UNIVERSITETET I AGDER

An evaluation of VDC in road maintenance projects

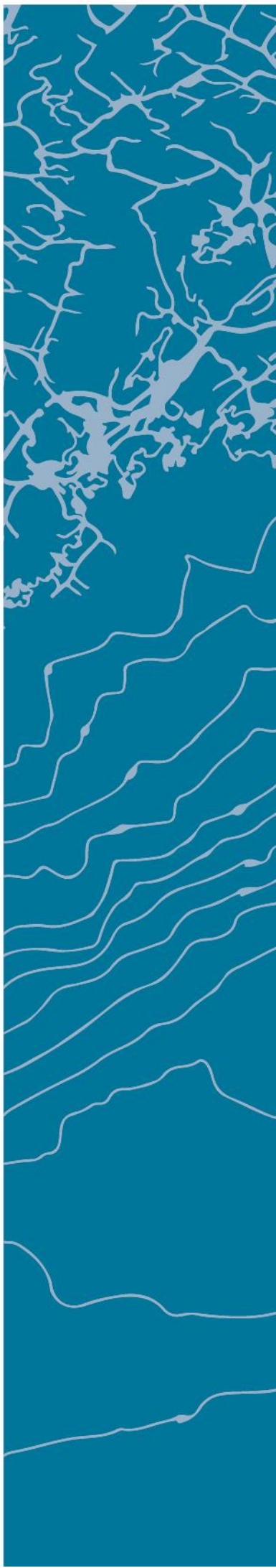
-The professionals view on the benefits and barriers of VDC in road maintenance

ALISA NILSEN

For the Master's Degree in
Industrial Economics and Technology Management

SUPERVISOR
Magnus Mikael Hellstöm

University of Agder, 2018
Faculty of Engineering and Science
School of Business and Law



I. Preface

This thesis concludes the Master Program in Industrial Economics and Technology Management at the University of Agder. It was written during the spring semester of 2018 and is worth 30 study points.

I have always had an interest in improving things, which is how BIM first caught my attention, and I later found out about VDC. During the summer of 2017, while working for NCC in road maintenance, I got the chance to investigate and write a report about their use of digital programs. This experience gave me a lot of insight of the industry, so when there were talks about how NCC wanted VDC involved in every possible project, I jumped at the chance of writing this thesis for NCC about VDC in road maintenance- especially since I knew this had never been done before.

This thesis has given me an understanding of how difficult it can be to implement new ways of doing things in the industry, and how complex projects can be. It has been both fun and frustrating at times working with this thesis, but it has been a very rewarding and great learning process. All the professionals I have been in contact with during the thesis, have been so positive and supportive; greatly motivating me throughout the work process.

A sincere thanks to Haakon Skretteberg (H.R. manager, NCC), and NCC for giving me the opportunity, support, and freedom of writing this thesis. I would especially like to acknowledge my supervisor First Amanuensis Magnus Mikael Hellström for his support, help and much-needed guidance throughout the thesis. Finally, I must express gratitude to the individuals who took part in the interviews for their time, honesty and positivity.

Grimstad, May 2018

Alisa Nilsen

II. Abstract

Purpose:

Give an overview of VDC in relation to road maintenance projects and make it easier for companies to decide if VDC is worth investing in.

Goal:

1) To find out if there are any differences in the definition and understanding of VDC in the Norwegian market, compared to the definition provided by the CIFE (Center for Integrated Facility Engineering at Stanford University).

2) To identify frequent problems in road maintenance that VDC could solve.

3) To identify the obstacles standing in the way of the use of VDC in road maintenance and to figure out why it has not been adopted in road maintenance projects.

Methodology:

The thesis takes a pragmatic, critical realist approach to the problem. It builds on qualitative studies through interviews where personal perceptions are interpreted from the standpoint of existing structures of the construction industry.

Findings:

1) CIFE's definition of VDC is prominent, but it seems like Norwegian companies have also adapted the definition to suit Norwegian workplaces better. There is a greater focus on collaboration, communication and involved planning. There is a similar understanding of what VDC entails throughout the professionals in the industry, but there is an obvious knowledge gap when it comes to VDC between the ones who perform the jobs and the upper management.

2) The most frequent problems in road maintenance projects lie in communication, knowledge, digital programs and metrics. In the three cases of communication, digital programs and metrics there is reason to believe that the use of VDC could impact road maintenance projects in a positive way. The lack of sufficient knowledge is not something VDC could solve and is rather an obstacle when it comes to the use of VDC.

3) The main obstacles in the way of implementing VDC in road maintenance are the lack of knowledge about VDC and the lack of metrics to back up how VDC can lead to improvements in road maintenance projects (or any other type of project).

Conclusion:

VDC can improve communication and collaboration through ICE and iRoom in road maintenance, though there are some costs and efforts associated with implementing and practicing VDC. The question is: Do the benefits outweigh the costs and efforts?

To be certain that VDC is worth investing in, there is a need for more quantitative research, but based on qualitative data gathered throughout the thesis, it could be worth looking more into the full use of VDC in road maintenance.

Table of contents

List of abbreviations and explanations

BIM- Building Information Model

BVP- Best Value Procurement

Client- The client mentioned in the thesis is the developer of the project or byggherre in Norwegian

ECI- Early contract involvement

IFC- Industry Foundation Classes

IPD- Integrated Project Delivery

KPI- Key Performance Index/Key Performance Indicator

LCI- Lean Construction Institute

LPDS- Lean Project Delivery System (LPDS)

OPS- Offentlig Privat Samarbeid (Public-private collaboration)

ROI- Return on Investment

RFI- Request for information

RIF- Rådgivende ingeniørers forening

R&D- Research and Development

SVV- Statens Vegvesen or The Norwegian Public Roads Administration

Turn Key (Contract)- This term has been used for the Norwegian term totalentreprise.

VDC- Virtual Design and Construction

List of Figures

List of Tables

1 Introduction

1.1 Background

The construction industry is one of the largest sectors in the world economy, but it has an intractable productivity problem. There has been a steady decline in productivity over a period from 1964-1998 (Khanzode, 2006). The industry is always getting pushed when it comes to cost, quality, safety, time and innovation. Many methods have been used to try to optimize and make processes easier and more effective. Lean principles is one of the methods introduced to construction that has had a great impact, and that is still being used (Barbosa, 2017).

The evolving technology has been taken in use because of higher requirements and more pressure on the construction industry. Digitalization is something that companies are working towards in almost every field, and the construction business is doing the same. Digital programs have shown great improvements and opened a lot of new possibilities for industries and companies. Because of this technical development, the industry needed to find new ways to make all the pieces in a project work together in the most effective way. This is where Virtual Design and Construction (VDC) comes in. Since its birth in 2008, VDC has become more and more popular and is now being applied in every large construction company in Norway. VDC is based on Lean principles as a base and includes digital tools in its processes to create a more efficient way of working in the construction industry.

VDC is becoming a more important part of the construction business. By using VDC, it is believed, and has in some cases been evident (Construction, 2014), that a company can increase its competitiveness in the industry by merging their experience and combine it with effective work methods and the newest digital technologies.

Although VDC has been widely used in construction projects, it has still not been integrated into road maintenance projects. Despite VDC's claims of making lean project delivery processes more effective by the use of digital programs and product, process and organization modeling tools (Khanzode, 2006). So it is interesting why it not been integrated into road maintenance yet. According to Rådgivende Ingeniørers Forening (RIF) report on the state of the nation (Norway), 2015, there is a need to invest 1900 billion Norwegian kroner for the upkeep of roads in the

country.(Forening, 2015) 1900 billion was calculated from the total sum of the national roads (riksveger), county roads (fylkesveger) and municipal roads (kommunale veger) that were mentioned in the report. There is a great potential and need for taking new methods into use in the road maintenance. This thesis is therefore, going to take a look at how VDC can be used in road maintenance projects.

1.2 Case

This thesis is written in cooperation with NCC. NCC is a large construction company working mainly in the Nordic countries. They are a hybrid between a centralized and decentralized company with many departments spread over several countries. Their headquarters have required the use of VDC in every project possible because it is seen as a part of an effective process. These requirements are causing some challenges when it comes to road maintenance projects. This is because VDC has never been fully used in road maintenance before. Another problem is that the company struggles with the profitability of their road maintenance projects.

Road maintenance contracts have become more common in the last 20 years (According to the head of operation and maintenance at NCC) In 1998 the first open tender competition in road maintenance with a function contract in Norway was held. After 2003, all road maintenance contracts were set out for open competition. Before this, the Norwegian Public Roads Administration (Statens Vegvesen/SVV) had the responsibility for the road maintenance of the roads in Norway.

Road maintenance projects have mainly the traditional way of working, meaning; being paper-based and without digital models or using a variety of complicated digital programs who do not communicate with each other. Digital models have to be handed over from the companies that built the roads. This has not been a requirement. It is something that has normally not been possible to do because 3D BIM programs were not commonly used at the time the roads were built. There is also currently no digital program being used in Norway that specializes in the full life cycle of a road which takes all the laws, standards and reporting systems into consideration. Another problem is that many unforeseen problems might occur throughout road maintenance contracts, such as heavy snowfall or flooding, and this can make it challenging to standardize processes.

1.3 Research question

This thesis focuses on the current use of VDC in the construction industry to evaluate if it could be used in road maintenance projects. VDC has never been used consciously in road maintenance before. It would therefore be interesting to try to find out if it is possible to use some of the methods that have been proven to work from the construction industry, and implement them into road maintenance. If VDC can make a construction project more efficient, why can one not use the same principles to make a road maintenance project more efficient too?

Three questions have been formulated to address the problem of VDC in road maintenance:

1) How do Norwegian companies define VDC?

2) What are the frequent problems in road maintenance projects and can VDC solve them?

3) What is preventing the implementation of VDC in road maintenance projects?

The first question investigates if there are any differences in the Norwegian marked and their definition and understanding of VDC, compared to the center for integrated facility engineering (CIFE.The main source of VDC).

Through the second question, the thesis wants to identify frequent problems in road maintenance and see if VDC could solve any of them. The third question focuses more on what has been standing in the way of the use of VDC in road maintenance and why it has not been adopted in such projects. These questions were chosen to answer the what, how and why of VDC. In other words; what VDC means in Norway, how VDC could influence today's problems and why it has not been taken in use in road maintenance yet. These answers could make it easier for companies to decide if VDC is worth investing in, when it comes to road maintenance.

1.4 Limitations

To answer the research questions, one would ideally interview several of the professionals in more than several construction/road maintenance companies in Norway. One would also gather good quality metrics on the subject, have a complete overview of all gathered metrics in every company relevant to the subject, investigate a few cases, work on construction and road maintenance contracts for at least one year and get a VDC certificate. This is, of course, impossible with the

five months' time frame of the thesis. Therefore, there has been set some limitations to the thesis to answer the research questions as effectively as possible.

The thesis only looks at the situation of VDC in Norway or things that can directly affect it. For example, if the top management in Sweden decides something for NCC as a whole, it would affect the situation of VDC in NCC Norway. The situation of VDC in Norway would also be affected if CIFE adds or removes something in their definition of VDC. This way one can also look into how VDC in Norwegian companies differs from the CIFE's definition of VDC. The thesis will also focus most on NCC, while supplementary information is gathered from other companies to triangulate and create a better overview of the subject.

Only general road maintenance projects will be looked at, in addition to construction projects that use VDC. This is to get a feeling of how the most common road maintenance projects see VDC and what kind of problems they handle. At the same time, one will be able to see how construction projects use VDC and how one can use the knowledge they have built on the subject and possibly transfer it to road maintenance projects.

There are a lot of things that can affect a project, such as the culture of the company, the contracts or the support from the top management, but those factors will be focused on during this thesis, as well as the Lean philosophy that plays a large role in companies, project management and is the base of VDC. Lean will only be described in a way that gives an understanding of how VDC works. These choices have been taken to limit the research questions and to keep the scope from creeping.

A technical limitation is that there are not many people who have a good knowledge of what VDC actually is and how it is supposed to work and those who know, might not work in road maintenance, which limits the number of people one can interview to get quality answers. This is one of the reasons it was essential to bring professionals from the construction industry for the interviews. The main reason was to transfer their knowledge to road maintenance projects, since they actually have been working on VDC projects.

There is unfortunately little quantitative data on the use of VDC and especially VDC in road maintenance, since it has never been used there. Even if there has been some gathering of hard data in regards to VDC, it has been kept within the company and is difficult to obtain. Because of

these difficulties, the thesis will focus on the qualitative data, and not gather quantitative data, which would be the ideal thing to do if one wished to have a larger scope and more backing of gathered data. To solve this in the thesis the qualitative data has been triangulated and quality assured.

1.5 The structure of the thesis

Chapter 1: The thesis starts with an explanation of the background for the case and why it is relevant. The case gets presented and the research question gets defined. Limitations and challenges are clarified.

Chapter 2: This chapter presents relevant theoretical information and explanations of important parts that VDC is based on, such as; BIM, ICE, iRoom and Metrics. The basic LEAN philosophy and Last planner that VDC includes is also presented. How the adoption of innovation is addressed.

Chapter 3: Chapter three describes the method used in the thesis. The process and choices taken throughout the thesis are also described to give the reader a good understanding of the thesis. The data gathering is explained and the quality of the researched is discussed thoroughly.

Chapter 4: In the empirical chapter, facts that are not necessarily scientific theory is looked into. It gives an understanding of the industry and explains how companies define VDC and how road maintenance projects work.

Chapter 5: This chapter discusses and gives an overview of the answers given throughout the interviews and presents these answers in pie charts and tables. They are structured in a way relevant to the research questions. The professionals view on VDC is discussed. Criticism towards VDC is mentioned. The thoughts of the writer are shared.

Chapter 6: The research questions are concluded and recommendations in regards to VDC are given. The purpose of the thesis is answered, and further research is suggested.

Chapter 7: This chapter includes a list of all the references used in the thesis.

Chapter 8: The appendix includes all the interview guides and interviews so that the reader can make their own opinion on the result. NCC's example of a life cycle can be closer analyzed, and the excel sheet of the analysis is presented.

2 Theory and definitions

This chapter gives an overview of VDC and its theoretical underpinnings. VDC is based on Lean principles. It also includes the digital way of working in its processes and is specialized to the construction industry. This is why the theory chapter will provide an overview of Lean and its principles. The digital way of working in VDC makes it highly relevant to the digital revolution that started not too long ago, and is ongoing. Theory on the adoption of technology is also discussed in this chapter as it is relevant to the third research question.

Finding literature on the topic was a challenge because it is fairly new and not completely defined. It depends on the situation, the people involved in a project and the lack of "hard data" (i.e. numerical evidence). This is typical for newer phenomena, and because of these challenges, extensive research has to be made to find the right information. Google scholar was used as a search engine to find the newest published information on this subject. To limit the amount of information, relevant search words were first decided based on the four main parts of VDC: BIM, ICE, iRoom and Metrics. The search words; "LEAN "and "Last Planner" was used to include the underpinning theory of VDC. In addition to this, "CIFE" (Center for Integrated Facility Engineering) and "Stanford" were used as search words because they have copyrighted VDC. Based on the case, search words such as "digitalization", "collaboration contracts" and "road maintenance" were also used. Naturally "VDC" or "Virtual Design and Construction" were also used as search words.

All the gathered literature was from peer-reviewed articles, CIFE or other thesis on the subject. If any quantitative data exists, it is usually kept within the company. This is why it is hard to get hold of it. When companies were asked to share their quantitative data, the usual answer was that they did not gather any quantitative data relevant to this thesis. They also claimed that it was generally hard for companies to gather data or find general KPI's on VDC.

Some of the theory in this chapter is also based on a former paper written by the writer of the thesis and other students. The paper is named "VDC and LP's role in bridging the interface between design and construction", and was written during the course IND419 in engineering management at UiA.

2.1 Virtual Design and Construction

VDC has been developed by CIFE (Center for Integrated Facility Engineering) at Stanford University, with LEAN as a foundation. It was developed as an answer to the digital development and its use in the construction industry. It is defined as the use of multi-disciplinary performance models for the design and construction of major construction and renovation projects (Khanzode, 2006). It can be seen as a method of visualizing the design and construction process, which allows "different stakeholders to simultaneously describe, present and evaluate a project from Product, Organization and Process perspectives" (Kunz & Fischer, 2012, p. 3).

VDC is "alive", meaning it is not fully defined and always under continuous improvement and adaptation. It is an integrated design process where every actor with relevant knowledge is supposed to contribute and be a part of the process from day one (Arge, Moe, & Westgaard, 2010).

VDC has highlighted three important parts of a project; the Product, the Processes and the Organization of it. This is called the POP model and is shown in Figure 1. The figure shows that these parts intersect and overlap in every design and construction project. They all intersect within an iRoom which is used to facilitate all parts (Rijsbergen, 2013, p. 2). VDC allows a practitioner to build symbolic models of the POP, early before a large commitment of time or money is made (Khanzode, 2006).

Figure 1 Shows three parts: product, organization, process (POP) which depict Virtual Design and Construction. Taken from (Rijsbergen, 2013, p. 2)

VDC is achieved using four elements: Building Information Modelling (BIM), Metrics, Integrated Concurrent Engineering (ICE) and the iRoom.

2.1.1 Building Information Modelling (BIM)

BIM can be defined as: "*A digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition*" (States, 2018). Yet, Kanaani and Kopec (2015) classify BIM from the technical perspective as "technologies that enable the building information model" (Kanaani & Kopec, 2015, p. 407). The tools can be applied in four aspects: representation, evaluation, collaboration, and realization. Technologies for representation help to convert drawings and designs, giving them a three-dimensional form (3D). Representation tools like computer-aided design (CAD) and BIM are the most important elements that are used to describe the design. Technologies for evaluation are used to simulate, analyze and optimize the design of the building. This can be used to simulate construction activities and identify clashes and interference problems, or evaluate the whole building's energy analysis. Technologies for collaboration include tools that capture, manage and share the digital information used by building teams. Finally, realization technologies are those that convert the digital designs to physical form. These tools operate on the boundaries of reality, e.g. Virtual Reality, Augmented Reality and 3D printing (Kanaani and Kopec (2015, p. 407)).

Philipp (2013) argues that BIM has many dimensions. 2D-BIM concerns two-dimensional models of the building, whereas 3D-BIM makes it possible for users to see a building in three dimensions, before starting construction. This can be concurrently updated throughout the project's life-cycle, making it easier for users to manage their collaborations and communicate more efficiently. It helps to identify problems before the start of a construction, so that issues can be resolved proactively.

4D-BIM concerns schedule-related information where the term 4D refers to the fourth dimension: time. Here it is possible for users to visualize the entire duration of the planned events, and the progress of the activities throughout the lifetime of a project. 5D-BIM consists of cost related information associated with the 3D model. The construction of 5D models enables the visualization of the progression of construction activities and their related costs over time. 6D-BIM involves the use of life-cycle management information. The 6D model is delivered to the owner and is used to aid in the operation and maintenance of the facility. This can contain

information concerning details and data about the product, maintenance/operation manuals, photos, warranty data, manufacturer information and contacts (p. 2).

