BI Norwegian Business School - campus Oslo

GRA 19703

Master Thesis

Thesis Master of Science

Digitalization of processes in the construction production phase: A case study from the Norwegian construction industry

Navn:	Johanne Finsrud, Emilie Myrdal Kristing

Start:	15.01.2021 09.00
Finish:	01.07.2021 12.00

Master thesis

BI Norwegian Business School

- Digitalization of processes in the construction production phase -

A case study from the Norwegian construction industry

Hand-in date:
01.07.2021

Campus:
BI Oslo

Examination code and name:
GRA19703 Master Thesis

Supervisor:

Lena E. Bygballe

Program:
Master of Science in Business
Major in Logistics, Operations and Supply Chain Management

Acknowledgements

Throughout this master thesis we have gained valuable understanding and insight into the practices of digitalization in the Norwegian construction industry. This would not have been possible without the help and guidance of several contributors. Thus, we would like to express our gratitude towards these individuals.

Firstly, we would like to thank our supervisor Lena Bygballe for guiding us through this process and providing us with valuable feedback along the way. We truly appreciate the enthusiasm and interest in our thesis work, which has been a great motivational factor. Secondly, we would like to express our gratitude to Veidekke for being a fundamental part of our research. We especially want to thank our contacts Sigmund Aslesen, Sigmund Reff, and Erik Knutsen for good dialog and hospitality. We greatly appreciate the flexibility Veidekke has shown us when faced with challenges resulting from the ongoing pandemic. We would also like to thank everyone who willingly participated in our interviews, as this has been of great importance for our research.

Lastly, we are grateful for the support of our families and friends. Their patience and encouragement have been of great value during this process. We would also like to emphasize the value of our well-functioning partnership and equal commitment - the collaboration has been seamless.

Emilie M. Kristing Johanne Finsrud

BI Norwegian Business School, Oslo

Abstract

The construction industry represents the building blocks of society, crucial for driving economic growth and long term development (Foulkes & Ruddock, 2007; Ofori, 2015). The industry is, however, characterized as being fragmented and complex (Dallasega, 2018). Additionally, a productivity decline has been identified, directing attention to the importance of digitalization in construction (Agarwal et al., 2016). A variety of research can be found regarding digitalization of different phases and levels of a construction project. Through dialogue with the Norwegian construction contractor Veidekke, the need for further investigation into the construction production phase was revealed. Thus, we have identified the research question **"How does digitalization influence construction production processes?"**. To answer this question, the various processes digitalized in the construction production phase have to be investigated, hence our first sub-question *"What type of processes in the construction production phase have been digitalized?"*. Furthermore, to understand the influence of digitalization on the identified processes, we have developed our second sub-question *"What are the perceived benefits and challenges of digitalization of construction production processes?"*.

Our research is based on a qualitative case study of Veidekke, as we find this to be a suitable approach to gain valuable in-depth insight to our research question. The case study consists of data collected from two of their large construction projects in Oslo, namely Ulven and Frysja, where we have conducted semi-structured interviews with project participants. Moreover, we have utilized the process of systematic combining, going back and forth between the literature and our empirical evidence to develop the findings. To conclude our thesis, we highlight that there are a wide variety of perceived benefits and challenges to digitalization of construction processes in the production phase. Furthermore, we found that there are intermediary benefits that influence the perceived performance and results of implemented digitalization. The findings of our research further revealed that digitalization efforts have been made at different levels in the production phase, shedding light on how the collective digitalization efforts, both out on site and in the on-site office, should be considered. Indeed, the efforts of the on-site office were found to have an indirect influence on the construction production phase.

Table of Contents

List of figures

List of tables

List of Abbreviations

Acronym	Full term
3D	Three Dimensional
AI	Artificial intelligence
AR	Augmented Reality
BIM	Building Information Modeling
CADD	Computer Aided Design and Drafting
COVID-19	Coronavirus disease of 2019
CSC	Construction Supply Chain
GDP	Gross Domestic Product
GDPR	General Data Protection Regulation
HSE	Health, Safety and Environment
ICT	Information and Communication Technology
IoT	Internet of Things
IT	Information Technology
LC	Lean Construction
NSD	Norwegian center for research data
QA	Quality Assurance
VDC	Virtual Design and Construction
VR	Virtual Reality

1. Introduction

1.1 Background and motivation

The Architecture, Engineering and Construction industry (hereafter: construction industry) represents the building blocks of a society, driving it forward by providing infrastructure such as residential buildings, offices, schools, and hospitals. It contributes to economic growth, thereby being of high interest and priority for the government (Foulkes & Ruddock, 2007). The nature of a construction project is highly complex, due to the great number of participating parties with interrelated processes, time limits, and a high degree of customization (Dallasega, 2018). The topic of productivity is heavily debated in construction literature, often emphasizing poor and declining rates (e.g. Aziz & Hafez, 2013; Barbosa et al., 2017). Furthermore, project success and performance have been a recurring topic in the field of construction for decades, where managers continuously strive to complete projects with the most favorable outcomes (Chan & Chan, 2004).

The evolution of today's society is highly influenced by an increasing implementation of technology. Digitalization is found to be among the most significant drivers transforming the society and business sphere at an ever-increasing rate (Hagberg et al., 2016; Kuusisto, 2017b). The construction industry is no exception, and a trend towards digitalization is found apparent (Renz & Solas, 2016; Whyte, 2019). According to McKinsey Global Institute's industry digitalization index 2016, however, the construction industry is among the least digitalized and is moving at a slow pace. This is a result of the nature of construction projects, and how it still heavily relies on manual labor. Furthermore, being a labor-intensive industry has caused less attention to, and need of, technology compared to other sectors. As a result of the low productivity rates and constant performance pressure, the industry is nevertheless incentivized to improve their practices by focusing on implementation of new technologies (Agarwal et al., 2016). Despite the development's slow pace, productivity measurements portray that the industry has a great deal of potential (Berlak et al., 2020). Digitalization is not just a phase, and several governments around the globe seem to be especially focused towards the construction industry in this regard (Blanco et al., 2019).

A similar digitalization trend can be seen in Norway, where new technologies are increasingly being tested and adopted within construction practices. Examples include widely adopted technologies such as Building Information Modelling (BIM), but also emerging tools including 3D-printing, Augmented Reality (AR), and Virtual Reality (VR) (BI Centre for the Construction Industry, 2019; Byggenæringens Landsforening, 2020). The opportunities of the technologies are many, likely to shape the future of the industry (BI Centre for the Construction Industry, 2019).

When looking into the Norwegian construction industry and the approach to digitalization, we got in touch with the largest main contractor in Norway, namely Veidekke. After being introduced by our supervisor, discussions with company representatives revealed that various processes and digital tools have been implemented in several stages and levels within their projects. There seemed to be a great interest in digitalization, as the company is continuously looking for ways to utilize digitalization to improve their processes. However, through further dialogue, a knowledge gap was identified in the construction production phase. What became evident, was that digitalization at the construction site is not found to receive significant attention. This further seems to coincide with literature, where digitalization is discussed and approached at multiple levels and in different phases of a construction project (e.g. Aguiar Costa & Grilo, 2015; Bryde et al., 2013; Elghaish et al., 2020; Kunz & Fischer, 2020). When exploring the literature, little research was however found focusing on the production itself. With this, a need for gaining more knowledge within this phase was revealed, including the perspectives of the ones involved as well as the effects of digitalization on production processes.

When discussing practices related to production with Veidekke, it became evident that they utilize collaborative planning combined with progress planning known as Takt. A natural link can thereby be made to the approach to Lean Construction (LC), often seen in connection with digitalization through the concept of Virtual Design and Construction (VDC). The utilization of VDC is however not within the scope of this thesis, as our focus remains on the digitalization within the construction production phase. Nevertheless, Lean methods are found to be widely applied at construction sites, crucial for the production phase. Therefore, we find it relevant

to address the connection between digitalization and Lean to a certain extent throughout our master thesis.

1.2 Research Question

Due to the limited focus on digitalization in the production phase of a construction project, we find it interesting to examine and understand how digitalization influences the construction processes on site where the physical work is completed. This is a critical phase of a construction project, and through dialogue with representatives of Veidekke, we have discovered that this is an area where our study can contribute. Therefore, we have developed the following research question:

RQ: How does digitalization influence construction production processes?

When referring to the construction production phase and its processes, we are addressing digitalization impacting both construction workers out on site, as well as staff and managers in the on-site offices. To answer this question, the various processes digitalized in the construction phase have to be investigated. Thereby, we have identified the sub-question:

- *What type of processes in the construction production phase have been digitalized?*

However, to understand the influence of digitalization, only identifying the processes is not enough. As the production often is associated with manual labor, perceived benefits and challenges accompanying the digital change is of the essence. By gaining employee perspectives of the positive and negative effects, insight into the influence of digitalization on the construction production processes can be revealed. Therefore, we have developed a second sub-question:

- *What are the perceived benefits and challenges of digitalization of construction production processes?*

1.3 Empirical setting

To explore the aforementioned research question, Veidekke provides our empirical setting. Veidekke is one of Scandinavia's largest construction firms and has several comprehensive projects around Norway where they perform services related to construction work, road maintenance and production of asphalt (Veidekke, n.d.). In terms of digitalization Veidekke has various digital processes and tools implemented in several stages and levels within their projects. By being a contractor with a focus on digitalization, we believe a case study of Veidekke will yield valuable insight into the practices and influence of digitalization in the Norwegian construction industry. After dialogue with company representatives, we found that they have great interest in the impact of the digitalization they have implemented and are continuously looking for ways to utilize digitalization to improve their processes. Thus, we find that Veidekke provides a well-rounded empirical setting, creating a suitable basis for exploring our research question. Our study will mainly focus on Veidekke, despite the construction production being heavily dependent on subcontractors. We will be looking into two construction projects that have implemented various digital processes and tools, further presented in Chapter 4. The projects have been chosen for our study in collaboration with our contacts in Veidekke, and we believe focusing on two construction projects gives us the opportunity of conducting in-depth research within the time limits of a master thesis.

1.4 Structure of the thesis

This master thesis consists of six chapters. Following this introduction, we will provide a thorough description of the research methodology applied. Thereafter, chapter three provides a narrative literature review, uncovering theories and previous research related to our main topics of interest. The results and analysis of our empirical findings will be presented in chapter four, followed by a discussion and comparison of the findings and the literature in the subsequent chapter. Finally, the sixth chapter serves as a conclusion, presenting the resulting practical and theoretical implications of our study, as well as some limitations and suggestions for future research.

2. Research methodology

This chapter aims to provide a detailed description and justification of the methodological choices made to answer our research question. Here, we will look at both our approach to literature and the methodology of the study itself. This includes the choice of research design and strategy applied to our study, as well as specifications of the data collection and the approach to analyze this data. Lastly, we will address the quality of our study as well as discuss some limitations related to our presented methodology.

2.1 Research design

A research design is according to Bell et al. (2019) defined as a framework for collection and analysis of data. In other words, this is a detailed description of how a study will be conducted, and will affect the results and quality of the study. Hence, choosing an appropriate research design is of great importance. For the investigation of our research question, we found a case study design to be a suitable approach, often applied in business research (Baxter & Jack, 2008; Dul & Hak, 2008). What distinguishes a case study from other designs is "[...] the focus on a bounded situation or system, an entity with a purpose and functioning parts" (Bell et al., 2019, p. 63). Yin (2014) highlights the "real life context" of such a design, implying that a phenomenon is investigated within contextual boundaries without any form of manipulation. A case study offers unique flexibility and allows us to dig deep into one case to assess the different elements of analysis within the same conditions (Bell et al., 2019; Ebneyamini & Sadeghi Moghadam, 2018). Thus, due to the exploratory nature of our research question we aim to gain unique insight into different aspects of the complex reality in the construction production phase by the utilization of a case study design.

When looking to select a case for our empirical study we considered the literature on case selection. Stake (1995) distinguishes between three types of case studies, namely intrinsic, instrumental, and multiple or collective case studies. Intrinsic case studies are suitable when looking to understand the particularities of a situation, rather than generic understanding (Stake, 1995). Instrumental case studies are found to be "[…] those that focus on using the case as a means of understanding a broader

issue or allowing generalizations to be challenged" (Bell et al., 2019, p. 64). Multiple or collective case studies are used for understanding a general phenomenon, connecting multiple studies. The lines between the different types of case studies, however, are often blurred (Stake, 1995). Furthermore, Yin (2014) have identified three different types of case studies, namely explanatory, exploratory, and descriptive. A descriptive case study aims to describe or define a particular phenomenon, an explanatory one aims to explain why a phenomenon occurs, while an exploratory case study explores topics and relations not yet clearly defined in research (Yin, 2014). As we are looking to use our case as a means to understand aspects of the broad impact of digitalization, we perceive our study as an instrumental case study. Moreover, the topic in question is how digitalization influences construction production processes. This is especially interesting as current research seems to have limited focus on the impact digitalization has on the physical production phase, hence finding an exploratory case study approach applicable.

When looking to select an appropriate case for our study, our supervisor introduced us to one of Scandinavia's largest construction firms, namely Veidekke. The company's focus on, and experience with, implementing digitalization made them favorable for our empirical study. Furthermore, through dialogue with company representatives, we became aware that knowledge of how digitalization influences the production phase seemed to be limited. Indeed, Veidekke seemed eager to understand the influence on the actual production processes on site. With this in mind, we believe that the case with Veidekke gives us a great opportunity to learn and provide valuable insight into an area with little current knowledge.

For our case study, the units of analysis are the construction worksites at Ulven and Frysja; two projects with different characteristics. More detailed descriptions of the two construction projects will be presented in Chapter 4. We do not consider these projects as subcases, but rather as examples related to the empirical setting. They provide a complementary approach rather than a comparative one, in pursuit of a broader and deeper understanding of digitalization in construction. This can indeed be valuable for our research, as the two residential construction projects seem to have different approaches to digitalization. The project at Frysja is recognized as

the digital flagship in Veidekke. Here, tools such as GateBrain and automated containers have been implemented, and we find them in the forefront of testing emerging technologies such as AR and VR. The construction workers at Ulven are also utilizing several digital tools daily, however the main tool is the mobile application Dalux. With this, flow becomes a focus through checklists and continuously updated models and drawings. The tool is also in use at Frysja, however it is not yet utilized to the same extent. By looking into two construction projects with Veidekke as the main contractor, we aim to enrich our analysis and gain understanding related to our research question and the broader issue of digitalization in the Norwegian construction industry.

2.2 Research strategy

Research strategy can be defined as "[...] a general orientation to the conduct of business research." (Bell et al., 2019, p. 35). The first step of our research was to develop a narrative literature review, which implies a thorough study of existing literature. This literature study became the foundation of our further research strategy, deciding on the specific research method suited for our case study.

2.2.1 Literature study

In order to conduct our research project, we were dependent on reviewing existing literature within our main fields of interest. This included suitable books, articles, reports, previous studies, and relevant conference proceedings, serving to shed light on theories and concepts of importance for our research. This was crucial for our understanding and provided the basis for development of a conceptual framework that further guided our data collection and analysis.

The methodology behind our study of the literature is of high importance as it involves making decisions about the limits of our research project, using the literature review as means to affirm our credibility in the chosen area (Bell et al., 2019). To gain an in-depth understanding of relevant theory and existing knowledge, we utilized several online platforms accessible in our search such as Google Scholar and BI Norwegian Business School's online library Oria. In addition, we consulted several relevant journals, some of which were specific to

the construction industry, while others were found to be more general journals basing some of the studies on the construction industry. The former includes journals such as *Construction Management and Economics,* while the latter can be seen through *International Journal of Organization Theory and Behavior,* and *Supply Chain Management: An International Journal.* In order to get an extensive pool of relevant articles we chose English as our search language and utilized several search techniques to gain the most appropriate results. The Boolean searching style, including AND or OR in between words, provided us with accuracy when needed, while adding a star at the end of a word broadened our searches.

2.2.2 Scientific approach

When approaching scientific research, the relationship between theory and research should be established (Bell et al., 2019). Researchers distinguish between two approaches in this regard, namely deductive and inductive. A deductive approach seeks to create hypotheses based on existing theory within the field, thereafter, testing them in the real world. This contrasts to the inductive approach, seeking to contribute to theory through empirical findings of the study (Wilson, 2014). For our research project, our aim has been to have an iterative process between theoretical analysis and data collection, a method combining the deductive and inductive approach (Bell et al., 2019).

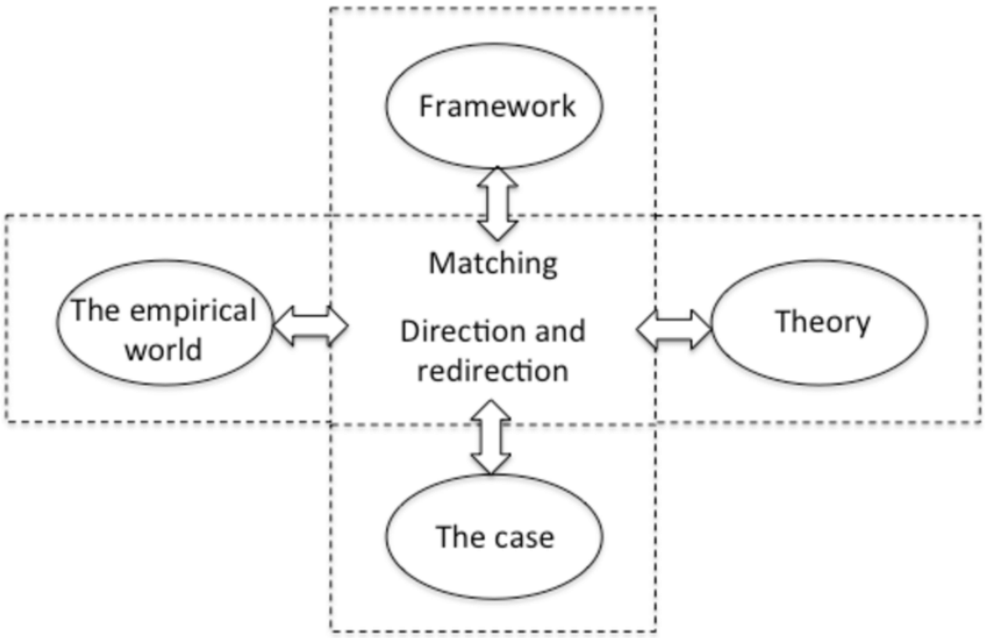

Figure 1: The systematic combining approach developed by Gadde and Dubois (2002)

Systematic combining is an example of an iterative approach we found suitable and is often referred to as being abductive. The approach is illustrated in *Figure 1*, portraying a process where "[...] theoretical framework, empirical fieldwork, and case analysis evolve simultaneously […]" (Dubois & Gadde, 2002, p. 554). This implies that data collected throughout the project directs attention to the theoretical analysis and vice versa, enabling a continuous interplay between theory and empirical findings. Systematic combining is found to be closer to an inductive approach than a deductive one, as it is particularly useful for developing theory (Dubois & Gadde, 2002). We found this suitable for our research, as we aimed to continuously combine our empirical findings with existing literature. This provided us with a thorough understanding of the concepts and opened the possibility of exploring theories and concepts not considered at the beginning of the process. Our approach to systematic combining throughout our research process is presented in *Figure 2*, inspired by Kovács and Spens (2005), illustrating our journey back and forth between the literature and the empirical.

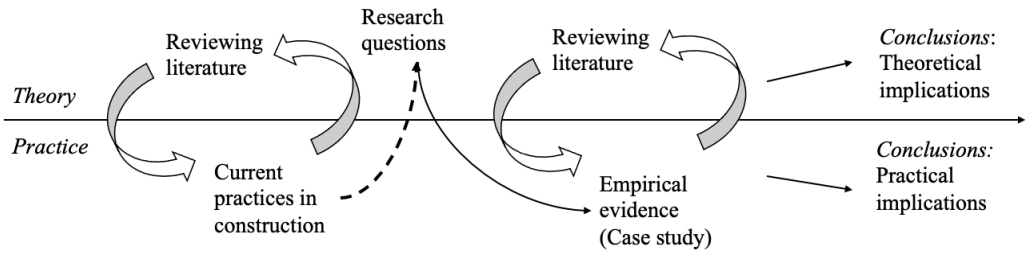

Figure 2: Visualization of systematic combining – an iterative approach

2.2.3 Research method

Bell et al. (2019) makes a distinction between qualitative and quantitative research strategies, describing the different methods researchers use to collect and analyze data in a research project. Case study research can take both forms, either through the emphasis on one of them or through a combination of the two. Qualitative research methods embody a focus on written or spoken words and images, often captured through for instance interviews and observations. Quantitative research, on the other hand, is based on the collection of numeric data, broadly attempting to measure social phenomena and the relationships between them. The latter is found

to be the dominant business research strategy, however qualitative research has become increasingly influential since the 1980s (Bell et al., 2019).

