuous improvements.

Hardin and McCool (2015) concludes that the industry for long have assumed that the same tools that have been digitalizing the design and planning stages would also enter the production phase. Recently there have been a shift in the software industry understandings, which is now looking for BIM application tools that can create value in the production phase. Anjou (2019) argue that despite the industry is working with some digital administration and digital tools it cannot be ascribed to be digital in relation to other industries. Hardin and McCool (2015) describes the digitalized workplace as a site where real-time information is shared almost instantly with high connectivity of involved actors on site. Further, Hardin and McCool (2015) describe that the trend in the industry is to consolidate and focus on cross-platform integration, where the suppliers of the tools admit for interoperability, which could be open source information sharing or APIs - *Application Programming Interface*s, which is an interface that allows for communication and data sharing between different applications and software.

When implementing a new tool, it is of value to ask how the new product will improve the organizational way of working, Hardin and McCool (2015) describe three different approaches for this. The first approach is when the organization see the tool as an addition to the current tools being used, as a sort of “piling on”. With this method the organization can perform pilot projects and evaluate where the tool fits in and what role it can play in relation to already existing tools. For an implementation this is argued to be the least painful as it is a quite long process. The second approach is a more defined replacement strategy, where a new tool is evaluated in comparison to an old tool, if the new tool is deemed more functional it will simply replace the old tool. The last approach focus around the process, where the team evaluates

how they wish to work and in relation to this identify tools that can fit these processes, this approach is regarded as time consuming, however it is more likely that the team will understand and accept the prerequisites of the tool.

Svalestuen et al. (2017) found that a challenge to introducing BIM on site is that the workers have insufficient knowledge about BIM devices and therefore cannot use them. It is concluded that the workers will need proper training to efficiently make use of the new technologies. In a study on the Swedish education system delivering skilled workers to the industry, M. Persson (2020) concludes that the education today does not give competence in working with digital tools. The rapid development with digitalization of the industry also increase the strain on the education. It is however important that the newly educated workers bring in new knowledge to the organizations, for this to be possible they will need to be educated in basic concepts such as BIM and digital applications (M. Persson, 2020).

3.2.1 Organizational change management

While trying to implement more digital tools into the construction process, the daily work will change for the individuals working in the industry. This can be complicated, especially when there are professionals who have a lot of experience and have done things in a certain fashion their whole careers. Introducing change that will alter the basic work pattern is often met with resistance (Long & Spurlock, 2008), this is partly an instinctual behavior as the employees try to protect the established power structures they feel secure in (Battilana & Casciaro, 2013). Common reasons for resistance are uncertainty, fear of failure, threats to status, lack of knowledge, and doubts in perceived benefits from changes (Erdogan, Anumba, Bouchlaghem, & Nielsen, 2005). To gain the acceptance of the employees, communication and the establishment of perceived need for the change are vital factors (Long & Spurlock, 2008). Furthermore, Long and Spurlock (2008) explain that greater employee acceptance is generally reached when clear communication plans and training are part of the organizational change. When the employees understand the reasoning behind changes they tend to feel more in control and thereby likelier to cooperate (Erdogan et al., 2005). Therefore, it is important for the organization to clearly communicate why the change is taking place and explain the benefits of the change to employees, as well as allocating time for education of the new methods. Malek and Yazdanifard (2012) claims that communication is key to effective implementation. When seeing communication as a key it is important to understand the nature of communication, as being a two way transfer of information. Malek and Yazdanifard (2012) argue that the problem in most change attempts is that the communication is more of a one-way informative monologue, rather than creating a dialogue that can decrease negative perceptions and resistance.

Turner, Hallencreutz, and Haley (2009) argue that there are six elements necessary for successful organizational change: need for change, define the outcome, effective leadership, create a plan, enable commitment, and create the environment. While these six elements are essential, they do not automatically result in successful organizational change, the elements are merely factors for enabling perpetual change. Furthermore, Erdogan et al. (2005) point out that employee empowerment is a key component since employees are the ones responsible for making the changes happen. Degermark (2018) suggests that an appropriate measurement for the top management to enhance change is by the use of ambassadors. The idea is that these ambassadors will help the management partly by serving as reference group and more specifically in converting information to dialogue and involvement. Lundberg et al. (2019) describes that individuals facing a change will perceive it as familiar and find it easier to assign meaning if it is coming from within the organization. This is followed up by Bosch-Sijtsema and Gluch (2019) who argues that leadership and individuals who can support the change are important change agents in the

pursue of new attitudes and practices. Furthermore, Degermark (2018) reflects that the ones most suitable to serve as these ambassadors is the ones showing most interest in the change undertaken.

To implement successful organization change it is vital to remember that organizations are alternating social systems with individuals who interact and influence each other (Turner et al., 2009). It is therefore important for the organization to keep in touch with their employees and ensure that they understand why the change is needed to allow the employees facilitate the change rather than resisting it. In a survey focusing on how to implement BIM, Bosch-Sijtsema and Gluch (2019) found that the change agents working with the tools were perceived as mediators between the new technology and its users. It was found that these actors supported others by explaining and showing the possibilities of the new tools. Further it was found that this was carried out in a diplomatic and pedagogical manner, in order to educate their colleagues. Battilana and Casciaro (2013) found that while change agents working in the organization will enable change through personal networks and relationships, they may find challenges with the ones resisting change, since minor initiatives for change can be pushed but the relationship will hinder the agency in larger changes. The high expectations resting on the roles introducing the new tools and technologies springs from a collective known about the needs for solving the communication and information sharing issues in the industry. However as stated the industry put a lot of the burden on the front line actors to prospect, promote and develop these new practices (Bosch-Sijtsema & Gluch, 2019).

When leading the organization towards change Cameron and Green (2020) describe three different leading roles. The local line leaders are the managers really driving change often quite isolated and focused to their specific projects, teams, and clients. There are also network leaders which functions as an interface between project groups, functions, and teams. The network leaders functions as guides, advisers, and active helpers, Battilana and Casciaro (2013) find that the network leaders is central for change at all levels in the organization. Cameron and Green (2020) describe that the network leaders often must battle to get recognized as important players in the organization. The last category of important leaders in the change process is the executive leaders, these have the responsibility to set up a healthy environment for change, this needs to focus on innovation, rewards, teaching, and mentoring, and serve as good role models strengthening the decided values and purposes of the organization.

In relation to what triggers or initiates change, Beer and Nohria (2000) describes that there are two theories about why change happens in an organization. It can either be stimulated by need of changes in relation economic value or organizational capabilities. If the company executives see the shareholder value as the reason for existence, it is more likely to have an economic value approach for changes. If the executives instead see that organizational capability will lead the company to its strategical goals, it is more likely that change will focus on enhancing the individual and organizational learning, employee commitment, or increased productivity. Malek and Yazdanifard (2012) elaborate on the same phenomenon but describe it as external and internal factors. Where the external factors can be new technologies, competitor activities, economic cycles, quality, and standards and much more. Whilst the internal factors being management philosophy, organizational structure and culture, or internal systems of power and control. Beer and Nohria (2000) argues that no change is pure in the scene that it is pure economic or capability focusing, instead it is important to find a balance so that the company can keep its shareholders satisfied whilst creating an institution that is sound and viable. The value approach is often associated to a process with clearly defined goals, whilst the capabilities approach circles more about top management creating the right environment and encourage experimentation from the ground and up, spreading ideas and innovations between workers and managers alike.

3.2.2 Organizational learning

The construction industry is many times said to be ineffective and insufficient in its learning and collection of experiences. The project-based nature of the construction industry can be an obstacle for organizational learning, partly because of the discontinuity of projects (Hartmann & Dorée, 2015). While project-based organizations can be well suited for innovation and learning within each project, there are difficulties in capturing and sharing knowledge between projects and across the whole organization (Bresnen, Goussevskaia, & Swan, 2004). One reason behind these difficulties is that project-based organizations tend to be run under time pressure, by temporary units, and with quite independent individuals (Wiewiora, Smidt, & Chang, 2019). These factors might be an aspect to explaining why adaption of digitalization and innovation have not come further across the entire construction industry.

Hartmann and Dorée (2015) explains that creating strategic goals which are transferred to each project can help connect different projects and create common goals throughout the organization. The aim is to convert the overall goals of an organization into more explicit goals for specific projects. Clearly defined goals is also an important aspect for an organization to learn systematically (Thomas, 2005). Furthermore, Hartmann and Dorée (2015) argue that creating cross-disciplinary meetings and organizing reflective workshops can be effective to help the employees create a better understanding of gained knowledge between projects. While such meetings are outside the everyday work of each project and can therefore seem unproductive, the meetings can help employees and the organization gain vital knowledge and experience, thereby increasing the effectiveness in the long run. While having reflective meetings, such as workshops, it is suitable to use feedback-loops where the teams compare their work with the goals previously set and thereafter adjust their efforts to help the teams reach their goals more efficiently (Synnott, 2013). This approach helps the organization analyze and develop their strategies and systems more productively. It is important that the learning, reflecting, and development is done closely to the work in order to create a continuous effort, which enables both short- and long-term learning (Hartmann & Dorée, 2015). Furthermore, it connects the learning with ongoing projects and makes it part of the process rather than a separate workload (Synnott, 2013).

While creating goals, implementing reflective feedback, and improving existing systems it is effective to work with standardized processes (Martin & Bell, 2011). Learning from experiences is about looking at processes, interact with the individuals in the process, extract the knowledge acquired, and return it to the process again (Lidelöw, Stehn, Lessing, & Engström, 2015). In order to create a standardized work process there are, according to Martin and Bell (2011), some preconditions that must be met. The work must be reasonable for the employees to complete, the work must contain a repeatable sequence, there must be high reliability in the tools, equipment and the workplace, and high-quality material must be used. These conditions are important to ensure that the standardized process is reliable and that discrepancies from the goals are due to the process, which then can be improved. These standardized processes must also be part of feedback-loops where they are reflected upon and improved continuously (Synnott, 2013). When implementing systems to increase learning in the organization it is vital to remember the social interaction between users and the users' perceptions of the new systems (Dulipovici & Robey, 2013). Therefore, it is important for the organization to communicate with the users of the new systems and listen to their perception in order align the results with the organizational goals.

Lidelöw et al. (2015) writes about metrics and what fundamentals that need to be in place to be able to work with these processes systematically. For gathering of metrics to be effective it should;

- Measure relevant parameters in accordance with process goals
- Measure relevant parameters in accordance with company strategy
- Be continuously gathered
- Continuously be followed up and analyzed

Wallström (2010) continue by stating that the collection of different quantitative metrics needs to increase to ensure proper organizational learning and, as a result, better management of the operational aspects. In the same study it is concluded that the main driver for information gathering is economy. The organizations needs to increasingly see metrics for productivity as a strategic asset, to succeed with this Wallström (2010) argues there need to be a shift in attitude.

3.2.3 Individual learning and competency

Cameron and Green (2020); Lines, Sullivan, Smithwick, and Mischung (2015) argues that without understanding what change implicates for the individuals undergoing it, the organization will not be able to change. It is therefore important to mention something about individual learning and competency. Berg (2009) describes learning in relation to knowledge in the profession as the process where the practitioner can do a specific task with less time consumption and better quality. Cameron and Green (2020) argue that learning is more than just merely acquisition of knowledge. The new knowledge needs to be applied to habits and behaviors, leading to new ways of doing things. The change of applying new knowledge to an individual's behavior is described by Cameron and Green (2020) as stress on the individual's psychological space, implicating that performance will initially drop as the individual need to focus time and cognitive abilities towards the change.

Buchanan et al. (2005) describes that in order for the change to sustain on an individual plane, there need to be an appropriate award, gain of competency, or a commitment to change that triggers the new habits or ways of working. The new ways of working will likely increase the performance once implemented, as shown in *figure 3*. Connected to this, Berg (2009) describe how the supervisor in an initial phase may need to put in more effort while delegating more of the work or changing routines, however when new processes or knowledge pass the implementation bump, it becomes cemented and will result in saved time. Exemplifying with a study on the implementation of digital production tools by Nguyen et al. (2018) which found that the implementation of digital production tools, saved 2,5 hours of the average workday for supervisors. However, this efficiency increase was preceded by up to a month of determined adoption.

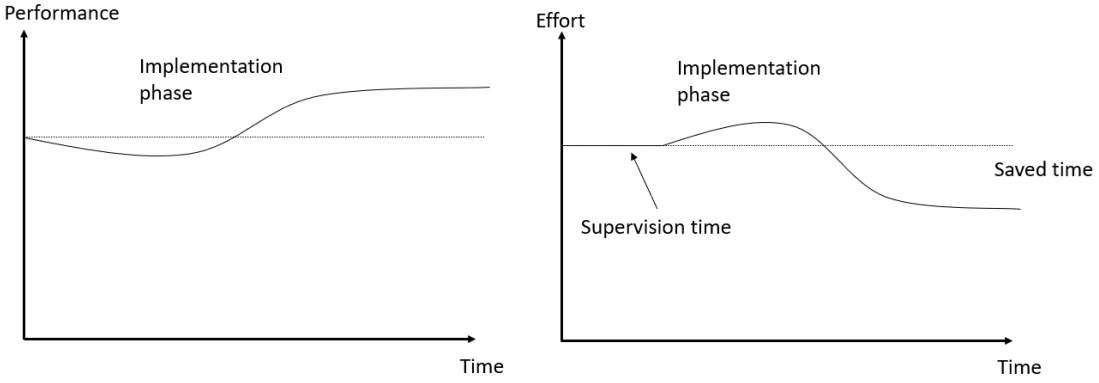

Figure 3 - the learning dip (Cameron & Green, 2020, p. 15) & delegation of work (Berg, 2009, p. 37)

When starting to work with new, ideally more efficient, methods it is anticipated that the workload will increase in the initial phase. However, over time the effort needed will decrease to a level below the initial one (Berg, 2009), illustrated in *figure 3*. Long and Spurlock (2008) explain that a disconnection problem caused by knowledge gaps between system designers and users could be reduced by training, preferably as early as possible. Two independent reports showed that 97% (Banka et al., 2019) respectively 87% (Brantitsa & Nordberg, 2018) of production teams requested more education regarding digital production tools, showing that there is a clear demand for more education within construction production. Although training or education is useful it is not enough to achieve successful implementation, technical assistance such as coaching enhances the utilization of innovations (Wandersman, Chien, & Katz, 2012).

Talamo and Bonanomi (2020) explain that while digitalization in construction lead to new formal roles, there are often employees who become informal support functions for their peers in the organization. These employees' function as an aid in the digitalization process but they do not have a formal role in doing so, leading to inefficiencies since they act as support outside their normal workload. This is further supported by Davies and Harty (2013) who studied the implementation of site BIM and found that the implementation in terms of adoption on the individual level were supported not by a centrally controlled IT function, but rather by informal personal relationships and arrangements. Talamo and Bonanomi (2020) argue that this informal support network must be acknowledged, and support groups should be created to facilitate further implementation of digitalized processes. Thereby, utilizing the informal support functions is an opportunity for the company to spread innovations and change effectively. This is supported by Rogers (2003), explaining that peer networks is an important part in spreading knowledge and innovation in an organization, since individuals tend to trust people they know personally.

Connected to individual learning and acknowledgement of work, Degermark (2018) describes a difference in attitudes between generations, where younger generations that are characterized as more digital also tend to be more selective in the choice of employer. This selection manifests in the younger generations looking for employers that have modern visions and goals. Connected to this it is also more important for this group to see that there is room for development in relation to their fields of interests. In relation to individuals seeking prominent employers, Singh and Holmström (2015) find that one such aspect that individuals may seek is the organizations developing through innovation. Russell et al. (2013) found that high skills within the BIM area increased the career opportunities of the individuals who possessed this knowledge. Gustafsson et al. (2015) argue that the unclear role of the digital management, including BIM and VDC, likely provide obscurity in the digital individuals contribution to project success, and uncertainty regarding what their current and future role will be in the organization.

3.2.4 Introducing innovation

Introducing innovation and technology is quite closely connected with introducing organizational change and learning since innovation often alter employees daily work and they need to learn the new tools or methods. Moscati and Engström (2019) argue that change management and developing technical capabilities, together with considering human behavior is some of the biggest challenges toward digitalization. Research has also shown the relevance of connecting organizational changes with digitalization in order to facilitate further utilization of digitalization (Talamo & Bonanomi, 2020). The relation between change and innovation is defined by Firth and Mellor (1999, p. 199) as *"Innovation means the application of new knowledge to industry, and includes new products, new processes, and social organizational change".*

Within the construction industry, technology innovations normally change quite slowly (Bröchner & Badenfelt, 2011). There are several reasons for the slow adaption, Bröchner and Badenfelt (2011) point out some underlying causes. One reason is that most construction projects have substantial direct environmental effects, meaning that the local environment is affected, which entails caution with experimentation. Another reason is that the production organization is normally consist of several subcontractors, often working together for the first time. In addition, Long and Spurlock (2008) argue that there is great potential for knowledge gaps between system designers and users when new technologies are introduced which leads to difficulties adapting new technologies. Connected to this, Samuelson (2010) explain that with more actors in different levels involved in the implementation of innovation, the process becomes increasingly complex. Several subcontractors working together, often for the first time, with new technology can therefore be a hindrance for implementing innovation. Other industries with more stable organizations and with less direct environmental impact might introduce innovation with greater effectiveness. Garud, Tuertscher, and Ven (2013) acknowledge the complexity of innovation and argue that the innovation process cannot be isolated to the organization that nourishes the innovation, instead the process permeates the business relations and interactions, multi-party networks and communities.

According to Rogers (2003) there are five components that determine at what rate innovations will be adopted. These are; *relative advantage*, *compatibility*, *simplicity*, *trialability*, and *observable results*. *Relative advantage* refers to the perceived advantage for the users of the innovation compared with other alternatives. *Compatibility* specifies how well the innovation is perceived to be suitable with existing practices and values. *Simplicity* is how difficult the users believe the innovation is to learn and use, the easier the innovation is to understand the more rapid the adoption of the innovation will be. *Trialability* is how easy it is for the users to try and experiment with the innovation. Finally, the easier it is to provide *observable results* of the innovation the likelier the users are to adopt the innovation. While these components are quite focused on the innovation, attention should also be given on how the organization work towards adapting innovations. However, before an innovation is introduced it must first go through a development process.

There are two main approaches for the development processes of new technology and innovations. Either the market demand drives the development, or the development can forego the marked demand (Choi, 2018). The first process is referred to as *market pull* and the second process is known as *technology push*. *Market pull* is characterized by unfulfilled customer needs or an recognized problem in the market (Maier, Hofmann, & Brem, 2016). Market pull is mainly driven by a potential market for new innovations that could improve a product or solve a known problem. Contrarily, *technology push* is normally not based on market research, instead a technological innovation is created to satisfy a previously unknown customer need or problem (Samuelson, 2010). A new better product or processed is created and thereafter spread. Although the processes are opposites, they are both needed for successful development of technology innovation (Choi, 2018). Successful technology push must recognize market needs, and market pull have to create new enhanced solutions which is often achieved through new technologies (Maier et al., 2016). In relation to technological push and pull Davies and Harty (2013) talk about introduction and spread of innovation in networks. It can be either top-down where clients, regulators or professional institutions drive the implementation, or it can be introduced bottom-up where contractors, consultants or suppliers drive the implementation. Garud et al. (2013) describes the elements of the innovation process where an emergence of an idea gives rise to an invention. Further elaborating with the idea will result in development and lastly the widespread acceptance of the innovation lead to the implementation.

Disregarding how the innovation is developed, once the innovation or technology is created it needs to be commercialized, spread, and implemented (Samuelson, 2010), leading to the diffusion of innovation.

3.2.5 Diffusion of innovation

Innovation process does not always follow a linear process from invention to implementation. Shibeika and Harty (2015) argues that the complexity of different stakeholders within and connecting to the organization enables processes to occur on multiple levels simultaneously. Rogers (2003) describe how an innovation diffuses amongst the members of a social system. The diffusion is described as the two-way communicated convergence towards a mutual understanding, which means that it is not a one-way communication where a knowledgeable colleague transfers a message to a receiving colleague. Further this diffusion can be regarded as centralized or decentralized depending on who communicates with who. If it is a centralized diffusion a small number of managers or technical experts will initiate and decide when the diffusion will start, what channels it will be communicated and how it will be evaluated. In a decentralized diffusion system, the innovation spread horizontally amongst the adopters.