Kamardeen (2010) states that over time, several dimensions have been added to BIM. He also adds the 7th and 8th dimension. The 7D is concerned with sustainability, regarding carbon targets. It can accurately estimate the energy consumption early in the design process, which might make it easier to reduce the overall consumption throughout the product's lifecycle. While 8D-BIM is concerned with accident prevention through design (PtD). In other words, dealing with hazards before they occur (Kamardeen, 2010, p. 288). There has also been discussions about 9D (Solutions, 2018) and 10D (Hassan, 2017), but there is no generally accepted definition of what those dimensions include.

The main point with BIM is that it acts as the tool and a model in a VDC project (Brostuen, Husby, & Løkken, 2013, p. 17).

2.1.2 Metrics

Rjisbergen, (2013) defines the use of metrics in VDC as measuring the performance on the three main components that are present in every design and construction project: product, organization and process (POP). Metrics can be seen as requirements and objectives of the performance of the main components. One main component can be the BIM. The project objective is important because when it is determined in advance, the project performance can be predicted and measured (Rjisbergen, 2013, p. 3).

Metrics are standards of measurements that are set up in advance of the project. They are used to achieve the objectives of the project. Metrics are set up differently from project to project. They are important because they facilitate and make it easier to adjust the project by finding where things are not going according to the plan. Key performance indicators (KPI) can be powerful tools that measure values that demonstrate how effectively a company is achieving its key business objectives and evaluates their success at reaching targets. There should not be too many KPI's as it becomes difficult to control and hard to prioritize them.

In the end, the field manager must identify the factors they want to control. They then use process performance metrics to monitor and judge the outcomes, so that they can evaluate the projects success (Kunz & Fischer, 2012, p. 25).

It can noted that there has been gathered metrics about the efficiency of VDC from companies. If not used as an advertisement for a company, metrics are generally hard to get hold of. Mortenson Construction studied 18 cases in the USA in 2014 and found that the use of VDC reduced schedules with 32 days on an average. They also found that VDC increased productivity by 25% and had an almost 3% average direct cost reduction (Construction, 2014).

2.1.3 Integrated Concurrent Engineering (ICE) meetings

Concurrent engineering (CE) emphasizes on performing tasks simultaneously. NASA's Jet Propulsion Laboratory's (JPL) design team, Team X, took CE and created ICE meetings in the middle of the 1990s (Kunz & Fischer, 2012, p. 34). They created a culture where the aim was to significantly reduce the time it took to design space missions, and successfully reduced the time schedule in design, from one year down to a few weeks. CIFE later implemented the ICE method into the VDC work and practices (Kunz & Fischer, 2012, p. 35).

ICE meetings were developed to cover the design phase. It was not developed for the whole project phase, nor did they attempt to cover the whole project analysis. During the first "pre-session" week, a customer representative met with a team of elected engineers to assure a common understanding of the design and scientific requirements. In the following week, the team conducted three, three-hour "design sessions". Design and documents were finalized in a more traditional approach during the succeeding two weeks (pp. 5-6). "The ICE design sessions consisted of informally coordinated and highly focused simultaneous development of interdependent material by all team members". They are similar to traditional meetings, however, engineers are placed close enough to pick up problems in the work of others'. They also have discussions between different participants and this is encouraged in order to solve problems. There were no supervisors present in these meetings and an appointed facilitator helped directing and opening up for discussions (p. 6).

ICE in VDC allows different stakeholder and disciplines with different objectives and complementary perspectives, to collaborate closely on projects, which is essential to ICE (Kunz & Fischer, 2012, p. 34). One of the aims during the ICE-meetings is to remove most non-value adding activities. The most important features of having an efficient meeting is firstly to have selected skilled and knowledgeable participants who can work independently. The second important thing is to be able to show and communicate the design intent quickly with its related options and

predictions (Kunz & Fischer, 2012, p. 35). In addition, structuring and preparing the agenda for these meetings are vital in order to have effective meetings. It is important that all the required aspects are present in these meetings in order to achieve the benefits of having ICE meetings (Chachere et al., 2004, p. 2).

As a result, ICE meetings are a collaboration from all the relevant actors who analyze and discuss a project with the aim of helping to streamline the development. This is done by performing tasks concurrently, sharing information and solving emergent problems (Chachere et al., 2004, pp. 4-6). Figure 2 shows an increased level of parallelism between four tasks. Traditional, sequential engineering is visualized in blue at the top of the figure, followed by the waterfall method (yellow). Concurrent engineering shows an increased level of parallelism (red). The green bars at the bottom of the figure, show the effect of integrated concurrent engineering, which is the most intense level of parallelism.

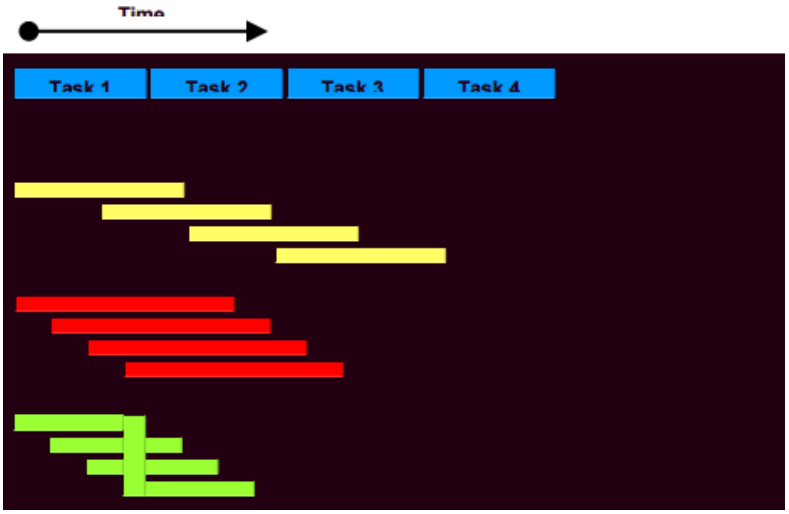


Figure 2 Levels of Parallelism (Source: Chachere et al., 2004, p. 6).

In short, ICE is a way to solve communication during the design phase. It is based on co-location of the main actors of the project and is guided by a facilitator. Everyone has an agenda and comes prepared for the sessions. The meetings are also evaluated at the end.

2.1.4 iRoom

Interactive multi-screen rooms were created at JPL(Jet Propulsion Laboratory, NASA) and CIFE independently as an improvement of ICE (Kunz & Fischer, 2012, p. 35). The CIFE iRoom XT was developed during the fall of 2002 and consists of two aspects: methodology and technology

(Kunz & Fischer, 2012, p. 35). The environment makes use of modern computer technology, such as BIM, and methods enabling data to be exchanged through shared databases. Obeya's or Big Rooms from TPS/LEAN are similar and in some cases used synonymously with iRoom.

In projects, stakeholders bring a large amount of data through different sources that show different sides of the project. This data can be challenging to integrate and compare with data from the other stakeholders (Fischer, Stone, Liston, Kunz, & Singhal, 2002, p. 1). Therefore, visual aids became an important part of ICE-meetings in order to have efficient meetings and enhance communication by showing and explaining everyone involved the design drawing (Kunz & Fischer, 2012, p. 35). As a result the iRoom "*allows presenting, describing and evaluating different project perspectives simultaneously, as well as using them to explain the reason for analyses and evaluate design quality*" (p. 43).

Figure 3 shows a photo of the CIFE lab (iRoom) of a construction-planning meeting using Virtual Design and Construction methods. There are multiple stakeholders in the meeting where models of the product, organization and process are displayed, explained and updated simultaneously on the separate displays. Computer models replace traditional paper documents. (Kunz & Fischer, 2012, p. 7)

According to Fischer et al. (2002, pp. 1-2), iRooms were intended as a platform where stakeholders agree on changes that could be implemented instantly based on up-to-date information and this would eliminate delays and errors. Any room can become an iRoom as long as it has an interactive workspace. This helps the facilitator to run the meetings more efficiently and coordinating the project by linking data and applications through active visual tools.

2.2 Lean

Lean construction was pioneered by the Lean Construction Institute (LCI). It is the application of the Toyota Production System (TPS) principles in the construction project delivery process. The goal is to eliminate waste and deliver a product that the customer wants. The production of the cars at Toyota after world war two was organized in a way that resulted in higher productivity, better quality and higher flexibility than their global competition. Toyotas model for organizing was named Lean Production.

The main principles of Lean Production are to reduce the number of processes, reduce the cycle times and most importantly to reduce any kind of waste in the production process and supply chain. According to Lean, there are 7 types of waste (mudas) that is non-value adding to the customers. These are as following; Transport, Inventory, Motion, Waiting, Over-Processing, Overproduction and Defects. Koskela argues for the 8th type of waste "making-do", which is to go through with processes without making sure that the other seven factors are "healthy" (Lauri Koskela, 2004). The Lean philosophy is based on making decisions based on long-term gain. It works towards standardization and continuous improvement. Lean is both comprehensive and imprecise at the same time, much like VDC, which brings a lot of discussion on cultural adaption versus general standardization. Lean is used today in industries that are not traditionally considered as working with production (Rolfsen, 2014). Koskela transferred the principles of Lean Production from factory production, to the construction industry in the early 90's. In 1993 it was decided to name this Lean Construction (Howell, 2003).

Construction projects are complex and unique. There is a lot of uncertainty, time pressure and general differences from a production line. According to Ballard and Howells, 2003, a system for project-based production systems and management was necessary, so that one could link it to some theory, rules and tools. Lean Project Delivery System (LPDS) is a result of The Lean Construction Institute's work on transferring Lean principles to construction projects. LPDS tries, similar to VDC, to involve relevant actors early in the design process and create better flow and collaboration between the actors (Khanzode, 2006).

2.2.1 Last Planner (Last Planner System of Production Control- LPS)

Tasks are defined in traditional project planning and monitored to determine what is done and compared with what should have been done. The problem arises when the projects are complex and involves several stakeholders. At this point, task dependencies may not be completely understood, and the duration of individual tasks are hard to estimate. This increases the risk that some activities start up before all prerequisites are met and cannot be completed within the timeframe. In Lean methodology, this would be known as waste (LJ Koskela, Bølviken, & Rooke, 2013).

The Last Planner System attempts to solve this issue with a collaborative effort, focusing more on what tasks that can be done rather than what should be done (Ballard, 2000). In this context, making tasks ready for completion and removal of constraints that prevent them from being performed is made the top priority of production planners. The responsibility of defining task interdependencies and estimating the duration of work activities is best entrusted to the employees who performs them.

In Last Planner, the scheduling is done over several stages on a hierarchical basis. The first and long-term stage has the highest abstraction level, whereas the last and short-term stage has the highest level of detail. Planning is essentially done by moving production steps downward in the hierarchy as they mature and are closer to be made ready for completion. Focus on the removal of constraints should always be on the activities towards the lower levels in the hierarchy. This requires a collaborative effort from all parties involved in the activities.

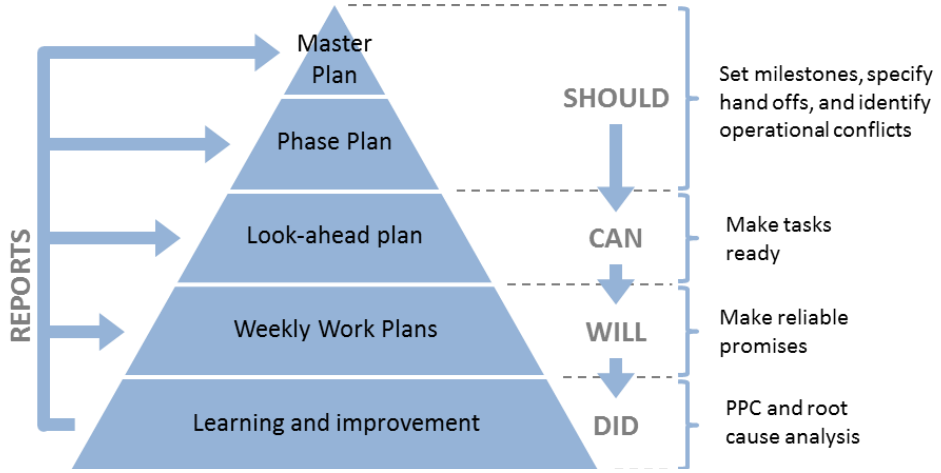


Figure 4 The Last Planner concept. Each of the levels represents plans and activities with different matureness. The work activities are transitioned downward in the hierarchy as the matureness is increased, and require more attention.

The Last Planner System commonly implements a concept of five main elements (Lauri Koskela, Stratton, & Koskenvesa, 2010), see Figure 4, although other variants with six elements are also known to exist (Baldwin & Bordoli, 2014, p. 175). It comprises four planning and scheduling stages with different timeframes, detail levels and objectives. While the last stage involves a continuous monitoring, evaluation, and improvement process.

Continuous improvement is a key concept of Lean methodology. Last Planner implements the improvement processes on an overarching level and utilizes it as a condition for subsequent scheduling of tasks. Even though Last Planner was used initially for production, it has also been useful in the design/planning phase of construction projects (Hamzeh, 2009). In VDC, Last Planner is used as a supporting tool when it comes to planning and to improve collaboration between the relevant actors involved in the project.

The planning of Last Planner is done similarly to ICE meetings in iRooms, where it is carried out in a co-localized meeting with all the relevant actors present. One should also have an agenda for the meeting, make sure that information on the project is available, visualize the plans and project, create a better flow and verify things immediately with the actors. A difference between ICE and Last Planner is that Last Planner uses backward planning (pull) to plan activities. ICE meetings might be more suitable for the beginning phases of a project, while Last Planner might be more suitable from the end of the beginning phase until the end.

2.3 Innovation adoption

An innovation that is clearly superior to their predecessors and creates opportunities for improvements in efficiency is not always adopted by all the potential users. This is because of the lack of transparency, imperfect information and the uncertainty about the operating conditions, risks and performance characteristics of the new technology. Whether the innovation translates into economic benefits depend upon the adopter's structural characteristics, such as the market share and the firm size. Another part that affects the economic benefits is the adoption process. The benefits of the adoption might change depending on if it is implemented part by part or all at once. The adoption can be classified into four groups. The innovators are the first ones to use a certain innovation. Early adopters are those who belong to the first quarter of adopters of certain

innovations. Late adopters are those who adopted the innovation, but who were not a part of the first quarter of potential users. The non-adopters is the last group, the ones who did not introduce any kind of new technology (Paul Diederen, 2003). These classifications are based on Rogers' bell curve, seen in figure 5. One difference is that the third group here is split in Early majority and Late majority. Early majority are the more conservative, but open to new ideas, and the late majority are fairly conservative, older and less educated. The last group in Rogers' bell curve are the Laggards, they are the very conservative and the least educated people (Rogers, 1983). Rogers used the words "technology" and "innovation" as synonyms (Sahin, 2006).

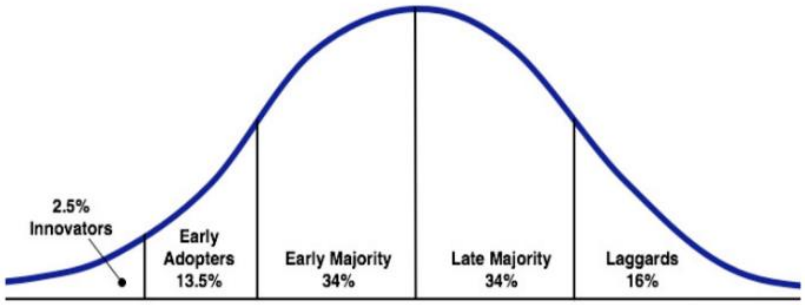


Figure 5 The Rogers' bell curve. Source: Gabriel Kabanda 2012 (https://www.researchgate.net/publication/224830081_The_Impact_of_ICTs_on_Innovative_Sustainable_Development_in_East_and_Southern_Africa?_sg=To-NHWnt8UdLwjsjz8JVK90gARZ7J0-yEQvkAhGdwGvawYVR8eCni1znAKeFCYSmx0Ki6YqzPg) (24.05.2018)

The adoption of new technology/innovation needs the right incentives or bonuses, because if there are no obvious benefits for the employees, it is not likely that they will adopt it. Khandelwal's research showed that successful adoption of new technology depends on broader organizational changes. The relationship between the employees and their employers had to change before innovation can catch on in a company. The employees need some sort of material incentive that does not work against their monthly pay. For example, if one gets money for implementing a new technology, but it ends up creating less income for the workers (Khandelwal, 2017). This is also backed up by Talkuder (2016) who writes " incentive is often considered a powerful motivator of employee behavior in adopting an innovation". He further writes that incentives motivate employees and can help achieve goals that the management has developed, but that the employees value individual benefits (Talukder, 2016).

2.4 Short summary table

Table 1 sums up chapter two in regards to VDC. This is done to give an overview of the chapter and to further compare it with chapter four. This way one can see if there are any differences in how VDC is meant to be in theory, and how it is in practice.

Table 1 Short summary and overview of VDC

VDC	**Rationale**
BIM	Digital aspect and shared knowledge.
Metrics	Requirements and performance.
ICE	Involvement and collaboration.
iRoom	Co-location, remove delay and errors.
Lean	Underlying philosophy
Last Planner	Execution tool from Lean

3 Method

This chapter explains what kind of research method has been used and what kind of choices that have been made throughout this thesis. Methodology maps out the approach to how one can answer a question and is a systematic way of investigating the reality (Knut, 2008, p. 15). A good methodology gives a transparent and clear "recipe" on how the study was conducted, so that the study can be redone in the same way and give the same results. At the same time, it explains the thoughts and choices made during the thesis, so that the reader can judge the credibility of the findings. The chapter also discusses the quality of the thesis.

3.1 Approach

The considerations for the approach of the thesis started from the research questions and how they could be best answered.

3.1.1 Ontology & epistemology

Ontology is the philosophical assumption of reality, while epistemology is the study of theory and knowledge (Easterby-Smith, 2015).

Since VDC depends on the situation and the user, similar to relativism, a pragmatic approach becomes natural to use for this thesis. A pragmatic approach means that it is impossible to answer which method is the best and that every type of approach has strengths and weaknesses depending on the situation. Deductive and inductive approaches are on the opposite sides of the scale and are ideally supposed to be completely objective. In the real world, it is naively to think that anyone can be completely objective. Practical knowledge evolves by deductive and inductive reasoning. A pragmatic approach is based on abductive reasoning and looks for possible descriptions and explanations through theory and empiricism. It is an ongoing process where findings lead to new questions that need further research (Jacobsen, 2015, p. 34).