Looking at the nature of our research question, we initially set out to apply a mixed method approach, aiming to combine both qualitative and quantitative data to investigate the impact of digitalization. However, throughout our data collection process, it became evident that our research mainly required deep insights and experiences, difficult to capture through quantitative methods such as questionnaires. Qualitative research methods, are used by researchers to explore areas and factors with limited previous knowledge, assuming that the reality is manifold and interrelated (Khan, 2014). It provides in-depth insights, allowing for thorough investigation of phenomena found in the real world (Bell et al., 2019). Additionally, there was an apparent time constraint of our research project, as well as an ongoing pandemic (COVID-19) further complicating data collection. The latter led to the decision to discard the quantitative aspect, as a questionnaire would have required physical follow-up at the construction site which was not possible. Hence, we found that a full qualitative research method was the most appropriate.

2.3 Data collection

Data collection is a critical phase of a research project, laying the foundations for further analysis. Eisenhardt (1989) argues that case studies tend to combine various sources in data collection. This is further emphasized by Yin (2014) identifying six sources of evidence to be documents, archival records, interviews, direct observation, and participant-observation. Not all six sources apply to all situations, however four principles are important in any case study research. These include using multiple sources of evidence, maintaining a clear chain of evidence, exercising care when using electronic sources of evidence, and creating a database containing all gathered evidence (Yin, 2014). Furthermore, a distinction is made between primary and secondary data. The former is data collected for the specific research problem at hand, while the latter is material gathered for other purposes available for reuse (Bell et al., 2019). An overview of our data collection for this study is shown in *Table 1*. Our approach to the data collection is closely related to the method of systematic combining, laying the foundations for an iterative process.

Primary data	
Semi-structured interviews	
Ulven	*Frysja*
Interview 1	Interview 2
Interview 6	Interview 3
Interview 7	Interview 4
Interview 10	Interview 5
	Interview 8
	Interview 9
Demonstration and attendance	
Ulven	*Frysja*
Initial meeting with our contact at Ulven	Initial meeting with our contact at Frysja
Meeting with our contact and another student	Demonstration of various digital tools through Zoom
Lean Construction Norway Webinar	
Secondary data	
Presentation received from class	
Presentation received from LC-NO Webinar	
Veidekke's webpage	
Existing literature	

Table 1: Overview of data collection

2.3.1 Primary data

Interviews

According to Yin (2014), one of the most important sources for gathering evidence in case study research is interviews. This is because interviews enable the researcher to gain important understanding into human affairs through well informed interviewees (Bell et al., 2019; Yin, 2014). This form of data collection is of wide use in numerous fields of research, aiming to access experiences as well as inner perceptions, attitudes, and feelings of reality (Wildemuth & Zhang, 2016). Fontana and Frey (2005) present three distinguished categories of interviews based on the degree of structure, namely structured interviews, semi-structured interviews, and unstructured interviews. In structured interviews a series of predefined questions are asked in the same order to all participants, with little room for variations in

responses (Fontana & Frey, 2005). Semi-structured interviews similarly follow a predefined interview guide, however they are more flexible, allowing for both close- and open-ended questions. The interviewer may also add or change the questions throughout the interview based on context and responses (Wildemuth & Zhang, 2016). Lastly, unstructured interviews, often referred to as informal interviews, provides a format relying on social interaction between the interviewer and the interviewee. The focus is centered around a list of topics or issues, and does thereby not tend to have any predetermined questions nor answer categories (Bell et al., 2019; Wildemuth & Zhang, 2016).

For our primary data collection, we have conducted semi-structured interviews, referring to the interview form balancing standardization with flexibility. With this, we started by creating an interview guide using the literature as a basis, containing mainly open questions allowing for elaboration. Our interview guide can be found in *Appendix 1*. We wanted to keep the form semi-structured, following the interview guide to be able to compare and analyze the answers. Moreover, the interview format allowed us to follow up on other interesting aspects that appeared beyond the interview questions we had prepared. This was of great use and helped us keep an open mind to concepts and themes not initially thought of. Furthermore, it allowed us to focus on the interviewee's area of expertise, following up with more questions on the topics they seemed particularly informed on.

In qualitative research, purposive sampling is a common way to deal with the selection of units such as organizations, departments, or people (Bell et al., 2019). This approach revolves around the research questions guiding the sample, sampling in a strategic way rather than emphasizing randomness. The samples thereby tend to be smaller than what is used in quantitative research, and the point of the data collection is not to generalize to a population but rather gain an in-depth understanding of a phenomenon (Bell et al., 2019; Dworkin, 2012). When sampling participants for our interviews, we applied a purposive sampling method emphasizing a non-random selection. This entailed an initial identification of relevant categories of people, where our contacts in Veidekke further provided us with suitable individuals. The candidates were predominantly employees of Veidekke, however some individuals working on the project through subcontractors

were also included. With the aim of gaining the most holistic picture, we asked for both individuals physically working on site as well as individuals in managing positions of the projects. The former seemed crucial in order to capture the actual experiences and perceptions of the ones working out in the production. In this category, we initially set out to interview a range of construction workers on site. This turned out to be a challenge, as restrictions were imposed at the worksites due to the pandemic, preventing us from conducting face-to-face interviews on site. With construction workers being highly occupied with the physical production, spending time and energy on online interviews was not seen as a priority. Thus, to capture the perspectives of this group, we ended up interviewing some construction workers in more managerial positions such as the team manager or foreman. Furthermore, interviewing individuals in managing positions such as project leaders and engineers, seemed interesting as it would provide some insights into the overall approach and intention of the digitalization at Veidekke. Additionally, this would capture the link between the on-site office and the construction site.

Throughout our data collection process, we conducted a total of 10 interviews with 11 interviewees. We ensured a somewhat even selection of participants from the two construction projects, Ulven and Frysja, such that we gathered a reasonable amount of information on both projects for our complementary analysis. An overview of the interview distribution can be found in *Table 2*, where 5 of the interviewees were associated with Ulven and the remaining 6 interviewees were participants at Frysja. Through the aforementioned sampling process, we ended up with a range of individuals in different positions. Furthermore, the duration of the interviews ranged between 30 - 60 minutes, and were, due to the ongoing pandemic, conducted online through the software application Zoom. This implied a synchronous online interviewing situation, combining audio with an added face-to-face interaction through webcam (Bell et al., 2019). The interviews were all held in Norwegian, and in line with Norwegian center for research data (NSD) requirements, a consent form was required to be signed before the interview. Here, the individuals were informed of their rights, such as that participation was voluntary and that they could withdraw at any time. The consent also contained the acceptance of us using job titles or work background in our thesis if relevant, as

well as permission to audio-record. The latter was of great value to ensure that no information was lost or forgotten.

Interview nr.	***Interviewee***	***Project***
1	Interviewee 1	Ulven
	Interviewee 2	
2	Interviewee 3	Frysja
3	Interviewee 4	Frysja
4	Interviewee 5	Frysja
5	Interviewee 6	Frysja
6	Interviewee 7	Ulven
7	Interviewee 8	Ulven
8	Interviewee 9	Frysja
9	Interviewee 10	Frysja
10	Interviewee 11	Ulven

Table 2: Overview of interview distribution

Demonstrations and attendance

As a case study is taking place in the real world, there is a great opportunity of directly observing the phenomenon in question (Yin, 2014). Thus, participant observations, where the researchers immerse themselves into a setting to observe interactions and events, can be seen widely applied in qualitative research (Hox & Boeije, 2005). Complementing our interviews with observation of the production phase was indeed a part of our initial plan for data collection, aiming to gain insight into the digitalization of construction production processes. However, as a result of the ongoing pandemic, on-site observations were not possible due to strict regulatory practice within the construction industry in Norway. In order for us to gain an understanding of the digital processes and tools at Veidekke without watching it "in-action", one of the interviewees gladly demonstrated several of the systems in use at Frysja. This included Gatebrain, Bimsynch, and live cameras at

the construction site, as well as statistics on Health, Safety & Environment (HSE) and Quality Assurance (QA). Through the online software application Zoom, the employee shared their screen and explained the processes in detail and how digital tools were in use. This was highly advantageous as it provided us with visuals and details on the practices of digitalization at Frysja.

Throughout our research project, we maintained continuous dialogue with our contacts in Veidekke. Meetings were conducted with the representatives of the two projects, providing us with background and context when moving forward. Discussions of interesting aspects related to digitalization were also made. Due to Veidekke having multiple thesis projects at Ulven, a meeting was also conducted with our contact and another master student to clarify that our scopes did not overlap. In this meeting, we also exchanged experiences and insights, useful for each other's research. Moreover, our knowledge and understanding of the construction industry and Veidekke's approach to Lean were further enhanced through attendance at a Lean Construction Norway Webinar, concerning Takt planning at the Ulven project. This provided us with an informative introduction to the concept and practices at Ulven, useful to bear in mind for our research.

2.3.2 Secondary data

When referring to secondary data, we consider data that is not collected for the purpose of the specific research (Bell et al., 2019). For our research, the information summarized in our literature review acted as a secondary source of data. By including an extensive literature review of previous studies and theories, the data was used when discussing our findings, putting it into perspective. Additionally, we utilized company specific information found online and received from our contacts at Veidekke. This included information gathered through the company webpage (www.veidekke.no), as well as two presentations received, one from the attended LC Webinar and one from a lecture held by Veidekke November 3rd, 2020, at BI Norwegian Business School. The data presented information regarding the company as a whole, as well as specifics of the two construction projects, further utilized in Chapter 4 to present the case study in detail. The information enhanced our understanding of the industry, the unique projects, as well as general practices in Veidekke.

2.4 Data analysis

Data analysis refers to the stage in a research project where the raw data collected is organized, analyzed, and interpreted (Bell et al., 2019). The qualitative data collection is typically derived from interviews, participant observation, or documents, thus resulting in a large amount of unstructured textual data. There are no clear-cut rules to be followed when it comes to qualitative data analysis, however it is of utmost importance to reduce and structure the masses of information collected (Bell et al., 2019). The data analysis is a crucial part of the systematic combining approach, where the empirical evidence retrieved through data analysis directs our attention to the theoretical analysis and vice versa (Dubois & Gadde, 2002).

Due to our main data collection consisting of semi-structured interviews, transcribing them was essential as a basis for further data analysis. There are several advantages to recording and transcribing interviews, as it for instance helps correct the natural limits of our memories and allows for repetition and thorough examination of what is said (Bell et al., 2019). Transcription is a time-consuming process and may be daunting, as e.g. Bell et. al. (2019) recommends five to six hours of transcription per one hour of speech. With this in mind, we decided to continuously find the time to transcribe in between interviews, which also served beneficial in the sense that the content remained "fresh" in our minds. What is important in qualitative research is the fact that it is not only *what* the participants say that has value, but also *how* it is said (Bell et al., 2019). To capture this aspect, we utilized indications such as exclamation points and brackets to capture the mood of the conversation. Laughter, pressure on certain words or phrases, as well as long pauses are examples of indications captured in the transcripts.

To further analyze the prepared data, we conducted a thematic analysis. This framework represents one of the most common approaches to qualitative data analysis and can be defined as "[…] a method for identifying, analyzing and reporting patterns (themes) within data. It minimally organizes and describes your data set in (rich) detail" (Braun & Clarke, 2006, p. 79). This can again be seen in relation to systematic combining, as our themes indeed were inspired by our literature study, further reviewed and revised as we progressed.

The thematic analysis is broken down to six recommended steps to follow throughout the data analysis process:

1. Familiarizing yourself with your data
2. Generating initial codes
3. Searching for themes
4. Reviewing themes
5. Defining and naming themes
6. Producing the report (Braun & Clarke, 2006)

The initial phase of familiarizing ourselves with the data was done through the aforementioned transcription process, as well as reading and re-reading the transcripts. This helped us become familiarized with the content, serving as the basis for the rest of the analysis (Braun & Clarke, 2006). During our transcription and re-reading, we also noted down some initial ideas for potential codes and aspects that seemed interesting. The transcription further enabled the data collected in the interview to be uploaded to a computer software program for analysis, making the data more manageable.

This started the second phase of generating initial codes, where we began by color coding the answers from the interviews in accordance with its relevance. This was done to filter out parts of our transcripts, seemingly off topic for our further research. We utilized green to emphasize answers with a high degree of relevance, either to the question itself or towards another relevant subject, while red indicated little degree of relevance. The latter included general statements and talk about topics of little relevance to our research, and thus not found important to analyze and address further. After color-coding the transcripts according to relevance, we utilized the data refinement program NVivo to further organize the transcribed data, creating a range of initial codes related to interesting aspects of the content. The initial structure of our codes can be seen in *Figure 3*. This coding organized the data into meaningful groups, providing a foundation for our further data analysis. As our research leans more towards "theory-driven" than "data-driven", the data was coded around our identified research question, emphasizing content of relevance (Braun & Clarke, 2006).

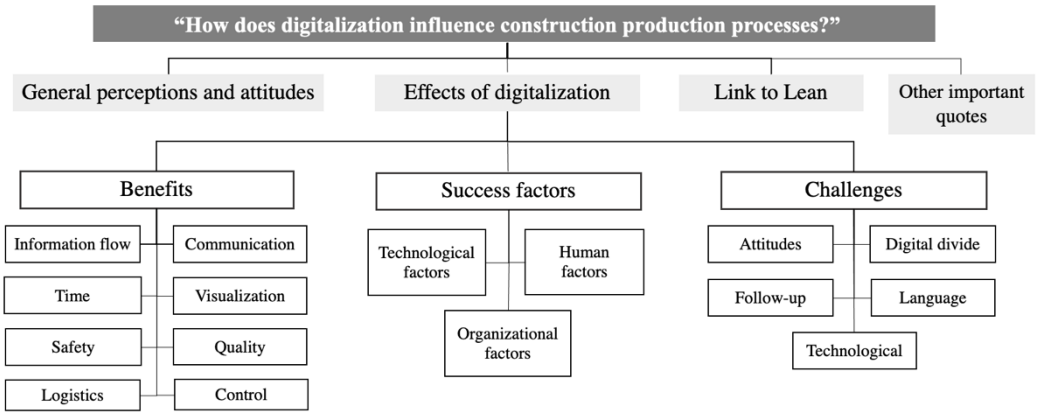

Figure 3: Initial coding structure

The third and fourth phase of the thematic analysis calls for a further refinement and broadening of the scope. We started searching for central themes, sorting the initial codes identified in the previous step, considering how they could be combined into themes and sub-themes (Braun & Clarke, 2006). Consequently, after identifying several candidate themes, these were reviewed and further refined. Through this process, we identified that some of our themes seemed too broad, while some too small, thereby rearranging them accordingly. For instance, we found that our category of success factors was indeed a reflection of the challenges, and therefore these categories were naturally merged. By the end of this phase, we felt like we had a fairly good idea of the different themes, their connections, and the overall story of the data collected.

In the fifth phase we proceeded to clearly define and name the themes by looking into the essence of the contents of each category identified, such that it was clearly portrayed in the name. This resulted in the development of the final coding structure, which can be found in *Figure 4*. Lastly, the final phase of the thematic analysis was constructing the final report. In line with Braun and Clarke (2006, p. 93) we wanted our final report to be able to reflect "[...] a concise, coherent, logical, non-repetitive and interesting account of the story the data tell". Moreover, the report should make an argument towards the research question, not only provide a

description of the data (Braun & Clarke, 2006). The report on our empirical findings and analysis can be found in Chapter 4.

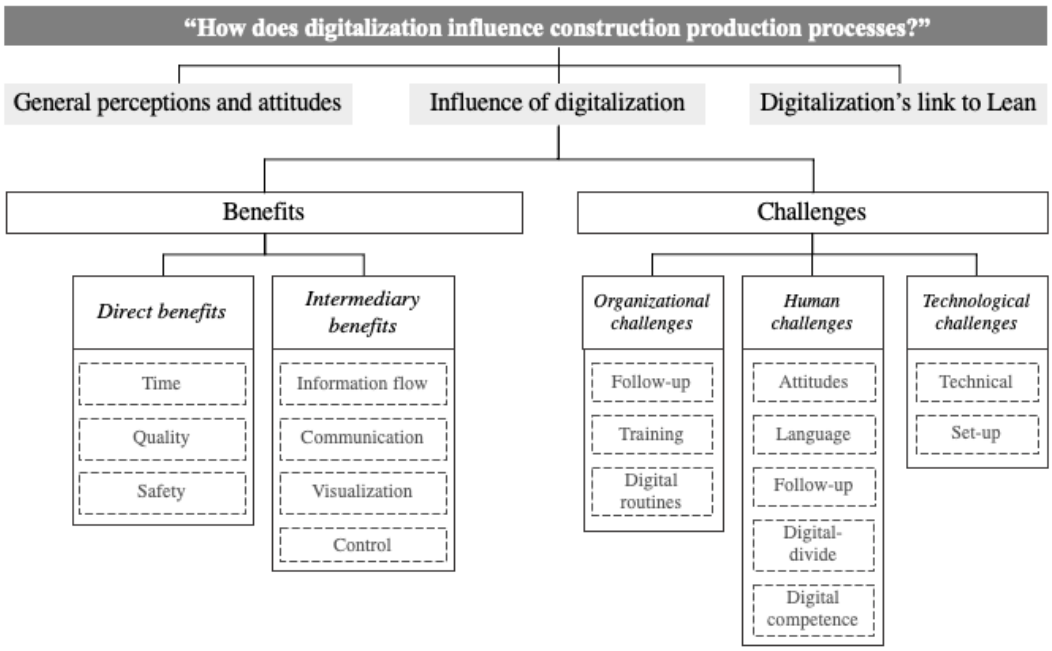

Figure 4: Final coding structure

In addition to our coding structure, we have created a table (*Table 3*) exemplifying findings within the central themes identified. The structure of the table follows our two sub-questions, firstly providing examples of findings related to digital processes, secondly providing examples of identified benefits and challenges. The latter is further separated into direct and intermediary benefits, as well as organizational, human, and technological challenges.

How does digitalization influence construction production processes?	
"What type of processes in the construction production phase have been digitalized?"	
Digitalized processes	Our findings indicated that there were three main processes that had been digitalized in the construction production phase, namely progress planning and monitoring, logistics, as well as HSE and QA deviation reports. This can be illustrated by the following: Interviews and demonstrations highlighted the importance of extensive progress statistics to monitor and assess the status of the project. For project planning, software systems such as Microsoft Project is utilized, accompanied by Microsoft Excel for further visualization. *"What makes us stand out the most is that we have tried to be technological on many levels. It could be small efforts, such as ensuring emptying of containers and registration of when they are full, to systems such as Gatebrain where people register their arrival with deliveries to the construction site beforehand [...]" Interviewee #4* *"[...] and there [in Dalux] we also have follow-up of QA, such as checklists for control and quality assurance in production" Interviewee #7* *"[...] reporting HSE deviations and such has become digital" Interviewee #11* *"Deviations, HSE deviations... that too, a couple of years ago, used to be only on paper notes that you delivered in a mailbox up with the management, but now that is digitalized as well, so it is registered immediately" Interviewee #8*
"What are the perceived benefits and challenges of digitalization of construction production processes?"	
Benefits	
Direct benefits	Direct benefits were identified through data collection, including benefits related to time, quality, and safety. This can be illustrated by the following quotations: *"[...] we can continuously update the systems on the phone instead of running back and forth to do it manually [...] and every time we update a sheet someone has to sign again. So, doing it this way is extremely timesaving, and it becomes more proper" Interviewee #4* *"When you have paper drawings a new audit can come out and remain here in the office for three days before it gets out. Now we know that when a new audit comes out, everyone has the newest version immediately" Interviewee #11* *"We might have lowered the barrier for reporting deviations, with Dalux in comparison to the green paper notes [...] where you delivered it, but then no one was able to understand your handwriting and it ended in the garbage anyway" Interviewee #1* *"This [Dalux] is a form of digitalization that allows us to act faster, and I would argue that it actually reduces the risk" Interviewee #3*

Intermediary benefits	Through our research, several intermediary benefits were highlighted as a result of digitalization. These included for instance control, visualization, communication, and information flow. The following statements illustrates some of these aspects: *"[...] I receive information exactly the way it was perceived at the place the deviation was observed, and I can handle it the way it was meant to" Interviewee #4* *"[...] the flow of information has reduced the number of parts in the process and made information much more available [...]" Interviewee #4* "*Because I believe that with digitalization and visualization, building errors will be reduced*" *Interviewee #3* *"And it [statistics displays] gives you greater control [...]" Interviewee #10* *"[...] It is very nice as a means of communication and makes it very easy to ... both for the ones outside [at the construction site] to come in contact with us [at the on-site office] and the other way around" Interviewee #5*
Challenges	
Organizational challenges	The following statements give an indication of some of the organizational challenges found related to digital production processes: *"Everything is supposed to be notified in a way, so you may have to write something about it later in some program anyway" Interviewee #9* *"[...] everyone who utilizes the technology must be on the same wavelength when it comes to the degree you plan to use it, and to what extent it should be a part of the everyday work" Interviewee #4*
Human challenges	The following statements give an indication of some of the human challenges found related to digital production processes: *"[...] I have experienced people using it, because they find themselves getting many deviations, thus becoming annoyed, thinking like "okay, but then I will send deviations back" [...]" Interviewee #4* *"For some it has been more difficult than others. It is often connected to age. Those who are a bit older, there you find more resistance than with those who are younger really. [...] and the older ones use more time to understand how it works and where you find things" Interviewee #11*
Technological challenges	The following statements give an indication of some of the technological challenges found related to digital production processes: *"[...] we are so many workers on the project that we are struggling with, to make the usage as easy as possible, the person who put in the task does not necessarily get a notification saying, "now it is done"" Interviewee #7* *"When we have been working outside during the winter or when it rains, we have had to leave the tablet in one place and go back and forth to check. So, it has been a real problem" Interviewee #11*

Table 3: Overview of central themes with accompanying examples

2.5 Ensuring scientific quality

An assessment of scientific quality is of high importance in research in order to demonstrate credible findings. There is, according to Hannah and Lautsch (2011), no clear consensus as to how qualitative research should be conducted in order to secure high quality. Yin (2014) for instance refers to the aspects of construct validity, internal validity, external validity, internal reliability, and external reliability. Additionally, Lincoln and Guba (1985) provides criteria related to trustworthiness, namely credibility, confirmability, dependability, and transferability. These two approaches to quality can however be seen in parallel, as reliability closely relates to dependability, while internal and external validity can be seen as credibility and transferability respectively. Thereby, to ensure the best possible quality of our research we have chosen to take the four trustworthiness criteria of Lincoln and Guba (1985) into account, and will further describe these measures in detail.