According to Rogers (2003) five different categories of adopters can be identified. In *figure 4*, below these 5 stages of adoption are displayed. It starts off with a new technology, quite radical to adopt. The first to adopt this new technology is the *innovator*, this person is characterized by venturesomeness and ability to understand and endeavor in complex technologies. Another attribute of the innovator is to seek relations outside the enclosed social network, in this way networks with other globally distributed innovators will form. The main role of the innovator as seen to the company as introducing the innovation to the company from outside the company's boundaries. After the innovator comes the *early adopter.* The difference between an innovator and an early adaptor is that the adaptor is embedded in the social context or system, this way the early adaptors will also influence their surroundings more. From the aspect of change management this group is the most important, other persons will look here to seek guidance and since the early adopter is not too far ahead this critical mass of users will feel that they can make it too. The *early majority* is amongst the average and does not have any greater problems or skepticism when adopting to an innovation, however, they might need to deliberate for a while. The *late majority* is also found around the average adopter often the adoption is a cause of economic or social pressure. The *laggards* can either be negatively set to innovations and change, as a result of a conservative view. However, the case might also be that they are isolated in a socially interactive perspective, and as a cause simply miss to have the benefits of the innovation communicated to them.

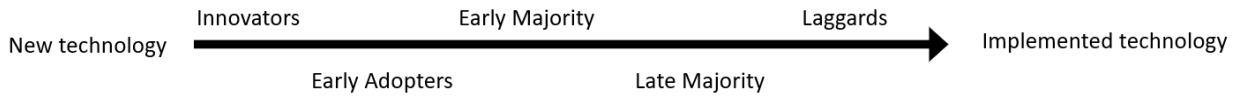

Figure 4 – The implementation timeline in relation to the five steps described by Rogers (2003).

In relation to *figure 4*, Singh and Holmström (2015) presents that around half of the individuals in an organization belongs to the more conservative and slow *late majority* and *laggards*, a third belong to the *early majority* category and the *early adopters* making up for around 13%.

Bosch-Sijtsema and Gluch (2019) and Merschbrock and Munkvold (2015) found that the key actor to diffuse the BIM and ICT technologies in the projects and organization is the actors working with the new technologies and tools. These actors advocate the tools among less digitalized colleagues and creates an

acceptance for them, this ensures that a higher value is derived and spread within the network of the firm. Shibeika and Harty (2015) performed a case study on a UK construction firm, findings indicated that multiple parallel diffusion and communication channels occurred simultaneously in the firm. The study further finds that a successful diffusion is made through a range of activities supported by changing strategies, actors championing the change, shifting social systems, and new channels for communication. In relation to this, Lundberg et al. (2019) finds that the same aspects that stimulate initiation of the diffusion may also be hindering the innovation, where aspects such as low centralization, high complexity, and low formalization will catalyze the initiation of the diffusion but at the same time low centralization can also hinder wide-spread implementation. Dubois and Gadde (2002) describes that an industry can have different degrees of coupling or dependencies. The construction industry is found to have mainly loose couplings between the central organizations and projects, indicating low centralization, relating to benefits in project structures. However, these loose couplings are found to impede innovation and learning within the projects. If a company have a low degree of centralization and framework which is symptomatic for loose couplings, it is likely that there is a great amount of variation in the organization. This variation results in projects adapting to the microclimate where they appear and thus innovate and adapt on a project level. However, the same organizational structure that allows this to happen is what hinders the innovations to spread across the organization (Dubois & Gadde, 2002).

Merschbrock and Munkvold (2015) argues that innovations in ICT and BIM do not follow the path of the traditional linear diffusion theory where an innovation does not change along the diffusion. Instead they argue that it has a combinatorial nature and as such mutate and evolve during the spread. Due to insufficient intra-project communication, Lundberg et al. (2019) argues that the project based nature of the construction industry hinders the diffusion and spread of innovations, this is due to the fact that most innovations in the contractor organization is made through problem-solving on the construction sites.

Merschbrock and Munkvold (2015) present the different aspects of the diffusion of a technology as, *individual factors* where the capability to learn and previous experiences and skills decide the phase of diffusion. The *environmental factors* of the workplace are important to enhance an open dialogue where discussion and sharing of knowledge can foster. The *managerial factors* describe how the management organize and support the digital work, whilst the *technological factors* tell what functionality, speed and accessibility the technology used in the diffusion have.

3.3 Digital tools in production

Davies and Harty (2013, p. 15) gives a basic definition of BIM as being; "*BIM in its most basic form is a combination of CAD, database and graphical technologies that allow users to design and represent buildings and their components in terms of an assembly of inter-connected objects in a coordinated, scaled 3D model*". However, they vouch for a broader definition of the term also including related digital technologies and business processes that are used for representing and managing project information. Mäki and Kerosuo (2015), argues that BIM software previously mainly has been used as a tool in the design phase, just recently the expansion into other fields of construction has started. One such is construction management. Bosch-Sijtsema and Gluch (2019) describes that BIM provides a platform for visualization, collaboration, automation, integration, and communication amongst different stakeholders.

Samuelson (2010) argues that some of the main benefits of BIM are;

- Shared access to all information
- Reduced “double work” since unique data is only available in one place
- Higher quality of information and which also improves process and in final product
- Reduced time and lower cost

Whatever definition one prefers for BIM and ICT, it is clear that the construction projects of today are becoming increasingly complex. This puts higher requirements on detailed drawings and sources of information (Svalestuen et al., 2017). Svalestuen et al. (2017) argues that one risk of the trend where all stakeholders can access all information is that it is difficult to control who receives what information and when, in worst case this can lead to individuals creating a sub perception of the project not aligning with the overall project objectives. Svalestuen et al. (2017) describes challenges of using mobile devices such as tablets or phones consist of amongst other, poor motivation amongst craftsmen, lack of trust in the BIM, dependence of network, and the hardware’s vulnerability to moisture and dust.

Some enablers for better utilization of BIM devices is given by Svalestuen et al. (2017) were better training in use of the devices, a higher level of detail in the BIM, changing the attitudes of the users, giving hardware better protection, promote success stories, conducting pilot projects, and gathering several functions in the same applications is lifted as keys. Resistance to implementation may relate to the initial costs of education, maintenance and cost of hardware, license costs and problem with accessibility to the network (Azhar, Jackson, & Sattineni, 2015). Davies and Harty (2013) describe findings indicating that stakeholders partaking in construction project do not only evaluate the project success in relation to time, cost, and technical factors. It is also found that experiences and inputs of project management is important for the attitudes, where negative experiences are important to limit and avoid, in the study it is found that digital tools help in this pursuit.

3.3.1 Dalux Software

Dalux is a software developer with headquarters in Copenhagen, Denmark. By 2019 Dalux had users in 115 countries. The overall projects uploaded in Dalux by 2019 reached 170 million square meters (Dalgaard, 2019). Dalux state that their strategy is assertive and the goal is to release four major releases per year (Dalgaard, 2019). The most recent development aims at enabling higher Dalux usage at infrastructure projects, where Dalux Infra will have similar characteristics as Dalux Build described beneath (Raundahl, 2020).

Dalux is divided into different modules which a customer can choose to use. The main package for production purposes is the Dalux Build package which contains the modules Dalux Box, Field, Tender and Handover. However, it is possible to buy the license for only parts of the package (Raundahl, 2020). For each of the modules several functions are provided. Dalux Box aims at meeting the needs of the planning and design stage, but also to serve as cloud file storage for the Field module. In this storage environment the planning team can collaborate with functions as for example reviews, public markups or comparing drawings. Further the software also has the ability to link drawings with hyperlinks (Dalux, 2020a). The Dalux Field module aims at serving the production phase, it has different functionalities related to

managing and documenting the production. The Tender module enables communication and file storing in relation to the tendering phase, further it provides valuable logging of tendering activities. The Handover module enables for the data collected and processed during the design and production stages, to continue into the management and operations phase of the project. The module allows for export of data trough PDF, Cobie, or transcending into Dalux FM.

For the facility management phase of the building lifecycle the Dalux FM package represents the role of the Dalux Build package during the construction phase. The FM package consists of around 10 different modules (Raundahl, 2020), which spans from budgeting, helpdesk, supplier management, work orders and much more.

All Dalux modules can be stand alone in usage, however, the main benefits of digitalization comes with the connectivity where all modules are interconnected, in that way that the information and data can flow and be exported to the next stage (Dalux, 2020a). Data can also be exported to file formats outside Dalux at any given moment, as Dalux is clear that the ownership of the data belongs to the customer (Raundahl, 2020). Dalux is supporting client ownership and open formats, one such feature is the open API.

The above described modules are provided under license to a price agreed between each company and Dalux, with other words there is no fixed pricelist. Currently there are a few different options on how the companies buy the Dalux license. Either the individual projects buy the software and pays from the project budget, or the company buys a company license and provide the software to the entire organization through an overhead cost, the last way is that the company buys a company license but charge the project budgets for the share of the license. The pricing is based on construction gross area and does not limit the amount of subcontractors, consultants, clients, or individuals working in a specific project (Raundahl, 2020)

In neighboring Norway, 4 out of the 5 largest contractors now have company license (Byggeindustrien, 2018). For the Swedish market there is no official metrics on how much of the modules and to what extent the customers use the software. However, four of the ten largest contractors in Sweden use the software to some extent and on the Dalux Field webpage it is displayed that many of the large segment contractors are customers as well. (Byggeindustrien, 2018).

The Dalux modules Tender, Box, Field and Handover can be stand-alone applications with functions for the different phases, however there is no clear boundary from Dalux Box or tender transitioning into Dalux Field transitioning into Dalux Handover. Instead they overlap, this has a natural explanation as a lot of the functions used in planning also have a role to play during production and later in the facility management package provided through Dalux FM. In many projects the production and planning take place side by side. When taking these characteristics in to account it can be argued that there are advantages in working in a common environment (Dalgaard, 2019). The common environment defined by Dalux is displayed in *figure 7* in appendix 3.

3.3.2 Dalux Field

As described in the previous Chapter Dalux Build and more specific the Dalux Field module is the part of Dalux that is aimed at supplying the construction site with BIM and ICT. The Dalux field software have four main functions namely *Locations, Tasks, Planning* and *Forms,* displayed in *figure 11* in appendix 3. The location functionalities of provide both 2D and 3D visualization. The Field software presents a link between 2D drawings and 3D model as can be seen in *figure 8* in appendix 3, where a green dot represents

the viewer location and direction of sight in the 2D drawing, relating to the 3D model view to the right. Another function is that a 2D-drawing can be visualized in the 3D-model, this is illustrated by *figure 9 and 10*, this is possible since the Dalux manager on site program the spatial relation between drawing and model. In the 3D view the user can use cut, box cut, and filter views to more easily visualize the information searched for. For example, that can be a structural cut showing how the installations should be built in a closed shaft.

In addition to the 2D and 3D visualization in Dalux Field there is also an AR- *Augmented Reality* function which works for mobile usage on site. Basically, the reality captured through a device camera is integrated with the model and displayed on the device (Dalux, 2020d), an example of the application is given by *figure 16* in appendix 3.

The task management provided in Dalux Field provides a relation to the spatial environment where tasks can be communicated. *Figure 11* displays a 2D blueprint where finished (green), ongoing (orange) and not yet started (red) tasks are displayed. *Figure 12* presents a real time statistical overview of the total project task progress. The task function can be used to delegate and manage site work through work orders, document and manage deviations, contract changes, quality, self-inspections, or any other administration that the site management think are suitable to document in a field application, the creation interface is displayed in *figure 15* and *figure 13* for mobile use.

The planning feature allows site management to set up tasks and forms in relation to time and a spatial location. In this way a manager can plan when and how for example a self-inspection should be performed (Dalux, 2020b). The forms function presents the user with an opportunity to integrate checklists in the project, one example of the forms interface is displayed in *figure 14*. The project administrator can build up and design project specific checklists or import from other projects or company templates. Commonly this function is used for self-inspections for skilled workers and sub-contractors, work site registration, safety inspections, work planning, or daily project journal. All above functions also have an interoperability, for example the team performing the safety inspection can use the same form to hand out tasks to responsible workers.

Dalux supports multiple file formats such as IFC, DWG, DWFX, RVT, PDF, PNG, and JPG, which corresponds to the most common formats for 3D models and 2D blueprints. For Revit users a plugin allows for direct import of models to Dalux (Dalux, 2020c).

The application is available both as a Webb service but also as a mobile application for field use, it is also utilizable for offline usage.

Dalux suggests that the field software can be used for:

- Deviation management and reports
- Change and modification management and reports
- Q&A, *questions and answers*
- Report of hindrance
- General documentation

- Tasks
- As built documents
- Health, safety and environment management and reports

Parallel with Dalux Field a free BIM viewer is also provided by Dalux. This can be used to view models of different formats. Both the field and viewer applications can be used on computers and other devices and applications support both android and iOS operating systems. The application can also work in an offline mode.

To end the theoretical Chapter on Dalux it is also appropriate to account for what previous academical knowledge and research that has been found on the subject. In a thesis looking at Dalux and Bluebeam implementation at one of the biggest construction companies, Håkansson and Dannfors (2019) found that in order to increase the acceptance for the software the management as well as the skilled workers need to be given education. In this way Håkansson and Dannfors (2019) argue that the acceptance will increase, further, they argue that offsite education can reduce the frustration on site. The need for education to increase the rate of implementation was also found a the study conducted by Sandahl and Sernemyr (2018). Further they elaborated on the need of clear guidelines, purposes, visions, and goals in order to understand and legitimize the change. Håkansson and Dannfors (2019) also argued that a prominent function in these software is the ability to adapt the interface and number of functions according to the needs of different user groups. Adding that a great way to start for skilled workers is to use the software for visualization, whilst site management need to show leadership by utilizing more of the tool. A study aiming at clarifying the situation in the Norwegian construction industry found that Dalux increased the efficiency in deviation handling and also that the number of reports increased (Banka et al., 2019). Fredriksson and Persson (2019) found that Dalux enhanced site communication, however for the full potential of the tool it was concluded that more of the actors on site needed to start using the tools. K. Persson and Gårdelöv (2017) found that Dalux improved site efficiency, reasons being less rework, less double work, elimination of unnecessary movement, and better document management. However, it was found that appropriate conditions for implementation required freeing time from the quite stressed work environment of the site management.

4.Result And Analysis

In this Chapter results and analysis of the conducted interviews and observations are revealed. Existing guidelines regarding digital tools in the studied company is also presented. Finally, the interviews and observations are compared to the theoretical framework from an objective standpoint, forming the analysis.

4.1 Interviews

This Chapter will present the results from the interviews conducted during this study. All interviewees where asked about digital tools in general and specifically about Dalux. However, since all interviews where done with connection to Dalux some answers might have been influenced by this fact.

Below is a table over the interviewees, what company they represent, and their abbreviation in the following text. Company A is the studied company, at which most of the interviews where concentrated. Various positions at several projects have been interviewed within Company A. Interviewee VDCD and VDCE were interviewed together as well as Head PD and Head VDC, other interviews at Company A where individual. VDCD, VDCE, CE1 and CE2 are part of Business region south, of Company A. Head PD and Head VDC are central roles in Company A. While SMN is a central role in the Norwegian part of Company A, SMN is the only interviewee based outside of Sweden. The rest of the interviewees in Company A are part of business Region west of Company A. Worth mentioning is that the role of VDC Developer (VDCD), which is a role that has responsibility for development of digitalization and also act as a support function for regional VDC-networks, is financed by each region and does not exist in any of the other Swedish business regions of Company A. The main focus will be on Company A since it is the studied company, a shorter comparison of interviews with representatives at other companies will be done separately in Chapter 4.1.8.

Company B is one of the top ten biggest construction companies in Sweden and CE-B works at a large project within the company. Company C is an affiliated company to Company A, BM-C and S-C are working at a large project within Company C and where interviewed together. QEHS-C has a central role but where interviewed in connection to the project where BM-C and S-C are working. Company D is a medium sized company where PM-D and SM-D where interview together at one of the company's larger projects. Company E is one of the top five biggest construction companies in Sweden and the visited project is roughly the same size as the project at Company D. However, the site visit at Company E did not result in a formal interview, therefore conversations with S-E will be presented as observations. Finally, a representative from Dalux was interviewed since Dalux is the main software discussed in this study.

During some site visits, observations have been made at site tours, team leader meetings, VDC-network meetings, Dalux workshops, or safety inspections, these will be presented separately in Chapter 4.2. Some skilled workers and other staff were also talked to briefly during a few site visits and relevant results from these discussions are also presented as observations.

Company	Position of interviewee	Designation in report	Date of interview
A	VDC Developer	VDCD	2020-02-25
A	VDC Engineer	VDCE	2020-02-25
A	Construction Engineer	CE1	2020-02-25
A	Construction-/VDC Engineer	CE2	2020-02-26
A	Head of Production Development	Head PD	2020-02-26
A	Head of VDC	Head VDC	2020-02-26
A	Site Manager	SM1	2020-02-27
A	Supervisor/VDC Engineer	S1	2020-02-28
A	Supervisor	S2	2020-02-28
A	Supervisor/VDC Engineer	S3	2020-03-12
A	Supervisor	S4	2020-03-13
A	Site Manager	SM2	2020-03-16
A	Supervisor	S5	2020-03-16
A	Supervisor/VDC Engineer	S6	2020-03-19
A	System Manager Norway	SMN	2020-04-10
B	Construction-/VDC Engineer	CE-B	2020-03-10
C	Block Manager	BM-C	2020-03-12
C	Supervisor	S-C	2020-03-12
C	Head Developer of QEHS	QEHS-C	2020-03-18
D	Production Manager	PM-D	2020-03-16
D	Site Manager	SM-D	2020-03-16
E	Supervisor/VDC Engineer	S-E	2020-02-06
Dalux	Digitalization Consultant	DC-Dalux	2020-03-12

Table 1 - List of interviewees, what company they represent, and their abbreviation in the text

4.1.1 Greatest advantages of digital tools in production

When the interviewees where asked about the greatest advantages with implementing digital tools into production, there were some answers that where quite common or similar. Improved and transparent communication concerning who should do what was emphasized by most of the interviewees. In addition, having information accessible at any given time was a commonly mentioned advantage. Most interviewees also agreed that the documentation that comes with digitalization is very useful. Furthermore, the usefulness of the documentation for follow-up was highlighted, both for knowing what work is done and for generation of information that can be used when discussing issues in a later stage. VDCE and CE2 argued that storing more information digitally helps with generating experience feedback that can be used for organizational learning. SMN stated that from a strategic management perspective, one vital benefit of working digitally is that the decisions can be based on statistics and information gathered from previous projects rather than personal knowledge. Another common advantage discussed was visualization, both while looking for mistakes in the 3D models and for ensuring that everyone at the project get a clear and unanimous picture of what they are building. Overall, most interviewees agreed that digital tools increase the quality of projects as well as saving time and money.

While asking the interviewees about their impression of Dalux there was also some similarities in the answers. Several interviewees pointed out the automatic documentation and follow-up as an important feature, both for monitoring tasks and for perspicuity of information. Furthermore, increased efficiency as a result of always carrying a lot of information in their phone or tablet and instant delivery of work orders was emphasized by several interviewees. The transparency and improved overview of the project while using Dalux was also highlighted as a prominent feature. All interviewees that had used Dalux to some extent in projects believed that Dalux makes the projects more efficient, and several interviewees emphasized that it also increases the quality of the projects. Furthermore, most interviewees agreed that the supervisors and subcontractors have the most to gain while talking about efficiency increase from using Dalux. Other roles such as site managers and construction engineers also become more efficient, mainly through a better overview of the project and automatic generation of information that can be used for handling issues. S3 explained that it has never been easier to get reimbursement from prefabrication contractors. This is a common issue area shared by several interviewees, which becomes easier to handle by using Dalux.

All interviewees were positive towards Dalux, even if several stated that there was room for improvement in some areas. SM1 and S5 experienced some difficulties while setting up the project in Dalux and troubles with getting the new users to properly describe issues when adding them to Dalux. Several interviewees stated that the construction journal function could be improved. S3 wanted the journal to be saved by date, not by number as it is now. CE2 did not use the journal function since Dalux was added to the project later than they start writing the journal and they did not want to pay the full cost of their Dalux version to only use the journal function. S4 felt that it is time consuming that information in the journal does not automatically follow to the next day, since a lot of information is the same for several days. Overall, most experienced issues with Dalux was either due to a smaller issue seen as an improvement area, or due to inexperience and lack of routines for using the software.

4.1.2 Biggest obstacles to implementing digital tools in production

When discussing obstacles to digitalization in production, unfamiliarity and lack of knowledge was the most common subject among the interviewees. The construction industry, especially production, is seen by the interviewees as lacking experience of working digitally. It was described by several interviewees that learning to use digital tools is seen as an obstacle, once individuals learn to use digital tools and realize how useful they are, the resistance is gone. S4 clarified that there is resistance to digitalization at all levels of the construction industry, while it might be more evident in production. Both S4 and CE1 have felt that there is often a lack of knowledge and interest from the client, especially among public clients. Contrary to this, S6 experienced great interest towards digitalization from the client at the specific project, even pressure to become more digital and improve the outcome of the project using digital tools. S4 experienced that there is often more knowledge among the contractors even if there is resistance present in these organizations as well. SM1 perceived that the management within the organization does not support digitalization enough, site managers often lack understanding and there is not enough initiative among some supervisors. Furthermore, S4, CE1, and CE2 described a lack of interest from some subcontractors, that some subcontractors feel they have done something successfully their whole careers and does not see the need to change their way of working. Connected to this, SMN argued that too much focus on the tools rather than human aspects, which was described as the biggest obstacle to digitalization. While S2 and CE2 explained that the lack of routines and common working methods in the organization is a substantial obstacle to digitalization.