IndØk (Industriell økonomi og teknologiledelse) or Industrial economy and technology management deal with problems and questions in the twilight zone between natural science and social science. This is why this thesis has a mix of critical realism and social constructivism. Social

constructivism is a reaction towards positivism, which argues for an absolute knowledge. Social constructivism argues that the reality is created socially and through interaction. Structure and personal contact through interviews are of importance and subjective meanings become a fact or reality. Critical realism can be seen as a compromise between positivism and social constructivism. It looks into empiricism in a structured way, which is based on the existing theory (Easterby-Smith, 2015).

The research questions calls for an exploratory approach, because VDC is a newer phenomenon and one has to explore what is out in the industry and in scientific reports. Here the data contain more words than numbers, hence a qualitative approach. Another reason for why a qualitative approach was chosen, was because of the lack of quantitative data on this particular subject.

The chosen approach gives the chance to compare and see VDC from different points of views, companies and projects, through the interviews conducted with the professionals. Therefore, the ontology of the thesis is like relativism where there are many truths and facts that depend on the viewpoint of the observer (Easterby-Smith, 2015, pp. 49-57). This is a natural development because of the uncertainty of VDC. Where the success of VDC depends on the situation and the user.

3.1.2 Qualitative

A qualitative approach in the form of interviews was chosen in this thesis. This was done because the goal of the thesis was to give an overview of the subject from inside the industry. Data on the phenomenon of VDC in the industry was gathered. A qualitative approach gives more room for flexibility, and focuses more on the human elements and words, and less on numbers. It can create a description of contexts, activities and the perception of the people who are involved (Karlsdottir, 2011, p. 16). This is very important because VDC depends on the people using it and their situation. Qualitative interviews are an attempt to gain an understanding from the respondent's perspective, which is not only their viewpoint, but also why they hold this particular viewpoint. The aim of qualitative interviews is to collect information that captures the meaning and interpretation of phenomena in relation to the interviewees' worldviews (Easterby-Smith, 2015, p. 135).

Throughout the process of gathering qualitative data through interviews, it became more evident that it was the right way to go, because of the lack of general quantitative data when it came to VDC. This can be because VDC includes processes in soft skills, which are hard to measure. This qualitative research can and should be used as a preparation for quantitative research (A. Johannessen, 2011, p. 241).

3.2 Overview

The research question of the thesis is formulated based on VDC, which can be seen as a phenomenon in the construction business. This means that the thesis' methodological framework has an informal, phenomenological, problem genesis according to James Martins (1976) definition (James R.Martin, 1976). The mode is neither inductive nor deductive, but abductive, as mentioned in the earlier subchapter. The strategy of the thesis was to gather opinions because VDC depends on the situation and the user, so the opinions would give the best description of the reality. It can be argued that the opinion is based on empiricism based on experience. The domain is the individual and the technique used in the thesis is the informal interview (James R.Martin, 1976). The framework is illustrated in figure 6, taken from the same source. The red circles around the chosen parts of the framework used in the thesis.

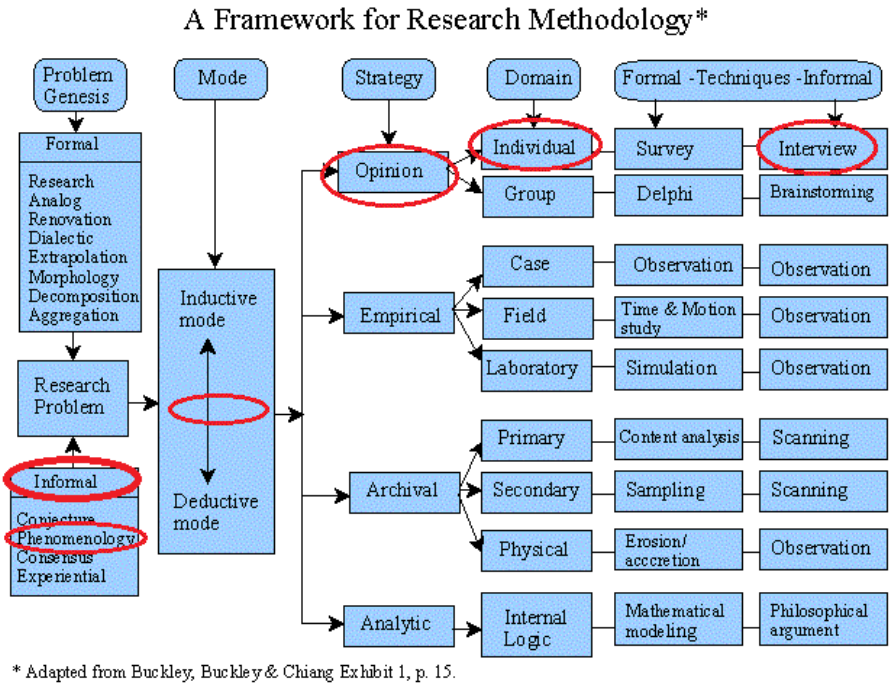


Figure 6 Framework for research methodology, from Buckley, Buckley & Chiang (Source 20.05.18: http://maaw.info/ArticleSummaries/ArtSumBuckley76.htm)

3.2.1 Pre-understanding

The writer had already worked at NCC during the summer of 2017 and had done a report about digitalization within road maintenance. During the summer job, there had been talk about how the industry has problems of turning road maintenance project into profitable projects and how VDC had been set as a requirement or a goal within the company. This seemed like an interesting problem to look into, especially since VDC had never been used fully in road maintenance. The first step was to ask NCC if they were interested in a thesis that looked into road maintenance and VDC. They were very positive and agreed on helping out with the thesis. The company would be pleased as long as the thesis could help when it came to efficiency in road maintenance.

3.2.2 Research questions

After deciding the theme of the thesis, the research question was formulated on the basis that NCC was using VDC in the construction department and it seemed like it was working there. Why

couldn't they use their systems for road maintenance projects too? The research questions were chosen because they would create a better understanding of what VDC was and why it was not used in road maintenance.

3.2.3 Planning the data gathering and choice of informants

The empirical, qualitative data gathering started with an application to "Norsk senter for forskningsdata" to be allowed to gather information from people. It was decided to include four groups of professionals in the interviews to get a wide view of the subject. A goal of getting at least two from each group was set to have a wider view of the subject.

The chosen informants consisted of at least:

-Two informants in the top management or clients. (Group 1)

-Two project managers of road maintenance projects. (Group 2)

-Two people involved in projects that use VDC. (Group 3)

-Two professors (researchers) with knowledge of VDC. (Group 4)

The time span of the thesis and the saturation of the interviews were the only factors that set a stop to the number of informants, which ended at 14 interviews.

These four types of informants were strategically chosen so that the information is triangulated. This was done to get enough points of view to understand the whole picture. The informants from group one, the top management or the clients, could tell what the companies are thinking, what they want to achieve, if they are gathering hard data and what kind of direction they are going. The project managers of road maintenance projects, group two, can tell what is actually going on, what they are doing, what kind of obstacles they have and what can be done. While the people who are involved in projects that already use VDC, like in construction, group three, can tell about the difficulties of VDC, what is good about it and their obstacles. The professors (researchers), group four, would give an insight of how VDC is viewed at a scientific institution.

The HR-manager of NCC was asked if he could recommend some professionals that could be relevant to interview within the company. Relevance means anyone that could fit within the four chosen groups and who was working with or had knowledge about VDC or road maintenance. He

mentioned some professionals and they were contacted. The professionals were contacted mainly through mail. It came very naturally for the people that were interviewed to recommend other people they knew of, that could be relevant for the thesis. Some of them were contacted and they recommended even more people and this continued. Interviews were set, held and then transcribed as soon as possible. Most of the interviews were done face to face, through Skype or phone calls. One was done through mail because it was hard to get a hold of the informant. One interview started on skype, but ended on the phone because there were problems with the internet (See table 2). Searches were done actively on NCC's database to find professionals to interview. This was especially when it came to the professionals in the top management. The University of Agder also had professionals holding classes that mentioned VDC, so they were also contacted. On coincidence, it was also noticed on LinkedIn that a former university connection worked with VDC, so he was also contacted and gave a few recommendations of professionals who could be contacted.

Table 2 Overview of the people interviewed

Company	Name	Position	Group	Media	Date
NCC NO	Jostein Myklatun and Bjørn Larsen	Project manager and Operational manager	2	Face to face	27.03.18
NCC NO	Steinar Løvseth	Operational manager	2	Face to face	22.03.18
NCC NO	Terje Andersen	Manager VDC	1	Face to face	22.02.18
NCC NO	Henrik Larsen	Operational manager	3	Face to face	23.03.18
NCC SE	Per Öberg	Head of digitalization and VDC	1	Mail	20.04.18

NCC DK	Karen S.G.Hansen	VDC Development manager	1	Skype and phone	26.02.18
Kruse Smith	Gunnar Skeie	Development manager VDC	1	Face to face	08.03.18
Kruse Smith	Jon S. Liknes	VDC Developer	1	Phone	21.02.18
SWECO	Erik Langørgen	Group leader	3	Skype	14.02.18
Nye Veier	Tor Alf Høye	Road maintenance manager	3	Skype	09.03.18
Nye Veier	Per Qvalben	BIM-VDC responsible	1	Skype	14.03.18
COWI	Siri H. Augdal	Project director	3	Skype	16.04.18
UiA	Bo Terje Kalsaas	Professor	4	Face to face	08.03.18
UiA	John Skaar	University lecturer	4	Face to face	17.04.18

3.2.4 Visiting projects

During the period of data gathering, a visit was made to what is considered the most successful VDC project in Norway by NCC, the site was a construction project in Trondheim. The HR-manager informed that this project was ahead in the use of technology and VDC. They use the most VDC (ICE, iRoom and BIM) in addition to BIM-kiosks and VR technology. The BIM was supported by other digital programs which had the 4D and risk (8D) aspect. At the same time a road maintenance project, which did not use VDC, in the same area was also visited. The reason to visit a road maintenance project in the same area was to remove the geographical differences and have the same premises. The construction project had come this far in the use of VDC, but the road maintenance project of the same company in the same area was not doing the same, which opens a question of why VDC was not applied on the road maintenance project. During these visits, the writer interviewed two of the professionals involved in the project and got an

understanding of how the processes worked and what kind of planning and digital programs that were used in the projects. Some of the purpose was also to look into how positive workers were to digitalization and digital programs in general and what kind of thoughts they had when it came to challenges and improvements in the way they work. This was done informally during the lunch break, to get a feeling of the company culture.

3.2.5 End of interviews and saturation

In total, 14 interviews were held, with in-total of 15 professionals representing five companies and one university. Six interviews were conducted face to face and one through mail. The rest were done through Skype, but one of these Skype interviews continued on the phone because of the bad internet connection. The reason it was done like this was because of the geographical distance and the time limit of the thesis.

Interviews were held from the beginning of February to the end of April to be able to get in contact with all the necessary informants and to schedule time with them. To increase the quality of the empirical data, an effort was made to gather as many interviews as possible. This way more interview answers would overlap or could possibly reveal new information. By the end of March, answers from the informants became repetitive. This showed that the number of interviews held was coming to a saturated level. The writer of the thesis kept holding interviews until mid-April because relevant professionals who could give new input were found.

3.2.6 Execution of the interviews

The informants were introduced to the research questions, but were not given more information about the subject because it might have fed the informant with biased information. The objective of the interviews was to get an understanding of how the professionals viewed VDC, find the problems that occur in road maintenance and construction projects, the challenges that project managers face in such projects and what the top management was thinking. Another objective was to understand how much of their processes use VDC. These objectives were meant to answer the research questions.

The goal was to let the informant's answers guide the interview, which is why a semi-structured interview method was chosen (Easterby-Smith, 2015, p. 139). There were no right or wrong answers. Interview guides were prepared in advance and contained questions regarding the subject

of the thesis. The interview guides can be read in Appendix C. The interview guides were mostly similar, but some questions were tailored to the informants (the four groups) to make the interviews more relevant for the purpose of the thesis. To allow a natural flow in the conversation the questions were not necessarily asked in a specific order. This would also let the informant share other information that might be relevant and important.

The goal was to keep the interviews under 30 minutes to not take too much of the informants time. Most of the interviews were around 30 minutes, but the interviews held face to face in Trondheim lasted about 2 hours or so. The first two interviews ended up lasting around one hour because the interviewer was not used to hold interviews.

Notes were taken during the interview. The complete interview was transcribed as soon as possible, so that everything was fresh in memory. The interviews were usually held in Norwegian and transcribed to English. The written interview was then sent to the informant for further review and verification. The interviews were fixed exactly as the feedback received from the informants. When returning the transcribed interview with the feedback they also gave their consent to use their answers, name, company name and job position. This was also agreed upon before the interview started and stated through mail. They also had the freedom to be anonymous or withdraw their interview at any time they wanted until the deadline of thesis on June 1st 2018. The thesis was also sent through mail to everyone who participated in the interviews, when it was finished.

3.3 Analysis

The goal of an analysis is to make it easier to create an impression of what the data is telling us. The analysis simplifies the material and one can conduct a data reduction. The data is grouped from the data one has and based on what one wishes to show (Larsen, 2007).

To get an overview and to make it easier to compare the qualitative interviews, a focused coding was conducted. No digital coding programs were taken in use, i.e. everything was done manually. The first order coding was done by sorting the data into groups. These groups were based in a way where, for example, everything mentioned about the implementation of VDC was gathered in one group, while every answer connected to the problems/challenges that can occur in a project were

grouped in another group. When the groups were decided, all the interviews were read through and all the relevant comments in the interviews were written under the theme in an excel sheet (See the Appendix A). If a comment was repeated in another interview it was noted in front of the comment. The analysis is based on the data gathered from the interviews. The first order data was arranged in tables and charts. An effort was made to be as objective as possible when gathering the data, but Tjora (2012, p. 203) argues that in the social constructivist approach it is impossible for a person to be completely neutral. This influence can be from former experiences or the education one has. During the gathering of the data, the former experience and education have helped in asking the right questions, rather than being a subjective influence or being subjectively influenced. An effort was made to be clear and reflective on where one stands, so one does not become biased or try to influence the informant. The second order coding was done by categorizing the data from the first order coding to make it more organized (Matthew Miles, 2014).

In Table 1 the interviews were sorted after their companies. The people interviewed were set into the mentioned groups and their name and position were also mentioned. This was to get an overview of who the majority of the people interviewed were.

Some of the results are presented with two pie charts that explain how VDC is understood. The rest of the information from the interviews were put into groups and tables.

3.4 Quality

The quality of a research project is determined by whether the reader of the research believes that the research is credible. The research has to reflect the candidates who have been interviewed and/or the reality. The requirement for the quality of qualitative research is therefore linked to the researcher's ability to think critically about the research and the results. The more open, thorough and critical the researcher is, the higher the credibility and quality will become (Jacobsen, 2005, p. 246).

In qualitative science the general criteria credibility, confirmability and transferability are seen as the indicators of quality. Willian Trochim adds a fourth criteria; dependability, for the quality of qualitative research (Trochim, 2008). However, Tjora says that the Norwegian terms "pålitlighet",

"gyldighet" and "generaliserbarhet" works as well for both qualitative and quantitative research (Tjora, 2012, p. 231). The Norwegian terms can be translated to reliability, validity and transferability. This thesis will however only look into the four general criteria that are more commonly accepted as quality indicators for qualitative research. Meaning: credibility, transferability, dependability and confirmability

To improve the quality of the data, an effort was made from the start to choose people to interview in a way where the data can be triangulated. The aim has also been to keep the thesis as transparent as possible. Names and job positions of the people interviewed are mentioned with their permission. The thesis also assumes a critical approach to the subject, to try to keep it as realistic as possible.

3.4.1 Credibility

By asking for the credibility, one establishes that the results of the research are credible or trustworthy from the perspective of the people interviewed or the reader. This is done because from the qualitative perspective the purpose of the research is to describe and understand the phenomena of interest, from the eyes of the people interviewed (Trochim, 2008). One asks the researcher to clearly demonstrate the truth of the findings. This has been done through two methods in this thesis; Member-check(ing) and triangulation. Member-check(ing) was conducted by sending the transcribed interviews to the people being interviewed and getting the transcription controlled by them. This was later sent back again with comments, controlled that the transcription was correct and that the translation was of good quality (Linda Birt, 2016).

Every method has a weakness, so by using several methods, one can outweigh a weakness by other methods' strengths (Larsen, 2007). In social science, triangulation means to look at a phenomenon from different points of view to gather and analyze data. One can get different methods that lead to similar results and with that increase the credibility of the results, or get different results and create more nuanced research (A. Johannessen, 2011, p. 421).

Data from different points of view were gathered through having interviews with professionals from different companies and in different job positions. This created a wide view of the subject from relevant angles. These were people in the top management, project managers in road maintenance that do not use VDC, project managers in construction who use VDC and professors

(researchers) from the University of Agder with knowledge and practice of VDC. This has been done with the intention to triangulate data. That way it is possible to see if there are parts that repeat themselves, that can be transferred to road maintenance or give a varied view on the subject. There is less room for misunderstandings if a claim is confirmed by another professional.

One should take into consideration that some of the people that were interviewed work with VDC professionally and that it could be in their job to promote and back it up. This means that their opinions on the case might be biased. One should also take into consideration that some of the people that were interviewed did not have full knowledge of what VDC is and has never worked with it. Thus this data could also be biased and depend on the impression they have. The opinion of the people that were interviewed could also depend on their views on change and digitalization.

3.4.2 Transferability

Transferability refers to the degree to which the results of the research can be generalized or transferred to other contexts or settings (Trochim, 2008).

The qualitative interviews or data gathered are highly relevant for construction companies that deal with road maintenance or companies that want to implement VDC in their processes. This information can be used internally in NCC and externally, in other companies. This is because the data gathers viewpoints from several companies, people related to the subject in different positions and experience from two different fields. This gives a wide overview of the subject. This overview can be transferred to other fields. The thesis looks into how one can transfer some of the experiences and knowledge about VDC in construction projects to road maintenance projects. The relativism mentioned earlier were there are many truths and facts that depend on the viewpoint of the observer, makes it harder to generalize the results. In addition to this, the success of VDC depend on the situation and the user which makes it even harder to generalize the results, but it is still possible to find some common problems and solutions which might make a difference in making projects more efficient.

3.4.3 Dependability

Traditional quantitative view of reliability is concerned with whether one could obtain the same results if the same thing was done. Dependability, on the other hand, is more suitable for qualitative research and highlights the researchers need to account for the ever-changing context of the

research. This means that the researcher is responsible for describing the changes that occur and how they affect the research (Trochim, 2008).

When it comes to VDC there are multiple truths depending on the person and situation. If the same people were interviewed in the same way, some of the results would be different because the person being interviewed now has been through the interview process and maybe read up or experienced more related to the subject. Even though it is possible to replicate the study, the results would not be identical. That is why dependability suits the approach of the thesis and is why the approach has been describing in detail as much as possible.

3.4.4 Confirmability

Confirmability refers to the degree to which the results could be confirmed by others. This is important because qualitative research often brings a unique perspective to a subject (Trochim, 2008).