2.5.1 Credibility

Establishing credibility is of high importance when conducting a study, as this acts as a measure to strengthen the trustworthiness of the findings (Bell et al., 2019). Lincoln and Guba (1985) recommend doing this through triangulation. According to Patton (1999), triangulation refers to utilizing several methods or data sources in qualitative research. This is done with the aim of ensuring a comprehensive understanding of the phenomenon, utilized to test validity through the convergence of information from several sources (Carter et al., 2014; Patton, 1999). There are several types of triangulations explored by Denzin (1978) and Patton (1999), more specifically: method triangulation, investigator triangulation, theory triangulation, and data source triangulation (Carter et al., 2014). All of these were applied in our research to a certain extent.

Method triangulation refers to the use of several methods of collecting data about the topic of interest (Carter et al., 2014). Our semi-structured interviews and data received from Veidekke were originally supposed to be seen in connection to on-site observations. This would have ensured credibility through various sources of information, however, due to the pandemic, observations were not found to be feasible. This was rather substituted with online demonstrations and webinar

attendance, aiming to gather information from various methods within the limits of what was possible in the challenging situation of COVID-19. Furthermore, investigator triangulation was applied, as we were two researchers in the same study at all times and in all stages. This is important to provide multiple and various observations and perspectives, further validating the final conclusions (Carter et al., 2014). Theory triangulation, involving various theories to analyze and interpret the data, is of use assisting researchers in supporting or refuting findings linked to the literature. This was continuously applied through our approach of systematic combining. Lastly, data source triangulation is according to Carter et al. (2014, p. 545) involving "[...] the collection of data from different types of people [...] to gain multiple perspectives and validation of data". By including interviewees both from the construction site and from the on-site office, we managed to gain different experiences and perspectives on the topics of interest. This was further enhanced by including interviewees not only from Veidekke, but also representatives from some of their subcontractors.

2.5.2 Confirmability

The concept of confirmability acknowledges that complete objectivity is impossible, but aims to ensure that the researchers are acting in good faith without any biases (Bell et al., 2019). This indicates that the researchers should withhold any personal opinions or values through the research process, not letting it affect the data collection or analysis. Both researchers were present when collecting the data, such as during interviews, gaining two individual perspectives and the ability to monitor each other. To ensure that the interviews were as unbiased as possible, both researchers contributed when creating the interview guide. Furthermore, the list of questions was sent to our contacts in Veidekke in advance for them to provide input on the content to ensure that our questions were relevant and interesting.

After the completion of the interviews, measures were put in place to prevent biases throughout the transcription process. We arranged this by assigning one of us to act as the main interviewer, asking the questions during the interview, while the other would listen to the interview and later do the transcription. Hence, we would not be biased by transcribing interviews we had conducted ourselves. Then, after the interview was transcribed the person who conducted the interview would listen

through the audio recording while reading the transcript to ensure its accuracy. Furthermore, in order to increase the confirmability, all interviews were completed and transcribed prior to any findings or discussions taking place (Bell et al., 2019).

2.5.3 Dependability

According to Bell et al. (2019, p. 365) dependability refers to ensuring that "[…] the complete records are kept of all phases of the research process […]". This implies that all methods and findings should be stored and secured in an accessible manner for peers to be able to check that the appropriate procedures have been followed (Bell et al., 2019). This includes field notes, interview transcripts and secondary data analysis, serving as accurate documentation of the research process. As our intended data collection involved some personal data, we started out by applying to NSD for approval of our research in accordance with the General Data Protection Regulation (GDPR) requirements. This process required us to address our plan for storing our data, further ensuring safe documentation of personal data. All data gathered were thereby stored locally on our password protected computers, as cloud-based platforms such as Dropbox or Google Disk were not seen as safe. The placement of the information and documentation was known at all times, available upon request from the individual interviewees. However, as our data included personal data requiring safe storage, the transcripts were not accessible for the public, limiting the transparency of our research.

2.5.4 Transferability

The concept of transferability is important for qualitative research and relates to whether findings can be transferred to other companies or settings. This is especially important in case studies due to its contextual uniqueness regarding conditions such as time, geographical location etc. (Bell et al., 2019). With this, we are aware that the transferability of our study is limited as we investigate a single case and focus our data collection on a construction company operating in Scandinavia specifically. The context of a case study is of the essence, as aspects and conditions found to be important in some regions may be seen as less relevant in others. An example could be the emphasis on worker involvement in decision making and attitudes toward authority, widely varying across the world. For instance, Norway is found to be highly consensual and egalitarian (Meyer, 2017).

Consequently, our results may not be transferable to other settings or companies unless they have similar conditions.

Despite the challenge of transferability in case study research, our research aims to provide some key findings that may be useful for further discussion within the field of digitalization in the construction industry. Through analysis, interpretation, and comparison of empirical findings with theory, analytical generalization can be achieved. This refers to contributing to robustness of current theories by providing evidence supporting the specific conceptualization (Firestone, 1993). With this, we hope to provide transferability to a certain extent, with the acknowledgement that our findings are indeed case specific.

2.6 Methodological limitations

Seeing that we have completed a qualitative study, there are certain limitations associated with this research methodology. Firstly, it is argued that qualitative research is too subjective, given that researchers often rely on unsystematic views about what is significant and important (Bell et al., 2019). It is also argued that qualitative studies are difficult to replicate, due to its unstructured nature. As a result of this subjectiveness and low replicability, singular case studies have been criticized for the difficulty of generalization (Tellis, 1997). In addition, the lack of transparency is highlighted as an issue, as it can be unclear for instance how people were chosen for interviews, to what extent research participants were selected to correspond to a wide range of people, and the process of the data analysis (Bell et al., 2019).

It is also important to note that our methodological choices have been limited by the capacity and time perspective of a master thesis, thus influencing the scope of our research. Thereby, not all aspects of the phenomenon of digitalization in construction will be covered, and the primary data collection is restricted to two construction sites contracted by Veidekke. However, through the aforementioned measures to ensure scientific quality we believe interesting aspects of digitalization in the Norwegian construction industry have been revealed, relevant for those interested in this field.

3. Literature review

To gain the most complete understanding of our research, we find it important to review literature on current practices, challenges, as well as the nature of the construction industry itself. Furthermore, digitalization is a term frequently used in various settings, calling for a review of general definitions and previous research, in addition to more specific insights related to the industry. In this chapter we will provide a narrative literature review covering the aforementioned topics to gain insight into the state of current research. A conceptual framework will be provided at the end of this chapter to illustrate the main findings, serving as an outline further useful for our data collection and discussion.

3.1 Characteristics of the construction industry

The construction industry represents the building blocks of a society, widely acknowledged as a crucial sector as it provides infrastructure such as residential buildings, offices, schools, and hospitals. Indeed, it contributes to driving economic growth and long-term development within a nation, thereby being of high interest and priority for the government (Foulkes & Ruddock, 2007; Ofori, 2015). However, as the world is changing faster than ever before, the industry is faced with several challenges crucial to overcome in order to transform and capture its vast potential (Renz & Solas, 2016).

3.1.1 Productivity and performance pressure

One of the main challenges within the construction industry is the long record of a worldwide decline in productivity (Aziz & Hafez, 2013; Barbosa et al., 2017). Productivity can be defined as the rate of output received per unit of input, which in construction can be measured as the number of actual work hours required to perform the appropriate units of work (Hasan et al., 2018). A recent study by McKinsey Global Institute (2017) portrays how construction related spending accounts for about 13% of the world's GDP every year, expected to increase further in the future. Despite that this portrays construction as one of the largest sectors of the world economy, the productivity growth is severely lagging behind other industries, facing weak or negative growth in many countries (Barbosa et al., 2017; Tran & Tookey, 2011; Zhi et al., 2003). As a result, time delays and cost overruns

can become a fact on the account of poor productivity rates, thus calling for a comprehensive understanding of what factors cause this negative trend in order to seize the opportunity of productivity improvement (Hasan et al., 2018).

The main causes of poor productivity within the industry have not been agreed upon. Continuous efforts are made all around the world to identify said causes, resulting in the literature portraying a wide range of potential influencing factors (Hasan et al., 2018). Some studies argue that the productivity decline roots back to the industry dynamics, being generally recognized as opaque and fragmented (Barbosa et al., 2017). Minimal standardization due to uniqueness of projects, poor communication and cooperation amongst supply chain actors, and a general lack of technological adoption and innovation across the industry are a few proposed causes (Hasan et al., 2018; Naoum, 2016). Other findings portray operational factors at the firm level to be decisive for productivity. Insufficiently skilled and experienced labor, poor management and leadership styles, inadequate process design, and poor communication structures are brought to our attention (Barbosa et al., 2017; Hasan et al., 2018; Naoum, 2016). Furthermore, Hasan et al. (2018) identifies a number of factors seemingly common across worldwide studies, including "[…] non-availability of materials, inadequate supervision, skill shortage, lack of proper tools and equipment and incomplete drawings and specifications" (Hasan et al., 2018, p. 916). Research related to construction productivity is currently widely explored, but far from conclusive. However, due to the heavy weight of the sector on the global economy, it is of common interest to improve the productivity level of the construction sector (Hasan et al., 2018).

Despite the emphasis on the poor productivity rates within the industry, a need for a massive investment in worldwide infrastructure by 2030 is recognized in order to keep up with global growth of GDP (Agarwal et al., 2016). This portrays an opportunity for the construction companies to capture the potential of improved productivity, thereby increasing overall performance. Project success and performance in the field of construction has been a recurring topic for decades, where managers have been striving to complete projects with the most favorable outcomes. A wide range of research can be found in regard to this topic, revealing the performance indicators of time, cost, and quality to be at the core in construction

projects (Chan & Chan, 2004). These indicators are recognized as basic criteria to project success, referred to by Atkinson (1999) as the “iron triangle”. The time criterion addresses the duration for completing the project determined by the client. This can further be split up into three categories, namely construction time, speed of construction and time variation (Chan & Chan, 2004; Naoum, 1994). Cost refers to the important measure taking the estimated budget into account, being the overall cost incurred throughout the project. Lastly, measuring quality in construction indicates an assessment of the total features required to satisfy a given need. This is for instance related to technical specifications, ensuring the standard of the construction (Chan & Chan, 2004).

There are, however, several other measures related to performance attracting increased attention. Health and safety is an example of an issue that has been raised for a long time, measuring to which degree the project is completed without major accidents or injuries (Bubshait & Almohawis, 1994). Functionality is another indicator, addressing to which degree the finished product fulfils technical performance specifications and the intended function (Chan et al., 2002). This closely relates to the aspect of quality. Furthermore, in recent years an emphasis has also been put on environmental performance due to major environmental impact caused by the industry. Thus, application of environmental standards and scoring has increasingly been used as indicators to reflect the environmental performance (Chan & Chan, 2004). Fewings and Henjewele (2019) also highlight sustainability, ethical requirements, and social responsibility and security to be important aspects in the project management process.

When looking to improve in terms of performance and productivity, training and follow-up is essential. Indeed, organizations must be able to learn, adopt and change. Hence, the literature puts emphasis on processes that help companies become “learning organizations", highlighting training and knowledge transfer to be of great importance (Martin, 2010). Moreover, follow-up has been identified to have great influence on the transfer of knowledge, as well as operations and firm performance. Five forms of follow-up have been identified by Martin (2010) to complement training. These are: action plans, performance assessment, peer meetings, supervisory consultations, and technical support.

3.1.2 The fragmented and complex nature of the construction industry

One of the possible contributions to the aforementioned performance and productivity pressure could be the fact that the construction industry is highly complex and fragmented by nature (Barbosa et al., 2017). A construction project is usually organized in temporary supply chains producing one-off construction projects, typically make-to-order (Dallasega, 2018; Vrijhoef & Koskela, 2000). The Construction Supply Chain (CSC) commonly includes an internal and external supply chain, both of which are converging towards the construction site where the object is assembled (Tserng et al., 2005; Vrijhoef & Koskela, 2000). From the perspective of a general contractor, being the project-based organization responsible for the completion in line with a set time and budget, the internal supply chain consists of the main office, on-site offices, and construction site (Tserng et al., 2005). The external chain can be understood as the broader organization of downstream firms, such as subcontractors and suppliers of materials and equipment, in addition to the upstream firms including architects, consultancy firms and supervisor firms (Tserng et al., 2005). At the end of the CSC we find the client who is awaiting a final product.

The nature of a construction project is further recognized as having a great number of participating parties with interrelated processes, time limits, and a high degree of customization (Dallasega, 2018). It is argued that the approach to interdependencies and interconnectedness between tasks, parts, and units involved, are critical for successful coordination. The patterns of interdependencies in construction differ from other industrial contexts, as interdependencies here are not sequential but rather reciprocal (Bankvall et al., 2010). This implies "[...] a need for continuous adjustment of the plans, in order to cope with unforeseen events within the individual construction project" (Bankvall et al., 2010, p. 390). With these adjustments, all activities found up-stream in the supply chain are consequently affected, requiring frequent and direct communication and coordination amongst the involved actors (Bankvall et al., 2010).

The construction industry is further characterized by a high degree of interorganizational teamwork. As a result of the project-based nature of construction projects, different people are needed based on their professional

knowledge and experiences. Thus, requiring them to collaborate and coordinate with other companies (Fong & Lung, 2007). This is both in terms of the CSC as mentioned, but also extended to the construction site, as some of the construction work is often carried out by subcontractors. Due to the interorganizational context, there is a need for a common understanding and alignment across actors to reach the goal. Indeed, communication and interaction across a broad inter-professional team is thereby of the essence (Fewings & Henjewele, 2019).

Moreover, a wide variety of legislations, regulations and governance requirements are present, ultimately leading to an added complexity in comparison to other industries (Fewings & Henjewele, 2019; Renz & Solas, 2016). As government legislation is an important factor in order to move things forward, a mass of legislation is designed to reduce the potential hazards found at a construction site. Legislation regarding accident prevention, management of health, safety and build environment, as well as pollution responsibility and less carbon usage are some examples found in the industry adding additional strain on the construction work sites. With this in mind, construction projects are in high need of documentation ensuring the quality and safety of the projects. Furthermore, Fewings and Henjewele (2019) highlight the importance of documentation when handing over the completed project, to provide information on the safe, efficient, and effective use of the building. Gathering documentation can be time consuming, especially if not followed up on throughout the life cycle of the project. Thus, digital technologies are increasingly being utilized, making this process more efficient (Fewings & Henjewele, 2019).

3.2 Digitalization in the construction industry

According to McKinsey Global Institute's industry digitalization index 2016, the construction industry seems to be amongst the least digitalized (Agarwal et al., 2016). During the previous decade however, there has been an increased need to reduce waste and improve productivity and performance in the construction sector, calling for new innovative technologies (Aguiar Costa & Grilo, 2015). Demonstrated in a report provided by The Center for Construction at BI Norwegian Business School (2019), recent digital technology has begun transforming the

construction process. A trend towards digitalization is apparent, crucial for the delivery of large projects as information technology (IT) is increasingly utilized across all stages of the construction process (Harty & Whyte, 2010).

There are numerous definitions of digitalization flourishing in the literature, without common consensus on a single and clear one (Bloomberg, 2018). For the society as a whole, several definitions refer to the term as the restructuring of social dimensions that follow from integration of digital technologies (e.g. Bloomberg, 2018; Gebauer et al., 2020; Gray & Rumpe, 2015). Schallmo and Williams (2018) further provide a definition capturing central business-related aspects, describing digitalization as "[…] fundamental changes made to business operations and business models based on newly acquired knowledge gained via value-added digitization initiatives." (Schallmo & Williams, 2018, p. 6). Digitization is distinguished from digitalization, referring to transforming information from analog to digital forms (Bloomberg, 2018; Schallmo & Williams, 2018). The degree and pace of digitalization differs severely across industries, strongly associated with regional economic performance (Muro et al., 2017).

Digital construction can be seen as an integrated approach to new technologies, aimed at making building safer and more productive (Fewings & Henjewele, 2019). A variety of digital technologies are employed in the construction industry, some of which have been available for some time while others are currently emerging. Virtual Reality (VR), Augmented Reality (AR), Artificial Intelligence (AI), drones and 3D-printing are examples of the latter, potentially to be used in industries such as construction when further developed. AI technology can substitute various repetitive, dangerous, and routine tasks in the construction project, while VR can support the design and decision-making process through visualization. AR supplements real environments with additional computer-generated materials, enabling users to visualize a full building structure during the work on site (Fewings & Henjewele, 2019). As these technologies tend to be expensive and are not yet fully developed, they are currently not the norm. These are, however, emerging technologies that industry professionals have seen and hope to see in future projects (Holt et al., 2015).

In terms of established technologies, a wide array can be found across different phases of a construction project, including Computer Aided Design and Drafting (CADD) systems, collaboration platforms, and document management (Aouad et al., 1998). Furthermore, the literature within the construction industry focuses heavily on the application of Building Information Modeling (BIM) (Agarwal et al., 2016; Aguiar Costa & Grilo, 2015; Azhar et al., 2011; Bryde et al., 2013; Eastman et al., 2008). This technology has changed the way in which design, construction, and facility management is conducted, and depicts physical and functional characteristics through the life cycle of a project, for instance through accurate geometry and detailed data (Eastman et al., 2008; Fewings & Henjewele, 2019). A report published by Sage (2016) further portrays how cloud technology is taking a hold of the construction industry, providing access to applications and software such as BIM models, emails, and drawings from anywhere with an internet connection. This allows workers to document, access and share information of importance in an easy and efficient manner (Fewings & Henjewele, 2019; Sage, 2016).

3.2.1 Motivations and potential benefits of digitalization

There are several motivations for investing in digital technologies and IT in a company's leap towards digital transformation. Cost cutting, increased quality, productivity, and revenue growth are potential general benefits sought out in hope of gaining a competitive lead (Brynjolfsson, 1993; Muro et al., 2017; Parviainen et al., 2017). This can be achieved as digitalization has been found to be a crucial enabling factor for providing internal efficiency. Furthermore, it can be a potential provider of new opportunities, as the concept utilizes new digital technologies to rethink current opportunities (Parviainen et al., 2017). The phenomenon is most beneficial when associated routines and processes within the business are altered to accommodate the improved efficiency enabled by the digitalization (Kuusisto, 2017b). The advancement and adoption of digital technology has the ability to fundamentally transform businesses by for instance automating work routines, serving as infrastructure for information and communication flows, or enriching the existing products and services (Legner et al., 2017).