Issues about who should lead the digitalization was also discussed. SM2 explained that one obstacle is that someone needs to maintain the digital tools and if that person leaves the project it is time consuming for someone else to familiarize themselves with the task. CE2 argued that it is up to the supervisors and site management to lead the digitalization and get the subcontractors to actually use the digital tools. S5 believed that digitalization is a generation issue, that the younger generation is more used to digital tools and that therefore digitalization will come naturally with younger generations. At the same time, S3 felt that an obstacle to digitalization is that it is mainly the younger generation that drives the digitalization and that everyone must partake in order to properly utilize the digital tools. Connected to this, S4 argued that digital tools must become more user friendly, tools such as Solibri or Revit are too complicated for users without education or experience from working digitally, which is the case with many skilled workers. S4 explained that in order to properly implement digitalization in production, the digital tools must be usable by everyone at the site. SMN described that one obstacle to implement tools is the size of the organization, a large and complex organization will naturally take more time and effort.

While talking about reasons for falling back to more traditional methods instead of digital tools the most common reasons were old habits, time pressure, and lack of knowledge about the software. The interviewees explained that when there is a lack of time or a stressful part of the project, many users tend to go back to traditional methods out of habit and because they are more comfortable with doing what they are used to. Furthermore, when there are problems with the digital tools, some new users lose faith and interest in the tools. S1, S6 and CE2 explained that it therefore is important to decrease the obstacles for digital tools and teach new users how to properly use them. S4 and S5 added that if a project decides to use Dalux for task management, it is important that all supervisors in the project are consistent in using the tool. Clarifying that if one supervisor go to the site and grab skilled workers telling them what to do without adding it to Dalux, other supervisors will not get any tasks done and the system will fail, since the workers listen to the supervisor asking them face to face. SMN stated that a key to not falling back on traditional methods is the management, they need to show that they believe in the new methods.

4.1.3 Time and support for implementation

Time and support for implementing digital tools was a subject with varying answers. SM1, SM2, S5 and CE2 felt that there was not enough time to properly implement digital tools. While CE1, S1, S4 and S6 felt that they do have the time. However, S4 explained that it was because of the type of contract, and S6 had time because the client was very driven about digitalization. Furthermore, S2 and S3 explained that the time pressure is periodical. They have time now because of where they are in the respective project, but when the supervision becomes more time consuming, they do not have the time needed to work properly with digital tools.

CE1 and CE2 felt that there is support for digital tools, mainly through their regional VDC-network and VDCD. However, both felt that there is less support for employees outside the VDC-network. CE1 and CE2 acknowledged that it is improving, but the support should be structured better with clear support roles for each project. All the employees in Business region west of Company A, except for S1, argued that these is a lack of support within the region. Most support is currently found through informal networks and more formal support is needed, preferably in new roles like the one of VDCD. Worth mentioning is that S1, who is the only one within Business region west who felt there was enough support, listed VDCD as one of the sources for support.

Head VDC, Head PD and VDCD explained that they do not have enough time to support the projects fully in the implementation of digital tools. Furthermore, that the organization needs to hire more personnel to act as support within the organization, adding that some new roles might be needed. VDCD acknowledged that it is difficult to find personnel with proper competences or educate existing staff, but that it is needed within each region to properly digitalize the production. Head VDC and Head PD felt that they get support in their roles but that they are understaffed to handle all the tasks needed to fully utilize the digitalization of the organization, since they also have to visit projects to teach and pitch the digital tools to the employees.

There are mixed views among the interviewees concerning how work with digitalization is rewarded within the organization. Several interviewees feel that they are highlighted within the regional VDC-networks, while less attention is given to digital work in the wider organization. S1 explained that sometimes work with digitalization is highlighted outside of the VDC-networks in central meetings or in the online workplace environment, but it would be desirable if it was given more attention. SMN shared similar thoughts about the situation in Norway. Several interviewees also explained that they feel that digitalization is rewarded but not as much as other more traditional areas such as economy, quality, and QEHS. S4 explained that these traditional areas might be affected positively by work with digital tools, but it is difficult to clearly point out what was improved explicitly by digitalization. Head VDC, Head PD and VDCD stated that they are trying to raise the status of digitalization within the organization. Some interviewees also stated that one of the main reasons for their choice to work for Company A is because the company is striving to work more with digitalization. However, several interviewees argue that more time and support is needed within the organization to ensure that all projects are working with digital tools in a common and structured way, and on the same level of digitalization. SMN argued that if a support package is presented and standardized for the projects pursuing digitalization, especially in the start phase, less time will be consumed from other duties.

4.1.4 Routines and guidelines

All the interviewees agreed that there is a lack of guidelines and routines for digital tools within the studied company. Some interviewees explained that there are a few guidelines for tendering- and planning tools, and that the existing BIM-manual is useful for project planning. However, they all felt that there is need for more and better guidelines. CE2, S3 and S4 explained that there is a will from the organization and employees to work with digitalization but there is no clear plan for how and to what extent. Several interviewees emphasized the importance of ensuring a common way of working with digital tools and a common minimum level of digitalization among all projects, to achieve more widespread usage of tools. CE2 argued that at the moment, a lot of knowledge about digital working methods comes from personal knowledge of VDCD, within Region south, and that with common guidelines the organization would become less dependent of individual knowledge. Building on this, S4 explained that there is often resources and competence but a lack of standardized working methods. However, S3 and S4 felt that while guidelines and a framework is needed, there is also a need for freedom and creativity while using digital tools so that the users can continue develop better ways of using the tools and have an outlet for their creativity.

SM1 and S5 explained that a basic framework for the starting projects in Dalux would lessen the obstacles for new users. SM1 brought Dalux into the current project because several colleges had described the software as useful for the projects. However, start using Dalux was described as a blank sheet of paper and SM1 had to spend a considerable amount of time getting to know the software alone. If a basic

framework existed, ideally combined with a support function where someone could come to the project and show the employees how to use the software, SM1 believes that Dalux would be used more widespread and to further extent. SMN revealed that in Norway they released a framework for deviation handling in Dalux in November 2019, and that they are working on more checklists. SMN also made a parable with the mechanic team in a Formula 1 racing team, where the driver makes a quick pit stop to get new tiers and then race on. Rather than having to exit the car, fetch the lug wrench and change the tires himself, the team is prepared and support the driver in this. The same support should be given with digital tools to the projects, where the project should focus on the production and the operational support should feed them with clear routines and solutions so that the project can simply race on producing.

VDCD explained that they are working on a better packaging of their toolboxes for the digital tools and Dalux in particular. This work is under progress in collaboration with Head VDC. VDCD wants the toolboxes for Dalux to be clear and user-friendly enough so that only a starting meeting is needed to allow the projects to use the software. VDCD elucidated that the aim is to create a framework that will be a standard for the whole organization in Sweden. The goal is to create standard functions that must be used by all projects and create common checklists and terms so that all users use the same terminology. This common way of using the software is needed to be able to generate metrics and statistics that can be used to develop the working methods within the organization, according to VDCD.

4.1.5 How to increase usage of digital tools

While discussing how to increase the usage of digital tools there was a lot of ideas from the interviewees. Although, the interviewees also acknowledged that this is a complicated issue to solve. Most interviewees pointed out education and support as two vital factors. The degree of education for digital tools could be varying. While talking about Dalux most interviewees agreed that bringing someone out to the site office to explain how the software works and show the project how to use it would be enough, especially for the personnel who would only be using Dalux. For staff that will be administrating in Dalux or wants to get a deeper understanding of the software, a more formal education was described by SM1, S2 and S5 as more suitable. However, several other interviewees argued that bringing someone out to the project to give an introduction and showing them the software would be adequate for all users, as long as there was support available when needed. Furthermore, some interviewees argued that web-based education or instructional videos should be enough for most users. While other interviewees believed that it is vital that someone comes to the project, at least until they reach a wider usage of the software. Arguing that web-based education would not be used by users that are not particularly interested. Most interviewees did however agree that a support function is very useful to lessen the obstacles for new users to start using Dalux, especially in the beginning of projects when there is most work to be done with setting up the software. When the projects are running the interviewees believed that less support is needed, even if on-site support is still useful to get the most out of the software.

Most interviewees also agreed that toolboxes and guidelines for the digital tools are vital to increase the usage of the digital tools. Furthermore, to increase the potential benefits that can be gained from digital tools since frameworks would ensure that they collect better and more structured data. CE1 and CE2 explained that the VDC-network in south support each other and are trying to create a common working method. However, CE1 and CE2 experienced difficulties with connecting the regional networks with each other, and problems with spreading the knowledge throughout the entire organization, outside the VDC networks.

When talking about Dalux, several interviewees stated that it would be helpful if it was stated in the contracts with subcontractors that Dalux needs to be used. Explaining that it would not be enough to try to force the subcontractors to use the software, selling the tool is still important, but adding Dalux to the contract will help when recalcitrant individuals simply refuse to use the software. Connected to this, several interviewees argued that the digital tools need to become more user friendly in order to reach a wider usage. S3 pointed out Dalux as one of the more user-friendly digital tools, while S5 argued that Dalux still need to become more user-friendly. Most interviewees agreed that it is important for everyone at the projects to use the tools in to get a wide-spread usage of digital tools. To achieve this, several interviewees believed it is necessary to keep reminding and encourage the users to continue working with digital tools. Some interviewees argued that to increase the usage of Dalux, the central organization needs to push it out more into production with a central decision that it is a tool that should be used by all projects. However, S4 underlined that the central organization needs to communicate with production to understand what tools they want and how they want to use them. SMN stated that the key to increased digitalization is the human aspects and processes, rather than solely focusing on the tools. Adding that standardized working methods and common processes are vital.

VDCD had many similar ideas as the other interviewees. VDCD wanted to create a toolbox that could be a support for the users, along with clear guidelines for how the digital tools should be used. Explaining that they need to show the utility of digital tools to the whole organization. With better guidelines for how to use the digital tools, VDCD believes that it will be easier to collect and export useful data from the projects, making it simpler to show the benefits of digital tools. Furthermore, VDCD underlined that new roles are needed, with clear responsibility for different digitalization areas or issues. Arguing that it is relatively easy to reach a high degree of digitalization in a few pilot projects, but more support and resources are needed to rise the digitalization level throughout the whole production. VDCD believe that they need to educate the organization about digitalization and that it is vital to better support the beginning of projects to introduce the digital tools as early as possible. At the moment, some projects are given digital tools with very little instructions and no learning period, often while the projects are already running. VDCD has also noticed so issues with the BIM-models, since the development is happening relatively quickly some suppliers cannot deliver by the new standards needed, which can cause problems for Company A.

Head VDC and Head PD believed that usage of digital tools has started to spread autonomously since employees have started talking to each other about digitalization. However, they argue that the most efficient way of spreading usage of digital tools is if someone comes out to the projects show the tools, and that the role of VDCD is vital to increase digitalization within the organization. Also, adding that it is a kind of internal selling and that they need to show good examples of when digital tools have been used to the organization. Furthermore, explaining that central education could be useful, but only once the usage has spread and the digital tools are used throughout the organization. Finally, Head VDC and Head PD argued that digitalization should be part of the job description of all employees working in production, the tools already exists, they simply need to become part of the standard work methods.

4.1.6 Follow-up on implementation and collected data

None of the interviewees working in projects have done follow-up on data collected from digital tools. Mainly because it is a new way of working and some of the projects are still running or even in the starting phase. CE2 had started looking at collected data but felt there had been a lack of time to do it properly. While SM1 explained that it would be interesting to evaluate collected data but did not really know how to do it. However, the interviewees were overall positive towards follow-up on collected data and saw

great potential for doing so in the future. S4 explained that in order to be able to collect useful data from the projects, they must have a system for collecting data. Clarifying that they are still learning to use tools that collect data from projects, therefore they are collecting data rather randomly and the data is at risk of becoming white noise instead of useful statistics. Head VDC and Head PD stated that they want to better sort data collected regarding suppliers, issues, and contract changes which can help them evaluate projects and suppliers.

VDCD explained that there are projects where they have used data collected about recurrent issues with prefabrication and was able to notify the supplier so that they could correct the issue for remaining parts. The prefabrication supplier had been surprised and, at first, a bit skeptical to the numbers of mistakes reported through Dalux, explaining that they had not gotten such direct feedback with documentation from projects before. Prefabrication have been a regular problem area for several interviewees. The interviewees explained that mistakes in the prefabricated parts are quite common due to various reasons. Adding that it is often quite time consuming to get reimbursement from the prefabrication suppliers and that sometimes the contractor instead solves issues, such as missing piercings, by themselves to save time and avoid conflicts. Therefore, VDCD saw great potential in this and other experience feedback areas. VDCD also stated that they have started to compile data in other areas as well, but that it is at a small scale at the moment and there is considerable potential for more.

SMN explained that in Norway they are analyzing data from the approximately 130 projects that have used or are using Dalux. The goal is to take more informed decisions and estimations in new projects based on information collected in previous projects, where decisions today often is mainly based on personal knowledge. Furthermore, they are trying to find areas where the different business regions within Norway are better or worse so that they can learn from each other. Adding that there is also potential for analyzing and improving safety at the construction site through data collected from Dalux.

While discussing the follow-up on implementation of digital tools, Dalux was the main focus. None of the interviewees at projects stated that they do any organized follow-up on implementation. CE2 was trying to do some follow-up but did not feel there was enough time to do it thoroughly, VDCD provided some aid in this area but more was needed. Otherwise the follow-up on Dalux was based on talking with users, seeing that phones were used for work at sites, and observing in Dalux that some functions were being used. S3 and S5 stated that they try to remind the staff to use Dalux, especially if someone came with questions that could be solved using the software. Furthermore, S1 brought up Dalux usage on a team leader meeting on the day of the interview and was planning to do more follow-up. SM2 explained that since there are no set goals for digitalization within Business region west, and that it is therefore difficult to follow-up on the progress of digitalization. Furthermore, that it would be helpful if they had a role who worked with this within the region, something similar to VDCD in south.

VDCD is responsible for following up on digitalization and give support within Region south but felt that there is not enough time to do this as thoroughly as desired. Head VDC and Head PD explained that they do not have any structured follow-up on implementation at the moment and argue that optimally they would have automatic follow-up. Clarifying that in the future it would be helpful if they would be notified automatically when projects are not using different functions in Dalux as much as they should or not at all, so that the organization can contact the projects and offer them support. SMN stated that in Norway they have started doing more organized follow-up on the implementation, where the central group have

regular meetings and they are working more actively to collect feedback from the users in production. Trying to implement the tools bottom-up rather than top-down.

When the interviewees where asked about if the felt that there was any encouragement or pressure to use digital tools, there were some variation in the experienced encouragement. None of the interviewees felt pressure, but most acknowledged different levels of encouragement. Most interviewees told that overall, the organization is encouraging digitalization, however, the attitude towards digitalization is varying at different levels and between individuals. Several interviewees stated that they feel encouragement from their closest superior or driven personnel at their current project, but that there was less support from higher levels in the organization. S3 and S4 felt that at the top levels of the organization, digitalization is encouraged but that there are mixed attitudes towards digitalization in the middle levels of the central organization, Head VDC, Head PD and VDCD also shared this perception. S4 elaborated that it is suitable if the production shows what digital tools should be used but that they need to be backed by the central organization as well. Arguing that the central organization needs to change the role descriptions and standards to be more suited towards digitalization, while acknowledging that this is often demanding and time consuming because of bureaucracy. Several interviewees experienced that the interest in digitalization has started to grow within the organization and S5 felt that digitalization is encouraged throughout the organization. CE1 argued that there has been more encouragement since VDCD became part of Region south, while SM1 was missing someone that can encourage and support the projects in Region west.

Head VDC and Head PD explained that they try to encourage individuals that show interest or are driven in digitalization and spread the digitalization trough these individuals to their colleagues. This perception is shared by several interviewees that felt that if they have ideas regarding digitalization, they are often encouraged to continue and be innovative. Head VDC, Head PD and VDCD explained that some colleagues are impressed and interested in their work, while others mainly view their work as playing around with computers and flying with drones. VDCD explained that they need to better show the advantages with digitalization in economic aspects to gain wide-spread acceptance, which often is quite difficult. Furthermore, that another reason for the lack of interest is that VDC is quite abstract as a concept and keeps changing.

4.1.7 Interview with representative at Dalux

The interviewee at Dalux, DC-Dalux, had many thoughts similar to interviewees at Company A, but there were also some differences. DC-Dalux agreed that one of the biggest advantages of digitalization in the construction process is that information gets documented. Less information is stored only in the mind of supervisors and can instead be documented and shared with others in the project. DC-Dalux believe digitalization gives a better overview and it makes it easier to structure work in the projects.

While talking about the biggest obstacles, DC-Dalux argued that construction companies has had a skewed focus when it comes to digitalization. Explaining that many companies have focused on the tools needed and recruiting someone to be responsible for the tools, without regarding the work processes that needs to change in order to implement digitalization. DC-Dalux believed that an increased focus in change management would be the most highlighted outside of the VDC-networks way to increase digitalization in production. Clarifying that companies should consider how they can change their organization to better utilize digitalization.

DC-Dalux stated that at the entry step to Dalux, the BIM-viewer is the most used function. When customers use Dalux Field and Box, the integration between 3D and 2D is one of the most used functions. DC-Dalux believes many skilled workers feels comfort in something that they are used to, like 2D drawings, and that they start using more functions as they get used to the software. Dalux focus on being user friendly and add many simple functions in order to get new users to get comfortable with the software, DC-Dalux explained. Adding that overall, the response from the users has been positive towards the software. Some skilled workers have experiences added work due to self-inspections that are forced to be done more directly and thoroughly, but most admit it will be favorable in the long run. DC-Dalux also entailed that Dalux has about 40 000 logins every day and only two employees working with support, which can still handle the workload, hinting that there are few issues regarding the software. DC-Dalux and representatives in other countries also talk to their customers and support them when they can, but normally not regarding technical issues.

Regarding the Development of Dalux, DC-Dalux explained that they have two main methods. One is where Dalux talk to their customers and try to understand what they demand and what features Dalux needs to develop from that. The other method is where Dalux work together with the Technical University of Denmark, DTU. Where they develop new function together, based on new technologies or innovative ideas that they believe can be useful for the construction industry. For instance, the Dalux AR-function, TwinBIM, is based on a master thesis from students at DTU working with Dalux. DC-Dalux also explain that Dalux try to work closely with their customers to get feedback on the development of their new functions. During the development they ask customers for feedback and thereafter adapt their functions if there are issues to be resolved or features to be added, this is done all the way to the release of the functions. Sometimes this leads to Dalux not having fixed release dates, which can be frustrating for some customers but is part of the development plan at Dalux.

Concerning ownership of information, DC-Dalux explained that the customer owns all the information stored in Dalux. Adding that after a finished project there are different ways of storing the information depending on the contract between the customer and Dalux. Either Dalux can archive and store the data for the customer or all the data can be exported from Dalux and stored elsewhere.

4.1.8 Interviews with representatives at other construction companies.

Here the results from the interviews with representatives from Company B, Company C and Company D are presented. The interviews showed that many of the problems described at Company A are recurrent issues at other construction companies trying to implement digital tools into production. QEHS-C, PM-D and SM-D pointed out the difficulties in showing actual numbers of economic gains from digitalization as one of the biggest obstacles. All the interviewees agreed that the time needed to properly learn how to use the new digital tools and the time needed to continuously administer in the tools is a difficult issue to solve. While all interviewees agreed that the visualization from digital tools in production is a great advantage. Furthermore, CE-B, QEHS-C, BM-C and S-C underlined quality control through digitalization as a very useful area. CE-B explained that in their project they do self-inspections through Dalux which forces the skilled workers to do the controls in direct connection to when the actual work is done. Additionally, the controls are done more thoroughly since Company-B can lock fields in the checklists, which prohibits sloppy self-inspections that previously has been an issue. While QEHS-C highlighted the automatic documentation that comes with digital tools as an important advantage. Clarifying, that the documentation becomes explicit, partly because photos can be added, and since everything is stored digitally there is better traceability.

CE-B, S-C and BM-C felt that there is often a lack of time for implementation of digital tools. CE-B explained, similarly to some interviewees at Company A, that the time pressure is periodical. While QEHS-C, PM-D and SM-D believed that it is up to the ones spearheading the implementation to make time for digitalization. QEHS-C argued that if the employees do not feel they have the time needed they should not be the one in charge of the digitalization. Adding that the implementation should be led by individuals who are interested and driven within digitalization, that will make time for the added work.