In this thesis the researcher examined the data first, then the person interviewed checked it and then the researcher reevaluated the data again. This means that the data gathered has been approved by the person giving the data. The thesis also has a high level of confirmability because of the wide choice of people interviewed, who were triangulated, confirmed each others answers by often answering the same or similarly on several questions. This way one can make the assumption that the gathered data is a general view of the situation in the industry which can be confirmed by other people in the industry.

3.4.5 Transparency

One of the most important requirements when it comes to research is the transparency of how it is done and what thought went behind each action. The goal is to be as open as possible and give the reader an understanding of how and why the research was done the way it was done. This way they could have an informed opinion of the quality of the research.

Transparency has been emphasized in this thesis and the method and process of the thesis have been documented in every step. Steps have been taken to be able to use names, company names and job positions to keep the thesis as transparent as possible. The interviews are also attached to

the thesis in their full form, so that the reader can read them and make up their own opinion on the results and analysis. See Appendix D for the full interviews.

3.4.6 Possible sources of error

The results can be influenced by the method being used throughout the thesis. In other words, every choice made has made an influence on the result. An example of such choices is how questions in the interviews were formulated. By formulating a question a certain way, it can increase the chances of getting similar answers. The people interviewed could also interpret the questions differently from each other and therefore maybe not answer the same thing. The questions answered were made general and open, so that the people interviewed could keep a relevant dialogue.

Prejudice and pre-knowledge that the researcher brings in the thesis could have influenced it. The pre-knowledge might have made the researcher read into things but the research was aware of it from the beginning and has tried to keep as objective as possible. In addition to this, the people interviewed could have been influenced by the person interviewing them. Data gathered from interviews can be affected by the interview effect where the person being interviewed is aware of the interview. The person is put on the spot and since he/she is aware of the answers being open for others, could answer in a way that is less open or honest. It can also be affected through the contact and impression the interviewee has with the one holding the interview. The goal is to try to not influence the person getting interviewed as much as possible. This factor is not possible to remove in any kind of examination process where the interviewee is aware of being interviewed. Another factor is that the researcher gets more knowledge of the subject the further in the process of writing the thesis. This might influence the questions asked or the way the questions are asked (Jacobsen, 2005, p. 242).

One source of error could be that the selection of people interviewed were not representative enough. A qualitative study might not get all the existing realities forth. It is unfortunately nearly impossible to get all the existing realities. One would have to interview everyone that had knowledge of road maintenance or VDC (Larsen, 2007).

Overall, there can be many sources of error, especially in qualitative research, but there has been made an effort to reduce the possible sources by being aware of them so that they could not

influence the thesis and the results. It is still good to mention the possible sources of error so that one could be aware of it and have it in the back of their mind while reading the thesis.

3.5 Ethical assessment

In all kind of research, the ethical sense should implicitly be present, like trust, confidentiality and respect. The national scientific-ethical committee for social science and humanities (NESH) has formulated a general requirement. This says that projects that have participants actively participating, can only be initiated after the participants have been informed and consented. The participants also have the right to cancel their participation at any time without any negative consequences (Tjora, 2012).

The gathering of personal data and information through interviews, without using a recorder, was applied for in advance, and accepted by Norsk senter for forskningsdata. The ones being interviewed were told how their information would be used in the thesis and they got the possibility to read through the transcribed interviews and do adjustments to them. This was done to make sure that the data was presented correctly. They were also informed that they could cancel their participation at any time.

4 Empirical findings

This chapter includes facts in the industry that are not necessarily scientific theory. In other words, it includes findings from the empirical investigation, for example, how Norwegian companies define and describe VDC, how general construction and road maintenance projects happen in NCC and what the main digital program is. This information was gathered through conversations with experts, the Norwegian public roads administration's handbooks, dissertations or pdf's from powerpoint presentations that construction companies have held. This is included to give a better understanding of how the industry works within the scope of the thesis. 4.1 addresses part of the first research question.

4.1 NCC and other Norwegian companies' definition of VDC, part of the first research question

At NCC, VDC is about delegating information in a systematic way so that it streamlines processes through the lifetime of a project. VDC contains four main principles:

1) Collaboration: How one should collaborate with partners in projects, like in NCC's projects studio (digital platform)

2) Processes: How one supports work that is linked to the core areas like planning, production and supplier processes.

3) BIM: How one creates and use information with digital tools like a visualization of the time schedule, coordination of work resources, collision control, obtaining quantities and more.

4) Metrics: How one measures the value of actions.

Note that NCC's definition is very close to CIFE's version, but with some small adjustments so that it fits the company better and translates better to the Norwegian language and culture. The difference between NCC's and CIFE's definition is that CIFE's principle, "iRoom", is called "Collaboration" and the second principle, "ICE", is called "Processes" in NCC's definition.

Figure 8 How NCC picture VDC (Source: Starnet)

NCC's definition is taken from their own closed company internet page called Starnet, from their VDC DAY 2016 presentation (12.04.18) written by the head of digitalization and VDC in NCC's Infrastructure department, Per Öberg, who also has been interviewed (See chapter 8).

SKANSKA, SWECO, COWI & Kruse Smith follow the general CIFE definition of VDC. [Source qualitative interviews]

SKANSKA and Kruse Smith often use figure 8 from CIFE to illustrate what VDC is. Figure 9 illustrates the objectives and the tools, LPS, ICE and BIM, they use to get there.

SKANSKA

Virtual Design and Construction (VDC)

Framework for designing, planning and executing construction projects using modern methods and tools.

Figure 9 SKANSKA and Kruse Smith's way to picture VDC. (Skanska, 2014)

SKANSKA also divides their VDC-model into three parts: Inclusive planning, BIM and ICE. SKANSKA has used the quantitative data from figure 9 to prove the benefits of VDC. Roar Fosse, the chief advisor of operational efficiency explains that they got the numbers shown in the picture from two surveys. The first survey was about LPS and it was answered by 186 people. While the second was the average taken from the surveys at the end of in total, 29 ICE meetings. Since there are 10 to 15 people in every ICE meeting it would mean the answers came from around 300 people. Figure 9 and 10 are taken from SKANSKA's powerpoint from their Lean Construction, Norway seminar (Skanska, 2014).

SKANSKA

Footprint and benefits of VDC

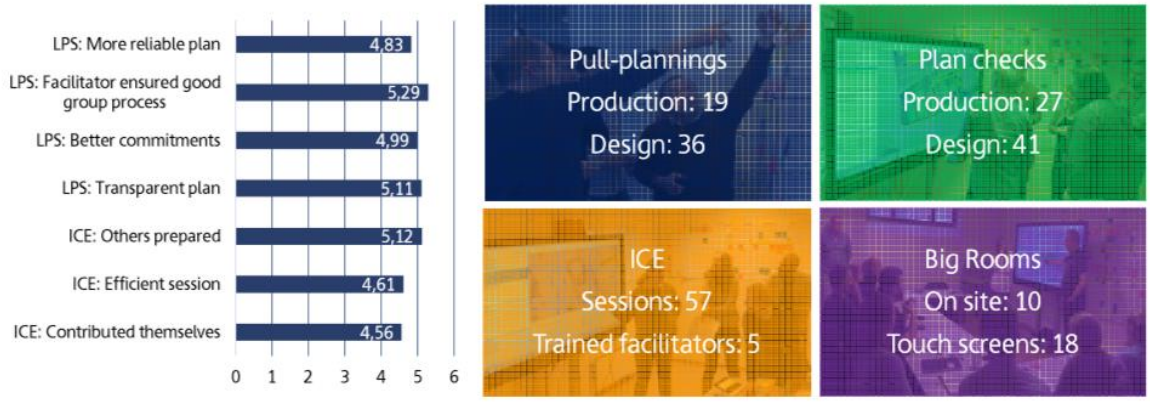


Figure 10 SKANSKA's metrics on the footprint and benefits of VDC(Skanska, 2014)

VEIDEKKE often use figure 10 to illustrate VDC. Figure 10 proves that VEIDEKKE use the CIFE base, but has modified it a bit to fit the Norwegian company and their goals better.

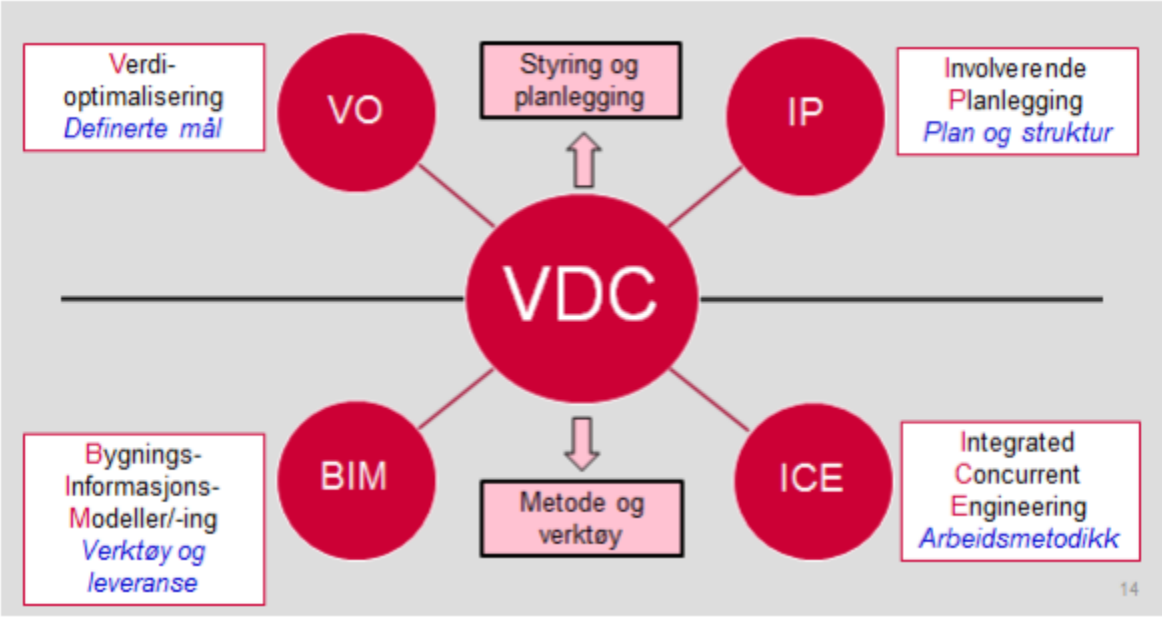


Figure 11 How Veidekke picture VDC (Brostuen et al., 2013).

On the upper left corner, they use value optimizing and defined goals instead of CIFE's "metrics" and have used "involved planning" in the upper right corner instead of "iRoom".

To sum it up; Norwegian companies use CIFE's definition of VDC, but they focus more on the collaboration and communication part. Their adaptation of the definition often changes iRoom and ICE to other forms of involvement, collaboration or/and communication.

4.2 Road maintenance projects

A roads life cycle has three important phases; design/planning, construction and the operation and maintenance phase (Vegvesen, 2015). Road maintenance projects focus on the last-mentioned phase. This means that these projects are highly influenced by how the two earlier phases are carried out. For example; if a road is designed with few culverts (to save money), it could lead to too much water accumulation which would likely reduce the quality of the road. This would mean higher costs and more work during the maintenance phase.

According to experts from NCC, there is no standard road maintenance contract. The most common road maintenance contracts in Norway are function contracts with execution requirements (Vegvesen, 2015). Because the client, the Norwegian Public Roads Administration (SVV), has very strict rules on how things are supposed to be executed, the contractor does not have much influence in what and how things are supposed to be done. The function contract usually has an annex describing how the client and contractor shall communicate and collaborate. These contracts usually last five years where one contractor gets the responsibility of all the roads and everything evolving around them over a certain geographical area. These contractors usually hire sub-contractors who are located in the area of the contract, or use the same sub-contractors who worked on the earlier road maintenance contract completed by the former contractor.

Road maintenance projects include the operation of the roads, meaning the effort and activities that are necessary for traffic to arrive safely and effectively every day out on the roads. The

maintenance of the roads is also a part of the projects and means to make sure that the infrastructure is working the way it is meant to work and is keeping it standard.

A road maintenance project includes a wide field with a number of disciplines. Examples of these could be reporting the state of the road, bridges and tunnels, the removal of dead animals, rocks or other obstacles in the roads, setting up signs and fix holes or cracks in the asphalt. The winter months are the toughest were the snow has to be removed, roads have to be salted and gritted and the weather and friction also have to be reported. During the summer the vegetation is taken care of, for example, the grass gets cut, trees and bushes that grow into the road and block signs or view are cut properly. Garbage along or on the road is removed and the grit from the winter is cleaned. Other examples of work included in a road maintenance project are inspections of all the roads within the area specified in the contract, inspections of bridges and bus shelters.

In addition to this, there are parts of the project that cannot be predicted. Examples of such are; when the snow will fall, the amount of snow that will fall, if it suddenly freezes and the roads become slippery so that the roads have to be salted, if there will be floods, rockslides, frost heaves that ruin the roads or even car crashes. This makes road maintenance projects especially hard to plan and the contractor always has to have emergency responses, priorities and have plans in case these things happen.

The contractor also has to constantly look out for new damages or faults on the roads and compare them to pictures and records taken from before their contract started. Such damages often happen on crash barriers, signs, bus sheds e.c.t. The contractor has to find the perpetrator and report it as soon as possible to the client. If the fault lies with someone other than the contractor, the contractor can ask if the client wants to order (pay for) this extra task. These tasks are what the contractor usually earns money on. The common practice for contractors is to price themselves low to win the contract and hope for many extra tasks. The reason it is done like this is because the client commonly gives the contract to the contractor with the lowest price. This statement is backed up by NCC and SVV through personal communication with experts in the field.

Annex B shows a full-size example of how NCC does a visual representation of an annual cycle of the inspections and controls necessary in a road maintenance project. Most of the deadlines mentioned in the annual cycle are obtained from the contract. A contract might state that the grass

on the side of the roads has to be cut twice during the growing season. The function part of the contract has the height and width requirements. The project manager usually decides to go on with the grass cutting once at the beginning of a growing season and once at the end of it.

The unpredictable nature of road maintenance, the large field of disciplines, the large geographical areas and all the "detective" work are the main differences between a road maintenance project and a construction project. Construction projects are more static compared to road maintenance projects. Therefore if the VDC practice from construction is to be transferred to road maintenance, it has to be altered in ways to make it more suitable. Although, some of the practice most likely could be transferred into use directly.

4.3 The digital part of road maintenance

The use of VDC usually comes when there are digital programs that can communicate with each other through Industry Foundation Classes (IFC). "*IFC is a global standard used to describe, share and exchange construction and facilities management information*" (McPartland, 2017). This is unfortunately not the situation when it comes to road maintenance according to Terje Andersen at NCC(22.02.18). This is because the data foundation is based on old programs and this makes it more complicated to collaborate. The consequence of the use of these programs is that some tasks become half-manual. Meaning; that there is a need for a person to complete a task that a digital program, in theory, could do itself, or that there in some cases is used several digital programs in a process and that the information needs to be manually transferred. This results in less seamless processes.

The digital part of a road maintenance project from a contractors view mainly revolves around Zeekit. Zeekit is based on GPS positioning technology with registration and documentation modules integrated. Zeekit can send reports directly to SVV's (clients) programs and has four different programs which complement each other. They are; Autozeek, Fleetzeek, Routeplan and Collector Pro. Autozeek records where the car has driven in their drivebook, so that it suits the tax authorities' rules. Fleetzeek has the planning tool, overview and documentation for the vehicles and machines, while Routeplan plans the driving routes and one can import the lists of customers

there. Collector Pro is one of the most important parts that have their work orders, timesheets, checklists, reports and documentation (Zeekit, 2018).

If Zeekit is a BIM depends on how one defines BIM. If BIM is defined strictly as a digital tool that shows the structure in 2D or higher, then Zeekit is not a BIM, but if BIM is defined as a digital tool that shows the structure, has information on it and enables the job, then Zeekit could be seen as a BIM and therefore a part of VDC.

4.4 Requirements and transitional phase

If there is no demand or need, there usually will not be any development happening in an industry. The construction industry right now in Norway is in a transitional phase where they are working on digitalization. Digitalization is according to the Big Norwegian Encyclopedia "To replace manual or physical tasks with digital solutions", it is further explained as "computer technical methods and tools to replace, streamline or automate some manual or physical tasks" (Leksikon, 2017). Digital tools such as BIM have come to stay, and BIM is starting to move from 3D to 4D and 5D in the construction industry. Even though this is happening, there is still a lot of unlocked potential. The situation today according to NCC and Siri H. Augdal from COWI (See the interview in Appendix D) is that many clients often require paper versions even though they have a BIM, pdf or other digital tools when it comes to documentation. This can create a lot of extra work for the contractor. The client does not use the BIM further in the life cycle of their construction, which reduces the need and demand for development in the industry.

The BIM handbook that NCC uses, explains that the goal is to work towards a BIM that includes the full life cycle of a project, from the design/planning to the recycling of the materials. This lies in the future but is as of now not possible with the existing digital programs. Every part of the process is split into their own digital program and many of them cannot "speak" with each other. With speaking it is meant that if you transfer one IFC file from one digital program to another, some parts would end up being wrong, missing or if it's a model, it can in some cases not be seen in the other program.

It seems, however, that the road construction sector is moving towards an increased use of digital models in their projects. The following is an example of such new requirements from a road construction contract with Nye Veier from 2017: "*All prosjektering skal foregå modellbasert med BIM på modenhetsnivå 3 eller høyere, slik det er definert av «UK Government Construction Client Group - BIM Working Party Strategy paper», mars 2011, side 16-17. Prosjektering og produksjon skal foregå etter prinsipper basert på Lean og VDC (Virtual design and construction). Prosjekteringsverktøyene må kunne ivareta og bygge opp under dette."* This requires the use of BIM and that the design, planning and production are based on principles from Lean and VDC.

4.5 Collaborative design and planning

Collaborative design and planning which is also used in VDC, in ICE and iRoom, seem to be a way of working that is becoming more and more used in Norway. Many new projects within the construction industry use this to prevent conflicts and create more value for every actor in the project. When it comes to collaborative ways of working you have for example ICE, iRoom, Involved Planning in Design (Involverende planlegging i prosjektering IPP)(Knotten, 2015) and PRIME (Project integrated mediating)(Bygg.no, 2018). The importance of collaborative ways of working is apparent in the newer forms of contracts which are being introduced in the construction industry in Norway. Such contracts can be Integrated Project Delivery and Offentlig Privat Samarbeid (Public Private Partnership). These are types of contracts focus on cooperation. The thought is that both the client and the contractor should benefit from the projects (i.e. a win-win situation). The contractor will often get bonuses if they can create more value or reduce costs of a project.

The most common way as of today, when it comes to road maintenance is still to use turnkey or function contracts that have parts or an annex with specification regarding the collaboration and communication between the client and the contractor.