There are indeed many claimed benefits resulting from applying digital technologies and processes in the construction industry. A study by McKinsey (2016) predicts significant efficiency improvements as well as cost reductions by adopting digital technologies such as drones, BIM, cloud technologies, and Internet of Things (IoT). Contractors and owners are increasingly deploying solutions for digital collaboration and field mobility, utilized in for instance scheduling, materials management, crew tracking, contract management and document management (Agarwal et al., 2016). According to Blanco et al. (2017) digitalization in the construction industry has aimed to improve several construction activities on site. It is claimed that digital tools have been developed to improve field productivity, speed of construction, safety monitoring and quality control (Blanco et al., 2017; Parusheva, 2019). Whyte and Lobo (2010) further highlight increased accountability and control resulting from digital objects, as well as laying the foundations for mutual and reciprocal knowledge sharing.

As a result of the nature of a construction project, many construction technology developers focus on creating tools for digital coordination and collaboration (Aouad et al., 1998; Blanco et al., 2017). Harty and Whyte (2010) emphasize that the information produced within the various domains of a construction project must be shared outside the specific areas, highlighting the utilization of IT coordination to bridge the division. Due to technology becoming increasingly widespread, cost-effective and powerful, digital information is seen utilized to a large extent in the industry (Whyte, 2019). Digital information is according to Whyte (2019, p. 190) "[…] enabling greater sharing, remote access, searching, and updating of information with visibility across supply chains and with owners, operators, and end users". In fact, Whyte (2019) argues that digitalizing information is found to transform how projects are delivered, emphasizing the information itself becoming the deliverable.

Fewings and Henjewele (2019, p. 385) further highlight that digitalization in the construction industry "[…] is a way of widening communication channels and integrating the working relationship between various members of the project […]". The various stakeholders hold different data and information, and effective communication channels should be developed and accessed by everyone involved.

This can in turn create a more transparent and collaborative culture, potentially enhancing the construction phase by providing useful and accessible information (Fewings & Henjewele, 2019). By implementing digital tools in the inter-organizational environment, waste and potential errors resulting from re-interpretation of information can be eradicated through electronic information exchange (Harty & Whyte, 2010). Digital communication tools can be used for instance when staff need to update blueprints and other project documents while on site. The tools allow them to make changes when in the field with the use of mobile platforms, rather than returning to the office to complete such tasks. These communication platforms increase the availability of information, which reduces time spent on acquiring information and also improves accuracy (Blanco et al., 2017).

3.2.2 Barriers to successful implementation and adoption of digitalization

Studies show that firms reluctant to "go digital" or combine digitalization with organizational readjustments are indeed falling behind (Muro et al., 2017). Despite this, new technologies are not always fully embraced (Kuusisto, 2017a). There are numerous barriers and pitfalls to successful implementation and adoption of digitalization found in the literature, not only delimited to technological issues. As accurately portrayed by Harty and Whyte (2010, p. 32), "[…] technological solutions are rarely that – solely technological", as they are incorporated into existing ecologies of practices. Kuusisto (2017a) for instance highlights issues such as organizational inertia and technological acceptance. The interaction and behavior of people in the construction process is thus of high importance, as the technology and the digitalized processes cannot function without them. Behavioral inertia, referring to the tendency to keep doing something the same way because it is the way it always has been done, can make changes difficult to implement (Kuusisto, 2017a). The accompanying individual working habits further influence organizational inertia and must be challenged for new working methods to be applied (Polites & Karahanna, 2012). Creating clear objectives as well as motivating people to take use of the new technologies is thereby critical (Fewings & Henjewele, 2019).

Harty and Whyte (2010) highlight that previous studies portray how new ways of working, enabled by IT, should supplement and alter the current non-IT practices rather than completely replacing them. Technologies have been found to be unevenly and differently incorporated into pre-existing practices, where some traditional aspects, such as the use of paper, still seem to persist despite attempts of removal (Harty & Whyte, 2010). Nevertheless, it is important to make use of the technology the right way and develop it incrementally. This must be done for the industry culture to evolve in line with the new digital ways of working. Without the approach of integrating technology with culture, more bureaucracy can be added to the construction industry (Fewings & Henjewele, 2019).

Furthermore, the cost and interoperability of technology can be seen as a major barrier to the implementation and adoption of digitalization (Fewings & Henjewele, 2019). Software compatibility and interoperability is of concern, as information can be generated in a range of different formats. This barrier is however argued to be lowered with time and training (Fewings & Henjewele, 2019). It has been highlighted in literature that investments in Information and Communication Technology (ICT) may not necessarily lead to the expected improvements of cost or productivity (Brynjolfsson, 1993; Stratopoulos & Dehning, 2000). This refers to the Productivity Paradox emerging in the 1980s, questioning the stagnation of United States' productivity growth despite the massive and growing investments made in IT (Brynjolfsson, 1993). The shortfall of IT productivity was argued by Brynjolfsson to have four possible explanations: measurement error, time lags between implementation and resulting payoff, redistribution of activities among firms without increasing total output, or the lack of alignment between developers and management (Brynjolfsson, 1993). In line with these explanations, Brynjolfsson in later works argued that the paradox was resolved after finding correlations between firm-level IT investments and productivity (Brynjolfsson & Hitt, 1998). However, several studies in the literature still claim the productivity paradox to be unresolved, or that it has simply shifted form (Acemoglu et al., 2014; Ark, 2016; Hajli et al., 2015; Polák, 2017). Stratopoulos and Dehning (2000) conclude that the implementation and management of the technology is more important than the size of investment itself. Thus, increased investments in technology may be at the expense of productivity.

3.2.3 Digitalization and Lean Construction

As previously portrayed, the digitalization of processes within a construction project is increasingly being utilized as an improvement strategy to tackle the performance pressure and poor productivity found in the industry. In the extension of this, a combination of digitalization and Lean Construction (LC) is receiving attention in the literature (Agarwal et al., 2016; Sacks et al., 2010). Virtual Design and Construction (VDC) is a newer concept, seeking to cover both the technology and the Lean principles, as well as the organization of the two (Alarcon et al., 2013). VDC is defined by Kunz and Fischer (2020, p. 355) as "[…] the use of integrated multi-disciplinary performance models of design-construction projects to support explicit and public business objectives". Indeed, providing a framework for describing, monitoring, and changing the product, process, and organization throughout the project life cycle. This allows for identification and analysis of potential complexities and pitfalls in a virtual world before it is encountered in the real one (Khanzode et al., 2006; Kunz & Fischer, 2020).

Several scholars highlight synergies between VDC and Lean concepts, portraying results like elimination of waste, increased customer value, better workflows and coordination (Gerber et al., 2010; Gilligan & Kunz, 2007; Kala et al., 2010; Khanzode et al., 2006; Rischmoller et al., 2006; Sacks et al., 2010). The idea of waste elimination refers to re-evaluating and potentially eliminating activities or processes that do not contribute directly or indirectly to customer value. Taiichi Ohno (1988) have identified seven sources of waste to be eliminated which can be seen in *Table 4*. By identifying waste in the system, one can pinpoint where work needs to be done to become more efficient.

1. *Waste of over-production*	
2. *Waste of time on hand*	
3. *Waste of transportation*	
4. *Waste of over-processing*	
5. *Waste of stock on hand*	
6. *Waste of movement*	
7. *Waste of making defective products*	(Ohno, 1988)

Table 4: Ohno's (1988) seven sources of waste

A software technology receiving much attention in relation to VDC is found to be BIM (e.g. Gerber et al., 2010; Sacks et al., 2010). Sacks et al. (2010) provides a rigorous analysis of the interaction between BIM and Lean concepts. In fact, they find that synergies between the two may, if understood properly, lead to an improvement of the construction process beyond the sole application of either. BIM has the potential to facilitate Lean measures throughout the lifetime of the construction project, enhancing coordination and value creation, as well as significantly reducing waste (Gerber et al., 2010). The achieved Lean principles by the utilization of BIM is however argued to depend on the skills of the ones involved in manipulation and execution of the BIM model (Hamdi & Leite, 2012).

By the implementation of digital tools, both the end product and the construction process can be clearly visualized, aiding LC in emphasizing continuous flows with a pull perspective (Sacks et al., 2010). A particularly practical technique utilized in LC presented by Ballard (2000) is known to be the Last Planner System. This is a system also referred to as pull scheduling, transforming the work that *should* be done into the work that *can* be done. The approach emphasizes the importance of the planning stages to ensure readiness, creating predictable workflows (Ballard, 2000; Fewings & Henjewele, 2019). Moreover, Howell (1999) depicts LC as being similar to traffic flow where the desired arrival at the destination is dependent on the speed of the slowest vehicle in each lane, as well as how smooth the driving experience is. This analogy clearly highlights the importance of pre-planning in construction, ensuring commitment and smooth flows. This can for instance be seen through the utilization of Takt, implemented at various construction sites. Utilizing Takt time means transitioning from uneven task durations for each trade in a sequence, to a task duration that is consistent for every trade (Frandson et al., 2013). This consequently embodies creating a continuous workflow in production, reducing variability by following the work pace or rhythm set by demand (Yassine et al., 2014).

3.3 Summary of literature review

Throughout our narrative literature review we have identified several interesting findings related to the construction industry and digitalization. Despite the size and importance of the industry, there are several challenges identified. Poor productivity has influenced the industry for a long time, generating a wide variety of studies trying to find the root cause. Due to the low productivity, efforts have been made to improve and complete projects with favorable outcomes. Thus, performance indicators have been utilized to identify areas of improvement and monitor the progress. The literature highlights the "iron triangle", which includes time, cost, and quality. In addition, health and safety, as well as environment and functionality have been brought to our attention as important performance indicators. The productivity and performance pressure can be related to how the construction industry is recognized as complex and fragmented, calling for the need for integration, especially due to its interorganizational nature. Furthermore, the construction sector is argued to be amongst the least integrated of all major industries, struggling with coordination resulting from interdependencies and interconnectedness.

As a result of the poor productivity rates and a constant performance pressure in the industry, we find the topic of digitalization to be of increasing interest. A number of digital tools are currently being developed for the construction industry including technologies such as AR, VR, drones and 3D-printing. Moreover, there is an uprising in the construction sector of the use of digital modeling tools such as BIM, as well as cloud technology allowing for use of mobile devices on the construction worksite. The utilization of such digital technologies can potentially provide several benefits, including improved visualization, information flow, and efficiency. Additionally, digitalization in the construction industry is claimed to widen communication channels, which can create a more transparent and collaborative culture. However, the literature highlights several barriers and pitfalls to digitalization in the construction industry. This can be seen through for instance organizational inertia, technological competence and acceptance, as well as low interoperability of technologies. The construction literature has also increasingly explored digitalization in relation to Lean through concepts such as VDC,

portraying results like elimination of waste, increased customer value, better workflows and coordination.

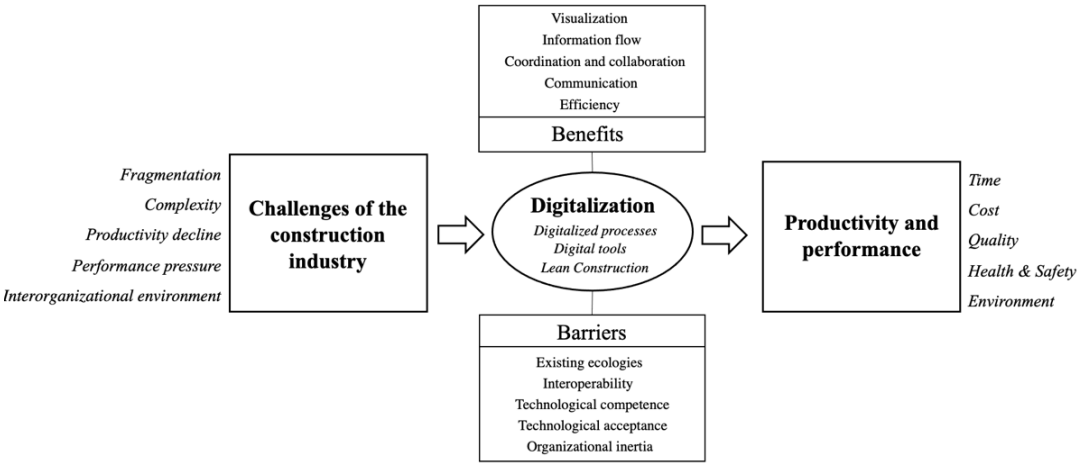

Figure 5: Conceptual framework

As a result of our literature review, we have created a conceptual framework useful for our further research. The framework is depicted in *Figure 5*, and will serve as a guide when gathering data, as well as help us gain insight related to our findings. The framework includes challenges of the construction industry and portrays that digitalization of construction processes and implementation of digital tools possibly can have a central role in overcoming these challenges. The model depicts that digitalization can potentially lead to several benefits, however, there are barriers and pitfalls to consider for successful implementation and adoption. Moreover, digitalization can influence productivity and performance, illustrated through the identified performance indicators.

4. Empirical findings and analysis

The consecutive chapter presents the empirical findings from our research combined with an analysis of the data. The main aim of this thesis is to investigate how digitalization influences the construction production phase, by identifying its digitalized processes and considering its perceived benefits and challenges. When further referring to the construction site, we refer to both out on site, involving the construction workers, and in the office barracks, involving staff and managers. By combining these two aspects, we aim to gain a holistic picture of how digitalization influences the production phase.

We began our analysis with coding and collating findings for the construction sites individually. However, the findings from our qualitative data collection will further be presented and analyzed across the two projects in relevant categories identified in the data analysis process and informed by the theoretical study. The first section in this chapter will present the details of our case study, while the second section will focus on the digital processes identified within the two construction projects. Furthermore, the third section will address the perceived benefits of digitalization, followed by the fourth section taking into account the findings related to perceived challenges of digitalization. Lastly, we will conclude this chapter with a summary of our empirical findings and analysis.

4.1 Presentation of case study

The findings of our thesis are highly dependent on the context in which the data is collected. Our case study of Veidekke, with their two projects at Ulven and Frysja, enables us to gain insight within the context of the Norwegian construction industry. Veidekke is in fact the largest contractor in Norway and fourth largest in Scandinavia, involved in a variety of different construction projects within four main categories: residential buildings, non-residential buildings, civil engineering operations, and industrial. The category of residential buildings makes up 24% of their operations and is the category that includes the projects of our case study. Furthermore, Veidekke, being part of an industry increasingly influenced by digitalization, seems to have a clear priority of staying competitive by utilizing digital technologies in their construction projects. The degree to which the various

projects seek out, experiment with, and implement digital processes and tools is varying, some further ahead than others.

The first project investigated in our case study is the residential project at Ulven, owned and requested by the largest housing developer in Norway, OBOS. A joint venture, Team Veidekke DA, has been created to take on this project, where Veidekke is the main contractor collaborating with several experienced consultants, contractors, and architects. The project was won through an innovation competition in 2017, where Team Veidekke DA offered the most intriguing and cost-efficient solution. The Ulven project is of great size, where the end product will consist of nearly 3 000 apartments as well as an underground parking garage (Veidekke, 2020a). This requires many stages and contributions from various contractors in addition to Veidekke. The construction started in 2018, and Veidekke has been involved in the first construction phase containing 372 apartments. Currently they are continuing with the second step (B2) consisting of 182 apartments (Veidekke, 2020a). In relation to digitalization, representatives at Ulven express that the project is not known for being especially digitalized. However, Ulven represents a typical residential project, and is interesting due to strict cost constraints brought by the innovation competition. Moreover, the Ulven project has committed to being a paperless construction site and uses a handful of standardized tools in the barracks and out at the site. These include Dalux, Microsoft Project and Microsoft Excel.

Frysjaparken is the second project included in our case and is another typical residential project, owned and requested by Stor-Oslo Eiendom and OBOS Nye Hjem. The construction started in 2018 and the Frysja project as a whole is due to be completed in 2022 (Veidekke, 2020b). The project consists of apartment complexes and accompanying infrastructure. The first step of 154 apartments is completed, while the 227 apartments of the second step are expected to be move-in-ready in the second half of 2021. A third step of 305 apartments is agreed upon, and can currently be found in the design phase, eventually moving on to construction (Veidekke, 2020b). The project at Frysja can further be seen as Veidekke's digital flagship, where emerging technologies are piloted and developed. This includes for instance automated containers with sensor technology, drones, and AR technology.

Looking at the projects in scope we find that Frysja and Ulven complement each other, as the two projects portray various degrees of digitalization, representing different ambitions and constraints. This makes it interesting to investigate both projects in conjunction, providing different experiences, perceptions, and attitudes toward digitalization. Furthermore, the notion of LC, seen through collaborative planning and Takt planning, is found to be of importance in the production phase of both construction projects, emphasizing smooth workflows through participative progress planning and close monitoring throughout the construction process. With this in mind, a natural link can be found between digitalization and Lean, as both can be seen as crucial for success. Our further analysis will therefore be seen in connection with LC to a certain extent.

4.2 Digitalized construction production processes

A general comment appearing in several of the interviews, was the acknowledgement that the construction industry is known to lag behind in the area of digitalization compared to other industries. This is however rapidly evolving, and it was pointed out by one of the interviewees that technology has become *"[...] one of the most important things to even stay afloat in a competition driven market" (Interviewee #4).* Indeed, this was reflected by some central processes being digitalized, as well as a wide range of digital tools being introduced. The Frysja project experiments with several intriguing technologies, such as 360-degree cameras, AR and VR. These are digital tools that are in the development stages at the managerial level of the project, potentially becoming influential in the future of construction. As explained by one of the employees at Frysja, an overall focus in the project is to continuously test out new technologies to find the ones with real effect. The on-site construction, however, seems mostly unaffected by such emerging technologies as they are still being tested and not yet implemented in the physical construction work.

What seemed to be a consensus amongst the interviewees across the two projects was the notion that no digitalization should be done merely for the sake of digitalization. As stated by one of the interviewees, *"[...] to digitalize just for the sake of digitalizing, if you cannot see that it makes everyday life easier, that is no*

benefit in and of itself" (Interviewee #7). Indeed, several of the interviewees emphasized that the focus of the construction worker is, and should remain, the actual construction work. The final product in a construction project is in fact dependent on physical construction, and there are thus several tasks at the construction site that simply cannot be transformed into digital processes. Arguments were made that the implementation of digitalized processes and digital tools at the construction site should rather be a supplement for the workers.

Throughout our research, we were introduced to a range of digitalized processes and accompanying tools at the two construction projects Ulven and Frysja. *Figure 6* depicts the digital processes recognized in the construction production phase, namely progress planning and monitoring, logistics, as well as HSE and QA. Furthermore, the figure includes some of the most relevant digital tools utilized within these processes. An extensive list of all the digital tools identified in the two projects can be found in *Appendix 2*.

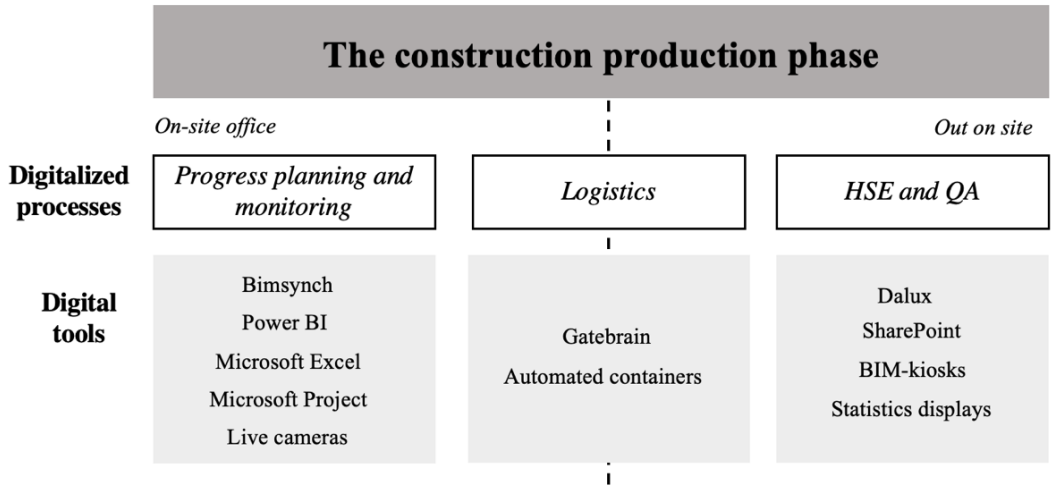

Figure 6: Digitalized processes in the construction production phase

4.2.1 Progress planning and monitoring

Many of the digitalized tools identified were found in the progress planning and monitoring process. This process is found at the on-site office and is primarily involving management. The progress planning at Frysja can be seen through for instance the digital software program Bimsynch, which combines an extensive overview of tasks with models, providing a BIM-tool to keep track of the progress. Moreover, the progress of the production is monitored and assessed weekly at the

office. PowerBI is used to capture and monitor extensive statistics of several aspects of the project, including statistics capturing HSE and QA deviations as well as progress statistics. Furthermore, the project utilizes cameras around the construction site to monitor the progress, continuously updated every 10 minutes. Discussions are made on this basis, as to the status of the project and potential correcting measures to make.