Regarding support, Company B and Company C did not have any formal support within the organizations. For issues concerning Dalux they contacted support at Dalux. A consultant working as BIM-coordinator at the specific project could be used by CE-B, but the support was limited. Furthermore, CE-B, BM-C and S-C did some informal support for other employees and projects since they were pilot projects in their respective organizations. Company D had a digitalization leader who was at the project in the beginning who could support PM-D and SM-D. However, the digitalization leader had left for another project whereafter the work with digital tools decreased. The digital leader could still be contacted for support, but the usage of that support was sparse.

While talking about if work with digitalization was rewarded within the different organizations, the views deviated. CE-B described something quite similar to what was described at Company A, that there are very mixed views about digitalization within Company B. Explaining that some employees were impressed and interested in work with digitalization while others had little interest. QEHS-C explained that at Company C they do not explicitly reward digitalization but if employees shows interest for a certain field and is driven, Company C tries to create possibilities for them to work within that field. Adding that if that field is within digitalization and they do a good job they reward their work, which can lead to rewarding work with digitalization. BM-C is part of a reversed mentorship within Company C where newer employees meet with the top organization to discuss future work areas for the organization. Pointing out that one reason for being chosen for the reversed mentorship is because BM-C is driven within digitalization. While PM-D and SM-D explained that Company D want to evaluate what value digital tools brings to the production, partly by observing efforts at other companies, before rewarding work regarding digitalization of the production.

All the interviewees explained that there is a lack of routines and guidelines concerning digital tools at their respective company. At Company C and Company D there were manuals for some digital tools, but they needed to be improved. While CE-B explained that there are no guidelines at Company B. PM-D and SM-D argued that at large companies there is a problem where the development department, deciding what tools to use, is quite far away from the production and they do not always understand what the production needs.

BM-C and S-C argued that guidelines and frameworks for how to use digital tools is important to increase the digitalization, especially in the beginning of projects. PM-D and SM-D argued that having someone in charge of digital tools with time allocated for the work is vital, along with improving the quality and reliability of documents in tools such as Dalux. While CE-B felt that the central organization needs to clearly communicate what tools should be used, steering the project in their digitalization. Adding that it is a change that needs to take some time, the construction industry is conservative and therefore things will not change in one day. QEHS-C in-turn suggested that if they can show economic gain from digital tools more explicit it will be easier to spread digital tools. Arguing that if they can show the economic

value, it would be of interest for the whole chain from the client to subcontractors to implement digital tools.

As in Company A, none of the interviewees had done any follow-up on collected data but they all felt that there is potential to do so in the future. QEHS-C argued that following-up on collected data is one of the areas where there is most to gain from implementing digital tools. Adding that it is important to show the value of the collected information, not simply present statistics with little or no meaning.

Company C and Company D did sporadic follow-up on the implementation of digital tools in the production. PM-D and SM-D simply helped the users if they came to them with questions. BM-C and S-C argued that they are working in a tight team in their project and therefore they notice quite quickly if anything is not working. Adding that they had done some follow-up, checking if some tasks in Dalux were completed or not, but very limited. CE-B tried to do some structured follow-up on implementation of Dalux. Through Dalux, CE-B checked if tasks were completed, if they were not, the users in charge of the tasks where summoned to a meeting to discuss why Dalux was not used. Most commonly the users where uncomfortable with the software or personnel had been replaced, CE-B then introduced the software to them again. CE-B explained that Company B are still new to Dalux and better routines are needed in this area.

4.2 Observations

The observations where conducted at the site offices and sites visited during the study. No visited site was "paper free", meaning that printed papers, such as 2D-drawings, could be observed to some extent. Site offices where located on varying distances from the actual site, in some cases a walk of more than a few minutes was observed, implicating that forgetting to bring something to site could be a quite substantial time-waste. None of the sites visited the had the site office located where it could oversee the entire site.

4.2.1 Site hardware and technologies

Some sites had sophisticated drawing racks whilst other projects barely had any presence of printed drawings. Many sites had some sort of collaborative multimedia station where meetings and visualization could be performed, and information spread. Either in form of a horizontal installation of a touch screen in a table, or in some cases as a monitor placed in the entrance of the office. The general assessment is that this was more developed at projects where the site management were outspokenly interested in digitalization.

The skilled workers employed at the companies had company phones in varying degrees. At Company C, only workers with special roles such as safety officer, was given a company phone. When discussing digital site tools and the usage of phones at Company C, the safety officer argued that those in the company who had a company phone would need to take an increased role in also being digital communicators on site. At Company A, who also have employed skilled workers in different degrees depending on site, all workers were given a phone. It was however among these skilled workers the biggest resistance was observed. One recurrent argument was that the phone was insufficient in performance. Some of the supervisors reflected that it seemed to be some sort of collective negativity based on a cultural belief, rather than objective factors. Some sites had tablets for on-site use, these were only observed at Company E on site, and the general situation were that tablets often remained in the site office. Amongst the subcontractors of varying disciplines found on site the situation seemed to be varying, some had a company phone whilst many used their private phone. Amongst this group no tablets were observed.

4.2.2 Attitudes

Attitudes observed at the sites varied quite a lot. Many users where enthusiastic and positive, expressing the benefits that a more digital work environment could bring to them. Aspects such as easier visualization and information interpretation were raised. One ventilation worker explained the superior visualization of piping, especially when the piping did not follow a horizontal plane. Some workers admitted that self-inspections performed digital was now more work-heavy and information-rich, however they agreed that that it is probably the intention when looking from a quality perspective.

The biggest resistance and negative attitudes were observed amongst those who had digital tools at their site however, not having tried the tools themselves yet. During team leader and morning meetings it was observed how site management tried to implement and enforce the use of digital tools such as Dalux Field and Solibri. These meetings were also observed to have enhanced communication, visualization, and collaboration thanks to the use of digital tools on monitors.

Some hands-on implementation was observed at a site where Dalux field was under the initial implementation. When introducing the tool during a team leader meeting a slight skepticism was expressed. However, after being on site for an hour or so with the responsible supervisor showing some hands-on usage and benefits a change in attitude could be observed. One of the workers that just an hour earlier issued statements of having no interest in ever using Dalux Field, after seeing colleagues being positive to the tool, even asked for an invite and some instructions.

4.2.3 Network meeting

Observations were made during a VDC network meeting in business regions south, at Company A. Attending was amongst other CE1, CE2, VDCE, and VDCD. VDCD was the manager for the meeting. Once a month the professionals responsible for VDC in this region meet for half a working day to discuss digital development in their respective projects and in the region in general. The meeting started with the attendees “checking in” by presenting broadly what they currently worked with. VDCE gave an account for the evaluation questionnaire that the project VDC responsible fill out in relation to the design of the projects, from this it was for example shown that 60% of the projects did not use the models to quantify. From the design stage the questionnaire showed that prefabrication and landscaping consultants sometimes fail to deliver IFC files. The general setup of these network meetings is to evaluate and spread knowledge about routines and ways of working, as well as developing and examining new methods. To do so the network utilize a project room in Microsoft teams where a Kanban chart keep track of progress in relation to different software’s and processes.

One of the main topics for the observed VDC meeting where to evaluate how each project performs the continuous time planning and it was found that there was a big spread amongst the participants, both in terms of who is responsible on each project and how and in what software planning is performed. The network discussed the issue and decided that the next step was to initiate contact with a site manager that they knew was doing a great job in the subject, to identify best practices for next meeting. Other main topics discussed in relation to the Kanban chart where Bluebeam and how drawings could be distributed to touchscreens on site, and Solibri about collision controls and also how to do classifications. The general conclusion of the meeting was that it was partly a meeting to enhance and develop performance in selected areas and tools, but just as much a meeting to spread knowledge and enhance individual learning to create a common way of working. In the studied company two tools, namely Dalux and Solibri, are perceived as the ones to invest most time and effort in implementing.

4.2.4 Workshop

In addition to the observed VDC network meeting, a workshop in Region west was observed. The workshop had participants from Company A and Company C, in an effort to combine the knowledge of the two affiliated companies. The workshop initiative was taken by two managers, S4 and BM-C, at the two companies, sprung from a will to learn how to implement mainly Dalux. Among the participants were also Head of VDC, S3, S4, S6, BM-C, S-C and QEHS-C. One of the supervisors from the studied company who had experience from working in Dalux connected the computer to the meeting screen and showed general prerequisites and setups of the application. Experiences and good user cases was displayed and discussed amongst the participants. It was discussed that the high rate of development of the software makes established knowledge rapidly outdated, a solution to handling this is to watch the release videos given by Dalux explaining changes. QEHS-C explained that they had calculated that each supervisor on site need to reach an increase in efficiency responding to a few hundred SEK each month for the software to be financed. The representatives at the workshop agreed that his is not done in a month, rather a day. In regard to subcontractors, the members discussed legal aspects affecting the application, one being how the use of Dalux to report and document deviations can be seen as a legal documents, but also how the standard contracts used in the industry can be used to ensure that all subcontractors are procured with the prerequisites that Dalux should be used and that they should supply the workers with hardware. Head VDC displayed how metrics about completion times can be derived from Dalux and made some statistics from this in Power BI.

4.2.5 Shadow a manager

Another initiative to increase the understanding and knowledge in the domain of digital tools and the prerequisites on the construction site were a “shadow a manager” initiative. Where the study was given the chance to follow and study a digital supervisor on site, working at one of the large Swedish contractor firms, in this study named Company E.

The project was a large complex construction of a new swimming and aquatic arena, putting a lot of challenges on managing the complexity and integration in terms of for example installations. Dalux were used on site, at the time of visit the project were in the foundation and structural phase and due to this fact Dalux was used mainly as a source of visualization. However, a large sub-contractor was procured to do all electricity, plumbing and ventilation and the idea from the sub-contractor and S-E was that task management, self-inspections, et cetera, should be done through Dalux. Dalux in this sense was argued to possibly be a key to success in regard to the complexity. An interesting function tested on the model on site was the AR function in Dalux displayed in *figure 16* in appendix. For the complex design of this project it provided heavy support in visually understanding the design on site.

An interesting observation were however a discussion at the site office where the project manager, site manager and S-E participated. The three of them having quite different perceptions and ideas of how the project should be executed in terms of documentation and digital tools. Where S-E was of the belief that the organization was in talks about implementing Dalux across the organization, while the project managers believed that the current portal, which mainly was a portal of storing documents through could services, is the tool to be used forthcoming. After some deliberation, a conclusion was made while talking to S-E that this probably was a cause of the operational supporting function in VDC within the company had a quicker channel of communication to S-E. This was because S-E was also more driven regarding digitalization and eager for the information, than for example the project manager that was found to be

a little more negative towards digital change. Showing that the view within Company A where there are deviating views about digitalization in different levels of the organization, is an issue at Company E as well. Furthermore, that the digitalization is led by interested employees in projects rather than the top management at the project, also quite similar to the situation in Company A.

4.3 Existing company guidelines regarding digitalization

At the studied company's intranet there are several guidelines and instructions for how the organization wants to run their business. One major theme in the organization is to work with involvement. Their involvement strategy is inspired by Lean and consists of three parts; Involved planning, VDC, and Team (Company A, 2019d). Involved planning aims to increase productivity and reduce waste. VDC is meant to boost understanding and minimize mistakes. Team is focused on increased engagement and participation. The main idea with involvement is to create more effective production with increased engagement (Company A, 2019d).

One of the guidelines found on the studied company's intranet is the Project Planning Manual, which describes the basics for how their project planning should be conducted (Company A, 2019e). The Project Planning Manual briefly describes VDC, BIM and ICE - *Integrated Concurrent Engineering*. It is prescribed that these tools and processes should be part of all their projects planning. Specific model demands and information regarding BIM and CAD are listed in the separate BIM-Manual (Company A, 2018). The main focus regarding digital tools and processes in the Project Planning Manual is concerning ICE, all projects in the organization that use VDC should also use ICE. ICE is explained as a method meant to reduce time spent on project planning through meetings where all disciplines involved in the project planning are gathered at the same location. However, while 3D-models are often used at these meetings, ICE is primarily a certain type of meetings rather than a digital tool or process. It is stated in the Project Planning Manual that a VDC-engineer should be part of the design management, showing that digital tools and models are a vital part of the project planning. The Project Planning Manual also emphasize the importance of using metrics in all parts of the construction processes to compare progress with the established goals and to continuously improve processes (Company A, 2019e). It is recommended in the manual to use digital tools to do measurement for metrics, but also stated that it could be done manually if individuals are not comfortable with digital tools.

Following the Project Planning Manual, there is also a Project Plan which is divided into eight parts: *General information*, *Risk analysis and monitoring*, *Occupational health and safety*, *Quality*, *Environmental planning*, *Planning/Preparation*, *Economy,* and *Purchasing*. The Project plan is a governing document for the execution of projects and needs to be fitted for each project (Company A, 2019f). The Project Plan is meant to establish rules and procedures for actors involved in the project, to ensure that goals and demands in the project are met. The Project Plan does not state any digital tools that must be used in projects, it does however state that each project can require that digital tools should be used and, in such cases, specify what tools.

Usage of Dalux is not mentioned in any manual mentioned above, other than as an example of a tool that could be used in production. However, there is some information at the studied company's intranet about Dalux. In something called *Dalux Toolbox* there is information in three categories; *Why do we use Dalux*, *How do we implement Dalux*, and *How do we use Dalux* (Company A, 2019g). The "*Why*" is directed towards employees taking decisions regarding usage of tools and describes some advantages with Dalux. There is also a list of some projects in the organization which has used Dalux, with contact information to

the Dalux-supervisor in each project. In "*implementation*" there is information for the employees who are in charge of implementing Dalux at the site. There is brief information on what to consider when implementing Dalux and some information on how to start up projects in Dalux. For more extensive information or instructions employees are referred to Dalux webpage or VDC-supervisors. "*How do we use*" present information for the actors using Dalux in the project. There is compressed information about deviation management, checklists, and tasks, with a reference on each subject to Dalux's webpage with more information and instructive videos.

At the intranet there is also information the about the company-specific costs regarding Dalux. Dalux is financed by the individual project within Company A and is based on the gross area of the project. The company argue on their intranet that these costs can easily be funded through, among other things, less time spent in deviation management (Company A, 2020b).

4.3.1 Supporting structure

There are functions and structures in the company that aim to support the company in its processes. The operational support aimed at supporting the production is organized as shown in *figure 5.* As described in previous section the company specific theme to work in accordance with Lean, this is manifested in the second column in *figure 5* where operational support is given to increase the functionality of involvement, VDC and team efficiency.

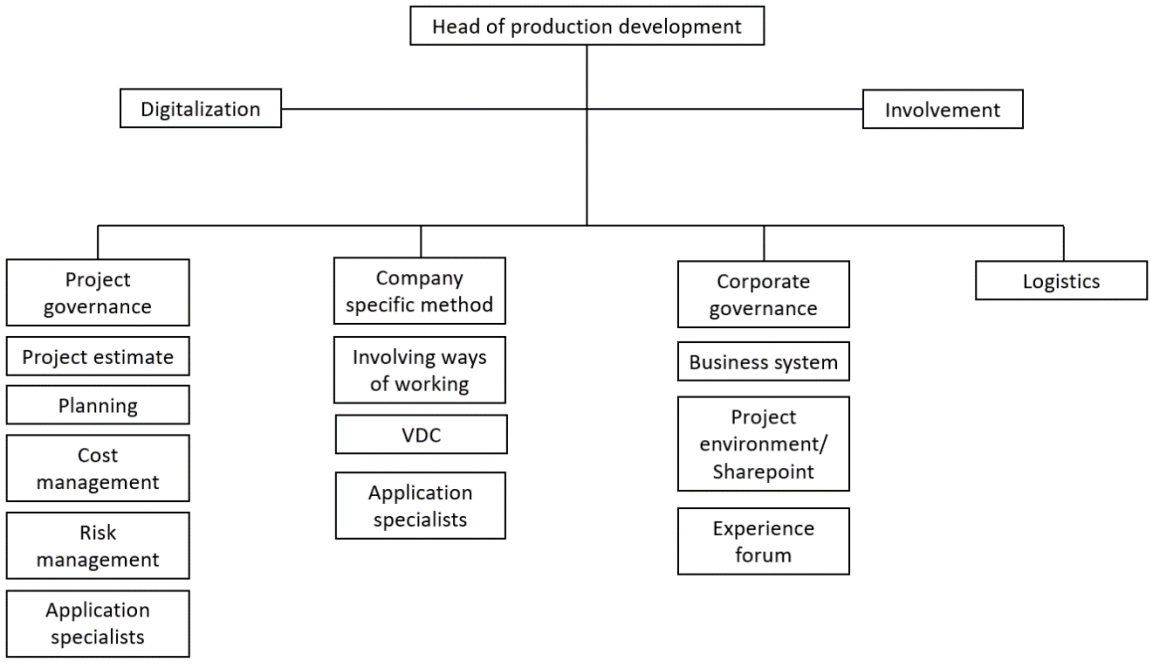

Figure 5 – organization of the product development functions in the studied company

Through the annual report it is possible to understand which are the key goals and where the company measures itself. Four major areas of goals are lined out and the performance in accordance to these are reported. The first area being QHES, where the main metric is number of serious injuries, another key area is expertise where metrics and goals in equality as well as employee ownership can be found. There are also focus on compliance, where a key metric is how many participants an ethically focused education

has. The last field of measurement is climate impact where a number of metrics is accounted for, one example being the reduction of carbon emissions. There also seem to be two identified areas where no goals or points of metrics are currently quantified, these being productivity and customer satisfaction.

At the studied company there is an internal specific school providing education in fields such as, project management, new technology, finance, contract law, energy and the environment, QHES, compliance, and leadership development (Company A, 2019b). However, there is a lack of in-house digitalization education, but Company A has for several years educated coworkers through the external Stanford VDC course. Networking groups within the company enable the engagement of more specialized skills development in key areas. These areas are presented as calculations, residential construction, and design. Further, the company state that a key strategy is to staff key specialisms within permanently employed skilled manual workers. This meant to enable a high degree of in-house production knowledge and experience transferee between the development and execution functions and that knowledge is transferred to and refined in new projects. The studied company acknowledge that "*a diverse workforce capable of utilizing individual insights, experience, and expertise is better placed to develop good solutions*" (Company A, 2019b).

Company A argue that since it is a project-oriented organization the main increase in productivity will come from process effectivization rather than economies of scale. At the project-level Company A argues that planning is crucial, this will ensure that all activities can be executed without hindrance, in the right order and on time, further, high productivity depends on expertise in core processes (Company A, 2019b). Company A also acknowledge that a key to increase productivity is data about the processes. For the building construction operation one such is the digital registration of non-monetary unit times, such as, number of hours per interior wall. Knowledge about different key figures will enable higher degrees of standardization which is related to improvement in productivity (Company A, 2019b).

4.4 Interviews compared to theoretical framework

Many of the thoughts that was brought up during the interviews have support from the literature study conducted in relation to this thesis. This section aims towards comparing the results from the interviews with the theoretical framework from a more objective standpoint, implications and suggestions for the studied company will discussed in the successive Chapter. While comparing the interviews and theory, the interviews conducted at Company A will be the main focus. Therefore, if nothing else is mentioned, the comparison is made with interviewees at Company A.

According to the literature, inadequate communication is a substantial aspect behind unsatisfactory project performance (Olanrewaju et al., 2017; Senaratne & Ruwanpura, 2016). While improved communication is one of the subjects brought up in the interviews as a great advantage with digital tools in production, showing one aspect where digital tools can improve project quality. Furthermore, the interviewees highlighted increased documentation while using digital tools and that this data could be used for follow-up and generating experience feedback. Which the theoretical study found to be useful concerning organizational learning, an aspect that historically has been a difficult issue to solve in the project-based construction industry (Wiewiora et al., 2019). More generated documentation makes it easier for the compare the results of projects with each other, and with organizational goals.

The interviews also revealed that there is a lack of clearly defined organizational goals for the digitalization. SM2 pointed out this aspect as one reason why it is difficult to evaluate and follow-up on

the implementation of the digital tools in production. Several interviewees also stated that there is no clear plan for how they should implement more digital tools in the production, which is an important aspect for successful implementation of innovation that will change the work processes in an organization (Long & Spurlock, 2008). Connected to this, it is evident from the interviews that there is a lack of common and standardized working methods and guidelines in the organization, regarding digital tools. This was an issue at the other interviewed companies as well. The literature study showed that standardized work processes together with strategic goals are vital to increase the organizational learning which is needed to spread the digitalization in the organization (Hartmann & Dorée, 2015; Martin & Bell, 2011; Thomas, 2005). The literature also show that clear goals and standardized processes allow the organization to analyze and improve their methods, and thereby their work with digitalization (Lidelöw et al., 2015; Synnott, 2013), an aspect emphasized by several of the interviewees.