4.6 Short summary table

This table shows how VDC in practice compares to how VDC is meant in theory. The table is built upon Table 1 from chapter two, sub-chapter four.

Table 3 Short summary/overview of VDC.

VDC	Rationale	Current practice	Shortcomings of current practice
BIM	Visualization, shared knowledge and risk aversion.	Many different and disconnected systems.	Systems do not talk. Investments in many programs
Metrics	Requirements, performance and development	Follow-ups on requirements and some performance.	Not gathering enough data for development, supporting current or new practices or for doing comparisons of projects.
ICE	Involvement and collaboration.	Used in construction, not used according to CIFE's definition in used road maintenance	Not fully integrated
iRoom	Co-location, remove delay and errors.	One screen and board.	Okay
Lean	Underlying philosophy for efficiency	Currently used for efficiency	Could be used more
Last Planner	Execution tool from Lean	Used in some cases, not in road maintenance.	Could be used more

5 Analysis and results

The goal of the analysis is to make it possible for the reader to easily get an understanding and overview of the research done throughout the thesis without the need for them to personally go through all the data gathered (Tjora, 2012). The analysis finds patterns and makes observations in the data that helps to answer the research questions.

The analysis of the raw data from the interviews was done manually, through a first order and second-order focused coding (See chapter three, sub-chapter three for a more detailed description of the analysis). The results of the analysis are presented and discussed in this chapter.

5.1 VDC knowledge, research question one

As earlier explained in the first sub-chapter of chapter four, Norwegian companies seem to define VDC the way CIFE defines it, but they also adapt this definition to include more communication and collaboration. The interviews add a new dimension to this by giving an idea of how the workers in the industry define VDC. In addition to this, it gives an idea of where the knowledge about VDC lies.

The pie chart below shows how the knowledge about VDC is among the people interviewed.

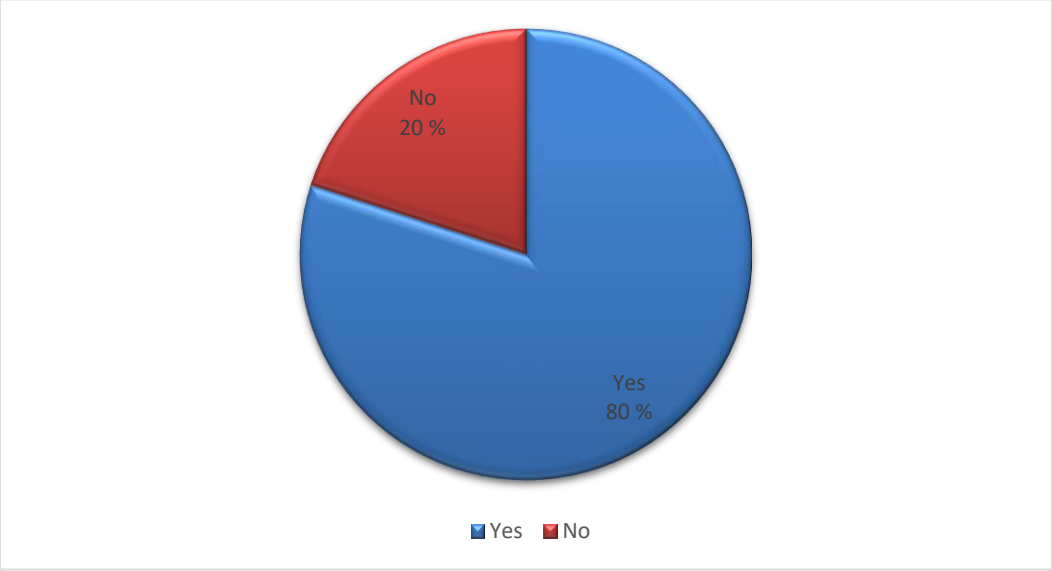


Figure 12 Knowledge of VDC

The first pie chart shows that when asked, 20 % (3/15) of the people interviewed said that they did not know about VDC, while 80 % (12/15) knew what VDC is. The interesting finding is that the ones who perform the job, especially within road maintenance, are the ones who did not know or have good knowledge about VDC. That means there is very likely to be a knowledge gap. The weight of the knowledge about VDC lays with the people who specialize in VDC or people in higher positions. This knowledge gap could also stand in the way of implementing VDC. If employees are told to work a certain way, but do not know how and why, it could create resistance and frustration.

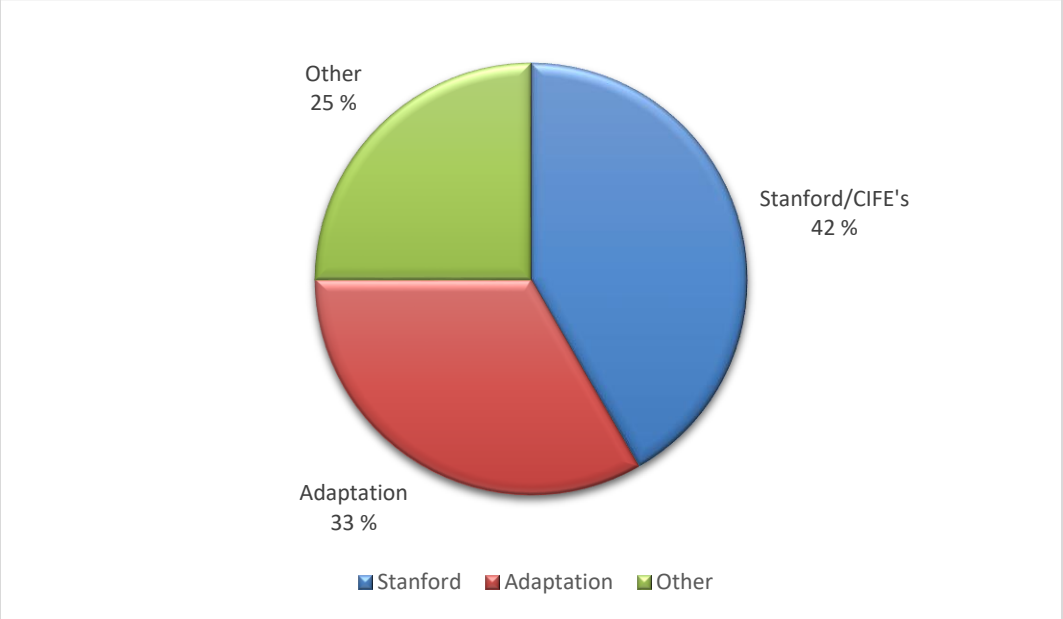


Figure 13 Definition of VDC

Figure 13 explains how the people who said they knew about VDC define it. 42 % define VDC exactly after CIFE's teachings. 33% use CIFE's definition, but have made some adaptation to fit their company and culture better. 25% defined VDC by completely other words than CIFE's definition, or just by parts of the definition.

The 25% percent who defined it differently might have interpreted the question asked during the interview as a personal definition of VDC. The question asked was: "How do you define VDC?" The 25% can also have defined VDC differently because they had been working with only some parts of VDC. Another reason to the "Other" definition could be because VDC often gets used synonymously with BIM.

Figure 13 shows that CIFE's definition of VDC is prominent, but that there are many who adapt their definition to suit their work better. This is supported by the empirical findings in chapter four, subchapter one. The pie chart also shows that there is a similar understanding of what VDC entails throughout the professionals in the industry.

5.2 What are the frequent problems in road maintenance projects and can VDC solve them?

The second research question asks for the frequent problems in road maintenance projects and if VDC can solve them.

The next table collects the comments about frequent problems in road maintenance projects and construction projects. It was done this way to give an understanding and overview of the problems the different projects go through. The first column has one or several comments taken from the qualitative interviews with the professionals. The first order coding tells in what kind of project the problem or challenge lies. If it is about road maintenance, construction projects or both. The second-order coding tells how it is related to VDC. It could be communication, collaboration, ICE, iRoom, BIM (Digitalization), VDC (knowledge), metrics or the "other" category. In the last column, there are comments to further explain some of the problems/challenges.

*Note that wherever there are a number and x before a comment, it shows how many times the comment was mentioned throughout the interviews. (For example: "2x", means that the same comment was said by two different people). Relevant comments are mentioned in the same "Problem/Challenge" square and are split with a space and a hyphen (See problem number 3 in Table 4).

Table 4 Common challenges/problems in projects

#	Problem/Challenge	First order	Second order	Comment
1	Other people plan the projects, but the project manager does not follow them.	Road maintenance	Communication	Early phase

2	Waiting time, RFI (Request for Information), is too high.	Both	Communication	
3	-Short distances and not uniform road network makes it hard to design and build contracts where contractors also maintain the roads and is why contractors do not maintain their built roads. - Find a better way to set good prices in contracts to not pressure contractor and get better quality, but where the client doesn't overpay for the job.	Road maintenance	Other	Set-up of contract
4	-2x Things can't be predicted, and makes it hard to follow a plan at times. -Complex projects with difficult design/planning processes.	Road maintenance	Other	Natural
5	Co-location and localization	Both	Collaboration (ICE, iRoom)	
6	Lose information after constructing and therefore can not continue the process to maintenance.	Road maintenance	Other	Earlier construction phase
7	Unknown how much the clients budget for the extra jobs is.	Road maintenance	Communication	Depends on collaboration and communication with the client
8	People involved in the project are not included in the planning, which creates rework and things being done in the wrong order.	Both	Collaboration (ICE, iRoom)	Early phase
9	Find competent people that understand the job and economy.	Both	Other	
10	-4x Maintenance in BIM or VDC is not a requirement from developers. -2x Information both on paper and digital version	Both	BIM	Requirements from client

11	-Understanding and expectations of what VDC is and requires. - Not good enough training	Both	VDC	Knowledge
12	2x Bad communication and misunderstandings.	Both	Communication	
13	2x Subcontractors sending information too late	Both	Communication	
14	-Hiring cheap sub-contractors who don't do quality work - Keeping costs low.	Both	Other	Cost-pressure
15	Conflicting interests	Both	Communication and collaboration	
16	2x Things happen in the wrong order.	Construction		
17	Hard to find good architects that participate in the collaboration process and draw and fix the BIM model during ICE meetings.	Construction	BIM, ICE & Knowledge	
18	Find out if grounds for decisions are realistic, have the right economical estimate and if one should go through with them.	Construction	Other	Early phase
19	The project has to budget to buy own extra digital programs.	Construction	Digitalization/BIM	
20	Keeping doors open for the client and documenting the cost of this.	Construction	Communication collaboration and metrics	Planning, documentation and costs
21	Hard to find sub-contractors that see the value of VDC	Construction	VDC knowledge	
22	-Maturity of BIM -Availability of BIM -Design planning has not reached same development as BIM	Construction	BIM	

There are several issues mentioned throughout the interviews, which can be seen in the table above. It is interesting to see that many of the problems are relevant to both road maintenance and construction projects. Comments addressing construction are not discussed because this thesis and the research questions focus on road maintenance. They are though, included in the table so that one can see the differences and similarities of the problems that construction projects and road maintenance projects have. They are also included because some of these problems, such as problem number 17, 19 & 21 could transfer into road maintenance if their way of working with VDC gets adopted into road maintenance.

Comment number 1, 2 ,7 ,8 ,12 ,13 & 15 (Table 4) address problems and challenges of communication in road maintenance. They can be dealt with instantly without any cost. (Problem number 7) If the client and the contractor communicate better the client could reveal how much their budget is regarding the extra jobs during a contract. With this information, the contractor can create better flow and hire resources in time. (Problem number 2&13) Late information from the sub-contractors seems to be a common problem in both road maintenance and construction. It is a problem that can be dealt with through upholding the agreed time of communication better, make the sub-contractors understand the importance of fast communication and in worst case increase the consequences of not following through the agreed time of communication written in the contract. (Problem number 1&8) It should not be too difficult to involve relevant actors in the planning phase to prevent rework because things are being done in the wrong order or that the project does not follow the plan. Problem number 12 & claims that there are problems in general when it comes to communication and that it creates misunderstandings and conflicting interests, which could be prevented and resolved. An important part of VDC is to improve communication through iRoom or ICE meetings. The definition of VDC used in Norwegian companies, as mentioned in chapter four and chapter five, sub-chapter one, put more weight on the communication and collaboration part of it. Therefore, the use of VDC, especially with the Norwegian companies' definition, could likely help solve the problems which are a consequence of bad communication.

Problem number 5 (Table 4) is a direct consequence of the efforts towards more collaboration and communication. If one works toward including relevant people in the planning and earlier phases of the project, the client, contractor and relevant sub-contractors have to be in the same place. This

can in some cases be problematic because of time, long distances and the cost of having people there.

Problem number 9,11 &14 in Table 4 address the competence of the employees, therefore the training within the company or/and the hiring process. The hiring of cheaper sub-contractors who do not do quality work is an unfortunate consequence of trying to keep the cost low and if there was a different way to set prices in contracts to not pressure the contractor this could be solved (mentioned in problem number 3). While finding competent people who understand the job, the economy and have an understanding of what VDC is, could be expensive for the contractor if they are supposed to train employees. If employees who are performing tasks do not know what VDC is or what it entails, it gets harder to implement.

Problem number 4, 6 & 10 (Table 4) happen because of the complexity or nature of projects, the way it is set up when it comes to the take over from construction to maintenance or the way the clients set up the contracts and requirements.

The professionals interviewed were also asked if they had any ideas or suggestions for improvements. It is basically asking the same question as in table 4, but by asking with another way, the professionals could share ideas on how one could improve the projects or their way of working. The answers were set up in a table and examined if they were related to VDC. The following table sums up the comments given during the interviews and their relations. The comments addressing construction will again not be discussed further, but are there for comparisons and to give an overview of the industry.

Table 5 Comments that suggest general improvements in projects

#	Comments that suggest general improvements in projects	Related to
1	Central database that collects numbers and compares projects.	VDC(metrics), research and development (R&D)
2	AR & BIM should be used more	Digitalization (VDC)
3	Getting everything into one digital system	Digitalization (VDC-BIM)

4	-2x Use SmartDok or something that can register people's work hours easier. - More user-friendly apps	Digitalization, NCC
5	Make processes more effective	General
6	4xTrain and educate worker more on most basic things like digital programs, at least have a pdf.	Training, Digitalization (VDC)
7	Plan better in regards to waste of time- like driving far to fix only one thing, when one can fix several things at once.	Planning, lean
8	-Make it easier to get ideas or propositions through -A more bottom-up approach with input from the workers	Communication (VDC)
9	Should be more incentives when it comes to road maintenance to increase innovation, because there is a lot to gain.	R&D
10	Extra income by creating more customer value (F.ex: Optimize use of an area or create more parking spaces)	VDC (ICE and iRoom)
11	Mark components better in BIM for further use in maintenance	VDC (BIM)
12	Become better at collecting KPI's and hard data to measure VDC and improvements	VDC(metrics)
13	More cutouts(utsparinger) from the factory	Production, Lean-Construction
14	Split work processes to get better utilization, especially when it comes to rig and operation	Lean-Construction
15	Include things that went well for a project, and not only focus on the bad	R&D
16	Use Synchro and plan the Gantt there to visualize and control the project better and deliver on time	Digitalization, VDC(BIM)-Construction
17	Transfer experience more within the company	Training

Every suggestion beside number 5, 9, 10, 13, 14, 15 & 16 (from table 5) were improvements that could be used in the VDC process to solve problems or make improvements in road maintenance projects. Number 2, 3, 4 & 11 mention improvements when it comes to digitalization and BIM. Some of the comments were general, like comment 2 and 3. Some were concrete, such as marking components better in the construction phase of the BIM, so that it could later be used in the

maintenance phase, as mentioned in comment 11, or for NCC's case register workhours through the digital programs used today, like Zeekit, or SmartDok, instead of having to manually register them, as mentioned in comment 4.

Comment number 8 (Table 5) addresses how the communication part could improve by being more open and creating possibilities for a more bottom-up approach with input from the workers. This will make the company more aware of what kind of challenges or problems that occur for the workers that might prevent them from doing their jobs. Solving this might also increase the workers satisfaction and make them feel more listened to.

Comment 1 & 12 (table 5)mention how one could improve metrics. They are important in VDC because it makes it easier to support ways of working, and easier to see where things go wrong or if they are doing well.

Educating professionals' in digital programs, or improving the current knowledge of professionals through transferring experiences within the company, was mentioned in comment 6 & 17 (Table 5). These are concrete suggestions of improvements which support how VDC can be used.

Through the comments of both problems/challenges and improvements, one can see how the most frequent problems in road maintenance projects lie in communication, knowledge, digital programs and metrics. VDC claims to solve problems of communication through ICE and iRoom. It also puts weight on metrics and how processes should adapt to the use of digital programs, such as BIM. In the three cases of communication, digital programs and metrics there is reason to believe that the use of VDC could impact road maintenance projects in a positive way. Having sufficient knowledge of something is the only way to be able to move forward, which is essential in every way of working. The lack of sufficient knowledge is not something VDC could solve and is an obstacle when it comes to the use of VDC.

5.3 What is preventing the implementation of VDC in road maintenance projects?

The second research question asks: "What is preventing the implementation of VDC in road maintenance projects?" All comments about the difficulties of implementing VDC was gathered in the table below to give an overview of the challenges.

Table 6 Difficulties implementing VDC

#	Difficulties of implementing VDC	Related to
1	Reach everyone because of being a large company, have a unison understanding of VDC	Knowledge
2	Standardization difficult for whole company because of different legislation.	Standardization
3	VDC demands extra work in the initial phases that later pays off, but agreeing on who is supposed to put in the extra effort and how it is paid, can create difficulties.	Collaboration/ Late pay-off
4	Some hard aspects to implement. If not done fully and everyone is on board, it is easier to use traditional planning.	Knowledge/ Way of implementing,
5	Some might not think VDC works because some projects have only used bits and pieces of VDC, and unless it is fully integrated, it cannot give the results it claims.	Knowledge
6	A lot of people don't understand VDC and it can seem more complicated than the traditional way of working.	Knowledge
7	2x You need a lot of support from the management. (Bottom-up pressure is needed)	Metrics
8	Find it fitting project managers to get everyone in the team enthusiastic about VDC	Professionals
9	Depends on the project and project manager because every project is unique and it is hard to standardize VDC.	Metrics/ standardization
10	Resistance from some people and the resource team	Knowledge/ metrics
11	Not enough time to do enough at the beginning of projects, which lock actions later.	Time management

12	People need to practice VDC once they have been trained in it, not wait a long time before being able to use it.	Knowledge
13	Lack of knowledge of VDC	Knowledge
14	Lack of knowledge between different actors in a project	Knowledge
15	Lack of good KPI's	Metrics
16	2x Finding right people who want to partake in the collaboration processes	Professionals
17	Finding good facilitators for ICE meetings	Professionals
18	VDC is very conceptualized	Knowledge

The biggest reasons that prevent the implementation of VDC seems to be the lack of knowledge about what VDC is, how it should be used and what kind of results it can give. 10 out of 18 comments in table 6, result in the lack of knowledge of VDC. This can be solved with the right training and by hiring people educated in the area or who have practiced in it. Comment 8, 16 & 17 address the difficulties of finding the right professionals to work with VDC. Without enough knowledge and support, VDC might be implemented half-ways, which might not let it reach its full potential. The lack of knowledge will also make it harder to implement since VDC might for some employees seem like an effort that will not give them enough benefits (see comment 4). It is illogical to require a way of working without having employees with knowledge of what it is, how it should be done and what it will do. It will also be hard to have people enthusiastic about it, if they do not know what it is.