An important part of progress planning and monitoring at Ulven, is following an overall schedule that has a set pace that the different trades are to follow. This is referred to as Takt planning and is a result of their approach to LC in production, striving for a smooth and continuous workflow. Such progress planning is developed in software systems such as Microsoft Project, often further visualized in Microsoft Excel. When asked if digitalization had affected their LC efforts such as Takt planning, one interviewee responded, *"No, I don't think I would say so. I think it would be relatively the same if you did Takt more paper-based… No, I don't think it has that much to say really." (Interviewee #7).* In fact, the majority of the interviewees did not seem to identify a conscious connection between digitalization and LC.

An important step of the progress monitoring within Takt was emphasized by interviewees to be the handover of zones between trades, serving as an update on the production progress and the prospect of maintaining the overall schedule. An interviewee explained that handovers at the Ulven project had been digitalized by introducing the application Dalux for this. However, the interviewee further explained that "*[…] I don't think it was used much because there was no one who… everyone thought it became too much really, out there [at the construction site]" (Interviewee #11).* Thus, it can seem that this particular digitalization effort was perceived as excessive and complicating. However, interviewees of managerial positions praised such digital handovers, due to how it contributes to documentation and visibility.

What is evident is that the digitalization of progress planning and monitoring may at first glance seem irrelevant for the construction workers. However, this seems to actually indirectly influence the construction production processes on site. The

extensive statistics monitoring at Frysja exemplified how the digital tools at the office were used to control the progress at the site, thus influencing the daily work of the construction workers. Furthermore, the aforementioned digitalized handover enables managers in the office to keep track of progress, potentially initiating correcting measures in case of deviations from the overall schedule.

4.2.2 Logistics

Through our data collection, we found that the logistics process had been somewhat digitalized and seemed to be affecting both the construction workers out on site and the employees at the site office. The automated gate system, Gatebrain at Frysja, was explained by interviewees to provide a smooth logistics system where time slots for deliveries to the construction site are booked and thus coordinated, both impacting the construction on site and the overview at the field office. Here, the suppliers have the possibility to see when others have booked time slots for delivery digitally, thereby adjusting accordingly to avoid waiting upon arrival. According to several of the interviewees, this system leads to less queues of deliveries on sites, bettering the overall logistics. Furthermore, smooth logistics processes were enhanced by utilizing automated containers. These containers automatically send a request for emptying when sensors register that the container is full. Interviewees explained that this ensured efficient logistics, removing the need for manually checking the containers several times a day. This concept has been developed at Frysja and is currently being improved for standardized use in Veidekke.

4.2.3 Quality Assurance and Health, Safety & Environment

An important process that we found to be digitalized in both construction projects, was the reporting and documentation of deviations within QA and HSE. Looking at the construction site itself, the digital tool in this regard, emphasized by interviewees from both projects, was the software application Dalux. In terms of HSE, Dalux is used on both Frysja and Ulven to register deviations and safety hazards to the application, and send them to the management at the site, who then directs the task to someone qualified.

Furthermore, the application provides digital tasks and checklists for QA, where workers can check off and document the work they have done. Additionally, at

Ulven the use of digital project drawings and detail drawings in Dalux has in fact allowed them to become a "*[...] not drawing-free, but paperless work site*" (*Interviewee #1*). At Frysja, Dalux has not yet been utilized for drawings, however the drawings can be found in the cloud-based platform SharePoint. Moreover, BIM-kiosks can be found at the construction site, enabling the workers to look at the models and drawings on a large scale. Although, as pointed out by an interviewee at Frysja, these are seldom in use.

An additional digital initiative emphasized by interviewees at Frysja, is big screens amplifying the importance of reporting deviations within HSE and QA. These screens are found in the barracks at the construction site and depicts the daily status of deviations for the respective trades at the site. The purpose of this initiative is to motivate the workers to swiftly address such deviations, while simultaneously providing an overview of the overall status.

4.3 Perceived benefits of digitalization in construction production processes

Our empirical findings portray that digital processes and tools in the construction phase of a project indeed result in both direct and intermediary benefits as depicted in *Figure 7*. Direct benefits can be seen through traditional performance measures, namely time, quality, and safety. However, throughout our data collection process, it became evident that there were several intermediary benefits affecting the direct benefits as a result of digitalization as well. These include visualization, control, information flow, and communication, which is further seen to affect the time aspect, the quality, and the safety of the project.

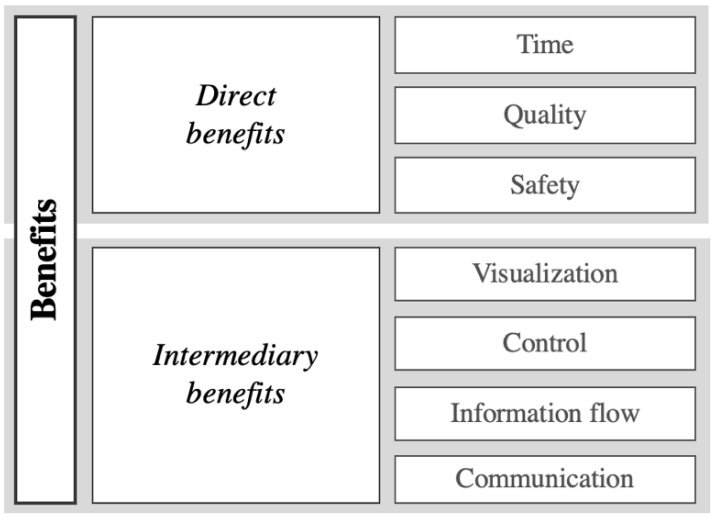

Figure 7: Overview of perceived benefits

4.3.1 Direct benefits

Several of the employees highlighted that a **time-saving** effect could be seen in relation to digitalization. At Ulven, interviewees explain that the digital tool Dalux, with continuously updated drawings, prevents the need for physically obtaining drawings. This indicates a link to LC and the seven sources of waste presented by Taiichi Ohno (1988), where digital drawings can reduce unnecessary motion. Several of the interviewees emphasized how they previously had to walk great distances to retrieve the latest audit from the office, whereas they now could simply open an application on a mobile device. As explained by one of the interviewees,

> *[…] we are very dependent on having updated drawings, so you will never have to stop to wait and see if this is the newest audit of the drawings for instance, because you always have it. So, then he [a construction worker] doesn't have to call me, so that I have to walk to the office and pick up the newest audit of the drawings, or if he needs a detail […] he can go right in [the application] and look instead of me having to find it and maybe walk half a mile. (Interviewee #11)*

According to several of the interviewees, the continuously updated drawings also seem to lead to less construction errors. This directly relates to another source of waste, namely defects. The detailed information easily available in the application causes more precise construction and less need of rework, in turn minimizing

unnecessary time spent. The application also provides a rich level of detail all in one place compared to physical drawings, where specific details are separate to the main drawings. In addition, as mentioned above, the assurance of working with the newest audits reduces the chance of building incorrectly. Thus, saving time and improving the flow on site.

Furthermore, by utilizing Dalux, arguments have also been made that less time is now spent on writing, delivering, and following up on HSE and QA deviations. With Dalux in extensive use at Ulven, including task management and checklists, the workers find that they save time.

> *[...] it has been a very nice effect to be able to go straight into the lists and check where it is, and just send out the points. Because then we can share the points to the workers that are going to do them, so in that regard we save time by not having to show them [...] we can just call them and say, "I have sent you a point you have to complete" or "now you have 20 points in Dalux". (Interviewee #11)*

Similarly, the application's checklist reduces the time spent on trying to remember, as the application provides an accurate and detailed overview.

The time-saving effect was also mentioned in relation to several other digitalization efforts implemented at Frysja. It became evident that the introduction of Gatebrain removed a lot of waiting at the construction site, as the deliveries were now scheduled in relation to each other. Waiting is a third source of waste, where for instance the limitation of space at the construction site could cause trucks to block other areas, impacting the progress. In addition, the automated containers removed unnecessary time spent on administrative tasks and improved the flow on the site. Indeed, by ordering emptying of the containers the moment they were full, they prevented buildup of waste on the work site.

Furthermore, progress planning and monitoring also portrays a great means to actually reduce waiting along the building process. The even pace initially set by

the utilization of Takt planning, is indeed beneficial for all the groups at the construction site to hinder delays and thus waiting.

In addition to the time-saving aspect, the digitalization further appears to have a positive effect on **quality**. As previously mentioned, less construction errors occur as a result of drawings and models being available digitally, and the drawings the construction workers utilize in their daily work is continuously updated with intricate details. This was accurately described by an interviewee at Ulven saying,

> *When you have paper drawings a new audit can come out and remain here in the office for three days before it gets out. Now we know that when a new audit comes out, everyone has the newest version immediately. (Interviewee #11*)

Furthermore, documenting deviations, completed tasks and experiences are found to be easier and more accessible with the use of digital tools, further enhancing the quality. This was mentioned both at the construction site at Ulven through the use of Dalux, but also a highlighted benefit by using Bimsynch at Frysja. In the latter example, the interviewee emphasized that the BIM-system enables comments and documentation to be pinpointed to specific areas of the model, which in turn provides useful historical data, transferring experience to production.

Another recurring theme in our interviews was the impact of digitalization on **safety**. Dalux and the digital processes of HSE and QA reporting was an example mentioned by several of our participants being significantly improved through digitalization. Arguments were made that digitalization enables a quicker process where deviations are easier to report by the construction workers, and easier to see and act upon by the ones responsible.

> *We might have lowered the barrier for reporting deviations with Dalux in comparison to the green paper notes [...] where you delivered it, but then no one was able to understand your handwriting and it ended in the garbage anyway. (Interviewee #1)*

This illustrates how digitalized processes can enhance the safety measures on site. With a digital grading system of the criticality of the deviation, the construction workers are also given a higher level of influence on their safety, as it is easier to involve the Headquarters if the deviation is assessed to the highest level.

At Frysja, the close monitoring of HSE and QA statistics, together with the big screens portraying the status of the different measures, seemed to have a positive influence on the safety on site. One interviewee claimed that,

> *[...] you get it up on the table, portray it and show that we [the office] have a continuous focus on improving the HSE on the project. I believe it is very useful to show that we have a focus on it. It makes it so that the ones outside [at the construction site] have a focus on it. (Interviewee #5)*

Thus, the clear visualization provides an incentive for the construction workers to improve and not stand out in a negative manner, thereby improving the safety. Another digitalization effort at Frysja that received attention in relation to safety was the automated gate system, ensuring a closed work site *"[...] so there is less risk of children or passers-by entering the construction site". (Interviewee #3)*

4.3.2 Intermediary benefits

Related to the direct benefits identified through our data collection, we found several intermediary benefits enabled by digitalization that seemed to influence the performance indicators. Throughout our interviews, several of the participants highlighted that digitalization had created a **visualizing effect**. A number of examples were made, both connected to the field office and out at the construction site. At Ulven, Dalux clearly visualizes the detailed drawings and models, as well as tasks that need to be done. Visualization was also emphasized as a positive factor in the progress planning and monitoring at both Ulven and Frysja, where statistics, Excel sheets, and systems such as Microsoft Project, visualizes the status and progress of the project. Portraying statistics of HSE and QA deviations on big screens at Frysja also clearly visualizes how the project is doing within these areas.

Visualization acts as an intermediate factor, seemingly influencing upon quality, time, and safety. By having a continuous visualization of detailed information on the progress and HSE and QA status, correcting measures can be made faster and more accurately. In addition, the visualization of the HSE and QA statistics seem to impact the priority of the construction workers to address the issues, as the big screens clearly portray how your trade is doing compared to the other trades. Thus, the visualization seemed to affect the safety at the construction site.

Control has also been identified as one of the benefits of digitalization, in which examples were made both from the workers at the construction site and from the on-site office. In the office at Frysja, the statistics enhance control and progress monitoring of the project, enabling close follow-up of the construction process. One of the interviewees monitoring the progress made an example related to the statistics capturing potential staffing shortages of the groups on site, saying that "*[...] then we can talk to them [subcontractors] about "okay, what can we do for you to gain a more predictable staffing or enough staffing to do the assigned tasks?"" (Interviewee #10).* Hence, it is argued to create a great and accurate overview of the project status, as well as being utilized to generate targeted measures to improve the production when needed. In terms of the construction work on site, it is evident that Dalux creates an overview for the individual worker of both tasks to be done and deviations to be addressed. This comes in addition to the worker always being in control of the precise construction work, made available by continuously updated drawings. Furthermore, the gate system at Frysja enables the employees to have control over the vehicles on site at all times.

Information flow was described as an intermediary benefit, as there was a general agreement between interviewees at the two projects that the digital tools seemed to enrich the information flow in several ways. The digital drawings found at Ulven provide updated information in rich detail, everything easily available through a mobile device. In the same sense, information on tasks to be done as well as specifics on reported HSE and QA deviations are easily found. The accuracy of the information received is also emphasized as a benefit, as explained by one of the employees handling deviations, "*[...] I receive information exactly the way it was perceived at the place the deviation was observed, and I can handle it the way it*

was meant to" (Interviewee #4). Furthermore, an interviewee from Frysja emphasized that the extensive monitoring and portrayal of statistics enriches the information by making it much more available for all to see, putting information at display while at the same time gathering useful historical information.

The improved aspect of information flow seems to be influencing several performance measures through digitalization. The richness and availability of the information can be seen as influential to both the time aspect as well as the quality. Rich, detailed drawings in the pocket of the construction worker may reduce the time spent on retrieving updated versions and lead to less construction related errors.

Another intermediary factor is recognized to be **communication**, as for instance Dalux creates an easy communication channel between the field office and the work site.

> *[...] It is very nice as a means of communication and makes it very easy to ... both for the ones outside [at the construction site] to come in contact with us [at the on-site office] and the other way around. (Interviewee #5)*

At Frysja, the additional focus on statistics also seemed to better the communication by enabling the office to use statistics as evidence when addressing progress or challenges with the workers out on site. Furthermore, the digital process of reporting HSE and QA deviations through the application at both construction sites seemed to be lowering the barrier for communicating issues of importance. Employees at Ulven pointed out that their use of digital drawings and tasks further reduced the need for excess communication in terms of clarifying information related to this.

With this in mind, digital tools and processes indicate enhanced communication by making it clear and efficient. This can further impact the time perspective by reducing the need for clarifications as well as speeding up manual processes such as HSE and QA reporting. Furthermore, there is a possibility to enhance safety and quality due to the lowered barrier for communication, as well as clear and precise communication.

4.4 Perceived challenges arising from digitalizing construction production processes

In addition to the presented benefits enabled by the digitalization, a range of challenges were also identified through the data collection process. These challenges can be categorized into three main areas, namely human, organizational, and technological factors.

*4.4.1 Human factor*s

The empirical findings portray challenges related to human factors to be one of the main issues hindering the success of the digitalization of the construction processes on site. Attitudes of the workers seemed to be one of the issues in this regard. A reoccurring statement that we heard during the interviews, was the notion that the construction workers are there to build, and not to do administrative tasks through digital tools. Thus, spending time learning new tools as well as following up on digital aspects such as notifications were often not prioritized.

Generally, the interviewees portrayed that there was initial skepticism when beginning to implement the digital tools, as utilizing digital applications for instance required the use of personal devices and mobile data plans. Furthermore, the workers were skeptical of the need for zooming in and out when viewing drawings, losing the overall perspective. As one of the interviewees put it,

> *I know there are many that have missed the paper drawings. [...] the feedback I have received is that they find it [digital drawings] to be a good supplement to the drawings, but it is not yet a fully functional substitute (Interviewee #11)*

At Ulven however, other interviewees emphasized that the majority seem to find these challenges to be only of initial character, where these functionalities have evolved into something they now would not want to go without.

Furthermore, the lowered barrier of creating deviations and sending them to other workers seemed to create a competitive environment of sorts, where one interviewee highlights experiences with misuse of the technology as a result of

internal rivalry. *"[...] I have experienced people using it because they find themselves getting many deviations, thus becoming annoyed, thinking like "okay, but then I will send deviations back" [...]" (Interviewee #4).*

A construction project is known for being highly complex, containing numerous groups of professions, nationalities, competences, and attitudes, enclosed in the project for various durations of time. One challenge seemed to be workers misunderstanding the use of the digital tools, for instance by categorizing tasks in the wrong places in the application, or simply being taught differently. Furthermore, due to the variety of nationalities, a severe language barrier was identified, as numerous workers neither speak Norwegian nor English, making them unable to utilize some of the applications.

Not prioritizing the follow-up of the digital processes is another issue related to the human aspect, as the digital processes are dependent on certain tasks and reports to be assessed and closed by the employees. Not following up on the tasks in the system certainly leads to frustration and time spent on waiting for responses. Sometimes, as emphasized by one of the interviewees, when tasks are not addressed within a decent time frame, they may even be "lost" in the system.

A digital divide was also identified, referring to the various digital backgrounds among people found at a construction site. The construction workers are indeed more practical than digital, thus having a varying knowledge level of handling digital tools. A number of the interviewees also stated that they observed a distinct difference in competence and hesitation towards digital tools and processes dependent on age, where the older employees seemed to be struggling more. When referring to the process of implementing new digital tools one interviewee said,

> *For some it has been more difficult than others. It is often connected to age. Those who are a bit older, there you find more resistance than with those who are younger really. [...] and the older ones use more time to understand how it works and where you find things. (Interviewee #11)*

*4.4.2 Organizational factor*s

Lack of instructions and follow-up from the main contractor on how to use the technology seemed to be a general issue, causing different usages across the work site. This was also due to the varying degree of experience with the technology amongst the subcontractors, as some of them have existing partnerships with some of the digital tools and are thereby more accustomed to the tools and less in need of training. Furthermore, groups only working on the project for a short period of time seem to have the greatest challenge adapting to the digitalization efforts on site, and the least amount of training. In addition, for some people it is not enough to have tasks in an application, needing more attention and follow-up.

The interviewees explained that they constantly have to plot in various information and documentation in the application, indicating that digitalization can have a formalizing effect. One interviewee at Frysja even argued that "*I don't think it benefits them [the construction workers] that much really. If they write a checklist on paper and deliver it, or they plot it into a phone does not matter I think." (Interviewee #9).* The interviewee further explained that matters at the construction site usually benefit from being solved on site through dialogue rather than digital tools. However, it was also noted that *"Everything is supposed to be notified in a way, so you may have to write something about it later in some program anyway*" (*Interviewee #9)*. At the same time, one of the interviewees at Ulven explained that *"[…] the last 10 years a lot has happened in terms of digitalization, but also a lot has happened in terms of demands for documentation in the construction industry" (Interviewee #7)*. Thus, arguing that if you had to do everything on paper that you need to do digitally today, it would be considerably more work than it was before due to stricter regulations and documentation demands.

Some interviewees also identified several aspects of the processes related to digitalization that could still be enhanced. A prominent example mentioned by many of the interviewees was the issue of the levels and hierarchies in the application of Dalux not being appropriate. This leads to daily waiting, as information in the system had to go through more people than necessary. This was especially prominent at Frysja, where both the workers at the construction site and the ones at the office acknowledged how this seemed to be causing problems for

the process as a whole. In line with the Lean philosophy of removing all steps that do not add any value, this could be a way to improve. In relation to the hierarchies and processes of the technology, another source of waste was identified to be the waiting that occurred when people did not follow up on information in the digital systems. This is another potential improvement area to be discussed, as it relates to organizational routines and priorities.

*4.4.3 Technological factor*s

The technology itself was highlighted as a challenge at the construction site, hindering the intended effect of the digitalization. Some digital tools are mandatory through contracts in Veidekke, however, an argument was made that the standardized set-up of the applications do not always cover all needs for unique projects. For instance, the system set-up of Dalux was indeed a cause of much frustration, both at Frysja and Ulven. At Frysja, one of the subcontractor's explained, *"If I write a point, then I send it to someone in Veidekke, who then sends it to another one in Veidekke, who then sends it to the relevant workers, right. It takes way too long" (Interviewee #9)*. Moreover, arguments were made that it should be possible within the application to send directly to the person responsible. At Ulven, this did not seem to be an issue, as anyone could freely send tasks and reports to others within the system. However, the lack of notifications when tasks were completed caused uncertainty and confusion as to whether tasks were in fact completed. One of the interviewees explained that,

> *[...] we are so many workers on the project that we are struggling with, to make the usage as easy as possible, the person who put in the task does not necessarily get a notification saying, "now it is done". (Interviewee #7)*

Another negative side of the digitalization is that not all necessary features are matched with the current technology. For instance, not being able to write notes or draw on the digital drawings seemed to be a disadvantage compared to the traditional physical drawings.