Connected to organizational learning, the literature study showed that reflective workshops and meetings can help facilitate knowledge between projects (Hartmann & Dorée, 2015). One workshop and one VDC-network meeting were attended for observation at Company A, showing that the organization is trying to utilize these methods. These meetings were done close to the work while projects where running, which is important to make learning part of the process rather than a separate workload (Synnott, 2013). However, the interviews revealed that the while the VDC-network and their meetings were effective in Business region south, there was a lack of connection between the regions and the network were not perceived to be as effective in Region west. Additionally, the workshop attended was initiated and organized by two of the interviewed managers and was not a regular recurrent organizational method.

The interviewees described that there is some resistance to new digital tools, such as Dalux, amongst the users. Unfamiliarity, lack of knowledge, and lack of perceived benefits from the tools was mentioned as reasons in several interviews. While the literature, in addition to these, also mentioned fear of failure and threat to status in connection to organizational change management (Erdogan et al., 2005). Showing, as both literature and several interviewees pointed out, that introducing digital tools is quite closely connected to change management and that the human aspects should be given more attention (Moscati & Engström, 2019). While also, further emphasizing the need for clear communication and illustrating the need to show the benefits from digitalization and change, as both interviewees and literature point out (Long & Spurlock, 2008; Malek & Yazdanifard, 2012).

To increase the implementation of digital tools the interviews revealed the need for more education and support within the organization. Aspects that are crucial in connection to both organizational change management and individual learning, the literature describe support and coaching as vital to enhance the utilization of innovations (Bosch-Sijtsema & Gluch, 2019; Long & Spurlock, 2008; Wandersman et al., 2012). In connection to this, the literature reveals that new informal are often roles created, where some employees become support functions for others, leading to inefficiencies since this is done in addition to their normal workload (Davies & Harty, 2013; Talamo & Bonanomi, 2020). The literature suggest that these informal roles should be acknowledged and turned into support groups to facilitate the digitalization (Talamo & Bonanomi, 2020). Furthermore, that employee empowerment is a key component and that ambassadors should be created to help aid the change process (Degermark, 2018; Erdogan et al., 2005). Adding that these ambassadors should be the employees showing most interest in the change undertaken. The creation of new roles and the need for more support functions for the production is something that was highlighted by the interviewees in central positions at Company A. Several of the interviewees at other companies also mentioned that since they were pilot projects for Dalux in their own

organizations, they became support functions for others. While they did not mind helping colleagues, this work was done outside their normal workload. Furthermore, the support they could provide was limited and varying depending on how the interviewees themselves had used the different functions in the software, which they had mainly experimented with on their own.

To attract skilled individuals interested in digitalization, the literature showed that that individuals with knowledge and interest for digitalization will look for an organization where there is room for development within their field of interest (Singh & Holmström, 2015). Furthermore, that younger generations are inclined to look for employers with modern goals and visions (Degermark, 2018). Several interviewees also stated that work with digitalization affect their choice of employer and that one reason for them deciding to work for Company A was their work with digitalization. Showing that Company A is seen, at least by some interviewees, as one of the front runners in the digitalization of the Swedish construction industry.

Several interviewees mentioned that in order to increase the usage of digital tools in production, the tools must become more user-friendly. Dalux was mentioned as one example of a user-friendly tool by S3, while S5 argued that it still needed to become easier to use. The literature supports the focus on user-friendly tools by explaining that *simplicity* and *trialability* together with *relative advantage*, *compatibility,* and *observable results* will determine how quickly an innovation will be adopted (Rogers, 2003). DC-Dalux stated that being user-friendly is a focus at Dalux as well. Explaining that Dalux are trying to make plenty of straightforward functions to get new users to start using the software. This is one measure in trying to overcome the issue described in the literature where there is potential for knowledge gaps between the system designers and users of new technology, leading to difficulties in adapting new technology (Long & Spurlock, 2008).

DC-Dalux also explained that Dalux tries to listen to their users regarding what functions they want and how Dalux can improve their functions, while also developing new functions based on technological advances. This relates to market pull and technology push in the theoretical study. Both DC-Dalux and the literature underline the importance of combining and utilizing both kind of development processes (Choi, 2018; Maier et al., 2016). It was also mentioned by several interviewees at Company A that it is important to listen to the employees in production to understand what digital tools or functions are needed and can be used in production. While several interviewees, at several companies, also pointed out that it would be useful if it the central organization would decide what tools should be used in production and clearly communicate it to the whole organization. Arguing that it would be easier to increase the actual usage of digital tools if it were a central decision and there would be less excuses for employees who are skeptical toward new tools.

As discussed in the Chapter about construction communication, it does not take long before the large networks of actors involved in the construction get complex (Chelson, 2010; Sattineni & Schmidt, 2015). A suggested measure to lower the complexity is to decrease the number of channels where communication occur which implicates that some actor needs to act as a hub gathering information and channeling it further to affected stakeholders (Chelson, 2010). Normally the site management and the contractor take this responsibility, which is also seen in the studies performed through the site visits and observations. A suggestion to cope with the large flows is according to the literature to use a digital system that can manage the communication flows (Alreshidi et al., 2017; Svalestuen et al., 2017). The study found

that sites around the studied company increasingly use Dalux as an effective tool to, for example, manage change orders, deviations, self-inspections, task management, Q&A, and communicate risks on site.

A digital tool is being described as a medium that help the construction process in adding more value, whilst decreasing the effort put at, for example, administrative whereabouts (Hardin & McCool, 2015; Sattineni & Schmidt, 2015). The value of the tools used is likely to increase with an increasing level of connectivity, which is the tools ability to increase the connection and synchronization of previously separated activities. This is according to the literature done either by combining more functions in the same tools or by encouraging information sharing amongst tools in a toolbox, such as API and open source data (Hardin & McCool, 2015). It is found that the studied companies all adopted Dalux since it is perceived to present solutions to more than one need. Dalux allows for the use of a single interface to access different functionalities such as visualization, task management, and blueprint access. Further the software is also supporting the user ownership of data and enables for the use of API.

5. Discussion

Throughout this study the idea has been to present the prerequisites, challenges, and opportunities of implementing digital tools. In this Chapter implications of the results from the interviews and some of the main findings with suggestions for possible solutions are discussed in greater detail.

Whether or not the digitalization of the industry is a change happening rapidly or incrementally can be discussed. Arguments have been made that there is a need for the construction industry to increase its productivity, and that productivity has started to increase with the increasing digitalization and use of digital tools and BIM. However, as both the literature and the interviewees describe, there is some inconclusiveness within the industry regarding the level of digitalization and the goals for the digitalization, especially within the production phase. The focus of the digitalization has previously been on the design phase and there seems to be some uncertainty about how to best implement digitalization into production, causing some actors to be cautious. Exemplified in this study by Company D, which want to see the value created by digitalization before fully committing towards digitalization. Therefore, there is an edge to be gained for organizations that can utilize digitalization efforts effectively. To not harvest the opportunities and properly manage the social and technological processes increasing the utilization would be unwise. Statements from top executives, both within the studied company but also from competing companies, indicate a belief that substantial amounts can be saved through new and more efficient ways of working, something that is strengthened by findings in the literature. However, it is also clear that in order to catalyze this change, there is a need to address the subject with efforts in time, engagement, and investments. Changing how the organization comprehend digitalization will also be a catalyzer and it is likely that goals and targets needs to be more clearly communicated.

5.1 Learning from digital tools

As the literature study indicates, mistakes made, and lessons learned during the production and maintenance phases of the building lifecycle are rarely or ineffectively communicated back to the design and planning organizations. Because of this, many errors of the same nature keep being repeated even if they might be relatively easy to solve. The communication aspects of digital tools, such as Dalux, where a larger portion of the team in the construction phase can communicate and report deviations and interferences more effectively, have in this study been observed to enable better learning from errors and mistakes. One example is the common problem with design deviations or errors in the prefabricated structure of buildings. The ownership of the mistakes can often be discussed, leading to time consuming efforts to get potential reimbursement from prefabrication suppliers. Furthermore, time pressure in projects sometimes causes the contractors to solve issues by themselves without requesting reimbursement since it is less time consuming and contractors might want to avoid conflicts with suppliers when there is a lack of documentation. Even if issues are resolved, there seems to be a lack of communication about the issues reported to the prefabrication producers. The interviews revealed that when Company A started documenting and reporting issues regarding prefabrication in Dalux and notifying the supplier directly, the prefabrication supplier was at first surprised and somewhat skeptical when a higher than usual number of issues was reported and stated that they had not gotten such direct feedback before. With documentation generated through Dalux, representatives from Company A argue that it is easier and less time consuming to get reimbursement for prefabrication issues. Furthermore, there has been cases where the prefabrication supplier could correct recurrent issues in an ongoing project. Showing that there is great potential to save both time and money, and for learning from digital tools for contractors as well as suppliers.

Connected to the learning and feedback from digital tools, the theoretical framework described that assembly of data should only be conducted if there is a clear purpose and a good idea of how to use it. The empirical findings show that the organization today have a quite good understanding of how to use data concerning deviations to settle economic issues in the projects. However, it is at the same time found that the project personnel interviewed does not have sufficient knowledge about what other information that should be gathered to best formalize knowledge gained during projects. The employees responsible for VDC at central positions presented that data could be used to evaluate projects, suppliers, and sub-contractors, however, there was no common way of collecting data and a lack of framework and guidelines for how to use the digital tools. By not providing a framework that streamlines and homogenize the data assembled, there will be less useful data to analyze and a lot of potential in the digital tools are lost. Instead of collecting common data that can be used to analyze and improve work processes, the data becomes more random and increasingly difficult to analyze. Common framework and guidelines will also help creating a standardized process for using digital tools in production. The literature study showed the advantages of a standardized process in terms of analyzing and continuously improving work processes towards increased productivity. The individuals currently tasked with increasing the digitalization and analyzing collected data within the studied organization already feel that they do not have enough time to properly do everything needed in terms of increasing the digitalization. Therefore, poorly structured collection of data becomes a substantial obstacle for the studied company and an important issue to solve.

Regarding the collected data and communication, the theory show that the richness and value of communication increases if the actor can access the flow of information from multiple communications simultaneously and both give and receive rapid feedback, the actor should also be able to tailor the communication to their needs. Dalux Field is found to enable such communication flows, where different trades get the information they need communicated. Users have the ability to search for information in accordance to geographical location, responsible, or subject, among other things, which allows for multiple flows. Therefore, Dalux Field seems to be a potential key element of improving the site communication. Enabling for both improved communication in projects, and for automatically generated documentation that can be used to analyze projects and work processes.

In the theoretical framework it was found that organizations pursuing a higher degree of digitalization needs to establish goals and a common vision to stimulate the change. The interviews revealed that there is a lack of clearly defined and communicated goals within the organization regarding digitalization, there were indications of visions but no clear goals or plans for how to get there. This leads to difficulties for project teams to measure and plan for their implementation of digitalization. Without defined goals, the literature explained that it is difficult to analyze and readjust efforts to promote organizational learning and change, which has historically been problematic within the project-based construction industry. Showing that there is a need in the studied company to create common measurable goals for the digitalization in order to enable the projects to analyze and improve their efforts towards digitalization. Analyzing their work process also encourage the project teams to create common best practices that can be spread throughout the organization, thereby promoting organization learning.

While analyzing efforts towards digitalization and promoting organizational learning, the literature described reflective workshops and network meetings as quite useful. While there seemed to be quite well structured and productive VDC-meetings in Business region south, they seemed to be less effective in Region west. According to some of the interviewees, the reason why the VDC-network was more useful

in Region south was much to be accredited to leadership of VDCD. The studied company would therefore benefit from continuing with VDC-network meetings and learn from Region south what could be implemented in other regions, moreover, hire someone in a role similar to VDCD in each business region. Furthermore, the different VDC-networks would also benefit from being connected better to each other, to contribute the entire organization rather than a specific business region. Which would also be made easier with a role resembling VDCD in each region. The only workshop concerning digital tools observed within the organization was organized by two of the managers, S4 and BM-C, themselves. While it is effective to have driven employees leading the digitalization, the workshops need to become more organized and a regular recurrence. In the future they could also be more reflective where the users can discuss issues and alternative methods for using digital tools in order to increase learning throughout the organization. It is also appropriate to discuss where costs for different digitalization efforts are located. Cost for workshops could be financed by the regional or central part of the organization and be mandatory to ensure that they are carried out closely to the production. As the literature describes it is important to do workshops close to the actual work to ensure that vital knowledge is captured and shared throughout the organization.

5.2 Need for support

One aspect that has been evident throughout all the interviews conducted during this study, within the studied company as well as the other companies, is that there is a need for improved support regarding digital tools in production. For tools such as Dalux, the most pressing need for support has been in the beginning of the production phase. The literature support this by explaining that innovation and change is most effectively implemented when training and education is part of the process, preferably as early as possible. The interviewees agreed that there is a need for education when introducing Dalux or other digital tools. The education can however be varying depending on role, ambition, and interest.

From this study the belief is that brief instructions for new users who are only going to use the tools is sufficient, as long as there is someone with more knowledge about the digital tools at each project. Either a central support function could introduce tools at the projects, or common presentation material could be prepared so that the experienced project teams can introduce the software themselves, with some guidance for what should be presented for basic usage of the software. For the employees that will administer in Dalux, a slightly more thorough introduction is needed, but the belief is that less than one day should be adequate. In addition, administrators in Dalux would benefit from being connected to a structured support network so that they know where to turn in order to get help with any kind of task. When setting up projects where the site management is new to digital tools, they would have the use of a central support function that provide guidelines as well as coming out to the projects to aid in this process. This will also ensure that the new users in the projects gets connected to a support network, knowing at least one person to contact if issues or questions arise. If the support function who initially aided in setting up the project is not available, they should be able to connect the users to someone else within their network.

As it is described today, support is often an informal support network that will have to support colleagues outside their everyday workload. The literature reveal that it is likely in early phases of introducing innovation, similar to where the studied company currently is, that there will be employees who are interested in the new tools and will become informal support functions. This is favorable seen from the aspect that it legitimizes the change and makes the peers trust that the change will be of benefit. However,

this informal support will often be done in addition to their daily work and can consequently lead to inefficiencies. Therefore, these informal support functions would benefit from being identified and formalized so that these individuals can be motivated to continue support their colleagues and can be given time to do so.

The development of Dalux and other digital production tools is progressing rather quickly, therefore it is important to have driven employees concerning these digital tools. The impression during this study is that the studied company has already started identifying driven employees regarding digital tools. Furthermore, the studied company is spreading the usage of digital tools through these employees. The operational support within the studied company express that the organic digitalization seen in specific projects driven by enthusiasts, ambassadors, and change agents, is enough to initiate the digitalization of the production phase of the organization, but that more efforts and resources are needed to achieve widespread usage of digital tools. The most evident and pressing need found in this study is the need for someone like VDCD in each business region. A role responsible for supporting the employees implementing digital tools, such as Dalux, in the projects, a central hub for the support networks and VDC-networks. A role that can also connect the different VDC-networks with each other more efficiently. However, this study also finds that there is a need for more support for the role of VDCD. The workload on VDCD is at the moment too high in order to properly aid in the increasing digitalization of production and act as a support function for all projects at the same time. Given a future increase in the speed and focus on digitalization this lack of supporting and developing capacity would be even more evident. The structure of the needed support networks and new roles will be discussed in forthcoming Chapters.

For the support networks to work more efficiently there is a need for common work methods while using digital tools. Therefore, it is important to create common frameworks and guidelines for Dalux and other tools being implemented within the organization. As previously mentioned, a common framework and guidelines will contribute to standardized work processes, better structured metrics and thereby increased organizational learning. Frameworks and guidelines can also aid in the support of digital production tools. When introducing tools like Dalux to a new project a common framework will help the new users get familiar with the new tools efficiently, instead of starting with a blank sheet of paper, which the current situation is described as. It will also help the support function since the learning period and instructions needed for the new tools will likely be reduced. The parable mentioned in Chapter 4.1.4 with a comparison to a Formula 1 team describes the usefulness of common framework and guidelines. Where a well-developed toolbox and a support team quickly can introduce digital tools to new projects, so that the project staff can race on producing, instead of an individual having to start from scratch and learn everything by themselves. While creating common frameworks and guidelines, it is also important allow for some freedom and creativity in order to let the employees be innovative and come up with improvements for the processes. As revealed in the interviews this work is already undertaken by VDCD and Head VDC, though as previously mentioned, there is already a quite heavy workload on these roles. Therefore, more resources could be allocated towards these efforts, further strengthened since it is found in this study to be vital for a wide-spread implementation of digital production tools and organizational learning.

5.3 Spreading digitalization

According to the theories around diffusion of innovation presented in Chapter 3.2.5, a system can be either centralized or decentralized, depending mainly if the implementation of a new innovation is

initiated and spread as a result of a strategical decision by operational management or if the innovations spread horizontally amongst the end users. The empirical findings indicate a mix of the two with an emphasis towards the decentralized diffusion. One indication for this is when the interviewees stated that the reason for wanting to implement Dalux in their projects was because they were recommended to use the software by colleagues who had used it previously. However, the findings indicate that when granted the tool, the individuals experienced a lack of guidance, SM1 described it as being given a blank sheet of paper.

In relation to the implementation and diffusion timeline, which spans from innovators to late adopters, the empirical findings indicate that the studied company is in the shift from early adopters to early majority. The reason for this is that almost all visited projects had one or a few enthusiasts working hard with digital tools and getting everybody on board with new technologies. However, the interviewees expressed that there was no common interest in managing the digital environment on site, instead the one responsible felt solely responsible. Both the literature and empirical findings indicate that the construction industry and the studied companies put a lot of the burden on the front line actors to prospect, promote, and develop these new practices. These actors are in a way seen as a key for successful change and to change the institutional boundaries. However, the organization and management need to support and enforce these actors, and where it is applicable create new roles or extend existing. The value derived from these tools is also ensured by these actors as they spread the new technologies and the knowledge about how to use them within the organization.

As presented by the theory the new roles will likely shift the institutional framework of the organization, giving more acceptance towards digitalization. If this is seen in relation to the three institutional pillars presented in Chapter 3.1, it is likely that these actors change the normative and culture-cognitive values of the institution. To encourage this, it could be argued that top management should enforce guidelines and a regulative framework for how individuals within the organization is expected to act and behave. If change and progress is implemented in all three pillars simultaneously it is likely that they will accelerate the needed development.

Throughout the literature study it is found that some implementation efforts such as network meetings and other activities that stretch outside the duties of everyday work, can be perceived as unproductive and not value creating. While these efforts have been found to create value in the long-run and for the entire organization. The empirical findings have not found such resistance in the studied organization, instead these types of initiatives have been encouraged by driven employees and management who recognize potential benefits of digitalization. However, the interviewees have mainly been employees interested in the digital development and there is likely to be some resistance to be found in the wider organization. Therefore, it could be argued that in order for a new innovation or a change to diffuse faster than the construction industry in average, the organizations need to work actively with these questions and it is likely that an increased investment in networks and cross-disciplinary meetings would speed up the diffusion and change.

From the theory about why an organization change, it is found that two main drivers can be identified, namely a change to increase the economic value or a change to increase the organizational capability, and almost exclusively a non-pure blend between the two. Reflecting upon the rate of diffusion or the rate of implementation it is likely that in order to increase the rate of which an organization builds up its organizational capability, a negatively influence will be stressing the temporary perceived economical

value. However, it is also likely that most efforts put in developing capabilities will pay off in an increased competitiveness down the line. As stated in the background of this thesis, digitalization has already increased business values and turned the tide on the productivity issue in the construction industry.

It has been described in the interviews that the management within projects sometimes are too oriented towards direct economic gains from digital tools. This is quite natural since they are evaluated on the results of the projects. For digitalization to spread this attitude needs to shift towards understanding that the benefits of digitalization might be an increase in quality and more long-term gains, often for the entire organization. Improved efficiency in production management while using Dalux might lead to supervisors and other project management having more time to plan activities, improve safety, investigating potential risks, follow-up on mistakes, collect more thorough documentation, and such activities. These activities might improve the overall result and quality of the project while it is very difficult to directly show that it is due to digitalization. For example, interviewee CE-B mentioned that doing self-inspection in Dalux allowed them to digitally lock fields as mandatory to answer. While it made the self-inspections more work-heavy, it increased the quality of the self-inspection which potentially can increase the overall quality of the project. Especially since there previously has been an issue that self-inspections have sometimes been of quite poor quality. These potential value adding aspects, are in addition to the long-term benefits gained from organizational learning while using digital tools, previously described. For the digitalization to spread, it is important that the digitalization is supported from management across the entire organization and within the projects.