Comment number 2 & 9 (Table 6) mention the difficulties of standardizing VDC because of legislation and the uniqueness of every project.

Metrics are mentioned in comments 7, 9, 10 & 15 (Table 6). The collecting of the right metrics can cost a company a lot, depending on how it is done. There is also the issue of long-time investments that might not give visible improvements at once, which makes it even more important for metrics to back up the investment. Without any metrics backing it up, the management will not have the incentives to back up the implementation because of the risk (See comment 7 & 10).

When it comes to standing stronger on something it is natural to show some hard data (statistics or numbers) to back it up. This is what the metrics part of VDC is supposed to do. During the

interviews, the participants were asked about metrics in regards to VDC. The following table has collected the comments from the interviews on this subject.

Table 7 Comments about hard data (metrics)

#	Comments about hard data (metrics)
1	Hard to collect ROI's linked to VDC.
2	Companies are not generally good at collecting KPI's or evidence of VDC.
3	Hard to convince people that VDC works without hard data. So workers are not as involved and top management might not give enough resources.
4	3x Hard to collect KPI's.
5	4x Lack of hard data.
6	No hard data on traditional projects to compare VDC projects with.

All the comments in table 7 support the fact that the collection of metrics is a problem and that there is a lack of it. To gather ROI's, KPI's or other types of metrics there is a need to invest and research what kind of metrics that should be collected. Most projects in the construction industry are unique, which make it hard to find standard measurements. It is a long time investment where the benefits might not show instantly. If other things are more pushing in an industry this will not be a priority. The gathering of metrics does not seem be a requirement since it was mentioned that there is a lack of data from "traditional projects" to compare with VDC projects (See comment number 6). This means that there needs to be a culture change in the industry when it comes to gathering enough metrics from projects. Comment number 3 addresses the difficulties of the lack of metrics and how it affects VDC.

These results show that the main obstacles in the way of implementing VDC in road maintenance are the lack of knowledge about it and the lack of metrics to back up how VDC can lead to improvements. Some of the reason for the lack of metrics is because of the difficulty of standardizing the projects and finding the right parameters that can be measured in every project and used for comparisons.

5.3.1 The professional's view of VDC and VDC's role in road maintenance

This sub-subchapter is included to show how professionals view VDC in road maintenance, how they believe or have experienced VDC influencing a project and what kind of criticism they have toward VDC.

Comments on what professionals think VDC's influence in road maintenance projects could be, were gathered in table 8.

Table 8 Comments about VDC's influence in road maintenance

#	Comments about VDC's influence in road maintenance
1	VDC influences the design of the contract
2	Information in regards to maintenance has to be planned in the design phase.
3	More transparency in processes
4	3xMore communication/interaction and collaboration with client
5	Structure and organize planning
6	Control progress of project and use of VDC during a meeting
7	VDC could give a better overview of projects and help with LEAN processes
8	There is talk about IFC program for infra services. When the programs can talk together, they might start merging.

Comment number 3 &4 in table 8 mention the increase of communication, interaction, transparency and collaboration with the client, which is what VDC work towards. This can create fewer misunderstandings, take on problems earlier, create a better flow in the project and generally better work satisfaction for the parts involved. There are also comments on how VDC can give better control of the project and help with Lean processes (See comment 5, 6 & 7). Comment number 1 & 2 shows that there is a need for changes when it comes to contracting and the earlier phases of a project before a road gets built. While the last comment in table 8 speculate where BIM in road maintenance is going to be in the future.

Data gathered on the thoughts of what VDC could do for a project, is presented in the table below. This was done to get a better understanding of how people who knew about VDC perceived it and in some cases had experienced it.

Table 9 Comments about what VDC can do

#	Comments about what VDC can do	Relevant to
1	Benefits in BIM models- reduce risk and give better control.	Construction
2	VDC works towards giving involved parties a chance at having something to say earlier in the project, which gives better results.	Communication
3	Using last planner in road maintenance can give good results when it comes to planning	Communication
4	Reduce the request for information (RFI)	Communication
5	Reduce time of design/planning around 30-40%.	Efficiency
6	Improve communication, therefore reduce e-mails by 80%.	Communication
7	Increase unproductive time by 25%	Efficiency
8	Cost could be cut by around 10%	Efficiency
9	2x Improve efficiency	Efficiency
10	Gather more metrics-document improvements	Metrics
11	2x Better communication	Communication
12	See collisions sooner	Construction-Risk
13	Save time	Efficiency
14	Increase value for the customer, don't know how much because of lack of hard data	Metrics
15	Improve buildability	Construction
16	2x More satisfaction in the teams through VDC	Teamwork
17	The pilot showed increased flow and reduced latency	Efficiency
18	ICE meetings give clearer goals	Communication
19	More clear what people have done or not	Communication

Most of the comments in Table 9 address the positive influence of VDC when it comes to communication in a project (See comment 2,3,4,6,11,18 & 19). Comments 5,7,8,9,13 & 17 talk about how VDC can improve the efficiency of a project, while two comments (10 & 14) mention the metrics.

It should be mentioned that the sources of the percentages claimed in the comments are unknown.

All the comments about VDC are positive and are things that would benefit a project greatly. The people who know about VDC seem to have a good impression of it, no matter their age or background, and it was said more than once during the interviews that once one had worked in a project that used VDC, it was difficult to see why other still used the traditional way of working. This is very promising when it comes to the implementation of VDC, because if those exposed to it and have seen how it works are so positive towards it, it is likely that others will have a similar reaction. The only problem is that there need to be done more research on it and gathered more evidence to support these claims. The issue with that is that companies cannot wait for this research because of the competition in the market. The companies want to stay relevant and have to make use of VDC even though they might lack the proper knowledge or resources to support it.

5.3.2 VDC criticism

When the participants were interviewed, they were asked if they had any criticism when it came to VDC. One of the things that were mentioned was the way it is promoted. It was very commercial and felt like a sales pitch, so that the ones holding the courses could earn as much money as possible. The companies that provide VDC classes gave the impression of VDC being the answer to all problems and were not too critical about their work, which made it harder to believe them.

Another important thing that was mentioned was that companies already use some tools, such as BIM, iRoom and ICE, in VDC and work towards VDC, but they have not called it VDC. It has come naturally to them to work this way when they are working towards efficiency. This makes the customers question the need of calling it VDC, and think of VDC as some sort of costly branding.

There was also some criticism towards VDC not being standardized enough. It really ends up depending on the situation and what the user makes out of it.

5.4 The writer's thoughts

In this subchapter, the writer will share a few her own thoughts in regards to what the thesis has brought up.

5.4.1 Knowledge

There seems to be a lack of training and understanding of VDC and digital programs. This seems to especially be the case for the ones who are not in the management. There is an obvious knowledge gap when it comes to VDC between professionals performing tasks and the top management. It does not help to have digital programs if you do not know how to use them fully. Because of this, it seems that companies buy other programs with simpler, more specialized use to make up for it, which create additional costs. If one works toward using VDC, one cannot just implement parts of it and not explain why things are done the way they are done. Some people that had been interviewed had been part of ICE meetings without knowing it and many work toward better communication and better collaboration strategies without know it is a part of VDC. It is also hard to get people involved in and enthusiastic about VDC and digital programs if they do not know what it is, what it does, how to use it and what kind of benefits it can bring. It should be noted that the ones who have been working on projects with VDC or have knowledge about VDC seem very positive about it no matter their age or background.

5.4.2 Adoption of new technology

The adoption of new technology is also relevant to the use of VDC. It would seem that the industry as a whole are early adopters if one base it on Rogers' Bells curve and if one started to use VDC in road maintenance, they would be considered innovators, since it's not been done before. It is difficult to change a culture that has been going on for many years and that is what VDC requires, a change of culture.

5.4.3 Lack of evidence (metrics)

There is a lack of data generally in the industry and especially when it comes to the use of VDC in projects. Gathering data is in many ways important for a company and its development. Without proper metrics, it is hard to support the use of VDC and get enough resources to implement it fully. If the top management is for example presented with a high ROI in a VDC project compared to a traditional project it would be less risky for them to invest in this way of working. A company could, for example, find out how much a client would spend and earn on getting VR of their project since many clients use it as a part of their marketing. By figuring out these numbers, the company could charge a fair amount for a job they might now do for free. One can also figure out how much a projects decrease their fines with more collaboration with the client, how the training of digital

programs saves time and create better flow in processes. One can even find out how a simple pdf handbook with a step by step instruction saves time instead of calling the programmers of the digital program or another project manager that use the program. With proper metrics, it could be easier to standardize projects.

A consequence of the lack of proper metrics is that there are few resources for the use of VDC and it often depends if the project managers want to use it. If a project manager decides to use VDC processes or new digital programs it affects the budget of the project and can affect the project manager's bonus. The incentives can in these cases be wrong and focused on the short run, and the bonus system should be fair for the ones who try out new technology or ways of working. If one loses more by using their energy trying out new ideas or new things it would kill the development of the company.

5.4.4 Communication and collaboration

There is also a lack of openness and communication, maybe because of the lack of trust and fear for opportunism. If one knew how much the budget for extra jobs was, one could plan resources in a better way. The way it is done now is that by the end of the contract the client tends to use the rest of the budget on extra jobs. The contractor does not know how much the budget is and how many extra jobs that will be ordered, which makes it very hard and risky for the sub-contractors to wait. They get involved in other jobs while waiting for the extra job orders because they need to earn money, and the contractor ends up with a difficult task of finding good resources to be able to do the extra job orders.

It does seem that ICE and iRoom could have some positive impact in road maintenance without a company having to invest too much in these processes. What I mean is that the positive outcome could outweigh the cost. If ICE and iRoom are used with involved planning, it could give great results. The unfortunate thing is that it is not that easy to say the same about the other parts of VDC without qualitative data backing it up.

5.4.5 Price setting

Price setting in the tender phase might put weight on the wrong thing. Instead of taking full price for normal jobs that almost always happen in road maintenance and setting reduces prices on extra

job orders, it is in the reality the other way around. This is because the contractor is trying to win the contract that way, but it should be looked into by the company.

5.4.6 Overall thoughts

There are many challenges in projects like construction and road maintenance. One problem can affect several things in the work-chain. You have the social aspect of a project, the economical aspect and the performing aspect. They all have to follow the law, in addition to the company rules and goals. To top it all of every project is unique in their own way and depend on the situation and the people involved. This makes it hard to find a recipe of how things are supposed to be done. To use VDC in such a situation without much quantitative data makes it much harder. There is resistance from several points, like the top management, the professionals who perform the jobs and the subcontractors, because change always is difficult. Many digital programs are not mature enough, they don't communicate with each other, and many people do not have enough knowledge to utilize them fully. Even though the situation as of today is as mentioned earlier, there is hope for improvements and VDC has a lot of potential.

Some of this potential has already been seen in the construction business. To transfer the success of these successful VDC projects it is necessary to gather more data. This thesis has gathered the qualitative data, but there is also a great need for quantitative data. The quantitative data will make it easier to find out if VDC is worth investing in, or if other ways of working is the most efficient. In my opinion, a good blend of different tools, philosophies, ways of working and methods will be the solution. VDC is a step towards that interesting future.

6 Conclusion

The chapter presents the conclusion of this thesis in the form of a brief answer to the research questions. It also presents recommendations from the writer, concludes if the purpose is answered and gives suggestions for further research.

6.1 The conclusion to research questions

The conclusion of this thesis is only meant as an overview of where VDC is today, how it can impact and why it is not used in road maintenance.

1) How do Norwegian companies define or use VDC?

CIFE's definition of VDC is prominent, but it seems like Norwegian companies have also adapted the definition to suit Norwegian workplaces better, where there is a greater focus of collaboration, communication and involved planning. There is a similar understanding of what VDC entails throughout the professionals in the industry, but there is an obvious knowledge gap in regard to VDC between the ones who perform the jobs and the upper management.

2) What are the frequent problems in road maintenance projects and can VDC solve them?

The most frequent problems in road maintenance projects lie in communication, knowledge, digital programs and metrics. VDC claims to solve problems of communication through ICE and iRoom. It also puts weight on metrics and how processes should adapt to the use of digital programs, such as BIM. In these three cases of communication, digital programs and metrics there is reason to believe that the use of VDC could impact road maintenance projects in a positive way. Having sufficient knowledge of something is a requirement to be able to move forward, which is essential in every way of working. The lack of sufficient knowledge is not something VDC could solve and is rather an obstacle when it comes to the use of VDC.

3) What is preventing the implementation of VDC in road maintenance projects?

The main obstacles in the way of implementing VDC in road maintenance are the lack of knowledge about VDC and the lack of metrics to back up how VDC can lead to improvements.

Some of the reason for the lack of metrics is because of the difficulty of standardizing the projects and finding the right parameters that can be measured in every project and used for comparisons. Even though there is some criticism towards VDC, the professionals who have worked with VDC are mostly positive about it. Long-term investments are needed to change a culture and its way of working.

6.2 Recommendations

The recommendations are based on the main findings in chapter 5. They are aimed at companies who work toward an increased use of VDC in their projects, in particular, in road maintenance projects.

6.2.1 Training

For NCC and other companies who are working with VDC and the implementation of VDC it is very important to educate the top management and especially the relevant workers who perform the job on how they should use digital programs and VDC. It would be a waste for the company to educate people who obviously are not willing to change. Computer program training should be updated regularly because there will always be newer versions of the program. When it comes to VDC it is not necessary to send them to Stanford to get certificates, because that will not always ensure that they would understand how to perform VDC and it would be costly, but they could get courses from other people within the company, who has worked with it and know what it entails, i.e. a type of "lead users". This way the training will also be more aimed at how VDC fits with the company's goals and ways of working.

6.2.2 Standard metrics

There should also be set some standard parameters of measurements on what kind of information (metrics) a project manager has to gather during a project, so that it could be refined and used for further development and improvements in the company. This would create a database where the company could go in and see where things went wrong or where they did well, so that they could remove any kind of waste and become better. With this, they would use resources better and invest in ways that make work more effective. This way they could actually use the Lean philosophies of removing waste, best practice and constant development. It would also be easier to argue for the

certain way of working if there is data backing it up. With data, the risk of investing in it will reduce and it will be easier for the top management to support VDC projects.

6.2.3 New ways of contracting

Norwegian companies are also into something when they focus a lot on collaboration and communication with the client. Newer types of contracts, like IPD, and new approaches to procurements like, BVP, also support these kind of thoughts. The goal of this collaboration and communication is to remove the fear of opportunism and create trust between the client and the contractor. The goal is to create a win-win situation. Through better communication and more collaboration, the contractor can create more value for the client and reduce the disagreements at the end of the contract. ICE meetings can be an important part of this process, and is a part of why VDC could be fruitful for companies and clients. In road maintenance projects, it could reveal the client's hidden budgets to make it easier to plan resources.

6.2.4 Incentives

Companies implementing VDC or wanting to develop should be careful that a manager's bonus would not stand in the way of trying new things or investing in new technology. This is also a part of the adoption process of new technology. There has to be some incentives or benefits for pitching and trying out new ideas. During these trials, a lot of metrics should be gathered so that one would know why it worked or did not work the way it was expected to.

6.2.5 Make use of what one already has-directed to NCC

NCC should also digitalize their way of registering work hours. They should look into if their existing digital programs, such as Zeekit for road maintenance, meet their company's standard and if they could use it. This way they could potentially save a lot of money.

6.3 Has the thesis reached its purpose?

The purpose of the thesis was to give an overview of VDC in relation to road maintenance projects and make it easier for companies to decide if VDC is worth investing in when it comes to road maintenance projects.

Chapters one, two, four and five give an overview of VDC in relation to road maintenance projects.

To make it easier for companies to decide if VDC is worth investing in, the thesis looks into the obstacles standing in the way of the implementation of VDC and the frequent problems in road maintenance projects. The main problems and obstacles are concluded as lack of knowledge about VDC, too little communication & collaboration, the lack of metrics and the efficiency in general. There is reason to believe that VDC could solve some problems when it comes to communication, collaboration, metrics and the efficiency of a project. It also seems like people who have worked with VDC are very positive about it. The question is if the benefits outweigh the costs or the effort that is needed to implement VDC. To know certainly if VDC is worth investing in, there is a need for more research. This research has to be based on quantitative data so that one could find sure evidence that would support the use of VDC. But if one is to rely on the qualitative data gathered throughout the thesis, it could be worth looking more into the use of VDC in road maintenance. The thesis can though conclude that when it comes to the improvement of communication and collaboration in road maintenance projects, VDC could definitely solve some of it through the use of ICE and iRoom, in addition to including the professionals who perform the work in the planning phase of the project.

6.4 Further research

There is a lot of research that can be done when it comes to what kind of metrics that should be gathered to have the base to make the right decisions about VDC in the future.

The further research has to be based on quantitative data so that one could find sure evidence that would support the use of VDC. This means that one has to find standard perimeters for measurements in projects. (Find general KPI's that could be used for any project that use VDC and/or gather data for ROI's directly linked to the use of VDC).

Another suggestion for further research is to create a pilot project that use VDC in road maintenance and compare it to a similar road maintenance project that does not VDC.

7 References

A. Johannessen, L. C. P. A. T. (2011). *Forskningsmetode for økonomisk-administrative fag*. Oslo: abstrakt forlag.

Arge, K., Moe, K., & Westgaard, H. (2010). Prosjekteringsplanlegging og prosjekteringsledelse. *Rapport to Byggekostnadsprogrammet, Norway*.

Baldwin, A., & Bordoli, D. (2014). *Handbook for Construction Planning and Scheduling*: Wiley Blackwell.

Ballard, G. (2000). *The Last Planner System of Production Control.* (Doctoral dissertation), The University of Birmingham, UK.

Barbosa, F. (2017). *Reinventing construction through a productivity revolution*. Retrieved from

Brostuen, L., Husby, H., & Løkken, S. F. (2013). *Utfordringer ved implementering av VDC i et byggeprosjekt.*

Bygg.no. (2018). BetonmastHæhre og Veidekke fornøyd med Nye Veiers bruk av PRIME. *Bygg.no*. Retrieved from http://www.bygg.no/article/1351032

Chachere, J., Kunz, J., & Levitt, R. (2004). *Observation, theory, and simulation of integrated concurrent engineering: Grounded theoretical factors that enable radical project acceleration*. CIFE Working Paper No. 87. CIFE. Stanford.