Another hindrance identified by the interviewees was the fact that the technology demands internet connection. This portrayed a challenge for the on-site construction

at Frysja, as the workers lost connection when for instance working in concrete cellars. Furthermore, exchanging paper drawings in favor of digital ones has its challenges as the technology is not suited for all types of weather, and the mobile devices are fragile. As one interviewee explained, *"When we have been working outside during the winter or when it rains, we have had to leave the tablet in one place and go back and forth to check. So, it has been a real problem" (Interviewee #11).* Additionally, regarding the statistics utilized at Frysja, one of the interviewees argued that the technology creates certain limits potentially excluding important aspects of the total picture. Thus, the statistics may provide an incomplete representation of reality.

4.5 Summary of findings and analysis

In summary, our empirical findings and analysis portray various interesting insights related to the digitalization of construction production processes. Several digital processes have been identified both at the on-site office and out in the production, including progress monitoring, logistics, as well as HSE and QA reporting. Furthermore, interviewees have identified perceived benefits and challenges, potentially influencing the digital processes. The highlighted benefits of digitalization can be separated into direct and intermediary benefits, where the direct ones refer to time, quality and safety, and the intermediary ones are identified to be visualization, control, information flow, and communication. In addition, key challenges recognized by the interviewees can be categorized into three, namely human, organizational, and technological factors. These benefits and challenges are interesting to further discuss in order to answer our main research question regarding how digitalization influences construction production processes.

Throughout our data collection process, several of the interviewees have also expressed thoughts on why digital tools and processes currently function properly and why they do not. Thus, indicating that there are certain conditions and prerequisites of importance for successful implementation and adoption. Language barriers, digital competence, technological hierarchies, and culture are some of the topics mentioned. Thus, the specific effects of digitalization, including the conditions and prerequisite of importance, may be interesting to investigate further.

This could include linking the empirical findings to for instance theories addressing technological adoption and organizational structure or culture when implementing digital tools. Such conditions for successful implementation and adoption of technology are however a large and extensive field of research, not within the scope of this master thesis. Our focus remains on uncovering practices and perceptions of digitalization implemented in the construction production phase.

5. Discussion

We have developed the following model (*Figure 8*), which will form the further basis for the discussion in this chapter. This figure portrays the findings resulting from our research, aiming to answer the research question of how digitalization influences construction production processes.

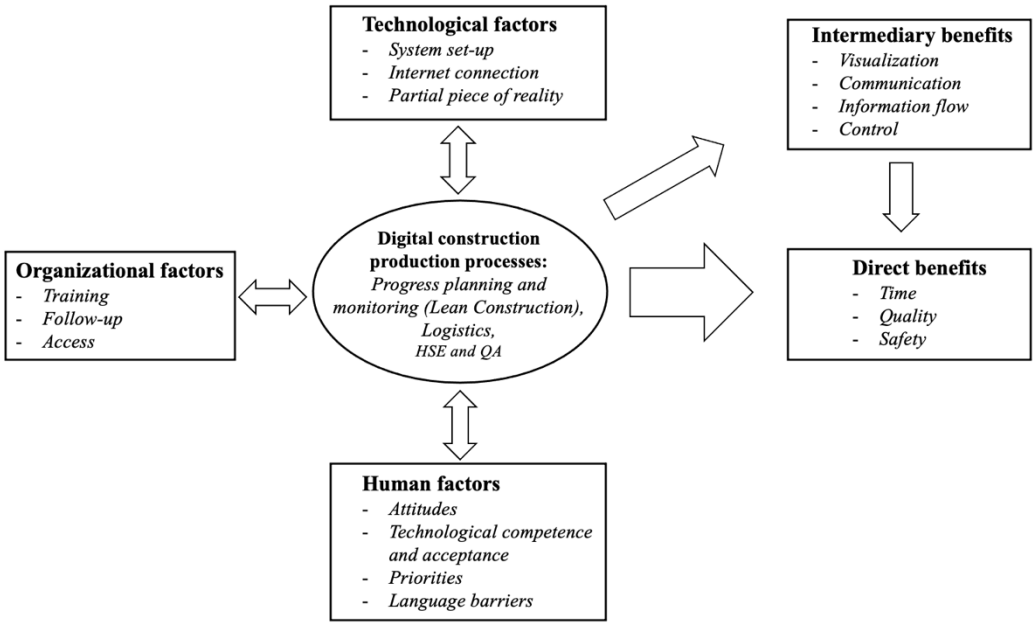

Figure 8: Revised conceptual framework

We have revised our conceptual framework from Chapter 3, and the figure depicts the core of our study. In the center of the framework, we see the identified construction production processes that have been digitalized. Surrounding these, we find three factors that influence and is influenced by said processes. These represent potential challenges related to technological, organizational, and human factors. Furthermore, we find that digitalized construction production processes can result in direct and intermediary benefits, where the intermediary benefits influence the direct ones.

Based on our insights retrieved from the previous chapter, this chapter will provide a discussion of our empirical findings in relation to prior research and knowledge explored through the literature review. This section will be centered around our two identified sub-questions, discussing the key insights from our study.

5.1 What type of processes in the construction production phase have been digitalized?

A discussion of our first sub-question regarding what processes have been digitalized within the construction production phase, is essential for answering our overall research question. In our literature study, we found that digitalization is increasingly shaping the world, transforming the society and business sphere as we know it (Hagberg et al., 2016; Kuusisto, 2017b). The construction industry is no exception, however it is seen to be among the least digitalized, moving at a slow pace (Agarwal et al., 2016). This was confirmed through our data collection, where interviewees highlighted the low degree of implemented digital processes in comparison to other sectors. Despite this seemingly slow pace of technological implementation, recent years have seen rapid advancements and adoptions of technologies to increase productivity and thus profit margins. At one of the construction sites investigated, we found interest in and development of technologies such as automatic containers, AR, VR, and drones. This confirmed digitalization's increased presence and newfound importance highlighted in the literature by for instance Holt et al. (2015) . The intriguing new technologies are indeed anticipated to be of importance for the construction project as a whole in the future. However, the development and testing of such technologies were found to be done at a managerial level in the project, not significantly influencing the construction production phase yet. The fact that the construction production seems mostly unaffected by such emerging technologies motivates our discussion on what processes have been digitalized in the construction production phase.

Our empirical findings show that the main digitalization effort is found at the on-site office of a construction project. This coincides with the wide range of construction literature focusing on digital tools and processes found at managerial levels, such as through progress monitoring systems or multidimensional BIM-technology (e.g. Bryde et al., 2013; Fosu et al., 2015). What is interesting, however, is that we find that the digitalization implemented at the office, which at first glance may seem irrelevant for the construction workers, is in fact indirectly influencing the daily construction work on site. A prominent example in this regard is the digitalized processes related to progress planning and monitoring, enabling an accurate overview of the project progress at the on-site office. In Veidekke, this can

be seen through the Lean work method known as Takt, striving for an even pace and continuous workflow. The process of progress planning and monitoring does not directly influence construction production, however through analysis and monitoring of project progress, correcting measures can be made to improve the production when needed. Thus, certain aspects of the digitalization found at the field office is in fact guiding and indirectly influencing the construction production processes on site. The enhanced control resulting from digital progress monitoring at the on-site office will be discussed later in greater detail.

In the extension of this insight, our findings reveal that the lack of digitalization at the construction site itself in fact seems to be intended, as it was emphasized by the interviewees that there is no need to digitalize just for the sake of digitalization. As the main focus of the construction worker should be the physical construction work, any digitalization effort implemented out on site should benefit the construction workers. Thus, any decision on whether to digitalize or not should be based on the intended digitalization's link to the tasks of the construction workers and to which extent it adds value. For example, our findings show that the process of registering QA and HSE deviations, as well as on-site logistics, have been digitalized. These digitalized processes are found to significantly add value, either directly by eliminating tedious administrative tasks or indirectly through improved documentation and knowledge transfer. This is supported by the literature, where Schallmo and Williams (2018) emphasize that digitalization initiatives should indeed be value adding for a firm to succeed in implementing changes to the business operations. Lean literature regarding waste such as Ohno (1988), focuses on the removal of non-value adding activities, which further supports the claim that digitalization efforts should only be made when it adds value to the process.

However, as the nature of a construction project is highly dependent on manual labor, certain processes and tasks at the construction site simply cannot be fully digitalized. This refers to for instance more or less obvious processes including physical construction. Furthermore, we have also found that even though some processes have the ability to become digital, it may not add any value to the construction production process. For instance, certain features important to the construction workers might not be accurately captured through the technology,

questioning the need for the specific digitalization. Our findings highlighted issues related to the ability to draw on the digital construction drawings, as well as difficulties related to weather conditions and the need for zooming in and out due to the screen's size. Such issues can potentially explain why Harty and Whyte (2010) find that certain traditional aspects, such as the use of paper, still seem to persist despite attempts of removal.

Nevertheless, our findings show that skepticism amongst the workers tends to be of initial character, which can be overcome and transformed into great success as the workers see the benefit of the digitalized process. This is of great importance, as the digitalization effort should be related to improving everyday life on the construction site. The digitalization should thus serve to benefit current tasks and processes in daily work on site. However, our findings show that this is a fine balance. The digitalized processes at the construction site can indeed make the everyday life of the construction worker easier, for instance seen through the deviation registration system in Dalux. Our findings show that not too much time should be spent on learning various digital systems, nor should construction workers need to spend much time on administrative tasks as a result of digitalization. The latter is claimed by interviewees to cause frustration amongst the employees, as the digital tools seem to have a formalizing effect, requiring the workers to plot in various information and documentation in the application. This can potentially be explained by Fewings and Henjewele (2019), stating that additional bureaucracy can be added as a result of not integrating technology and culture. Thus, the culture should develop in line with the new digital ways of working, setting clear objectives while motivating the employees to utilize the technology the right way.

What appears to be evident is that the information and documentation apparent with digitalization, which does not seem to directly influence construction processes, is of utmost importance for Veidekke as a whole. As pointed out by one of the interviewees, whether the construction workers write their lists and points in an application or on a sheet of paper does not matter for them, however it makes a considerable difference for the ones receiving the information. This indicates that the ones at the office can easily make use of the data and information in a much

more efficient and time saving manner, which further can benefit the project as a whole, for instance through faster handling of deviations on site. Indeed, our findings are reflected in the literature, where Whyte (2019) also emphasized the value of information. Here it is argued that digitalizing information is transforming how projects are delivered, and that information itself is becoming the deliverable (Whyte, 2019). Moreover, our findings show that the demand for information and documentation throughout the construction process is also a result of what we see in literature with increasing compliance requirements, as the industry is facing increasing legislation, regulations as well as governance requirements (Fewings & Henjewele, 2019). An example relates to the construction industry being a highly regulated industry in relation to HSE due to the many potential hazards found on site. This demands documentation and close follow up, thus making this specific aspect of digitalization of great importance.

In addition, documentation and traceability is essential in a construction project, serving as a record of what has happened throughout the project. This helps ensure consent and expectations amongst participating parties, serving as evidence in potential disputes that may arise. Fewings and Henjewele (2019) also point out that documentation is important when handing over the completed project, providing information on the safe, efficient, and effective use of the building. With these aspects in mind, the somewhat formalizing effect digitalization on site brings is in fact benefiting the project as a whole, whereas the same processes without the digital tools would have been much more cumbersome.

5.2 What are the perceived benefits and challenges of digitalization of construction production processes?

To gain insight into our research question regarding the influence of digitalization on construction production processes, we developed the sub-question addressing the benefits and challenges of said digitalization. Through our empirical analysis we have identified that digitalization in the production phase indeed has a positive influence on performance and productivity. This is in line with claims found in the literature of digitalization aiming to improve field productivity, speed of construction, safety monitoring and quality control (Blanco et al., 2017; Parusheva,

2019). As identified in our conceptual framework (*Figure 5*), performance and productivity can be visualized through direct benefits portrayed as performance indicators. However, our study has revealed some intermediary benefits that we find potentially influences the performance indicators as portrayed in *Figure 8*. We will therefore discuss such performance indicators through the scope of the identified intermediary benefits that can be achieved through digitalization.

As a basis for our discussion, we have identified three main direct benefits from our case that have been influenced by digitalization, namely time, quality, and safety. As presented by Chan and Chan (2004), a wide range of research reveals time, cost, and quality to be the basic criteria to project success in construction. Time and quality have been continuously highlighted throughout our data collection, seen as direct benefits of digitalization on project performance. Moreover, the LC literature also claims to influence the quality and time aspects, through for instance increased efficiency in operations and reduced defects (Hu et al., 2015; Melton, 2005). However, we found that we do not have sufficient data to be able to make an assessment on the cost factor, thus, excluding this from our discussion. Additionally, we found the aspect of safety to be of great importance within the construction sector in general, and further highlighted by both our study and the literature (Chan & Chan, 2004). Health and safety are amongst the measures found to receive increasing attention in the literature and has according to Bubshait and Almohawis (1994) been an issue raised for a long time due to major hazards found at a construction site. We thereby find it meaningful to investigate digitalization's influence on safety in addition to the traditional factors of quality and time. Thus, further extending empirical research in relation to relevant performance indicators.

5.2.1 The influence of intermediary benefits and accompanying challenges

In addition to the direct benefits identified, we found that there are several intermediary benefits that have an impact on the performance measures. We found these intermediaries to be visualization, information flow, communication, and control. Thus, we shall discuss each of these in greater detail in order to understand how they influence construction production processes through the aforementioned performance indicators.

Visualization

The first intermediary benefit seen to influence the direct benefits, is the increased level of visualization that is achieved through digitalization at the construction site. Visualization was found to be an important factor, leading to improved understanding and overview of the construction project. The visualization in mind is two-fold, firstly visualizing the construction process through 3D models and digital progress systems. Visualizing the project through sophisticated BIM-models contributes to the workers' understanding and ability to envision the final product and how to get there. This in turn may lower the chances of construction errors, as it is easier to detect potential challenges that might occur, further impacting the quality on site. Similarly at the office, the digital tools for progress planning and monitoring creates a beneficial visualization of the project status. This further seems to have an impact on the time aspect of the project, providing an accurate picture of what has been done and where the focus should lie in order to complete the construction process without severe time lags. This can be seen in connection to Sacks et al. (2010), claiming that by implementing digital tools, both the end product and the construction process can be clearly visualized, aiding LC in emphasizing continuous flows with a pull perspective. Thus, with the great overview the visualization brings, a continuous flow can be achieved, further seen as beneficial for the project as a whole.

Secondly, visualizing progress and tasks through statistics on monitors around the construction site were argued to influence certain performance indicators. Displaying statistics around the worksite regarding the number of deviations that are unresolved within a team, was found to create incentives to address these issues sooner rather than later, as the teams did not wish to stand out in a negative manner. With this in mind, we see that the visualization of the unresolved tasks has a positive influence on the quality and safety of the project. There are, however, some disadvantages to the statistics displays that were brought to light throughout our study. Firstly, there is a potential for rivalry to arise between teams. Because the deviations displayed are reported by workers on the site, the interviewees shared experiences with workers targeting other trades with deviations to avenge them registering unreasonably many deviations to their trade. This can be seen in connection with literature, as a challenge to digitalization is indeed the existing

ecologies of practice where the interaction and behavior of people involved is of high importance to the success of IT (Harty & Whyte, 2010; Kuusisto, 2017a). Secondly, the statistics that are displayed only show a partial picture of the whole progress and state of the construction site, potentially excluding important aspects. This is a common challenge when interpreting statistics of any kind. Thus, the lack of crucial context may lead to wrong decisions or assumptions being made, potentially reflecting negatively on the performance outcomes. Nonetheless, our research revealed that experiences were mostly positive, and that the general effect of the statistics was eagerness to work harder for better results. Furthermore, this can be connected to the culture of the work site. As long as the culture is inclusive and uniting, the internal rivalry and exposure does not negatively impact the atmosphere on site.

Control

Another intermediary factor related to visualization is the aspect of control. We identified that some of the same digital measures that provide visualization at the construction site also can contribute to better control. Our findings portray that digitalization enables an accurate overview of the project progress and hence results in better control. This is done through monitoring the project and analyzing on-site statistics, enabling the generation of accurate correcting measures to improve the production when needed. Even though this particular aspect does not directly relate to the physical construction on site, it can be argued to indirectly influence the production process. This can for instance be through the aforementioned correcting measures made at the office as a result of the monitoring technologies, influencing the time and flow of the actual construction on site.

Furthermore, the aspect of control can be seen in connection to LC literature, as emphasis on Takt and progress planning is closely linked to the principle of creating a continuous workflow in production, and reducing variability (Yassine et al., 2014). The connection between LC and digitalization was investigated in our data collection, however, the interviewees did not seem to perceive a clear connection between the topics. The literature clearly suggests that there is a connection between the two, where synergies are highlighted by for instance Khanzode et al. (2006), Gilligan and Kunz (2007) and Sacks et al. (2010). This contradicts our empirical

data, where the connection does not seem to be of high importance or value. Nevertheless, despite interviewees claiming little direct connection between digitalization and LC efforts on site, indirect connections could be seen in other sections of the interview. Links to LC were found when interviewees explained benefits of progress planning, such as increased control and improved flow in the production phase. Hence, this indicates that there can be a perceived connection between digitalization and LC, even if it is not made consciously.

In addition to the enhanced control found at the office, the digitalization also facilitates the construction worker to be more in control in their everyday work on site. By having easily accessible hand-held devices containing individual tasks, deviations to address, as well as continuously updated digital drawings, the workers are in constant control of the precise work to be done. This control is further an important factor influencing the quality, safety, and time aspect of a project. Being in control of which deviations that need to be addressed may for instance cause the employees to address them quicker, thereby increasing safety and quality. Furthermore, as previous deviation reports were handled through green paper notes, easily lost or misplaced, the digital system of reporting HSE deviations is indeed bettering the safety aspect. In addition, by increasing the individual worker's control of everyday work, less time can potentially be spent on wondering what to do. What is important however, is still that the focus of the construction worker remains on the actual construction. The potentially increased control of the worker depicts how digitalization can supplement the everyday work, but as seen through the examples, this solely addresses a minor part of the work on site.

Information flow

Another intermediary benefit identified through our empirical analysis, positively influencing the performance indicators, was found to be the factor of information flow. Due to a construction project containing numerous interrelated parties, there is no doubt that the quality of information is of great importance.

One of our main findings in this regard relates to the enhanced accuracy of the information conveyed in the construction production process. The digital systems enable the information to be captured and forwarded to the right person in the exact

moment it is perceived or thought of by the employee, capturing the content in a factual and efficient manner. The possibility of including pictures and pinpoint the exact location in the application is further enriching the accuracy of the information. The literature similarly highlights that a benefit from implementing electronic information exchange is the reduction of waste and potential errors resulting from re-interpreting information (Harty & Whyte, 2010). With this in mind, information functions as an intermediary factor, influencing upon safety as HSE deviations are conveyed and understood the exact way it was supposed to. Similarly, the accurate information will benefit the quality of the project, as well as reducing time spent on for instance figuring out the location of the deviation needing to be addressed.

Another important aspect of the digitalization in this regard is indeed its ability to gather a large amount of detailed data, all in one place. Through the use of hand-held devices, the information is always available at easy access. The richness and availability of the information can indeed be seen as influential to both the time aspect as well as the quality. Rich, detailed drawings in the pocket of the construction worker reduces the time spent on retrieving updated versions and leads to less construction related errors. This is in line with what we found in the literature, where Blanco et al. (2017) claim that communication platforms increase the availability of information, which reduces time spent on acquiring information and also improves accuracy. Thus, with rich, accurate and available information, the waste of rework and time on hand can be eliminated, improving the workflows in the construction process. On the other hand, Liu and Chua (2016) emphasize that the LC success of the digital information flows is dependent on the commitment and involvement of all entities. Hamdi and Leite (2012) also points to the individual skills of the ones involved in manipulating the technology as crucial for the achieved Lean benefits. Information as an intermediary benefit of digitalization should thereby not be taken for granted, as the people involved are crucial for the success.