VDCD explained that it is relatively easy to digitalize a single pilot project and quite different to digitalize a whole organization. Showing the importance of spreading the digitalization among all project and the entire organization. This can be compared to the Swedish project Rörforsbron that 2013 was completely digital without 2D drawings, and that seven years later the standard in the Swedish industry is still 2D drawings, often printed on physical paper. Showing that problems with implementing digitalization in a wide context is not an issue unique to the studied company. This study emphasizes the need to increase the minimum level of digitalization along with leading the way with some projects that can show the benefits of being increasingly digitalized, as several interviewees also mentioned. The importance of learning from these pilot projects must not be underestimated. Initially the aim could be towards adapting to the most basic digital functions, such as digital self-inspections or task management in Dalux, in all projects. When employees start using basic functions, it is likelier that they are willing to start using more functions later on as they get used to working digitally and see potential benefits. This will help spread usage of digital tools and aid in the diffusion of innovation within the organization. This pattern was also described in the interviews where it was revealed that the individuals most reluctant to using Dalux was the individuals who had not yet tried using the software. Once they tried some basic functions and realized how useful the tool is, the resistance was often dissolved. While introducing digital tools to new users and thereby increasing the minimum level of digitalization in projects, it is also important to follow-up on the implementation to ensure that the tools are being used continuously and actively ask the users what support they need.

Another key to change the attitudes of the users undergoing change, as well as spreading knowledge, is to inform employees about successful projects. Information about projects successfully using digital tools is currently spread mainly through informal personal networks, and in some extent also in the more formal networks such as the VDC-networks and intranet. However, to better manage the change it can be argued that spreading best user cases and success stories should be more strategical and in a managed practice.

This could for example be done by tasking the communication function to increasingly monitor and report about the subject. It could be done by summarizing best practices and communicate this information through the intranet or network meetings as well as on more informal site visits.

An important factor to become more digital is to encourage and reward the individuals pursuing digitalization. Findings from the interviews indicate that many of the interviewees working increasingly digitally felt seen and acknowledged within their digitalization-networks, both formal and informal. However, they did not really feel that efforts towards digitalization is rewarded monetarily. In relation to these findings it is likely that a clear picture of what the digital dedication will bring in the future, both in terms of roles and rewards, is likely to boost the commitment further. Elaborating on this, there can be benefits in rewarding these professionals not only by allowing for stimulating work tasks and being active in interesting networks, but also allow for rewards and incitements to influence the salary of the professionals in regards of digitalization.

5.4 Organizational structure towards digitalization

The question of the organizational structures effect on digitalization can be seen can be seen in relation to both the structure in the project organization but also in relation to the structure of the operational support. Starting off with the organizational support it is found that there are resources aiming at supporting the company with routines and development in the fields of digitalization, BIM, and Lean, amongst others. However, it was found during the interviews with some of the professionals working in these structures, that time and capacity is the limiting factor, not the need from the organization. Seen from a theoretical perspective it is found that whilst a lot of change and implementation occur in the projects, research show that operational support have a clear role and responsibility in both enforcing and supporting the change.

As previously mentioned, the need for a role similar to VDCD in each business region was evident from the interviews, moreover, the need for more support for the role of VDCD. This study finds that the VDCD role needs a support team that can be sent out to the project teams in addition to VDCD. The number of employees to do this should be evaluated but the belief from this study is that somewhere around one to three employees in each region could be enough initially. Furthermore, the belief is that these support functions does not have to work with this full-time, they can also have other functions such as construction engineers part time. However, the support part of their work should be financed centrally to prevent economic hesitations from the projects. The idea is that these employees introduce the tools to projects that has not previously used digital tools, such as Dalux. Thereafter, at least one person at each project gets further instruction and can act as some support for the project, while in turn having the new support functions and a role like VDCD as their direct support for any issues. This will enable roles such as VDCD to focus more on developing technical solutions to production issues and develop a digital toolbox, while still continuing to offer some support to the projects. Long-term there will be employees with knowledge about digital tools at all projects and the support functions can focus more on being support, rather than introducing the tools and educating new employees. With added resources the support functions could also work more organized towards follow-up on the implementation of Dalux and other digital tools in projects. This is an area which seems to be lacking today and that is described in the literature as quite effective.

The work with identifying driven employees interested in digitalization is well on the way in the studied company, not the least shown from this study where several employees was quickly identified as suitable

for interviews. While identifying these employees it might be helpful to have some diversity, for example, not solely identifying younger employees who are interested in working with digitalization. Since this might lead to not fully utilizing more experienced employees who often have a lot of knowledge. Furthermore, it might further enforce the image described by some interviewees, where digitalization is something for younger generations which does not concern older generations. An image this study found not to be true, since several interviewees driven within digitalization can be describes as part of "the older generation". It can also be important to consider what role the support have. As described in the literature different titles sends different signals to the one supported. If the role is to enforce or create a strict implementation, titles like supervisor, foreman, or manager helps create authority. If the role more aims at working together with the team in developing and creating higher value terms such as leader, team leader, or coach is suitable to create an appropriate spirit.

Some observations concerning the central organization and digitalization of the studied company have also been made. There seems to be some divergence in the attitudes towards digitalization. The top management, such as the CEO, have stated that they believe digitalization is the future and must be prioritized and there are roles, such as Head VDC, Head PD and VDCD, directed towards digitalization of the organization. However, the work with digitalization is often seen as something done outside the normal routines. The interviews disclosed that many employees not directly connected to digitalization does not seem to believe digitalization concerns them, and that they should continue work as they always have done. This leads to digital efforts often ending up as experiments or pilot projects and something that other employees does not need to partake in.

Within the studied organization there seems to be an informal digitalization network with their own sort of structure detached from the rest of the organizational structure. While these individuals are often quite driven and have support from the top management it is quite difficult for them to increase the digitalization throughout the organization without the support from the rest of the organization. The literature and interviews have described one issue with introducing digitalization to the project as the view among some individuals within management that it is enough to request that a project use a digital tool, Dalux or similar, and put one person in charge of that tool. Believing that this is what makes the project digital, while in reality it is often only the single employee working with the digital tool without being able to utilize the full potential benefits of digitalization. This study finds that it is important for the leadership within the organization to clearly communicate and show that digitalization is not a side project with a start and end date, but rather something that is going to be central part of the entire organization, pushing for both radical and incremental change and continuous improvement.

In addition to the leadership showing more clearly that digitalization is part of the entire organization, this study argues that the existing central digital roles in the organization, like VDCD, Head PD, and Head VDC, could be raised to the level of other central roles in the organization. This will show the importance of the digitalization to the entire organization and show that digitalization is part of the future core activities. Furthermore, it will give digital leaders in the organization more formal authority and enable them to make more decisions towards a more digitalized organization. It is also an effort to make the part of central organization which previously has shown little interest in digitalization realize that digitalization is a vital part of the business. A step towards changing the mindset of employees who consider work with digitalization as playing around with drones.

Connected to different roles within the company, it would be beneficial for the widespread digitalization if work with digital tools was added to the job descriptions of all employees expected to work with digital tools. This shows that digital tools are meant to be part of the everyday work for all employees, not something handled by a specific employee. Initially this could be supervisors which are the ones that the interviewees believe to have the most direct potential gains from digital tools. In addition, digital tools would benefit from being more clearly described and prescribed in the project manuals, such as the Project Planning Manual and the Project Plan described in Chapter 4.3. This will show that digital tools are part of the core project activities in a more explicit manner.

A positive aspect for the studied company is that they do have a central function for digitalization, while some of the other interviewed companies did not formally have this function. However, to fully utilize the economies of scale that this operational support can give, it is important that the supported organization has some degree of homogenization and similarities. Currently, the organization have different structures depending on business region and the role descriptions of the professionals in these structures differ as well. It is likely that a higher degree of similarity would increase the benefits of this central support function. This fact is also strengthened by findings in the literature vouching for clearly defined roles and structures as an enabler for change.

5.5 Functionality in current tools

Both the literature and the interviews described that most projects are evaluated and measured on how well they perform in relation to aspects such as cost, completion time, and technical performance. As previously discussed, digital tools can affect these aspects indirectly by creating more time during projects for the teams to handle various activities. It is also found that digital tools can help strengthening the project success by creating a positive image of the site management. If the site and project management use digital tools to increase control over the project it is likely that involved stakeholders will perceive information as clearer and less contradictory, creating a positive project climate and positive individual attitude. Strategically increased digitalization is concluded to be an appropriate measure short-term as it will give the above listed benefits. Long-term digitalization will increase the likelihood that clients will rehire a contractor that has well-structured data, as it creates valuable products with high quality in a safe manner and with a good project climate.

It is found that site teams use Dalux for a diversity of procedures, some that was before carried out analogy and some that has brought a new aspect to the site. A function that has not been available before is the BIM viewer that also is available for offline use. This function was found to for example increase the performance of installation workers as it is now possible to visualize and understand spatial relations outside the 2D plane. Some functions that has been improved by digitalization is self-inspections where a checklist provides a structured way of collecting data, it is also easier to save pictures of the work if any future disputes or problems would occur. Workers spoken to during this study acknowledged that even though self-inspections may not be quicker to execute digitally, the quality is higher, and it is more likely that they are executed at the same time as the task is being done. This relates to Chapter 3.2.3, where it is described how digital tools will at first increase the burden, but over the period of a project it is likely that tools and digital methods will create increased productivity. As described, the implementation of digital tools aim at decreasing the workload and increase the capacity for site teams and other responsibilities in the organization. At the initiation phase it is likely that some time will be spent on getting used to using the new tools. However, once the new working method is adapted, efficiency is likely

to increase, with the addition of increased quality and documentation. There seem to be a great potential to further utilize Dalux for different types of tasks, as increased task management, safety inspections, quality controls, report deviations, job planning, and much more. But there is a lack of a structured toolbox handed to the projects, which if provided would increase usability.

An identified problem has been high project autonomy and low degree of centralization in the ways Dalux functions has been used. The reason for this is that the projects themselves has configured the layout of used forms and tasks. When interviewing the VDCD, Head PD, and Head VDC, it was discussed that the next step is to try to standardize and make sure that at least some of these procedures will be executed in company standardized documents. During the study, the general impression was that many projects used Dalux to write the daily construction journal, safety inspections, manage and report deviations, and self-inspections. These could therefore be appropriate processes to standardize. If the company manage to streamline the quality and diversity of the data gathered in these fields the value of the data on an organizational level will also increase. Especially as Dalux is spreading across the organization and a lot of projects use it for the first time. Reflecting on a future situation the data could bring values in providing good information for both strategic decisions about framework agreements with large suppliers, but also as a way of analyzing where dangerous procedures on site or time-consuming tasks occur.

As described in the theoretical framework, communication networks quickly get complex, and increasingly so with more actors being involved. A great way of taking control of the complex communication and make it more efficient is if the contractor or any other coordination responsible acts as a hub, which all information flows through. The communication in the production phase of the studied company is increasingly going through Dalux, which can be a tool to enable a communication hub. This was something a lot of interviewees elaborated on as a benefit, getting a clear accountability of communication, enabling stakeholders to see for example Q&A, workflows, and safety inspection protocols. Another example is communicating work orders for subcontractors or skilled workers. Where the usage of Dalux allows for both the supervisors and the skilled workers to plan their work better. While having all tasks documented digitally and easy to overview, the sequence of the tasks can be planned better and it is easier to prioritize different tasks. It also minimizes the time spent by both supervisors and subcontractors running back and forth to the construction site. Thereby, minimizing waste in accordance to the Lean principles. As the literature showed around half of the cost for production could be related to waste, and that this waste often is connected to inadequate information management. Therefore, there is potential to reduce large costs in construction production by using Dalux and other digital tools.

In the future it is likely that a more structured way of doing tasks will enable for data about unit times and on-site efficiency enablers can be gathered more successfully, bringing operational value cross-projects. It is of importance that the tools available for communicating design, drawings, and other information produced in the design stage, are utilized so that the site management does not have to waste time looking for information, or in worst case put valuable time on solving a problem already solved previously. And that the shortcomings and flaws of the design stage can be efficiently solved and documented, furthermore reported back to the design department for future learning and improvement among all actors.

The empirical findings showed a diverse understanding of the main benefits of using digital tools in production, one of the most useful and easily applicable aspects is the visualization enhancement that BIM on site can enable. Dalux provide a platform for more established visualization functions such as

3D-models on site, while also providing newer function with great potential for more future usage, such as twin-BIM. This is an AR function that can merge the reality of the site with the model and view it on a screen such as on the tablet or smartphone. Showing that Dalux is aiming at adapting existing function to the production site, as well as newer functions suited for production.

Dalux might not necessarily be the solution or optimal tool to solve all site communication and management for the time being, but as the study found, Dalux and other similar tools are developing rapidly and it is likely that ICT abilities alongside BIM abilities will be developed in various software. During this study, different communication tools were also found to be used to various extent at different companies and projects. The best suited tool to be used in the future of construction production management is not for this study to evaluate. However, it was found that Dalux is a tool that is quite well adapted to be brought into the construction production of today, at least as an initiation to digital tools. Furthermore, the software is found to be appreciated by the users. It could also be elaborated that digitalization in the future might reshape the way construction is being conducted, removing the need of the site tools of today. However, for a foreseeable future it is likely so that the digital tools will mostly aim at fulfilling needs of the "traditional way of building", this study finds to be one of the strengths of Dalux.

5.6 Future benefits of digitalization

As previously discussed, better structured data collection is of great potential future value for construction production, both for analyzing efforts in ongoing projects and for making informed decision regarding future projects. Furthermore, increased digitalization will likely be found in increasing the connectivity and automation of processes. Through the literature and the interviews, it is found that by integrating more functions in the same software or application, the user friendliness, and the likelihood that the functions will be used increases. The CDE providing the users with solutions and functions for an array of processes is seen as an enabler for this. In the case of Dalux, the CDE capabilities manifests in both having connected the different phases of construction, from tender to production and further on in to facilities management, but also in the modules for each phase where multiple functions support a multitude of actions. Another way in the pursuit for increased digitalization could be the cross-platform integration where it is found that Dalux amongst other software suppliers try to open up the data to be accessible and transferable, creating values much similar to those of CDE. As DC-Dalux mentioned, Dalux tries to listen to their users about what functions they want and how the software can improve, and the interviewees mentioned that the development of Dalux is progressing rather quickly as new functions are continuously released and improved. This shows that Dalux is striving to be user friendly and trying to keep up with the rapid development of digital tools and expand the areas where Dalux can be used. This might be precarious since it will cause Dalux to expand beyond their initial main functions, which can cause the functionality of the separate functions to decline. However, for the time being no such indications have been found among the interviewed users, who instead tend to appreciate the expanded functionality and the gathering of more functions into a single software.

As the literature described, younger generations tend to look for employers with modern visions and goals. Moreover, individuals with knowledge and interest for digitalization will look for an organization where there is room for development within their field of interest. From this, arguments can be made to invest in employees interested in digitalization, as staff turnover in this area is then likely to decrease parallel with higher investments in organizational capabilities. Furthermore, if the company manages to

appeal to competent professionals because previous investments in digitalization and thereafter failing to create a clear path or strategy for the future, there is a risk for backlash where the gained competency is not utilized and instead result in high personnel turnover within the area. This topic was also manifested in the interviews where several interviewees stated that their choice of the studied company as employer was partly due to their efforts towards digitalization. Showing that it is of great interest for organizations to work actively with digitalization to attract driven and skilled employees that contribute to the long-term growth of the organizations. Furthermore, that is important to create potential career paths and room for personal development for these employees, within the organization. This also shows that the studied company, at least partly, has succeeded in profiling themselves as a front runner in the digitalization of the constructions industry. However, this study finds that there are still efforts needed in regards of creating development plans and clear career paths for employees interested in digitalization. There is also a lack of digital roles within the organization. Solutions could be, as described earlier, to create more clearly defined digital roles or make work with digital tools part of the everyday work for more employees. This study finds the creation of more digital roles as an appropriate direct and more short-term solution. While making digital tools part of the work process for more employees as a suitable long-term solution, and that a combination of the two would probably be most effective. Employer branding benefits the studied company gained from being in the forefront of digitalization is at risk of being lost if the organization does not continuously work with following the digital development. Therefore, incorporating digitalization in the business strategy is likely a good enabler to communicate both to clients and future coworkers a vision of being an innovative company.

It is quite difficult to find information exactly where the industry is today and thereby understanding where it is going with its digitalization. This might be an indicator in itself that the industry is nowhere close to be fully digitized. As described in the Chapter 3.2, a quite surprising 13% of the Swedish contractor have the impression of already being fully digitalized. While this study finds the studied company to be considered a front runner in digitalization within the industry, and that they are merely in the phase of the *early adopters*. Therefore, the fact the there are other companies which believes to be fully digitalized is interesting. While it illustrates the confusion within the industry in regard to different levels of digitalization, it indicates that it is likely that there are a great portion of the industry that is not seeing the urge and need of rapid digitalization as a way of strengthening its competitiveness and securing its survival. Furthermore, it also raises the question if it is possible to be fully digitalized.

This study finds digitalization to be a continuous effort rather than a project to be completed. In accordance with the principles of Lean, digitalizing organizations should always analyze and improve their methods to improve productivity and quality. It is very unlikely that digitalization will lead to a new working method within construction production and thereafter simply stop, having found the best method possible. Apart for questioning how any Swedish contractor can find themselves to be fully digitalized by any definition, this study also questions if the goal for any contractor should be to become fully digitalized. The belief in this study is that that digitalization instead should be a core activity in the construction industry at large and the goal should be to continuously improve with the help of digitalization. The future values created in the construction process is likely to reach outside the physical product of the finished construction. In addition, values can be created from data created in all steps of the construction process. It is also likely that the increased societal requirements, such as environmental aspects may require that actors present data which certify compliance. The companies that can utilize the

data both to fulfill own needs and to present it as a business offer for its clients will probably succeed in the digital environment of tomorrow.

6.Conclusion

This study is aimed at analyzing how the usage of digital tools at the construction site can be increased. The focus is on the studied company, and it is in regard to the studied company the conclusions have been made. However, it is found in the study that the issues described are quite common among the other studied organizations, hinting that solutions might be applicable in an industry wide context. It is evident from the study that to increase the implementation it is vital to not only consider the construction site and the technicality of the specific tools, but to also look beyond at the wider organization. It is crucial that the organizational structure and leadership, both centrally and in projects, is adapted towards increased digitalization in order to enable effective implementation of digitalization in the production phase. As several studies has pointed out, the human and managerial aspects of changing the work processes towards digitalization are as important as the technical possibilities of the digital tools.

The potential benefits of digital tools are quite clear to the employees working with digital processes within the organization. However, there is a diversity of views within the wider organization regarding the actual value of the digital tools in production. Furthermore, there are differencing views of how the potential benefits are realized. While the employees working with digitalization realizes the importance of wide-spread usage across the entire organization, other employees less interested in digitalization indicate an image of digitalization only concerning the employees directly responsible for different tools. This study finds that there needs to be a shift in attitude among the wider organization, towards realizing that digitalization can bring value to entire organization and should therefore not be seen as a separate process. Furthermore, all management should endorse and acknowledge the work with digitalization since it is of value to the entire organization. It is important for the organization to enable such an attitude through education and information sharing.

The study argues that the potential benefits of digital tools in the production phase is not nearly realized. The implementation of digital tools has merely been initiated and while some direct benefits from tools such as Dalux can be seen through improved production management, increased documentation and quality, accessibility to information, and visualization, amongst other aspects. In addition, the long-term benefits are considerable. These long-term benefits are both in connection to organization learning and thereby improved work processes and productivity, but also regarding competitive advantages and attracting future competency to the organization.

6.1 Research questions

- What support does the organization and projects need in order to better implement digital tools in the construction phase?

The studied company should consider their strategies towards digitalization, and in relation to this establish clear goals and visions of what to achieve with the digital implementation. The digital vision and goals would benefit from having different timespans, describing the immediate implementation and change, but also communicating the change towards increased digitalization over the coming decennia. There is also a need for a formal and well-structured support network regarding digital tools across all projects and business regions. Connected to this, a toolbox with common frameworks and guidelines is needed in order to introduce digital tools efficiently. Finally, continuous follow-up on the implementation of digital tools is needed to ensure a perpetual digitalization and improvement of work methods.

- What is the current state regarding digitalization of the worksites within the studied company?

This study argues that the studied company is the among the companies in the forefront of digitalizing the production phase of construction in Sweden. However, regarding the 5 stages of adopting innovation described in 3.2.5, the studied company is considered to be around the stage of *Early adopters*, shown in *figure 6.* Showing that there are still considerable efforts needed to remain in the forefront of digitalization. Furthermore, digitalization is in this study not seen as something to succeed with and settle, instead it is a continuous process of improvement.