Construction, M. (2014). Viritual design and construction, research results. Retrieved from http://www.mortenson.com/vdc-report

Easterby-Smith, T. J. (2015). *Management & business research*. Los Angeles: Sage.

Fischer, M., Stone, M., Liston, K., Kunz, J., & Singhal, V. (2002, June 12-14). *Multi-stakeholder collaboration: The CIFE iRoom.* Paper presented at the Proceedings CIB W78 Conference.

Forening, R. I. (2015). Norges tilstand.

Hamzeh, B. a. T. (2009). Is the Last Planner System applicable to

design?—A case study. *Proceedings of the 17th Annual Conference of the International*

Group for Lean Construction(IGLC, 2009), 13-19.

Hassan, P. A. (2017). *BIM 10 Dimensions*. Retrieved from https://www.linkedin.com/pulse/bim-10-dimensions-prof-akram-hassan-phd-mba-opm3-pmp-/

Howell, G. B. G. (2003). Lean project management. *Building Research & Information, 31*, 119-133.

Jacobsen, D. I. (2005). *Hvordan gjennomføre undersøkelser? Innføring i samfunnsvitenskapelig metode* (Vol. 2): Kristiansand: Høyskoleforlaget.

Jacobsen, D. I. (2015). *Hvordan gjennomføre undersøkelser?* Oslo: Cappelen damm.

James R.Martin, B., Buckley and Chiang. (1976). Research Methodology & Business Decisions. National Association of Accountants.

Kamardeen, I. (2010). *8D BIM modelling tool for accident prevention through design.* Paper presented at the 26th Annual ARCOM Conference, Leeds, Association of Researchers in Construction Management.

Kanaani, M., & Kopec, D. (2015). *The Routledge Companion for Architecture Design and Practice: Established and Emerging Trends*. New York: Routledge.

Karlsdottir, T. M. R. (2011). *Sentrale aspekter ved kvalitativ forskning*. trondheim: Tapir akademisk forlag.

Khandelwal, A. (2017). Innovation Isn't Enough: Employees Need the Right Incentives to Adopt New Technologies. Retrieved from https://www8.gsb.columbia.edu/newsroom/newsn/5631/innovation-isnt-enough-employees-need-the-right-incentives-to-adopt-new-technologies

Khanzode, F., Reed and Ballard. (2006). A guide to applying the principles of Virtual Design & Construction to the lean project delivery process. *CIFE*(#093).

Knotten, V. (2015). *Involverende Planlegging i Prosjektering (IPP)- Lean i prosjektering*
Knut, H. (2008). *Å forske på samfunnet: en innføring I samfunnsvitenskapelig metode*. Oslo: Capellen akademisk forlag.
Koskela, L. (2004). Making-do - The eighth category of waste.
Koskela, L., Bølviken, T., & Rooke, J. (2013). *Which are the Wastes of Construction?* Paper presented at the Proceedings for the 21st Annual Conference of the International Group for Lean Construction.
Koskela, L., Stratton, R., & Koskenvesa, A. (2010, 14-16 July). *Last planner and critical chain in construction management: comparative analysis.* Paper presented at the 18th Annual Conference of the International Group for Lean Construction, Haifa, Israel.
Kunz, J., & Fischer, M. (2012). *Virtual design and construction: themes, case studies and implementation suggestions*. CIFE Working Paper No. 97. CIFE. Stanford.
Larsen, A. K. (2007). *En enklere metode*. Bergen: Fagbokforlaget.
Leksikon, S. N. (2017). Digitalisering. Retrieved from https://snl.no/digitalisering
Linda Birt, S. S., Debbie Cavers, Christine Campbell and Fiona Walter. (2016). Member Checking: A Tool to Enhance Trustworthiness or Merely a Nod to Validation? *SAGE*.
Matthew Miles, M. H. J. S. (2014). *Qualitative Data Analysis, A Methods Sourcebook* (Vol. 3). USA: SAGE.
McPartland, R. (2017). What is IFC? Retrieved from https://www.thenbs.com/knowledge/what-is-ifc
Paul Diederen, H. V. M., Arjan Wolters & Katarzyna Bijak (2003). Innovation adoption in agriculture : innovators, early adopters and laggards. . *Cahiers d'Economie et de Sociologie Rurales*, 29-50.
Philipp, N. H. (2013). *Building information modeling (BIM) and the consultant: Managing roles and risk in an evolving design and construction process.* Paper presented at the Proceedings of Meetings on Acoustics ICA2013.
Rijsbergen, M. V. (2013). The application of Virtual Design and Construction in civil engineering projects. *The International Journal for Design Research in Engineering, Architecture, Products and Systems*.
Rjisbergen, M. V. (2013). The Application of VIRTUAL DESIGN AND CONSTRUCTION IN CIVIL ENGINEERING PROJECTS.
Rogers, E. M. (1983). *Diffusion of innovations*. USA: The free press.
Rolfsen, M. (2014). *Lean blir norsk: Lean i den norske samarbeismodellen*. Bergen: Fagbokforlaget.
Sahin, I. (2006). Detailed review of Rogers' diffusion of innovations theory and educational technology-related studies based on Rogers' theory. *The turkish online journal of educational technology, 5*(2).
Skanska. (2014). *Viritual Design and Construction in Skanska Norway.* Paper presented at the Lean Construction Norge-Seminar, BI
Solutions, S. (2018). Building Information Modeling(BIM) 3D-4D-5D-5D-6D-7D-8D-9D-10D.
States, N. B. s.-U. (2018). What is a BIM?
Talukder, M. (2016). *Managing Innovation Adoption: From Innovation to Implementation*. New york: Routledge.
Tjora, A. H. (2012). *Kvalitative forskningsmetoder i praksis* (Vol. 2). Oslo: gyldendals akademisk.
Trochim, W. M. K. (2008). Qualitative validity. *web center for social research methods*.
Vegvesen, S. (2015). *Lærebok Drift og vedlikehold av veger*: Vegdirektoratet.
Zeekit. (2018). Våre produkter. Retrieved from https://www.zeekit.no/home/Default.cshtml

8 Appendix

8.1 Appendix A: Analysis

Problems

Road maintenance
Other people plan the projects, but the project manager does not follow them.
Waiting time, RFI, is too high
Short distances and not uniform road network makes it hard to design and build contracts where contractors also maintain the roads. Why contractors don't maintain roads
Keeping costs low
Find competent people that understand the job and economy
Find a better way to set good prices in contracts to not pressure contractor and get better quality, but where the client doesn't overpay for the job
Lose information after constructing and therefore can not continue process to maintenance.
2x Things can't be predicted, and makes it hard to follow a plan at times.
Unknown how much clients budget on extra jobs are

Construction
Latency
2x Things happen in the wrong order
Too little planning
2x Rework
Early phase: Grounds for decisions, if they are realistic, have right economical estimate and if one should og through
Keeping doors open for the client and documenting the cost of this
Make descisions at the right time
Maturity of BIM
The project has to budget to buy own digital programs
Hard to find sub-contractors that see the value of VDC
Hard to find good architects that participate in the collaboration process and draw and fix the BIM model during ICE meetings
Design planning not reached same development as BIM
Availability of BIM

Both
4x maintenance in BIM or VDC is not a requirement from developers
Understanding and expectations of what VDC is and requires
Misunderstandings because of different names for same thing-Standardize
Lost info
2x Bad communication and misunderstandings
Complex projects with difficult design/planning processes.
Handling changes
Handling developers
Hold progress
People involved in the project is not included in the planning, which creates rework and things being done in the wrong order
Hiring cheap sub-contractors who don't do quality work
2x Sub contractors sending information too late
Collocation and localization
Outdated handbooks
Not good enough training
Conflicting interests
Finding solutions during the design planning stage
2x Information both on paper and digital version

General improvements-suggestions
Central database that collects numbers and compare projects.
AR & BIM should be used more
Getting everything into one digital system
2x Use SMartDok or something that can register peoples workhours easier.
Make processes more effective
4xTrain and educate worker more on most basic things like digital programs, at least have a pdf.
Plan better in regards to waste of time- like driving far to fix only one thing, when one can fix several things at once.
Follow up sub-contractors more
Make it easier to get ideas or propositions through
Change pricing strategy by not pricing standard jobs too low to win contract and try to earn on extra jobs
More user friendly apps
Should be more incentives when it comes to road maintenance to increase innovation, because there is a lot to gain.
Extra income by creating more cutomer value (F.ex: Optimize use of area or create more parking spaces)
Mark components better in BIM for further use in maintenance
Become better at collecting KPI's and hard data to measure VDC and improvements
More cutouts(utsparinger) from the factory
Split work processes to get better utilization, especially when it comes to rig and operation
Include things that og well for a project, and not only focus on the bad
Use Synchro and plan the Gantt there to visualize and control the project better and deliver on time
Transfer experience more within the company
A more bottom up approach with input from the workers
Be more included in the planning phase

Contracts thought to support VDC

Partnering contracts, IPD, BVP	5
All contracts	3
Turn key	7

Some answered turn key and BVP
Two were not questioned about contracts

Road maintenance projects asked used turn key contracts

Knowledge about VDC

No	3	
Yes	12	
Y/N BIM+	3	one was using it everyday without being aware of it being VDC
Stanford	5	
Adaptation	4	

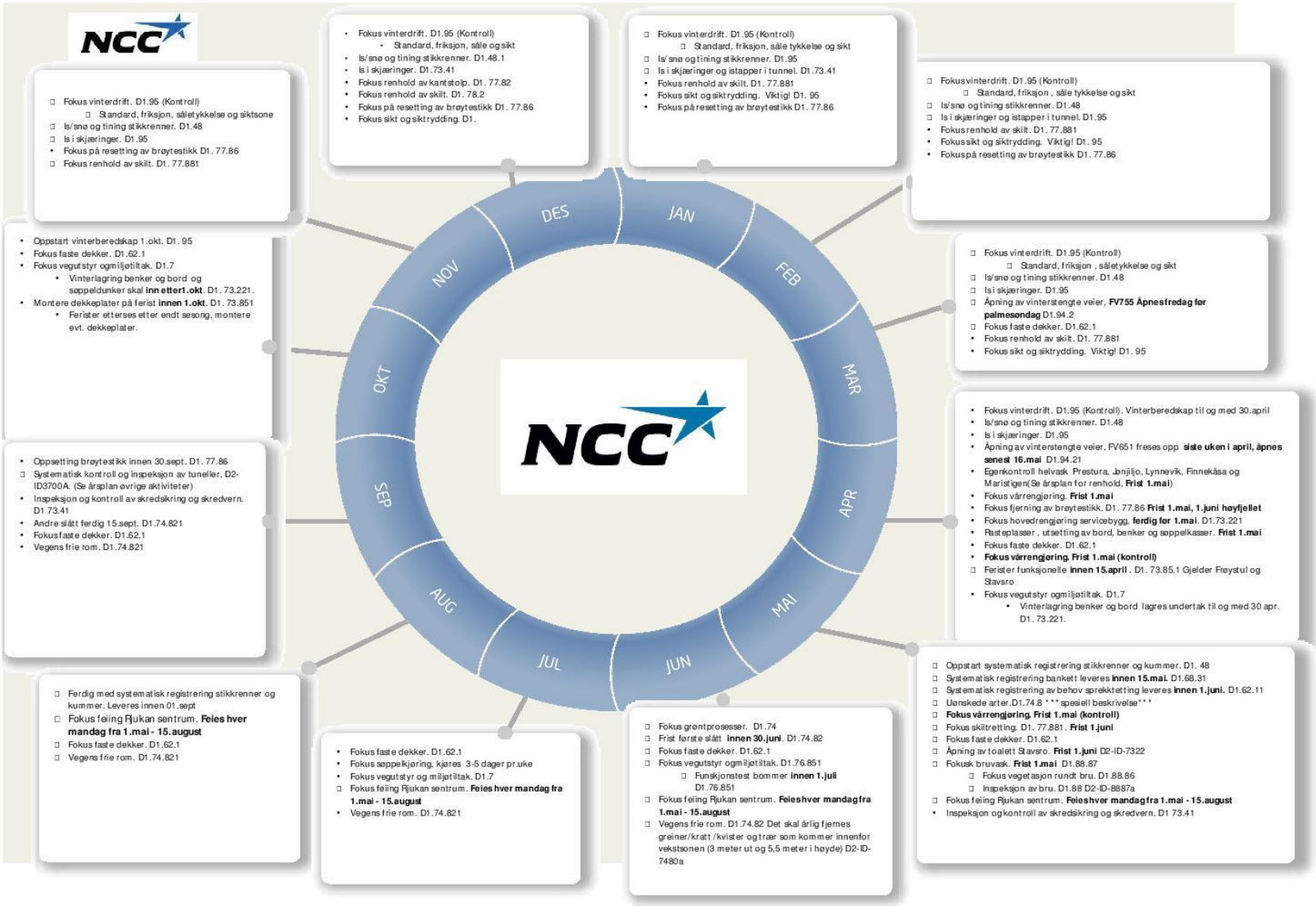
VDC Influence road maintenance
Design of the contract
Collaboration and interaction between client and contractor
Information in regards to maintenance has to be plannes in the design phase.
More transparency in processes
2xMore communication and collaboration with client
Structur and organize planning
Control progress and use during meeting
VDC could give a better overview of of projects and help with LEAN processes
There is talk about IFC program for infra-services. When the programs can talk together they might start merging.

Hard data
NCC gathers and have found out that VDC requires that the ground pillars are done right
Hard to collect ROI's linked to VDC
Companies are not generally good at collecting KPI's or evidence of VDC
Hard to convince people that VDC works without hard data. So workers are not as involved and top management might not give enough resouces.
3x Hard to collect KPI's
4x Lack of hard data
No hard data on traditional projects to compare VDC projects with

Difficulties implementing VDC
Reach everyone because of being a large company, have an unuson understanding of VDC
Standardization difficult for whole company because of different legislation.
VDC demands extra work in the initial phases that later pays off, but agreeing on who's supposed to put in the extra effort and how it is payed, can create difficulties.
Some hard aspects to implement. If not done fully and everyone is on board, it is easier to use traditional planning.
Some might not think VDC works because some projects have only used bits and pieces of VDC, and unless it is fully integrated it cannot give the results it claims.
A lot of people don't understand VDC and it can seem more complicated than the traditional way of working.
2x You need a lot of support from the management. (Bottom-up pressure is needed)
Find it fitting project managers to get everyone in the team enthusiastic about VDC
Depends on the project and project manager because every project is unique and it is hard to standardize VDC.
Resistance from some people and the resource team
Not enough time to do enough in the beginning of projects, which lock actions later.
People need to practice VDC once they have been trained in it, not wait a long time before being able to use it.
Lack of knowlegde of VDC
Lack of knowlegde between different actors in a project
Lack of good KPI's
2x Finding right people who want to parttake in the collaboration processes
Finding good facilitators for ICE meetings
VDc is very conseptualized

What can VDC do?
Benefits in BIM models- reduce risk and give better control.
VDC works towards giving involved parties a chance at having something to say earlier in the project, which gives better results.
Using last planner in road maintenance can give good results when it comes to planning
Reduce RFI
Reduce time of design/planning around 30-40%.
Improve communication, therefore reduce e-mails by 80%.
Increase unproductive time by 25%
Cost ould be cut by around 10%
2x Improve efficiency
Gather more metrics-document improvements
2x Better communication
See collisions sooner
Save time
Increase value for customer, don't know how much because of lack of hard data
Improve buildability
2x More satisfaction in the teams through VDC
Pilot showed increased flow and reduced latency
ICE meetings give clearer goals
More clear what people have done or not

8.2 Appendix B: NCC's Life-cycle



8.3 Appendix C: Interview guides

8.3.1 Group 1

-How do you define VDC?

-Is there a requirement to use VDC in every project in the company?

-Are there any plans for implementation of VDC in road maintenance?

-What have been the difficulties during the implementation of VDC?

-What are the largest problems/obstacles that occur during the time of a project?

-How much would you save by solving these problems?

-What kind of contracts do you know about that initiates the use of VDC? (Is it you as an enterprise that initiates it or the client?

-Do you have any criticism when it comes to VDC?

8.3.2 Group 2

-What do you know about VDC?

-(Explain what VDC is, the 4 parts) Do you recognize any of these in your project? Do you have any opinion of it and its place in Road maintenance?

-What kinds of contracts do you use in road maintenance?

-What are the largest problems/obstacles that occur for you or the project during the time of the project?

-Do you have any idea on how one can improve, save costs or make processes more effective in a road maintenance project?

-Do you have any idea of how VDC could improve these problems? Do you think it is worthwhile?

-What is the reason that some contractors win road maintenance contracts, while others don’t?

8.3.3 Group 3

-How do you define VDC?

-Does the contract type of your project support the use of VDC?

-What have been the difficulties during the implementation of VDC and how do you do it?

-What are the largest problems/obstacles that occur for you or the project during the time of projects?

-How much would you save by solving this?

-What could the company do to create more profits?

-What could the company do to create more profits during this project?

-What are your thoughts on VDC in road maintenance?

-Do you have any criticism towards VDC?

8.3.4 Group 4

-How do you define VDC?

-What kind of contract types do you think support the use of VDC?

-What are the difficulties of VDC?

-What are the largest problems/obstacles that occur during projects normally?

-How much do you think one would you save by solving this?

-Do you have any idea of how VDC could improve these problems?

-Do you have any ideas about VDC in road maintenance?

-Do you have any criticism towards VDC?

8.4 Appendix D: Interviews

8.4.1 Interview 27.03.18

Jostein Myklatun & Bjørn Larsen, Operation Manager & Project Manager, NCC road maintenance

What do you know about VDC?

-Not much

(After explaining what VDC is) Do you have any opinion of VDC and its place in road maintenance contracts?

-We do have some collaboration between us and the client, where we have meetings dedicated to collaboration twice or more every year of the contract. We also have meeting every month that rule over the contract if we agree on something there. And when we win a contract we use the first year to collaborate and agree on processes and requirements.

What kind of contracts do you use in road maintenance?

We usually have turnkey contracts. We usually follow a set price list and/or use hours.

What are the largest problems/obstacles that occur for you or the project during the time of the project?

-A lot of things can't be predicted. We plan as much as we can, but we sometimes have to drop everything we're doing at that moment because of the urgency of it.

What could the company do to create more profits during this project?

Plan better when it comes to waste of time, we also end up driving very far for fixing one or two things instead of taking everything in one drive. We should also become better at fixing things at once, so the problems or things that have to be fixed builds up. And we should follow Vegvesenets rules better so that we don't get as many fines. Especially when it comes to following subcontractors up on things that they have to do or report.

Do you have any ideas on how one can improve, save costs or make processes more effective in a road maintenance projects?