Communication

Closely linked to the aspect of information comes another intermediary factor interesting to discuss, which is the way digitalization seems to influence communication in the construction production process. An important point we have

found through our research is how digital processes and tools enhance communication by making it clear and efficient. For instance, through the use of Dalux a communication channel is created between the office and the construction site, enabling the workers to easily and accurately communicate for instance deviations observed on site. With this, information is conveyed in an exact manner which in turn impacts the time perspective by reducing the need for clarifications. Enhanced communication can also serve as timesaving through speeding up manual processes such as HSE and QA reporting. The precise and efficient way of communicating thus enhances the safety and quality of the construction project, through addressing deviations sooner, as well as potentially avoiding major misunderstandings. However, there is a challenge to these benefits, recognized in the literature as well as through our study, regarding the nature of the construction industry. Not only is a construction project highly fragmented, but as a result of the project-based nature, different people are needed based on their professional knowledge and experiences (Fong & Lung, 2007). Therefore, it also consists of a large share of foreign workers with various nationalities. According to insight retrieved from our data collection some of the foreign workers may not speak Norwegian nor English. Hence, they are not able to use the systems, causing more coordination and work for their colleagues. A prerequisite for the aforementioned beneficial communication platforms is thereby that everyone is able to utilize the digital tool for it to function optimally as a communication platform.

Another interesting aspect we discovered through our research, is that the means of communication differed amongst the two sites. This was due to the structure and access limitations in the application being set up differently. Fewings and Henjewele (2019) claim that effective communication channels should be created and accessed by everyone in the project. This implies the need for a platform that allows for communication between all parties involved in the project. This worked to a certain extent on one of the sites, as Dalux served partially as a communication channel between various actors at the construction site. This was exemplified through the possibility to send action points to address on site across different trades, thus making the communication process more efficient and direct. This has in turn reduced the need for walking long distances, looking for the right person to fix something. On the other construction site, however, one of the main challenges

was the hierarchical set-up in Dalux. They did not have the same possibility of sending deviations across trades on the work site, instead all communication was gathered and redirected through employees at the office. This led to extensive routes that the information had to travel and caused waiting and frustration.

In the extension of the technology set-up not being appropriate, frustration also emerged from the lack of individuals within the system following up on the communication and information received. Such challenges could potentially be a result of poor routines in the follow-up phase or simply arising from individuals not perceiving it as a priority. With this, unnecessary time is spent on waiting for a response, potentially not receiving any at all, as tasks or reports may be "lost" in the system. Such behavior can be seen in relation to research on behavioral inertia by Kuusisto (2017a), describing the tendency to keep doing something the same way because it is the way it always has been done, making changes difficult to implement. In turn this can challenge the final outcome of the construction project, potentially leading to time-lags, quality deficits or safety breaches. It is clear that in order for digitalization to supplement the construction work properly, the technology and everyone involved have to coincide with the appropriate level of hierarchy and commonly understood routines and prioritization. Moreover, creating clear objectives as well as motivating people to make use of new technologies is critical (Fewings & Henjewele, 2019).

The aforementioned hierarchical barriers can result in the workers choosing not to utilize the digital tools because of its inefficiency, and rather seek to solve problems "the old way" by seeking out the responsible actors on the work site by foot, or by calling. In fact, it seemed like some construction workers still prefer communication at the construction site to happen spontaneously and through actually talking to each other. Furthermore, this indicates that, even though digital tools have the ability to fully function as communication platforms around the whole construction site, it may not be a necessity. This relates back to our previous discussion on how digitalization should supplement rather than substitute, which also is brought forward by Harty and Whyte (2010). They state that previous studies emphasize how new ways of working enabled by IT, should supplement the current non-IT practices rather than completely replacing them.

Despite the benefits brought by enhanced information and communication through digitalization, the increased utilization of technology as information and communication platforms are also introducing other challenges. As we spoke to a few of the subcontractors working on the two projects, it became evident that previous experience with the specific technology was indeed impacting the utilization and the perceived benefits of the tools in the construction process. Thus, varying knowledge and experience with the digital tools found at site seemed to be a hindrance, causing different usages across the work site. Furthermore, our findings show that there is a clear division in understanding and use of digital tools related to age. Interviewees claimed that the older employees had a longer learning curve and more initial skepticism to new tools, often as a result of little digital engagement in their private lives. However, it can be reasonable to believe that naturally with time, the older segment of the construction workers will be phased out. Indeed, most of the workforce are already accustomed to learning to use digital tools.

Through our analysis of the empirical data, we found that learning to utilize digital tools is not only dependent on each individual's technological competence, but also the training and demonstration offered by the employer. Our findings identified a need for clear instructions, training, and follow-up on the use of the systems from the main contractor. This coincides with Martin (2010), highlighting training and knowledge transfer to be of great importance, requiring close follow-up for optimal results. This can be of particular importance in the construction process, as it is characterized by a high degree of interorganizational teamwork, requiring close collaboration and coordination amongst various professions (Fong & Lung, 2007). The varying technological competence and acceptance makes it challenging to decide on the correct amount of training and instructions, especially when creating a standardized training module. Furthermore, there is a plethora of additional information the construction workers must familiarize themselves with before working at a new site regarding for instance safety. Consequently, this could lead to digital tools not being prioritized. Hence, the workers that are involved with a project for a short period of time, seem to have the highest barrier for adopting the new technology.

Other findings revealed that some of the project's subcontractors were already familiar with some of the more complex digital tools. Indeed, one subcontractor had for instance initiated a partnership with Dalux prior to collaborating with Veidekke, while others had experiences with the tools due to several other big contractor firms using them as well. This seemed to give a clear advantage, causing less challenges at the construction site. This is closely aligned with Love et al. (2004), suggesting that the interorganizational environment could benefit from creating cooperative relationships, such as alliances or partnerships, to increase learning and build mutual trust. Thus, standardized tools that can be utilized and customized for individual contractors seems to have a clear positive impact by reducing time spent learning and understanding new tools.

5.3 Summary of discussion

To answer our research question regarding how digitalization influences construction production processes, we have created a figure *(Figure 8)* depicting the insight gained through our study.

In this chapter we have discussed that despite the large efforts to test and research emerging technologies for construction sites, the current production is not heavily influenced by digitalization. As of today, we have found that most of the digitalization efforts are at the on-site office, rather than out on site. This is in line with existing literature, where for instance progress monitoring and BIM are in focus. Thus, our research contributes to extending the scope by mapping digitalized processes in the construction production phase. We find that the current processes that have been digitalized include progress planning and monitoring, logistics, and QA and HSE deviation reports. Furthermore, the notion of the construction worker's focus remaining on construction work has been repeated in our data collection, providing insight as to why digitalization is currently utilized to a lesser extent by construction workers. However, through our findings we have seen that there are indirect influences from the digitalization efforts made in the construction site offices, positively affecting the construction production processes. This is in line with existing literature, highlighting digitalization efforts to benefit the construction process as a whole.

To further understand the influence of digitalization on production processes, we have discussed potential benefits and challenges. Through investigating how digitalization influences various performance indicators on site, we argue that there are intermediary benefits that impact traditional performance indicators through digitalization. This is seen to extend the traditional performance measure literature, where we have identified visualization, control, information flow and communication to influence measures such as quality, time and safety. Through digital processes and by utilizing digital tools, various benefits have thereby been identified through these factors. However, we have also discussed several challenges further serving as a negative influence on performance. Ultimately, the influence of digitalization on performance indicators highly depends on addressing and overcoming challenges within organizational, technological, and human factors.

6. Conclusion

This chapter serves to provide an overall conclusion of our study with accompanying implications related to our research question. Both theoretical and practical implications will be presented, followed by the limitations of our study as well as recommendations for future research.

6.1 Theoretical implications

The overall objective of this research has been to investigate how digitalization influences the construction production phase, including identification of digitalized processes as well as perceived benefits and challenges. This has been done through a complementary case study of two construction projects at Veidekke, namely Ulven and Frysja, providing us with in-depth insights into the influence of digitalized processes and digital tools. Semi-structured interviews were conducted, and further analyzed and discussed in relation to our theoretical background.

Through our literature study, we have recognized the theme of digitalization in construction to be of increasing importance and emphasis in research. Implementation and utilization of digital processes and tools are applied in various stages and levels in a construction project, seen through our empirical research to be especially applied in the design and planning stages. However, the influence of digitalization on construction production processes seems to be investigated to a lesser extent. Hence, our thesis set out to explore this area with a case study including two construction projects, leading to a contribution with the addition of new empirical data. In doing so, our aim has been to contribute to extend the research to focus on digitalization in the construction production phase, as most of the previous theory puts emphasis on other stages and levels (e.g. Aguiar Costa & Grilo, 2015; Azhar et al., 2011). The influence on the actual production phase is indeed of great importance, as this is what both the internal and external supply chain converge towards (Tserng et al., 2005; Vrijhoef & Koskela, 2000).

Our study makes several contributions to understanding how digitalization influences construction production processes. To theory, our study first highlights the close connection between digitalization at the on-site office and out at the

construction site. Indeed, this indicates that digital efforts made at the office has consequences for the physical construction on site, and vice versa. Thereby, from a theoretical perspective, our research contributes with valuable knowledge and insights into both levels and their accompanying digital interactions in the production phase. This provides nuances to current literature on digitalization in the construction industry, where for instance Bryde et al. (2013) and Elghaish et al. (2020) emphasize efforts at the office in a project. Accordingly, our research suggests that digitalization of construction production processes involves both processes out on site and at the office, closely related and influenced by each other.

Another contribution to theory evident from our research, is the presence and impact of intermediary benefits on traditional performance indicators enabled by digitalization. Literature has portrayed such performance indicators in the construction industry to be focused around the "iron triangle" referring to the aspects of time, cost and quality (Atkinson, 1999; Chan & Chan, 2004). As our study highlights the importance of including the dimension of safety in the measurement of direct performance as well, the frequently emphasized theory of the "iron triangle" is extended. The inclusion of this particular aspect has been highlighted in previous research as well, confirming its relevance and necessity (Bubshait & Almohawis, 1994).

The literature related to direct influence on project performance is further extended through our identification of intermediary factors, including control, visualization, information flow and communication. The degree to which the digitalization enhances these aspects is influential for the achieved quality, time, and safety of a project. We further find this to complement the benefits of efforts within LC, which are implemented at the sites of our empirical case, strengthening the indirect link between digitalization and LC (Sacks et al., 2010). We find LC to be closely related to the intermediary benefits in terms of waste reduction and progress planning and monitoring, as such initiatives are intertwined with the intermediary benefits enhanced by digitalization. The direct link between digitalization and LC is however not recognized by the interviewees, questioning the combination of the two.

6.2 Practical implications

Our study further provides some practical implications, important to consider and bear in mind for practitioners and managers. These implications further complement the theoretical ones when looking to digitalize construction production processes.

As highlighted in our discussion, findings were clear toward the notion that one should not digitalize just for the sake of digitalization. Indeed, the implemented digitalization should add value to construction production processes on site, which can be done either by directly benefiting the construction worker, or more indirectly through the on-site office. By aligning the initiatives of the on-site office and the construction activities, the combined efforts will benefit the construction process as a whole. Thereby, we see building and maintaining a connection between the on-site office and the construction activities in terms of digitalization to be of the essence. The main contractor should further explain and emphasize the importance of doing this, as the construction workers out on site might not find certain digitalization efforts to be of immediate value for them. This is however dependent on the context and cultural setting of the project, as some countries tend to have a more hierarchical approach to the management of on-site workers. We have, however, found that the focus of the construction worker first and foremost should remain on the actual construction. Due to the nature of construction projects demanding manual labor, another practical implication identified is that potential digitalizing initiatives out on site should supplement the workers rather than substitute existing processes.

We have through our research identified both benefits and challenges emerging from digitalizing construction production processes, influencing the performance of a project. Thus, a practical implication identified is the need to recognize and address the challenges related to digitalization of processes. Hence, we propose some precautions to bear in mind for the main contractor looking to implement digitalization in the production phase.

1. **Seek a conscious relationship to the use of the technology and what the key objectives are.** Through our study, we found that there is a wide variety of actors involved in the construction production phase of a project. This clearly portrays the importance of ensuring the correct and unison use of the technologies, as different usages across the construction site may hinder the intention of the digitalized processes. The main contractor should thereby aim to seek a conscious plan for how and how much they want to utilize digitalization. However, it is important to bear in mind that too much formalization through digitalization should be avoided.

2. **Adjust the technology to utilize its full potential.** We find that there is a need for adjusting the technology to fit the unique construction project, ensuring that the set-up is tailored to the intended use. We find it beneficial to ensure that everyone relevant is included in the digital platform and has the appropriate access and reach. Moreover, it can be beneficial to be familiarized with all aspects of the technology, to be able to benefit from all functions and possibilities with new digital products or processes.

3. **Ensure proper training.** To be able to achieve the desired outcome from the digitalization efforts, proper training and follow up is of the essence. Especially due to the large number of actors present at the construction site, the main contractor should seek to create a conscious relationship with subcontractors and other key actors on site. Moreover, creating a clear vision for the use and purpose of the digitalization can help to ensure commitment and proper usage from the people affected by the digital change.

4. **Be open to possibilities for partnerships.** Our study has shown that when subcontractors already had relationships with suppliers of digital tools utilized by the main contractor, it showed a positive influence on the ability to utilize and accept digitalization. Thus, aiming toward common digitalization partnerships or alliances across contracting firms, leading to a larger network of aligned digital construction sites would be beneficial for the project as a whole. Indeed, effects such as reduced time on training, more

efficient use of existing technology and better workflow can potentially be achieved.

We believe that the proposed measures are feasible and beneficial to consider when faced with digitalization efforts. The digitalization trend is indeed of great importance, influential for the future of construction. Thereby, the implications presented underlines the importance of including the construction production phase in the scope of digitalization.

6.3 Limitations and recommendations for future research

Our main limitation in regard to our data collection was indeed the ongoing COVID-19 pandemic. Due to Norwegian construction sites containing a substantial number of foreign workers, the construction industry was heavily affected by preventive measures and strict regulations enforced by the contractors and the Government. Thus, we were not able to visit any of the construction sites to make our own observations as planned, nor have any of our semi-structured interviews face-to-face with our interviewees. This was indeed a limitation, whereas we could have gained useful insights into the practices on the work site.

Furthermore, another limitation of our thesis is the number of projects we studied and interviews we conducted. Indeed, a more complete picture could have been made if we had included even more construction projects and in-depth interviews. However, due to the time and resource constraints of a master thesis, in combination with challenging circumstances, this was not possible in our case. Despite these limitations, we believe that our findings provide interesting and relevant insights as digitalization in the construction industry is receiving increasing attention.

Moreover, due to the limitations of this thesis project, we find that there are several interesting opportunities for further research. By conducting multiple case studies on the effects of digitalization in the construction industry findings could potentially be generalized. Research could also be extended to include other phases of the CSC, such as the planning or procurement phase, providing a holistic view of the effects of digitalization. Furthermore, there seems to be little quantitative data on the actual

effects of digitalization and the implementation of digital processes and tools in construction and could thus be interesting to investigate further. An example could be to conduct several measures on key areas over a longer time period, in which a process or a tool is digitalized.

References

Acemoglu, D., Autor, D., Dorn, D., Hanson, G. H., & Price, B. (2014). Return of the Solow Paradox? IT, Productivity, and Employment in US Manufacturing. *American Economic Review*, *104*(5), 394–399. https://doi.org/10.1257/aer.104.5.394

Agarwal, R., Chandrasekaran, S., & Sridhar, M. (2016, June 24). *Imagining construction's digital future*. https://www.mckinsey.com/business-functions/operations/our-insights/imagining-constructions-digital-future

Aguiar Costa, A., & Grilo, A. (2015). BIM-Based E-Procurement: An Innovative Approach to Construction E-Procurement. *The Scientific World Journal*, *2015*, 1–15. https://doi.org/10.1155/2015/905390

Alarcon, L., Mandujano, M., & Mourgues, C. (2013, August 31). *Analysis of the implementation of VDC from a lean perspective: Literature review*. 21th Annual Conference of the International Group for Lean Construction., Fortaleza, Brazil. https://www.researchgate.net/profile/Maria_Mandujano/publication/282303357_Analysis_of_the_implementation_of_VDC_from_a_lean_perspective_Literature_review/links/560e9b5b08aec422d111c7de.pdf

Aouad, G., Hinks, J., Cooper, R., Sheat, D., Kagioglou, M., & Sexton, M. (1998). Map for a generic design and construction process protocol. *Journal of Construction Procurement*. https://eprints.lancs.ac.uk/id/eprint/39899/

Ark, B. van. (2016). The Productivity Paradox of the New Digital Economy. *International Productivity Monitor*, *31*, 3–18.

Atkinson, R. (1999). Project management: Cost, time and quality, two best guesses and a phenomenon, its time to accept other success criteria. *International Journal of Project Management*, *17*(6), 337–342. https://doi.org/10.1016/S0263-7863(98)00069-6

Azhar, S., Nadeem, A., Mok, J. Y. N., & Leung, B. H. Y. (2011). Building Information Modeling (BIM): A New Paradigm for Visual Interactive Modeling and Simulation for Construction Projects. *First International Conference on Construction in Developing Countries*, *1*, 435–446.

Aziz, R. F., & Hafez, S. M. (2013). Applying lean thinking in construction and performance improvement. *Alexandria Engineering Journal*, *52*, 679–695.

https://doi.org/10.1016/j.aej.2013.04.008

Ballard, H. G. (2000). *The last planner system of production control* [Doctoral thesis, University of Birmingham]. https://etheses.bham.ac.uk/id/eprint/4789/

Bankvall, L., Bygballe, L. E., Dubois, A., & Jahre, M. (2010). Interdependence in supply chains and projects in construction. *Supply Chain Management: An International Journal*, *15*(5), 385–393. https://doi.org/10.1108/13598541011068314

Barbosa, F., Woetzel, J., Mischke, J., Ribeirinho, M. J., Sridhar, M., Parsons, M., Bertram, N., & Brown, S. (2017). *Reinventing construction: A route to higher productivity*. McKinsey Global Institute. https://www.mckinsey.com/~/media/McKinsey/Industries/Capital%20Projects%20and%20Infrastructure/Our%20Insights/Reinventing%20construction%20through%20a%20productivity%20revolution/MGI-Reinventing-Construction-Executive-summary.pdf

Baxter, P., & Jack, S. (2008). Qualitative Case Study Methodology: Study Design and Implementation for Novice Researchers. *The Qualitative Report*, *13*(4), 544–559. https://doi.org/10.46743/2160-3715/2008.1573

Bell, E., Bryman, A., & Harley, B. (2019). *Business research methods* (Fifth edition.). University Press.

Berlak, J., Hafner, S., & Kuppelwieser, V. G. (2020). Digitalization's impacts on productivity: A model-based approach and evaluation in Germany's building construction industry. *Production Planning & Control*, *32*(4), 335–345. https://doi.org/10.1080/09537287.2020.1740815

BI Centre for the Construction Industry. (2019). *Digital innovation in the Architecture, Engineering, and Construction Industry*. BI Norwegian Business School. https://www.bi.no/globalassets/forskning/senter-for-byggenaringen/publikasjon/digital-innovation-in-the-construction-industry-2019.pdf

Blanco, J. L., Dohrmann, T., Julien, J., Law, J., & Palter, R. (2019, October 4). *Governments can lead construction into the digital era*. https://www.mckinsey.com/business-functions/operations/our-insights/governments-can-lead-construction-into-the-digital-era

Blanco, J. L., Mullin, A., Pandya, K., & Sridhar, M. (2017). *The new age of*

engineering and construction technology. McKinsey & Company-Capital Projects & Infrastructure. https://www.mckinsey.com/business-functions/operations/our-insights/the-new-age-of-engineering-and-construction-technology

Bloomberg, J. (2018, April 29). Digitization, Digitalization, And Digital Transformation: Confuse Them At Your Peril. *Forbes*. https://www.forbes.com/sites/jasonbloomberg/2018/04/29/digitization-digitalization-and-digital-transformation-confuse-them-at-your-peril/?sh=433e38f2f2c7

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Bryde, D., Broquetas, M., & Volm, J. M. (2013). The project benefits of Building Information Modelling (BIM). *International Journal of Project Management*, *31*(7), 971–980. https://doi.org/10.1016/j.ijproman.2012.12.001

Brynjolfsson, E. (1993). The Productivity Paradox of Information Technology. *Communications of the ACM*, *36*(12), 66–77. https://doi.org/10.1145/163298.163309

Brynjolfsson, E., & Hitt, L. M. (1998). Beyond the productivity paradox. *Communications of the ACM*, *41*(8), 49–55. https://doi.org/10.1145/280324.280332

Bubshait, A. A., & Almohawis, S. A. (1994). Evaluating the general conditions of a construction contract. *International Journal of Project Management*, *12*(3), 133–136. https://doi.org/10.1016/0263-7863(94)90027-2

Byggenæringens Landsforening. (2020). *Digitalt veikart 2.0*. Byggenæringens Landsforening. https://www.bnl.no/siteassets/bilder/generelle-bilder/digitaltveikart_2020.pdf

Carter, N., Bryant-Lukosius, D., DiCenso, A., Blythe, J., & Neville, A. J. (2014). The Use of Triangulation in Qualitative Research. *Oncology Nursing Forum*, *41*(5), 545–547. https://doi.org/10.1188/14.ONF.545-547

Chan, A. P. C., & Chan, A. P. L. (2004). Key performance indicators for measuring construction success. *Benchmarking: An International Journal*, *11*(2), 203–221. https://doi.org/10.1108/14635770410532624

Chan, A. P. C., Scott, D., & Lam, E. W. M. (2002). Framework of Success Criteria for Design/Build Projects. *Journal of Management in Engineering*, *18*(3), 120–128. https://doi.org/10.1061/(ASCE)0742-597X(2002)18:3(120)

Dallasega, P. (2018). Industry 4.0 Fostering Construction Supply Chain Management: Lessons Learned From Engineer-to-Order Suppliers. *IEEE Engineering Management Review*, *46*(3), 49–55. https://doi.org/10.1109/EMR.2018.2861389

Dubois, A., & Gadde, L.-E. (2002). Systematic combining: An abductive approach to case research. *Journal of Business Research*, *55*(7), 553–560. https://doi.org/10.1016/S0148-2963(00)00195-8

Dul, J., & Hak, T. (2008). *Case study methodology in business research*. Elsevier Ldt.