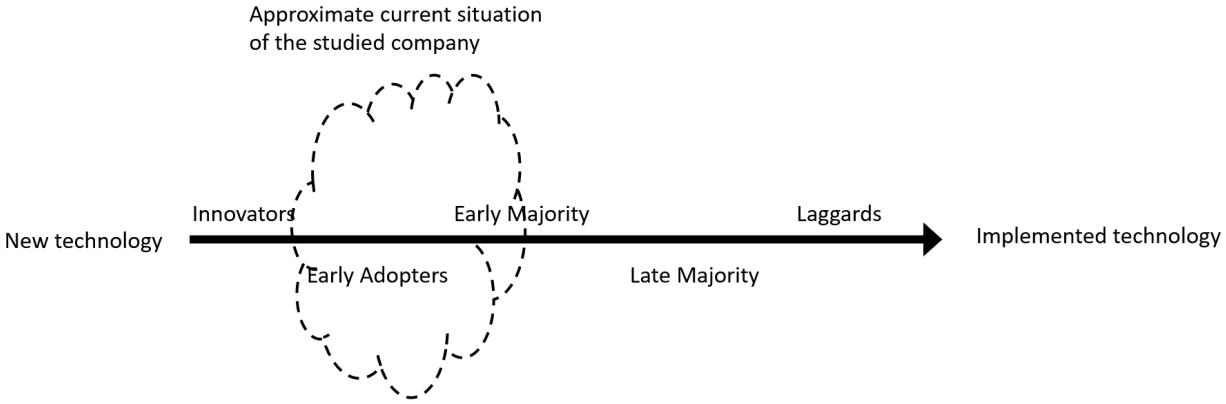

Figure 6 – approximate of the current situation of the studied company

- How can the organizational structure affect the usage of digital processes?

This study finds there is a need for more digital roles within the studied company, both new roles and a change of existing roles towards digitalization. These roles should be considered horizontally as well as vertically in the organization. Furthermore, transparency and clear responsibilities regarding these roles is needed. While creating digital roles and acquiring digital competency it is crucial to enable development for employees in these roles, moreover, to create clear career paths to ensure long-term growth of this digital competency. The existing digital roles would also benefit from an increased and well-defined hierarchical status, thereby showing that digitalization is a core activity. This is also an effort in changing the attitude within the middle level management with little interest for digitalization. The leadership of the management is vital to achieve wide-spread usage digital tools, it is therefore important that all management show that digitalization is a core organizational activity.

6.2 Suggestions for improvement

To start with, it is important to be humble and stress that the studied company in general, and the interviewed professionals in specific, already has come a long way in shifting mindset and managing to digitalize. However, there must be a continuous change in attitudes, ways of working, and performing processes, both internally in projects and organization, but also in the industry at large. The digital

environment and development is here to stay, and the companies that manage to not only adapt, but also harvest the advantages is likely to have a competitive advantage in the future of the construction industry.

Considering the literature study together with the interviews and observations made during this study, some suggestion for how the studied company can increase the implementation of digital tools at the construction site are listed below:

- Create a toolbox with common frameworks and guidelines for the digital tools, especially Dalux. The toolbox should be continuously be evaluated and improved to increase efficiency and productivity.
- Create common goals and visions for the digitalization. Break the overall goals down into measurable goals to enable analysis of progress. Both long-term and short-term goals are needed.
- Increase the minimum level of digitalization, initially adapting to the most basic digital functions such as digital self-inspections in Dalux, in all projects.
- Establish a common understanding for what data and which working methods will create synergy for the projects and value for the entire organization.
- Hire someone similar to VDCD in each business region. This role should be responsible for developing digital work processes within the organization and act as a support function for the digital tools. Furthermore, this role should be responsible for the VDC-networks and aid in connecting the different VDC-networks to each other.
- Continue having well-organized VDC-network meetings in all business regions, learning from Region south, and regularly have reflective cross disciplinary workshops regarding digital tools.
- Create a well-structured support network and hire or identify employees to work with support and introduction of digital tools to projects. These employees should work for a role similar to VDCD, at least partly. Current and emerging informal support functions should be identified and formalized, in the cases where employees are interested in becoming support functions to various extent.
- Create common introduction material for Dalux, aimed at employees only using the tool, not administrating.
- Existing central digital roles in the organization should be raised to the level other central roles in the organization, both hierarchically and culturally.
- Leadership within the organization must clearly communicate and show that digitalization is going to be part of the entire organization, not a side project done solely by employees in digital roles. The organizational strategies and goals should be permeated by digitalization. Digitalization should be communicated as an institutional culture, both internally and externally.
- Create more digital roles and make work with digital tools part of the job descriptions for more employees. Creation of more digital roles in considered an appropriate direct and more short-term solution. While making digital tools part of the work process for more employees as a suitable long-term solution, and that a combination of the two would probably be most effective.

- Create development plans and clear career paths for employees interested and skilled in digitalization.

6.3 Further studies

As this study concludes, digitalization is a continuous effort and the pace of the digitalization is likely to increase. Therefore, the recommendation for the studied company, as well as other companies, is to continue supporting research, such as this, on the topic. While this master thesis has found many interesting results there is a lot more research to be conducted, some interesting topics for future research are listed below:

- Research and evaluation of the monetary value from using digital tools in the construction phase.
- A thorough investigation of digitalization efforts in the production phase among the leading companies in the Swedish construction industry.
- Compare digitalization of the construction phase in Sweden to other comparable countries.

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Appendices

Alla appendix ska tydligen ha egna sidnumreringar. ” Bilagorna har egen sidnumreringsordning och därför anges inte sidnummer för dessa i innehållsförteckningen. Om bilagorna är många kan i innehållsförteckningen en bilageförteckning anges.”
https://student.portal.chalmers.se/sv/chalmersstudier/programinformation/maskiningenjor/examensarbete/Sidor/Utformningavrapport.aspx

Appendix 1 interview manuscript

Can we record this interview?

Introduction

Name:

Age:

Educational background:

Professional background:

Role in the company:

Years working at current company:

Current project(s):

Contract form:

Contract sum:

Role in current project(s):

Do you have a personal interest for digitalization?

Digital tools:

Do you use any digital tools in the construction process? If so, what tools?

What do you consider to be the biggest advantage of implementing digital tools in the construction process?

What do you consider to be the biggest obstacle to implementing digital tools in the construction process?

How do you think the usage of digital tools in production could be increased?

Is there any encouragement from you company to use more digital tools?

Is there any guidelies from the company conserning the use of digital tools? If yes, are they aplicable/usable?

Do you feel that those who strive for increased digitization in their work is rewarded? If so how? By who?

Do you feel that you get enough time and support to use digital tools properly?

Do you know where to get support if you need it?

Do you know who is responsible for the digital tools in the production? Who?

Do you work with monitoring of data collected from digital tools? (quality control, deviations, QEHS etc)

Do you work with follow-up on the implementation of digital tools? How they are used, how much etc.

Dalux

Have you used Dalux in production?

If no:

- Do you know what Dalux is?
- Why not?
- Would you be willing to use Dalux in the future?

If yes:

- What was your impression of Dalux?
- How did you use Dalux?
- Did you mainly use 2D or 3D views?
- How do you work with the function Tasks in Dalux, do you use the deviation function? What kind of work orders do you typically send out.
- How do you work with checklists in Dalux? Which lists is most important? Have you created them yourselves?
- How do you feel the reliability of Dalux is? Latest drawings, do you trust info from the model etc?
- How did Dalux compare to other similar tools (if you used any)?
- Is there any education needed in order to use the Dalux properly? If so, did you get any education?
- Who on the workplace does currently have access to Dalux (Skilled workers, site manager, construction engineer, customer, Inspection manager, project manager)?
- How do you think the individuals using Dalux feel about the tools? Positive/negative/reluctant?
- How have these individuals received education or knowledge on basic usage?
- Du you feel that the project is more effective while using Dalux?
- Do you feel that you in your role is more effective in the everyday work while using Dalux?
- Who on this construction site is responsible for Dalux?

How could the usage of Dalux be increased?

Do you think that more projects would use Dalux if the cost was allocated overhead rather than project? (stress use, not only have but accually use)

Do you think that Dalux is the application that will bring BIM in to the production phase of the construction industry?

Supervisor

How do you communicate tasks to your subcontractors or skilled workers?

How do you follow up on the tasks given? How do you ensure that they are completed?

How do you keep track of tasks? Do you write down the tasks you request?

Do you use Dalux for these tasks?

- If yes, Do you think it's more effective/better than before Dalux?
- If no, Would you consider using Dalux for this? Why/why not?

How do you experience the preparation work in Dalux? Prepare models, connect drawings ect. Is it very time consuming? Is it worth the time? Is there any easier way to do it?

Site manager

Do you encourage your subordinates to use Dalux?

If yes, do you feel that they use Dalux to its potential?

If no, why? Is there any other method that you believe is superior?

In the site manager position, what is the biggest benefit of Dalux?

VDC responsible

Do you feel a responsibility not only for BIM process/ modell, but also for building management through for example Dalux?

Do you think Dalux is sufficient to bring BIM to the construction site / production?

How do you experience the preparation work in Dalux? Prepare models, connect drawings ect. Is it very time consuming? Is it worth the time? Is there any easier way to do it?

Skilled worker

What is your profession?

Are you the team leader?

Did you receive any introduction to the software when you first arrived to the site?

Do you know who from the contractor who is responsible for the software?

Who do you go to if you need help with Dalux?

Do you think that Dalux is a good tool for future projects?
If yes
- What function did you have the most use of so far?
- What function haven't you tried yet, but think can be valuable?

If no
- Why not?

Do you think that the software can effectivize your work?
If yes
- How much do you think it helps your work?
- How much do you think it helps the construction site as a whole?

If no
- Does it slow your job down?
- Is there any way the software could be used differently to make it effective?

Is there any other "innovative" methods or technologies in use on site that you use? (for example, BIM-kiosks)?

Do you use a company device (phone/pad) browsing Dalux?

Construction engineer

How could Dalux as it functions today, be used for production planning activities?

How should Dalux function in the future to also enable greater production planning?

How do you experience the preparation work in Dalux? Prepare models, connect drawings ect. Is it very time consuming? Is it worth the time? Is there any easier way to do it?

How can Dalux be used to measure and develop quality?

Last questions

Can we get an invite to the project specific Dalux site, in order to view checklists and tasks?

Can we use what have been discussed today in out master thesis?

Can we use your name and/or the company name?

Appendix 2 observation template

In Site Office

Presence of paper drawings / printed blueprints, what discipline do they belong to?

Can any digital monitors (not computer screens) be found, what information do they supply?

What other printed information can be found around the office (that could be in digital form)

Are there any skilled workers in the office? What do they inquire for?

Is the office located close to the construction site? How long is the average walk to get here?

On site

Presence of paper drawings / printed blueprints, what discipline do they belong to?

Can any digital monitors (not computer screens) be found, what information do they supply?

Can any individuals be observed browsing tablet/phone? Can we ask what they browse?

What on site communication is performed between supervisor/worker? Does this concern anything communicated in Dalux? If not, could this first have been communicated digitally? Is it added to Dalux?

Is the construction site big? Is it easy and fast to access the whole site?

Is it easy to overlook the site and see/locate whomever you look for?

Appendix 3 Charts, figures and pictures

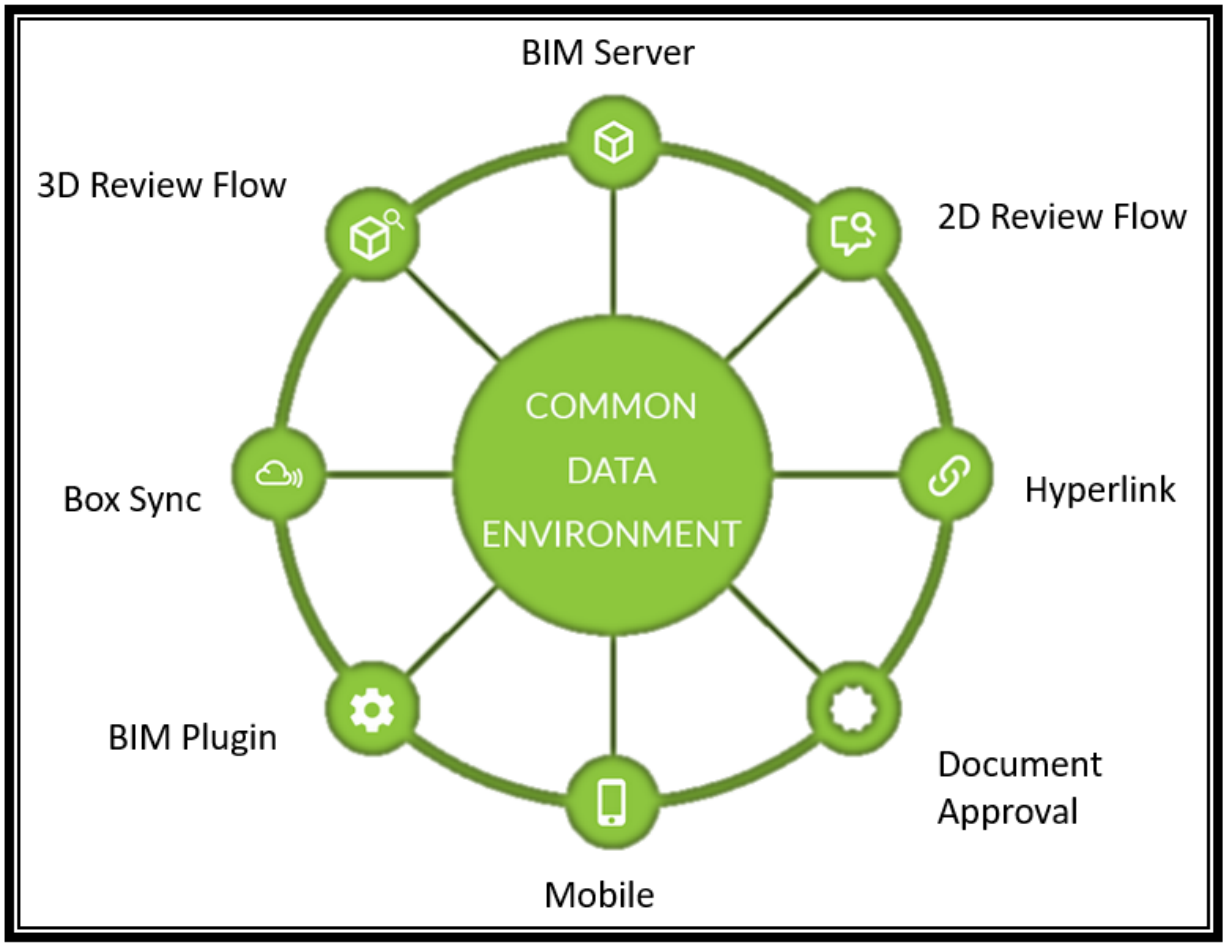

Figure 7 - CDE – Common Data Environment (Dalux, 2020a).

Figure 8 – the visualization of 2D drawing in relation to 3D model.

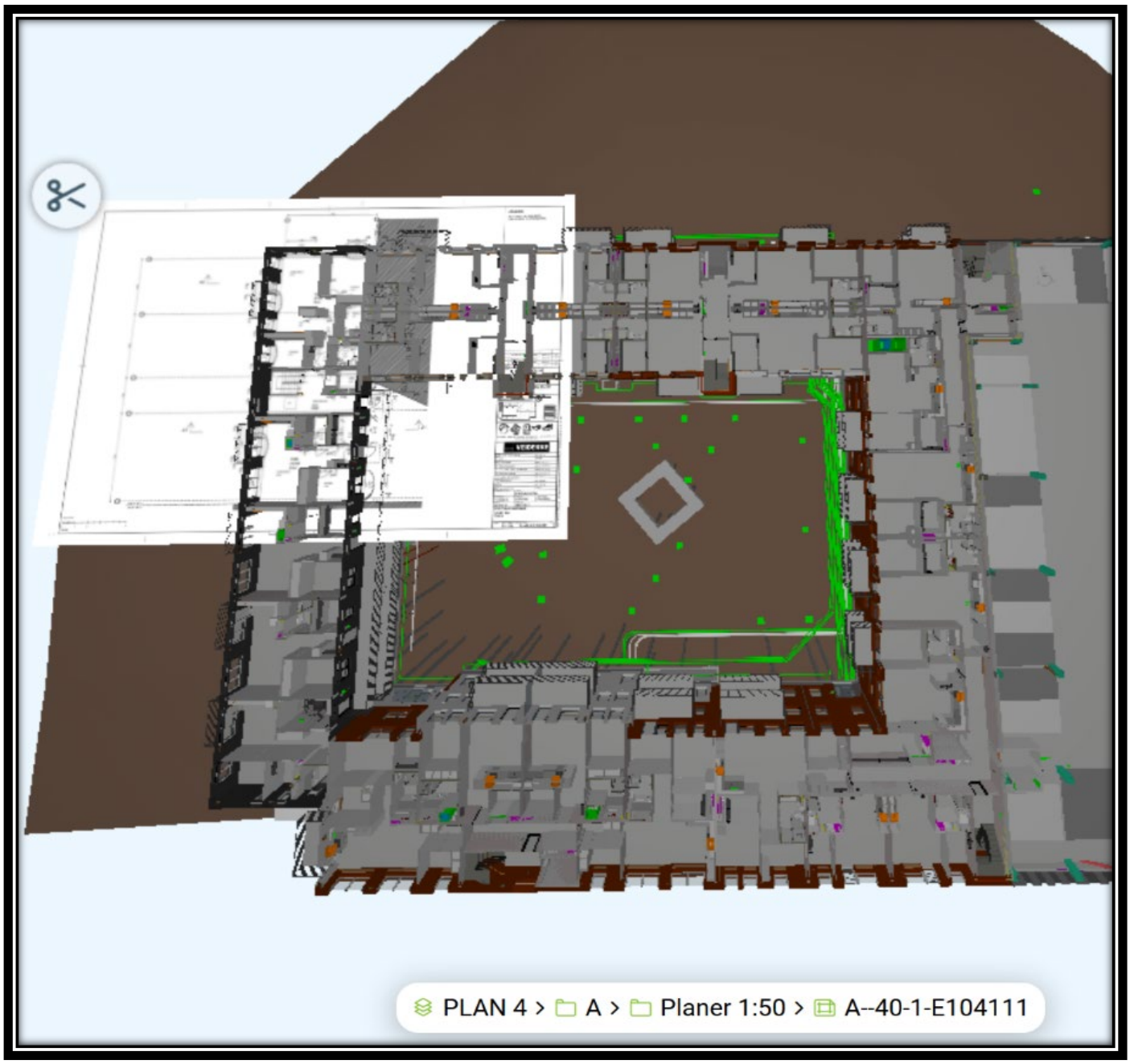

Figure 9 – a 3D model plane cut with underlaying plane drawing for one of the sections.

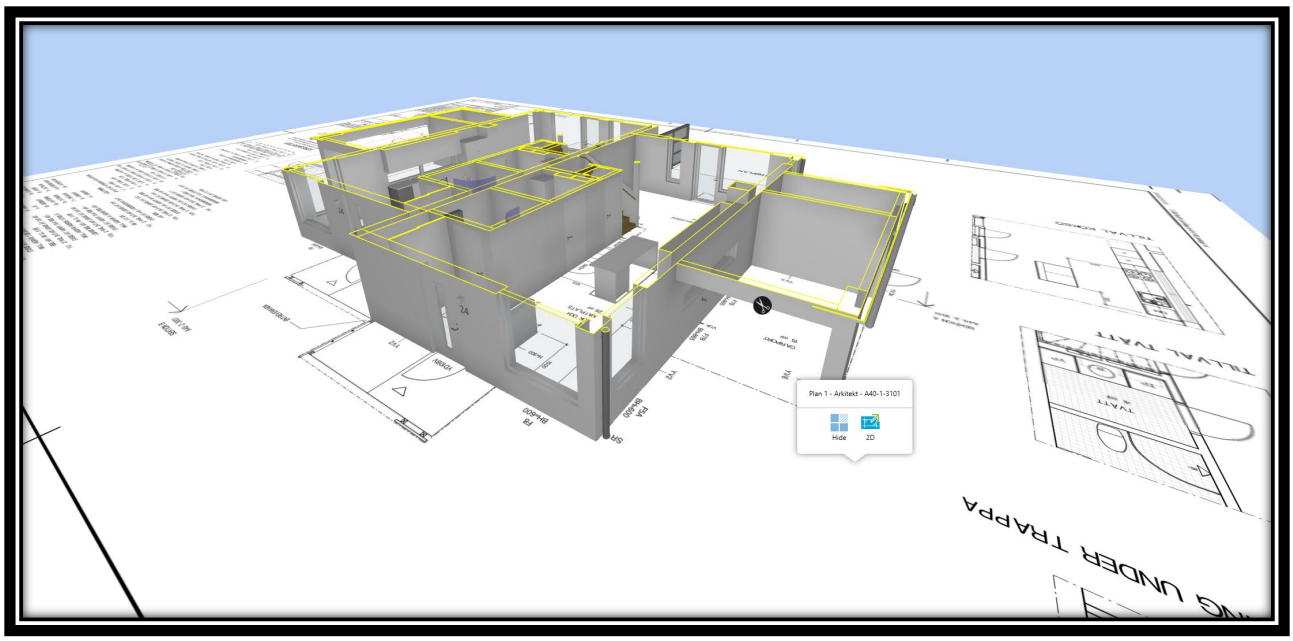

Figure 10 - the relation between drawing and model.

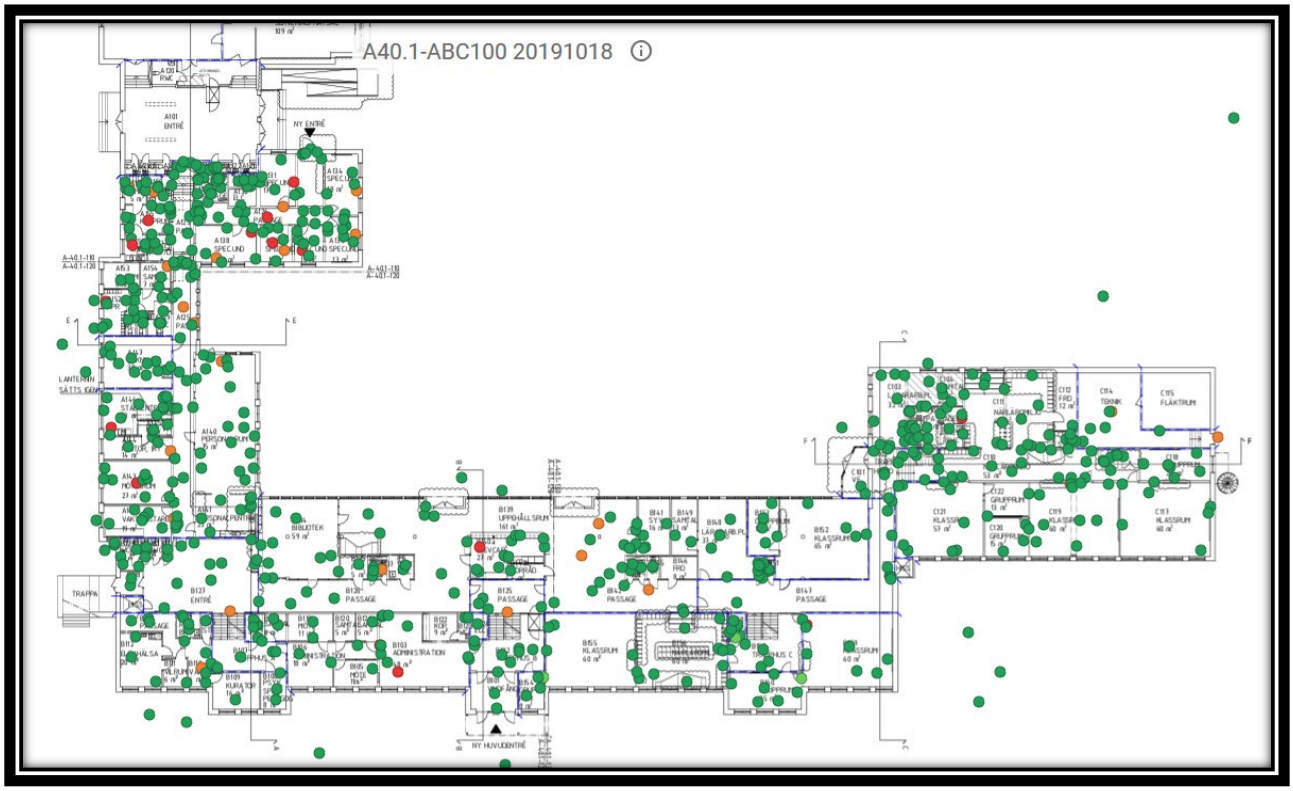

Figure 11 - spatial location of tasks with different status of completement

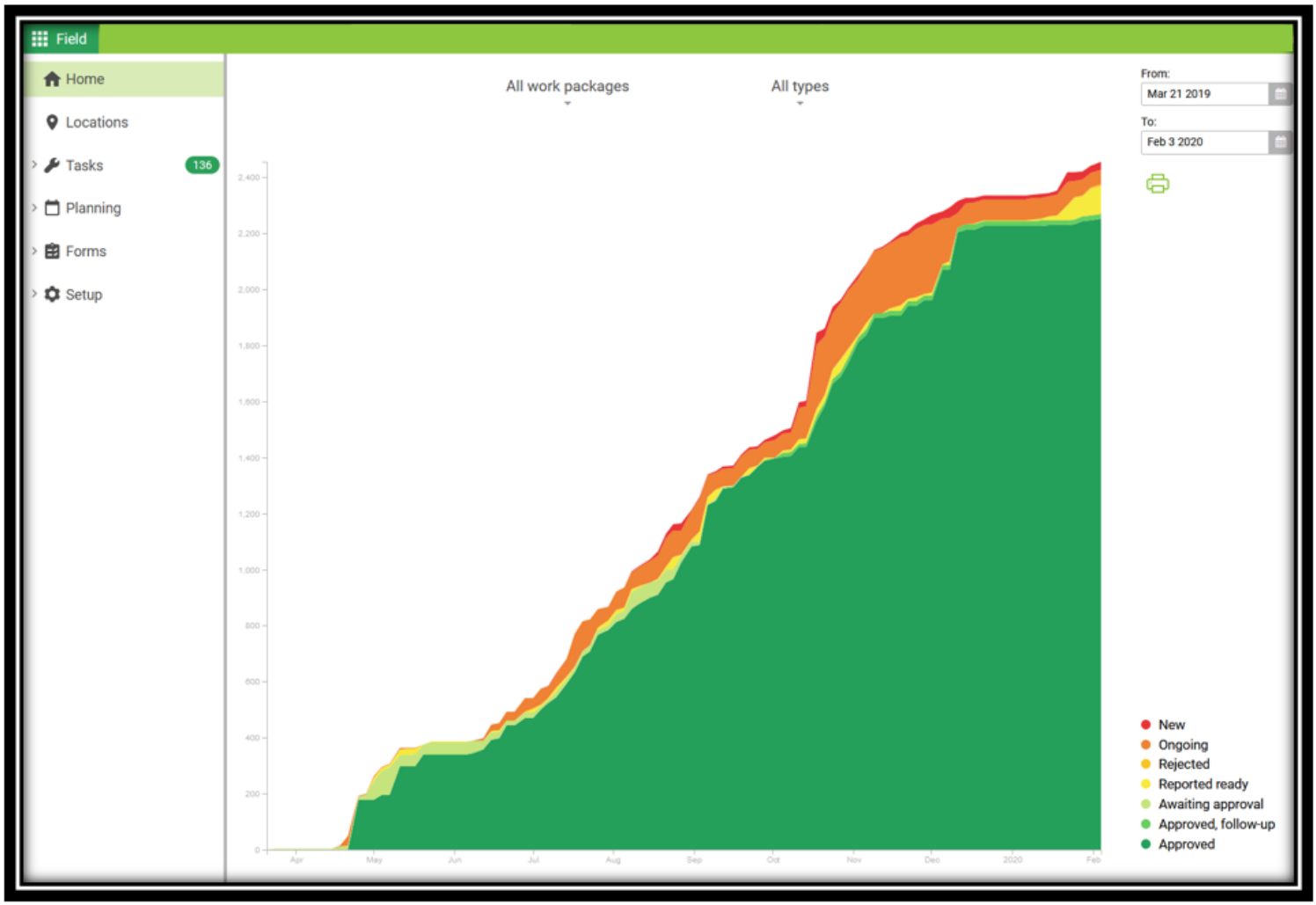

Figure 12 - the interface in Dalux to keep track of project progress.

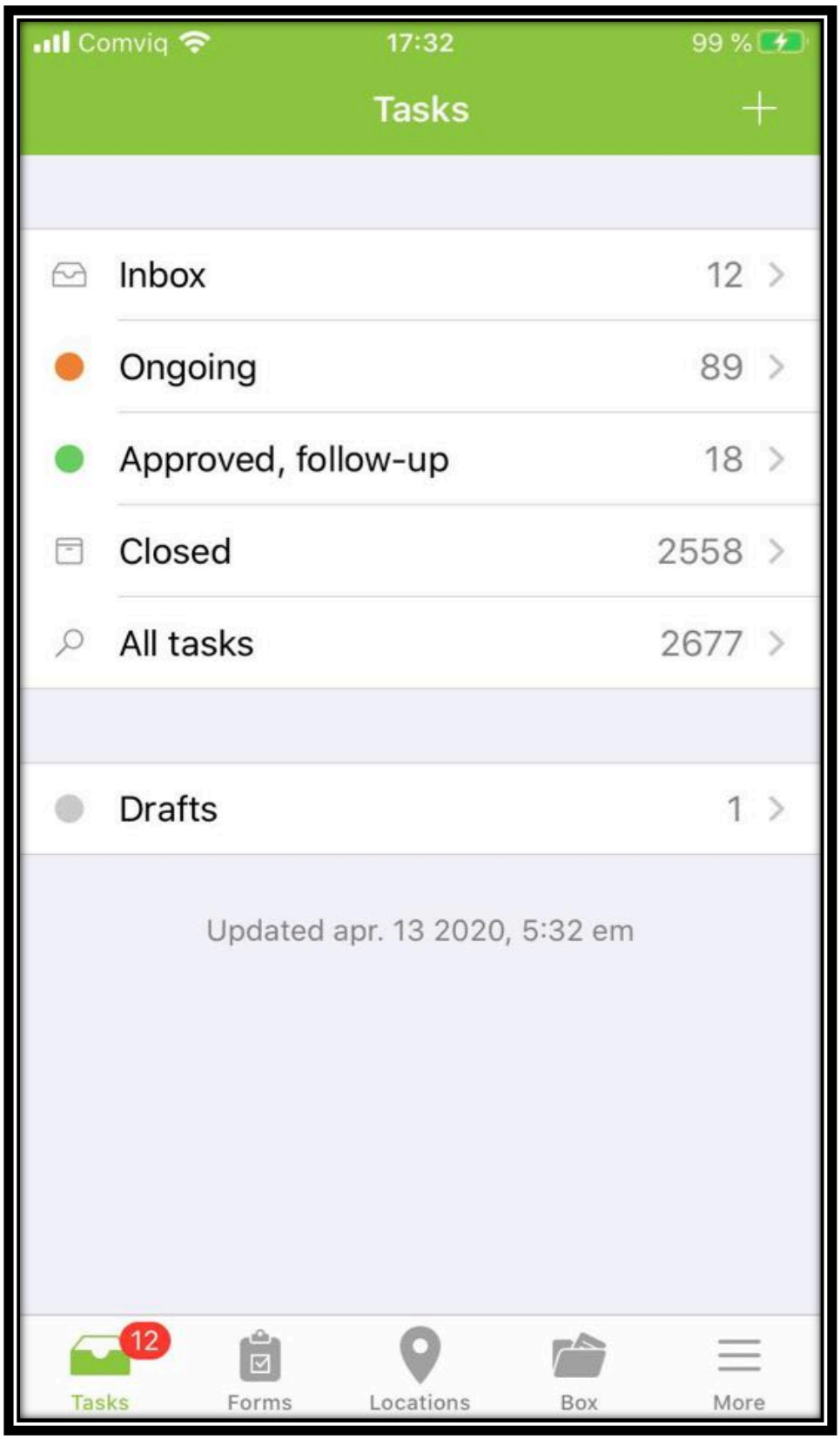

Figure 13 - Dalux Field mobile interface

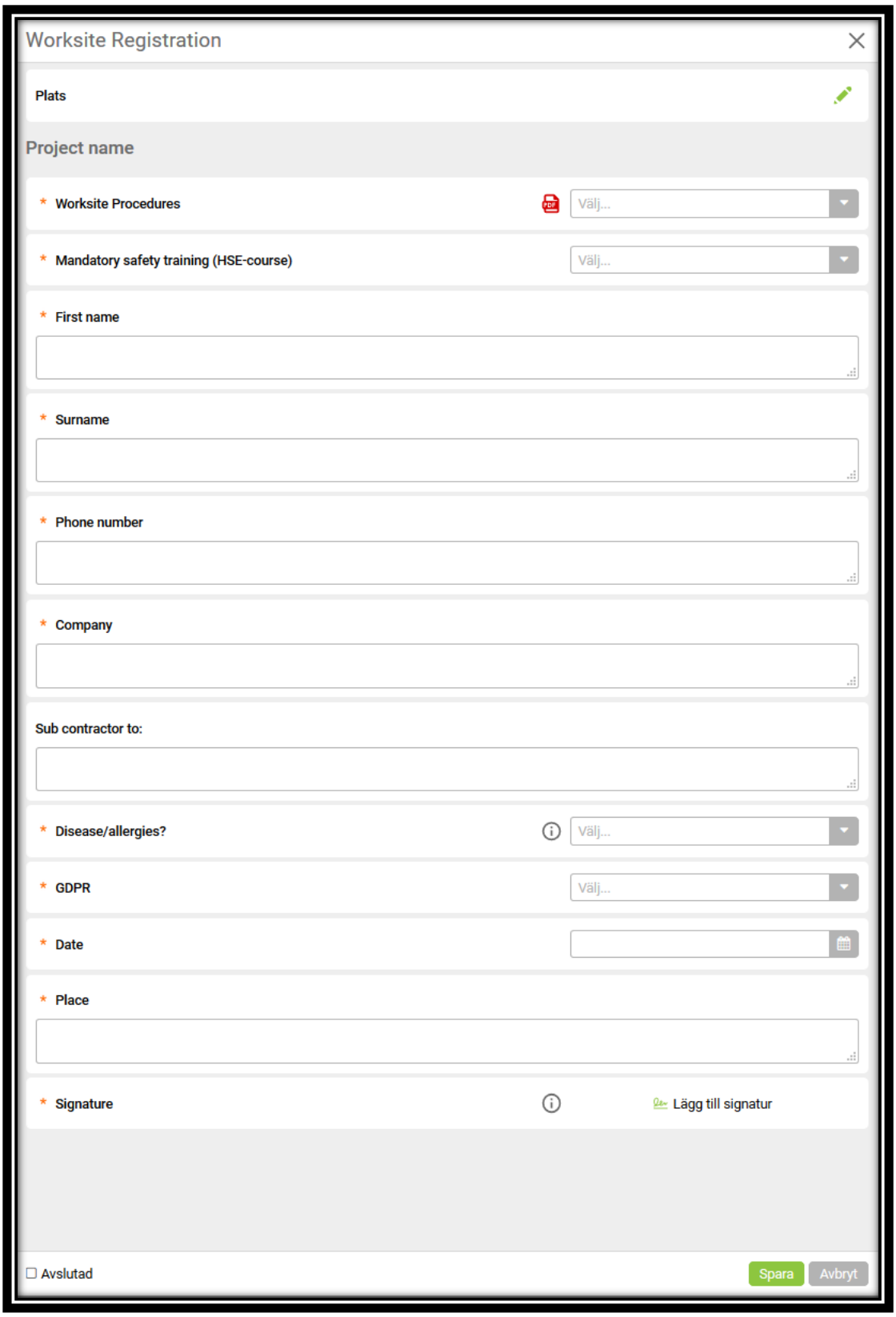

Figure 14 - example of the forms interface in Dalux field.

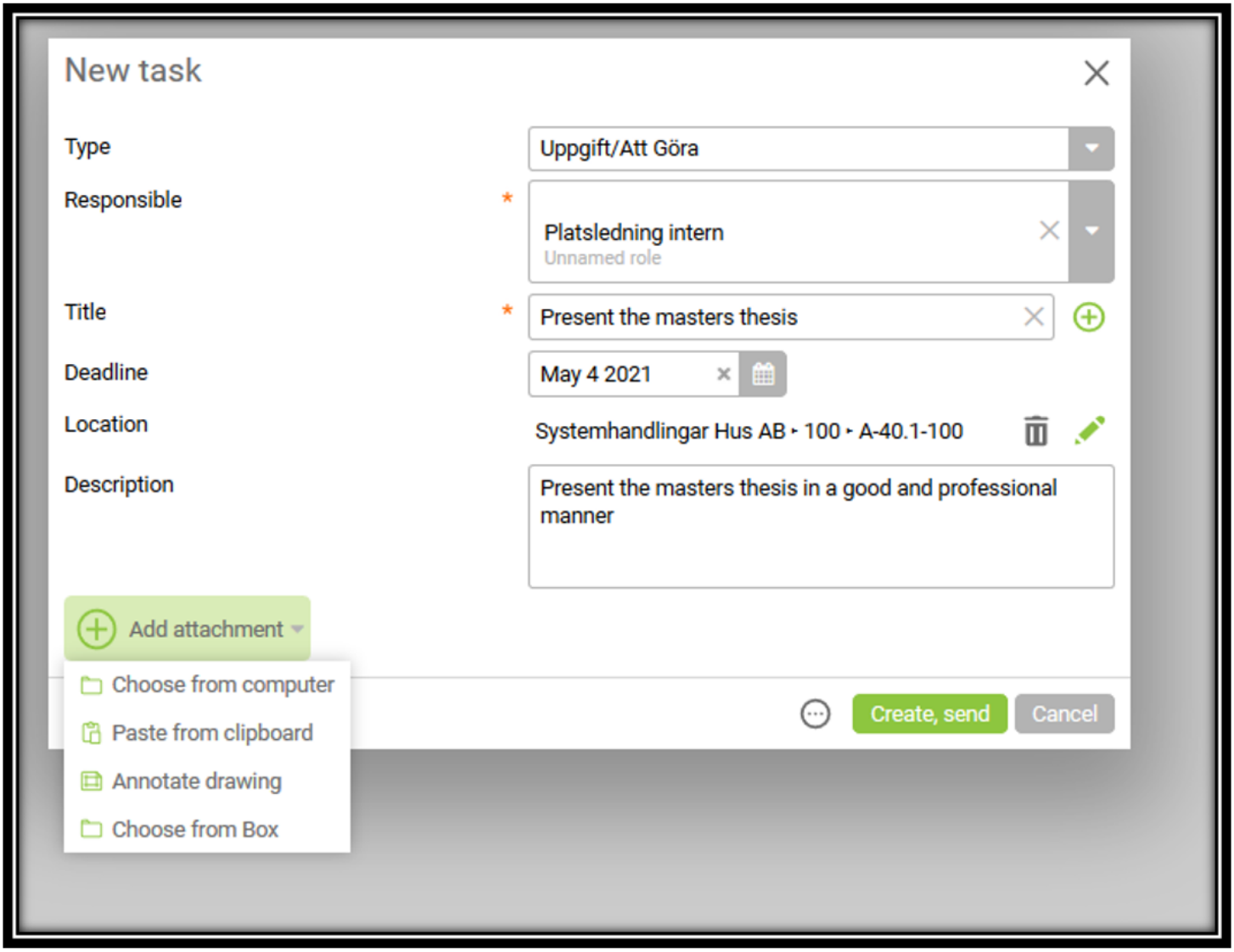

Figure 15 - task creation interface of Dalux field.

Figure 16 - AR through the Dalux TwinBIM application. Visualizing steel staircase in and open shaft.

Appendix 4 Evaluation of annual reports

Company (1-10 in size)	Mentions digitalization	
PEAB	Yes, vaguely	Development towards digitalization which permeate the business from design to production (PEAB, 2019).
Skanska	Yes	Digitalization gives opportunities to increase reliability and efficiency and will foster for collaboration and knowledge exchange. Digitalization will further provide information for better decisions. Increased usage of digital work processes, data and sustainability can increase the operational efficiency, give clients better solutions and lower costs (Skanska, 2019)
NCC	Yes	Digitalization will increase effectivity as well as customer relations. A key for future success is to own information. An increasing control and integration of the information flow through the building process will be the key to shortened lead times and better quality. NCC see themselves as branch leading and drivers of change in the digital processes. Recently they reorganized their way of working with IT (NCC, 2018).
JM	Yes, vaguely	Since 2018 JM works with digitalization of processes and project information, with focus on implementing BIM (JM, 2018).
Veidekke	Yes	Effective project management is Veidekke's highest priority, this is why digitalization and sustainability are prioritized as keys for future competitiveness. Knowledge is a base for productivity, through collecting data digitally that relates to key figures in repetitive production, the processes can be made more productive. Develops new tools for better monitoring of site safety, by gathering data from currently used systems to provide a real-time overview of compliance with rules and procedures on individual construction sites (Company A, 2019a). Develops new tools for better monitoring of site safety, by gathering data from currently used systems to provide a real-time overview of compliance with rules and procedures on individual construction sites (Company A, 2019a).
Svevia	Yes	Digitalization enables new possibilities for effective and sustainable ways of working. The ability to benefit from digitalization is increasingly becoming an important aspect of competition. Digital tools enable for increased operational efficiency and improves and simplifies interaction between colleagues, clients, partners and suppliers (Svevia, 2019).
Erlandsson (Brixly)	No	
Serneke	No	
Riksbyggen	No	
OBOS	No	

Table 2 - Evaluation of annual reports

DEPARTMENT OF ARCHITECTURE AND
CIVIL ENGINEERING
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden
www.chalmers.se

CHALMERS
UNIVERSITY OF TECHNOLOGY