Dworkin, S. L. (2012). *Sample Size Policy for Qualitative Studies Using In-Depth Interviews*. *41*(6), 1319–1320. https://doi.org/10.1007/s10508-012-0016-6

Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2008). *BIM Handbook: A guide to Building Information Modeling for owners, managers, designers, engineers and contractors* (2nd ed.). John Wiley & Sons, Inc. https://epress.lib.uts.edu.au/journals/index.php/AJCEB/article/view/2749

Ebneyamini, S., & Sadeghi Moghadam, M. R. (2018). Toward Developing a Framework for Conducting Case Study Research. *International Journal of Qualitative Methods*, *17*, 1–11. https://doi.org/10.1177/1609406918817954

Eisenhardt, K. M. (1989). Building Theories from Case Study Research. *The Academy of Management Review*, *14*(4), 532–550. https://doi.org/10.2307/258557

Elghaish, F., Matarneh, S., Talebi, S., Kagioglou, M., Hosseini, M. R., & Abrishami, S. (2020). Toward digitalization in the construction industry with immersive and drones technologies: A critical literature review. *Smart and Sustainable Built Environment*, *ahead-of-print*(ahead-of-print). https://doi.org/10.1108/SASBE-06-2020-0077

Fewings, P., & Henjewele, C. (2019). *Construction Project Management: An Integrated Approach* (3rd ed.). Routledge. https://doi.org/10.1201/9781351122030

Firestone, W. A. (1993). Alternative Arguments for Generalizing from Data as Applied to Qualitative Research. *Educational Researcher*, *22*(4), 16–23. https://doi.org/10.2307/1177100

Fong, P. S., & Lung, B. W. (2007). Interorganizational Teamwork in the Construction Industry. *Journal of Construction Engineering and Management*, *133*(2), 157–168. https://doi.org/10.1061/(ASCE)0733-9364(2007)133:2(157)

Fontana, A., & Frey, J. H. (2005). The Interview: From Neutral Stance to Political Involvement. In N. K. Denzin & Y. S. Lincoln (Eds.), *The Sage handbook of qualitative research* (3rd ed., pp. 695–727). Sage Publications Ltd.

Fosu, R., Suprabhas, K., Rathore, Z., & Cory, C. (2015). *Integration of Building Information Modeling (BIM) and Geographic Information Systems (GIS) – a literature review and future needs.* 196–204. https://itc.scix.net/pdfs/w78-2015-paper-020.pdf

Foulkes, A., & Ruddock, L. (2007). *Defining the scope of the construction sector*. 89–98. https://docplayer.net/63517597-Defining-the-scope-of-the-construction-sector.html

Frandson, A., Berghede, K., & Tommelein, I. D. (2013). *Takt time planning for construction of exterior cladding*. 527–536. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1088.3258&rep=rep1&type=pdf

Gebauer, H., Fleisch, E., Lamprecht, C., & Wortmann, F. (2020). Growth paths for overcoming the digitalization paradox. *Business Horizons*, *63*(3), 313–323. https://doi.org/10.1016/j.bushor.2020.01.005

Gerber, D. J., Becerik-gerber, B., Kunz, A., & Words, K. (2010). *Building Information Modeling and Lean Construction: Technology, Methodology and Advances from Practice*. The 18th Annual Conference of the International Group for Lean Construction, Haifa, Israel. https://www.researchgate.net/publication/278667977_BUILDING_INFORMATION_MODELING_AND_LEAN_CONSTRUCTION_TECHNOLOGY_METHODOLOGY_AND_ADVANCES_FROM_PRACTICE

Gilligan, B., & Kunz, J. (2007). *VDC use in 2007: Significant value, dramatic growth, and apparent business opportunity* (CIFE Technical Report No. TR171). Stanford University.

http://cife.stanford.edu/sites/default/files/TR171.pdf, 40.

Gray, J., & Rumpe, B. (2015). Models for digitalization. *Software & Systems Modeling*, *14*, 1319–1320. https://doi.org/10.1007/s10270-015-0494-9

Hagberg, J., Sundstrom, M., & Egels-Zandén, N. (2016). The digitalization of retailing: An exploratory framework. *International Journal of Retail & Distribution Management*, *44*(7), 694–712. https://doi.org/10.1108/IJRDM-09-2015-0140

Hajli, M., Sims, J. M., & Ibragimov, V. (2015). Information technology (IT) productivity paradox in the 21st century. *International Journal of Productivity and Performance Management*, *64*(4), 457–478. https://doi.org/10.1108/IJPPM-12-2012-0129

Hamdi, O., & Leite, F. (2012). *BIM and Lean Interactions from the BIM Capability Maturity Model Perspective: A Case Study*. The 20th Annual Conference of the International Group for Lean Construction, San Diego, USA.

Hannah, D. R., & Lautsch, B. A. (2011). Counting in Qualitative Research: Why to Conduct it, When to Avoid it, and When to Closet it. *Journal of Management Inquiry*, *20*(1), 14–22. https://doi.org/10.1177/1056492610375988

Harty, C., & Whyte, J. (2010). Emerging Hybrid Practices in Construction Design Work: Role of Mixed Media. *Journal of Construction Engineering and Management*, *136*(4), 468–476. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000146

Hasan, A., Baroudi, B., Elmualim, A., & Rameezdeen, R. (2018). Factors affecting construction productivity: A 30 year systematic review. *Engineering, Construction and Architectural Management*, *25*(7), 916–937. https://doi.org/10.1108/ECAM-02-2017-0035

Holt, E. A., Benham, J. M., & Bigelow, B. F. (2015). *Emerging Technology in the Construction Industry: Perceptions from Construction Industry Professionals*. 26.595.1-26.595.10. https://peer.asee.org/emerging-technology-in-the-construction-industry-perceptions-from-construction-industry-professionals

Howell, G. A. (1999, July). *What is Lean Construction?* Seventh Conference of the International Group for Lean Construction, Berkeley, CA.

https://iglcstorage.blob.core.windows.net/papers/attachment-616a489a-8e13-46a6-85b3-34eedd72ac8b.pdf

Hox, J., & Boeije, H. (2005). Data collection, primary versus secondary. In K. Kempf-Leonard (Ed.), *Encyclopedia of Social Measurement* (Vol. 1, pp. 593–599). Elsevier Inc. https://doi.org/10.1016/B0-12-369398-5/00041-4

Hu, Q., Mason, R., Williams, S. J., & Found, P. (2015). Lean implementation within SMEs: A literature review. *Journal of Manufacturing Technology Management*, *26*(7), 980–1012. https://doi.org/10.1108/JMTM-02-2014-0013

Kala, T., Seppänen, O., & Stein, C. (2010). Using an integrated 5D & location-based planning system in a large hospital construction project. *Lean Construction Journal*, 102–112.

Khan, S. (2014). Qualitative Research Method: Grounded Theory. *International Journal of Business and Management*, *9*(11), 224–233. https://doi.org/10.5539/ijbm.v9n11p224

Khanzode, A., Fischer, M., Reed, D., & Ballard, G. (2006). *A Guide to Applying the Principles of Virtual Design & Construction (VDC) to the Lean Project Delivery Process* (CIFE Working Paper No. 093). Stanford University.

Kovács, G., & Spens, K. M. (2005). Abductive reasoning in logistics research. *International Journal of Physical Distribution & Logistics Management*, *35*(2), 132–144. https://doi.org/10.1108/09600030510590318

Kunz, J., & Fischer, M. (2020). Virtual design and construction. *Construction Management and Economics*, *38*(4), 355–363. https://doi.org/10.1080/01446193.2020.1714068

Kuusisto, M. (2017a). *Barriers and Facilitators of Digitalization in Organizations*. SQAMIA 2017, Belgrade, Serbia. https://www.semanticscholar.org/paper/Barriers-and-Facilitators-of-Digitalization-in-Kuusisto/89511c9ad2c8373a10646c97baf55a27fe71d891

Kuusisto, M. (2017b). Organizational effects of digitalization: A literature review. *International Journal of Organization Theory and Behavior*, *20*(3), 341–362. https://doi.org/10.1108/IJOTB-20-03-2017-B003

Legner, C., Eymann, T., Hess, T., Matt, C., Böhmann, T., Drews, P., Mädche, A., Urbach, N., & Ahlemann, F. (2017). Digitalization: Opportunity and

Challenge for the Business and Information Systems Engineering Community. *Business & Information Systems Engineering*, *59*(4), 301–308. https://doi.org/10.1007/s12599-017-0484-2

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry* (Vol. 75). SAGE Publications, Inc.

Liu, R., & Chua, V. C. (2016). Theoretical Digitalization of Information Flow in the Construction Supply Chain. *International Journal of Management Research and Business Strategy*, *5*(1). https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.741.8448&rep=rep1&type=pdf

Love, P. E. D., Irani, Z., & Edwards, D. J. (2004). A seamless supply chain management model for construction. *Supply Chain Management: An International Journal*, *9*(1), 43–56. https://doi.org/10.1108/13598540410517575

Martin, H. J. (2010). Improving training impact through effective follow-up: Techniques and their application. *Journal of Management Development*, *29*(6), 520–534. https://doi.org/10.1108/02621711011046495

Melton, T. (2005). The Benefits of Lean Manufacturing. *Chemical Engineering Research and Design*, *83*(6), 662–673. https://doi.org/10.1205/cherd.04351

Meyer, E. (2017, July 1). Being the Boss in Brussels, Boston, and Beijing. *Harvard Business Review*, *July-August 2017*, 70–77.

Muro, M., Liu, S., Whiton, J., & Kulkarni, S. (2017). *Digitalization and the American Workforce*. Brookings India. https://think-asia.org/handle/11540/7892

Naoum, S. G. (1994). Critical Analysis of Time and Cost of Management and Traditional Contracts. *Journal of Construction Engineering and Management*, *120*(4), 687–705. https://doi.org/10.1061/(ASCE)0733-9364(1994)120:4(687)

Naoum, S. G. (2016). Factors influencing labor productivity on construction sites: A state-of-the-art literature review and a survey. *International Journal of Productivity and Performance Management*, *65*(3), 401–421. https://doi.org/10.1108/IJPPM-03-2015-0045

Ofori, G. (2015). Nature of the Construction Industry, Its Needs and Its

Development: A Review of Four Decades of Research. *Journal of Construction in Developing Countries*, *20*(2), 115–135.

Ohno, T. (1988). *Toyota production system: Beyond large-scale production*. Productivity Press. https://doi.org/10.4324/9780429273018

Parusheva, S. (2019). *Digitalization and Digital Transformation in Construction-Benefits and Challenges*. 126–134. https://www.researchgate.net/publication/336699474_Digitalization_and_Digital_Transformation_in_Construction_-_Benefits_and_Challenges

Parviainen, P., Tihinen, M., Kääriäinen, J., & Teppola, S. (2017). Tackling the digitalization challenge: How to benefit from digitalization in practice. *International Journal of Information Systems and Project Management*, *5*(1), 63–77. https://doi.org/10.12821/ijispm050104

Patton, M. Q. (1999). Enhancing the quality and credibility of qualitative analysis. *Health Services Research*, *34*(5 Pt 2), 1189–1208.

Polák, P. (2017). The productivity paradox: A meta-analysis. *Information Economics and Policy*, *38*, 38–54. https://doi.org/10.1016/j.infoecopol.2016.11.003

Polites, G. L., & Karahanna, E. (2012). Shackled to the Status Quo: The Inhibiting Effects of Incumbent System Habit, Switching Costs, and Inertia on New System Acceptance. *MIS Quarterly*, *36*(1), 21–42. https://doi.org/10.2307/41410404

Renz, A., & Solas, M. Z. (2016). *Shaping the Future of Construction: A Breakthrough in Mindset and Technology*. World Economic Forum. http://www3.weforum.org/docs/WEF_Shaping_the_Future_of_Construction_full_report__.pdf

Rischmoller, L., Alarcón, L. F., & Koskela, L. (2006). Improving Value Generation in the Design Process of Industrial Projects Using CAVT. *Journal of Management in Engineering*, *22*(2), 52–60. https://doi.org/10.1061/(ASCE)0742-597X(2006)22:2(52)

Sacks, R., Koskela, L., Dave, B. A., & Owen, R. (2010). Interaction of Lean and Building Information Modeling in Construction. *Journal of Construction Engineering and Management*, *136*(9), 968–980. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000203

Sage. (2016). *The Challenges Facing a Growing Industry: The 2016 Construction*

Hiring and Business Outlook. The Associated General Contractors of America. https://www.agc.org/sites/default/files/Files/Communications/2016_Construction_Hiring_and_Business_Outlook_Report.pdf

Schallmo, D. R. A., & Williams, C. A. (2018). *Digital Transformation Now: Guiding the successful digitalization of your business model*. Springer International Publishing AG. https://doi.org/10.1007/978-3-319-72844-5

Stake, R. E. (1995). *The Art of Case Study Research*. SAGE Publications, Inc.

Stratopoulos, T., & Dehning, B. (2000). Does successful investment in information technology solve the productivity paradox? *Information & Management*, *38*(2), 103–117. https://doi.org/10.1016/S0378-7206(00)00058-6

Tellis, W. M. (1997). Application of a Case Study Methodology. *The Qualitative Report*, *3*(3), 1–19.

Tran, V. D., & Tookey, J. E. (2011). Labour Productivity in the New Zealand Construction Industry: A Thorough Investigation. *Construction Economics and Building*, *11*(1), 41–60. https://doi.org/10.5130/AJCEB.v11i1.1841

Tserng, H. P., Dzeng, R.-J., Lin, Y.-C., & Lin, S.-T. (2005). Mobile Construction Supply Chain Management Using PDA and Bar Codes. *Computer-Aided Civil and Infrastructure Engineering*, *20*(4), 242–264. https://doi.org/10.1111/j.1467-8667.2005.00391

Veidekke. (2020a, March 7). *Veidekke med nytt boligoppdrag på Ulven i Oslo*. http://veidekke.no/om-oss/nyheter-og-media/pressemeldinger/article34201.ece

Veidekke. (2020b, December 17). *Veidekke ASA: Suksessen fortsetter på Frysja i Oslo*. http://veidekke.no/om-oss/nyheter-og-media/pressemeldinger/article35547.ece

Veidekke. (n.d.). *Om oss*. Veidekke i Norge. http://veidekke.no/om-oss/

Vrijhoef, R., & Koskela, L. (2000). The four roles of supply chain management in construction. *European Journal of Purchasing & Supply Management*, *6*(3), 169–178. https://doi.org/10.1016/S0969-7012(00)00013-7

Whyte, J. (2019). How Digital Information Transforms Project Delivery Models. *Project Management Journal*, *50*(2), 177–194. https://doi.org/10.1177/8756972818823304

Whyte, J., & Lobo, S. (2010). Coordination and control in project-based work: Digital objects and infrastructures for delivery. *Construction Management and Economics*, *28*(6), 557–567. https://doi.org/10.1080/01446193.2010.486838

Wildemuth, B. M., & Zhang, Y. (2016). Unstructured Interviews. In B. M. Wildemuth (Ed.), *Applications of Social Research Methods to Questions in Information and Library Science* (2nd ed., pp. 239–246). ABC-CLIO LLC.

Wilson, J. (2014). *Essentials of Business Research: A Guide to Doing Your Research Project*. SAGE Publications Ltd.

Yassine, T., Saleh Bacha, M. B., Faek, F., & Hamzeh, F. (2014). *Implementing Takt-Time Planning in Construction to Improve Work Flow*. 23–27. https://doi.org/10.13140/RG.2.1.4721.8726

Yin, R. K. (2014). *Case study research: Design and methods* (5th ed.). SAGE Publications Ltd.

Zhi, M., Hua, G. B., Wang, S. Q., & Ofori, G. (2003). Total factor productivity growth accounting in the construction industry of Singapore. *Construction Management and Economics*, *21*(7), 707–718. https://doi.org/10.1080/0144619032000056126

Appendices

Appendix 1: Interview Guide

Intervjuguide

1) **Om intervjuobjektet**
   a) Fortell litt om deg selv, din rolle i Veidekke og din yrkesbakgrunn

2) **Digitalisering på byggeplassen**
   a) Hvilke arbeidsoppgaver og -prosesser i din arbeidshverdag er digitalisert?
      i) Har du noen eksempler fra din arbeidshverdag som illustrerer hvordan disse digitaliseringene påvirker deg?
   b) Hvilke spesifikke digitale verktøy benytter du i arbeidshverdagen?
      i) Fortell litt utdypende om bruken
      ii) Hva er dine holdninger og erfaringer til bruk av disse digitale verktøyene?

3) **Digitaliseringens effekter og nytte**
   a) Hvordan opplever du at digitaliseringen har påvirket ulike effekter som for Eksempel

      i) flyt
      ii) Effektivitet
      iii) HMS
      iv) avvik
      v) budsjetter
      vi) kommunikasjon
      vii) informasjonsflyt
      viii) miljø

   b) Opplever du at digitaliseringen / de digitale verktøyene hjelper deg i din arbeidshverdag?
      i) Hvis ja: Hvordan?
      ii) Hvis ja: Har du noen tanker rundt hva som gjør at det hjelper (teknologisk, sosialt, organisatorisk, økonomisk)?
   c) Kan du tenke deg noen andre områder digitaliseringen / de digitale verktøyene kommer til nytte på byggeplassen?

4) **Digitaliseringens utfordringer og forbedringspotensial**
   a) Opplever du at digitaliseringen / de digitale verktøyene skaper noen form for støy eller ulemper for deg i din arbeidshverdag?
      i) Hvis ja: Hvordan?
      ii) Hvis ja: Har du noen tanker rundt hva som gjør at det skaper støy / ulemper (teknologisk, sosialt, organisatorisk, økonomisk)?
      iii) Hvis ja: Har du noen tanker rundt hvordan dette kunne vært løst?
   b) Er det noen deler av din digitaliserte arbeidshverdag som du ville endret hvis du kunne?
   c) Opplever du at det er noen arbeidsoppgaver eller -prosesser som kunne hatt fordel av å bli digitalisert / ytterligere digitalisert?

5) **Digitaliseringens kobling til Lean**
   a) Hva er din relasjon til Involverende planlegging/Taktplanlegging og Lean?
      i) Hvordan brukes dette i din arbeidshverdag, og hva er din opplevelse av å bruke dette?
   b) Hvordan er digitalisering knyttet til Involverende planlegging/Taktplanlegging?

Appendix 2: Overview of digital tools identified at the case sites

Frysja	Ulven
	
2018 - 2022	*2018 - 2021*
Out at the construction site	
Dalux • HSE registration • Quality assurance	Dalux • HSE registration • Quality Assurance • Drawings and models • Check lists
SharePoint	BIM-kiosks
BIM-kiosks	
In the on-site office	
360-degree camera	Solibri
Live cameras	Microsoft Project
Drones	Microsoft Excel
Automated containers	
AR and VR technology • HoloLens • Trimble Site Vision	
Bimsynch	
Solibri	
Microsoft Project	
Miro	
Power BI statistics	
Out at the construction site and in the on-site office	
HSE and QA statistics display	
Gatebrain	