-We need to train people better when it comes to the digital tools and even what their job is

about. For example to let them follow a person of the same job position in a similar project for a few days to understand what their job is and to see what they can improve from a different point of view.
-It is also hard to get your ideas or propositions through because there is so much bureaucracy.
-The company should also be in contact with the client to find out how much they have budgeted when it comes to the extra jobs, because we often find it difficult to find enough resources by the end of the contract when the client often has to use up their budget on getting as many jobs done as possible with the money they have left. That way we can plan our work a lot better, and the client wins on it too.

What is the reason that some contractors win road maintenance contracts, while others don't?

-It's all about the pricing. The lowest price wins the contract and that is why contractors set their prices too low and try to earn more on extra jobs. We think that they should change their strategy to rather have the prices on the extra jobs lower, while the standard jobs should be priced correctly and not too low.

8.4.2 Interview 22.03.18

Orkdalen, Steinar Løvseth, Driftsleder, NCC, road maintenance

What do you know about VDC?

-Never heard about it, my project manager might know.(Gro Hege)

What are the largest problems/obstacles that occur for you or the project during the time of the project?

-A lot of things can't be predicted. Often things occur that make us drop everything to fix it. This makes it hard to follow a plan, but the plans are the foundation of our progress.
During the summer it could be flooding or avalanches. During the winter, it could be the amount of snow, freezing rain or ice/snow avalanches. All around the year things like dead animals or traffic accidents and detours that follow these accidents create unpredictable obstacles.

What could the company do to create more profits during this project?

-Use SmartDok or something that could register the sub entrepreneur's work hours easily. That would save a lot of time. Possibly try to use the Arbeidsordre part in Zeekit.

-Communicate more and collaborate with the client. This way one can also redo (agree on) some parts that one can see is not working in the contract through the "Byggemøter".

What kind of contracts do you use in road maintenance?

-Turnkey contracts. There is more and more collaboration between us and the client.

What is the reason that some contractors win road maintenance contracts, while others don't?

-It's all about the pricing. If you can have the lowest price, they will choose you.

-We earn the most on the extra work that we do through the contract.

What kind of collaboration do you have with the client and within the project?

-Before the contract starts we go through most processes with the client (SVV) (Anne Lise Hovin has full overview of the contracts in Trøndelag. She holds very effective and good meetings.) She does not hold any evaluation after the meeting, only a verbal one and we use a beamer.

-We are supposed to have collaboration meetings every three months.

-We hold two "Byggemøter" per month. Team meetings once a month, monthly meetings, HMS (health, safety and environment) weekly with daily reminders. In addition, we start the day with some coffee and conversations where we resolve problems and conflicts.

How do you plan a project? What kind of plans do you use?

-We have work plans, weekly plans, progress plans, yearly wheels, Gantt charts that I can remember right now.

What kind of programs do you use in this project?

-We use Veivær, Elrapp(entreprenør), Zeekit and Starnet. (no use of prosjektportalen)

-We had a course on how we should use zeekit a little while after the project started.

Do you have any ideas on how one can improve, save costs or make processes more effective in a road maintenance projects?

-If I have to say one thing: One should look into making the processes more efficient.

-One should look into training people more in the most basic things, like the programs that are being used or at least have a step by step video or pdf on the most common problems.

(After explaining what VDC is) Do you have any opinion of VDC and it's place in road maintenance contracts?

-If you can use better digital tools to make the work more effective and easier, it would be welcomed even though it takes a bit of work to change or to get used to it in the beginning.

8.4.3 Interview 26.02.18

Karen Sarna Grill Hansen, VDC Development manager, NCC DK. Construction

How do you define VDC?

-NCC mainly follow the Stanford definition, but has adapted it to their own version.
Workers from NCC are certified from Stanford.
The BIM part is important and the rest depends somewhat on it. For example, NCC uses Project studio as a platform for their digital collaboration.

Why did you decide to require the implementation of VDC in every project in the company?

-Because we see that the company benefits in using a BIM model and it is proven to reduce risk and give better control. Better control also makes it easier for the company to give better offers. VDC combines digital programs with collaboration and communication, which is good for the company.

-We are working on something we call integrated VDC in building, which is a central database that gathers all the digital programs and data and information from outside collaborations in a project and coverts and enriches it to NCC's standard. For example, the same thing can be named differently from one company to another, and the program is supposed to detect it. Because this has created misunderstandings in the past.

Are there any plans for implementation of VDC in road maintenance?

-I work in building, so I don't know much about it. You should talk to Anna Neidenstöm, she might know it because she's in infra.

What have been the difficulties during the implementation of VDC?

-NCC is a large Nordic company, and it is hard to reach everyone, especially under the re-organization we have had the last years, but we try to make everyone have a unison understanding of what VDC is.

-The details need to be standardized (for example named the same way) to reduce misunderstandings.

-NCC works in different Nordic countries with different legislation so standardization and agreeing on demands can be difficult.

-We like to have things in-house, because it gives better control.

What are the largest problems/obstacles that occur during the time of a project?

-Lost information and misunderstandings

-VDC demands extra effort in the initial phases, and this means more work that then pays off later in the process. Agreeing who has to put in the extra effort and how this is paid, can be a point of disagreement between the parties.

How much would you save by solving this?

-It is hard to say because companies are generally not good at collecting KPI's, evidence on VDC and it is hard to collect ROI's that are linked to VDC.

-One wishes to have a central database where one can collect numbers and compare projects.

What kind of contracts do you know about that initiates the use of VDC? (Is it you as an enterprise that initiates it or the client?)

-I am not sure about contract types and they vary a lot, but we always have an appendix with ICT requireements (in Denmark. Also sometimes called BIM execution Manuals or BIM Guidelines in different countries.)

Do you have any criticism when it comes to VDC?

-There are some aspects that make it hard to implement. If one does not use it fully, it is not set up well and everyone is on board, it can make it more difficult for the project than using the traditional way of working.

-Because some project has only used bits and pieces of VDC some people can get the impression that VDC does not work.

-A lot of people also don't understand the VDC concept and it can seem more complicated than the traditional way.
-You also need a lot of support from the management (now the management even require the use of VDC). A combination of top management demands as well as "bottom-up" pressure from enthusiastic workers are usually the most efficient way to convince the middle management and succeed in implementing VDC and creating progress.

8.4.4 Interview 22.02.18

Terje Andersen, Manager VDC, NCC. Infraservices

How do you define VDC?
-75% processes, 25% BIM (Stanford version)

Why did you decide to require the implementation of VDC in every project in the company?
Developers have higher requirements than before, and we see that having a say in the project earlier in the contract gives better results. VDC works toward this.

Are there any plans for implementation of VDC in road maintenance?
-No, not that I'm aware of, but there are a lot of possibilities especially in the BIM field where there is talk about creating IFC programs for infra services. This will create programs that talk together more efficiently and maybe the programs will merge.
- When it comes to the planning in road maintenance, last planner is likely an effective way.

What has been the difficulties during the implementation of VDC?
-One of the difficulties are to find fitting project managers and to get everyone in the team to be enthusiastic and try to change their way of working. Some are introverted or not fond of working in a team, and they are mostly hard to change.
-It is hard to show hard data to convince people of the use of VDC. It is difficult to find good quality KPI's that can be used in every project. This is because all projects in building are mainly some sort of prototypes. It would be possible to compare a VDC project with a non-VDC project

if there were good data available.

-It is very hard to get the top management to put in resources without hard data.

What are the largest problems/obstacles that occur during the time of a project?

-Bad communication and misunderstandings There are rarely pure professional mistakes.

-There are usually people who plan the projects. The project manager does not use these plans fully and they get put to the side.

-The waiting time when it comes to RFI's (Request for information) is too high.

How much would you save by solving this?

-The time of design/planning could be halved. 30-40% reduction in the time it takes to build something. The goal with VDC is also to improve the communication so that the number of e-mails get reduced by 80%.

What kind of contracts do you know about that initiates the use of VDC? (Is it you as an enterprise that initiates it or the client?)

-Usually, the contractor initiates it, but more and more often clients ask for it. (4 main clients in Norway: Statsbygg, BaneNor, SVV and NyeVeier.)

-ECI (Early contract involvement), BVP (Best value procurement), OPS (offentlig-privat samabeid) & IPD (Integrated project delivery) can initiate the use of VDC.

-Sometimes it does not profit to use VDC resources for some turnkey contracts.

Do you have any criticism when it comes to VDC?

-There are no tools for production when it comes to BIM.

-It is hard to find good KPI's that can be used as a standard and hard data to convince people.

-Because every project is unique it is hard to create one standardized way of using VDC, so it depends a lot on the project and the project manager.

8.4.5 Interview 08.03.2018

Gunnar Skeie, Avdelingsleder VDC, Kruse Smith. Construction

How do you define VDC?

- We try to practice VDC as we were taught by CIFE at Stanford. As far as we see it, we share the basic understanding of VDC with companies like Skanska, Veidekke and AF.

Is there a requirement to use VDC in every project in the company?

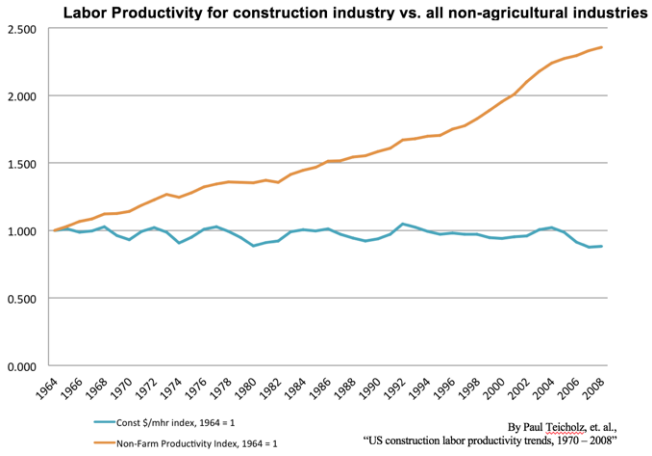
- We do not have a policy of forced or unified execution of all our projects today. But our new strategy is pointing towards a direction for more use of VDC as our preferred way of project execution.

How does VDC improve problems in construction projects?

-In general, you could say that VDC helps us to plan and execute project more efficient, but we have no hard data/evidence. Most of all since we have no exact data on how we perform in "traditional" projects, and we have not been able to collect data on the performance of VDC projects either. Likewise we have no evidence that VDC does not work. VDC is formed as an execution strategy based on BIM. BIM adds visualization and data.

How much would you save by solving these problems?

-Hard to say. Some are speaking of 30%, others say 50%. If you look at productivity comparison between Construction and other industries you find that other industries have an increased their productivity by a factor of 2,5 since 1964, while construction has a slight decrease (see graph). Some points on the introduction of data to the process and focus on the actual process of fabrication as two major differences to explain the gap. VDC represents both Data and Process.



What kind of contracts do you know about that initiates the use of VDC? (Is it you as an enterprise that initiates it or the client?

- VDC can be used regardless of contract type. VDC is more efficient if it is used throughout all phases of the project, and when there is a contract that supports collaboration.

Do you have any ideas on how one can use VDC in road maintenance projects?

-What is the Client Objectives for the project? What does the project team have to deliver to make sure they meet the Client Objectives? Can you use BIM to produce construction documents? Could ICE be a good strategy to get a better process? Can you improve your process of work by applying LEAN methods? Could focus on controllable factors in your daily work improve chances of meeting the Project Objectives and the Client Objectives? If Yes, then you have an idea.. ☺

Do you have any criticism when it comes to VDC?

-Change is always difficult.

8.4.6 Interview 14.03.2018

Per Qvalben, fagansvarlig veg, Nye veier. Roads

How do you define VDC?

-Stanford definition. Wish to have a Norwegian certification program and it is being worked on now.

Is there a requirement to use VDC in every project in the company?

-Yes, we started in 2016, so we have not had too many projects yet. The first projects did not use VDC, but we are working now on how we should use it and have set is as a general requirement for projects. For us it is not important what you call it, if it's VDC or not, we wish to have more involvement, have a method of working and better collaboration. VDC works towards that.

How much would you save by solving these problems?

-There is no hard data, so it is hard to say. We look at VDC as a part of the whole project where

processes should be more transparent and that there are higher requirements for the BIM among other things.

What kind of contracts do you know about that initiates the use of VDC? (Is it you as an enterprise that initiates it or the client?

-BVP procurement and turnkey contracts. We are not using IPD contracts. We are working toward having contracts that engage everyone more and initiates better interaction in the planning processes. Nye veier tries to be a lean construction client. Digitalization and planning need good tools and we want to use these tools to have better insight and evaluate risks. With this, we can decide what steps to take and implement controls after that.

Do you have any ideas on how one can use VDC in road maintenance projects?

-No, you should talk to Tor Alf Høye, he manages road maintenance. But when it comes to constructing roads I can see a lot of use of VDC, especially when it comes to BIM and the production line.

Do you have any criticism when it comes to VDC?

-For us it is very new, we have not used it fully yet and we are still in the process of certifying people now. But from the E6 moelv project we have with Veidekke and Sweco I've heard that there is a need for practice, especially when it comes to ICE meetings and how one should involve everyone in a good way and create a good structure.

Do you think that BIM is mature enough for road maintenance or in general?

-When it comes to basic 3D BIM, yes, it is okay and it has been used for a long time. We build after the model and automate machines after GPS and GPS coordinates.

Traditionally there is a good control when it comes to transportation/infrastructure projects. We deliver good quality projects, and deliver the BIM on a disk. Usually, after that, the BIM is forgotten and never used again. This is one of the problems, that we with this lose a lot of information and cannot continue the process into the maintenance part. We want to use AIM (asset information modeling).

Are there any particular programs you use when you are constructing roads?

-We don't have any requirements because we want to give the constructor some freedom and let them use the program that they have specialized themselves in. We are working toward using

open formats.

The programs used traditionally in Norway when it comes to planning and engineering when it comes to transport is Trimble(former Novapoint) This is a tool that use an Autodesk platform and produces dwg-files among others. The largest competition is Bentley's systems, which are more common in for example Britain. When it comes to tunnel work I know that those projects require the use of Plania. When I talked to Plania I was told that if we could use open formats in the programs we already use, that they would continue the process in their own programs.

8.4.7 Interview 20.04.2018

Per Öberg, Head of digitalization & VDC, NCC infrastructure

How do you define VDC?

-NCC's definition, almost same as Stanford.

Why did the company decide to require the implementation of VDC in every project possible?

-It's part of an effective building process.

Are there any plans for implementation of VDC in road maintenance?

- Yes, it influences the design of the contract.

What has been the difficulties of VDC in road maintenance?

-Expectations and understanding of what it is and what it requires.

What are the largest problems/obstacles that occur during the time of a project?

- It's hard to give a general answer.

How much would you save by solving this?

-We save or reduce waste in a lot of ways, time, quality and correct deliverances.

Does NCC gather KPI's and metrics when it comes to the use of VDC? What have you found out?

-Yes, VDC requires that the ground pillars are done right (planning, etc…)

Who initiates the use of VDC and does the contract support the framework?

-We always try to use VDC if we can, contracts are built on a 20-year-old way of working, so they need to be updated.

Do you have any criticism when it comes to VDC?

- Yes, insufficiency when it comes to using it fully, but we are getting there.

8.4.8 Interview 14.02.2018

Erik Langørgen. Group leader, SWECO. Construction

How do you define VDC?

-Coordinated progress, common platform. Coordinated planning.

Does the contract type of your project support the use of VDC?

-Only had total enterprise contracts, but VDC should be possible to use in all contracts.

What are the largest problems/obstacles that occur for you during a VDC project?

-Localization or collocation has been a large problem.
-Finding the right people who are driven and have the right competence.
-Finding a good facilitator for the meetings. Need a good person with integrity that can handle all the different personalities.

What have been the difficulties during the implementation of VDC and how do you do it?

-Resistance from workers has been some of the biggest difficulties. People already have a lot to do and they are used to doing it a certain way. Making them do it another way takes effort and time.

-Because every project is different it's hard to find good metrics that one can compare with other projects. This makes it difficult to create proof/data that VDC works. If it was possible, one could show these data to people who are resisting and get them more involved faster. It would also give the company and developers more incentive to use VDC,

Do you have any idea of how VDC could improve these problems?

-VDC creates better workflow. By sitting in the same room with the right people one takes faster decisions and solve problems faster.

-It makes it more fun to work for everyone involved because they can use their knowledge, get their voices heard and contribute in a totally different way.

When working on projects with NCC that have used VDC, have you noticed any difficulties that this company have when it comes to VDC?

-In the projects where the developer did not want to use VDC, I have noticed dissatisfaction in workers and myself. The coordination was worse and the progress was slower.

What are your thoughts on VDC in road maintenance?

- One can gain a lot in using VDC in road maintenance. VDC is built on Lean, and since road maintenance is repetitive processes, one can standardize a lot and create a better workflow. One can, for example, align fixing the asphalt with inspections.

8.4.9 Interview 23.03.18

Henrik Larsen, Prosjekteringsleder, NCC. Construction

How do you define VDC?

Yes, we use ICE with evaluations, improvements, an agenda with timers and summaries. We have more collaboration, projectstudio, PDS (project document system) and last planner.

Does the contract type of your project support the use of VDC?

-We have only worked with turn key (general contracts [Totalentrepriser &hovedentrepriser]). We usually delay writing the contract for half a year. During these 6 months, we usually collaborate with the client, advisors and suppliers to optimize the building and try to agree on how the processes and construction design. With this, we end up not sending a lot of change requests, but tend to talk to find the best and most optimal solutions during our meetings.

What have been the difficulties during the implementation of VDC and how do you do it?

-In this and the few former projects I've been involved in I've been so lucky to have a project

manager that sees the value of VDC and that sets resources towards the use of better technological systems and more collaboration.
-Unfortunately, we don't have any hard data when it comes to VDC and it is hard to measure it. This makes it difficult to have support from people not familiar with it or the ones who have never used it and can't see how one gains more through using VDC.

-Finding the right people to work with, where we exclude the ones who don't want to collaborate or partake in the collaboration processes.

What kind of digital systems do you use?

-Solibri, ArchiCAD, Revit and Tekla. We put in a lot of effort to make sure that we all have the correct basis so that the BIM becomes good. We also use PDS and make sure that everyone doesn't work on the same part of the model at the same time and that they are using the newest model.
-We also use Synchro for 4D. And we have HMS in the model (Ramirent also use it).
-There is unfortunately not any requirements for the use of BIM in maintenance (the rig plan, assembly model gets updated before project studio meetings)
-We also use BIM stands and people are very happy with it.
-For the Lyngården project, we use InsiteVR so that KLP can use it for promoting their project and get more sales. We also use it for 360 pictures, coordination, HVAC and ceilings.

What kind of plans do you use usually during your projects?

-Drawing delivery schedule, Drawing deliverances, progress plans, communication matrix (Last planner), design plan, tact plans, critical paths, 3 weeks plans, Gantts, weekly meetings, but we have to follow people up and make them aware that a delay on their part often leads to higher costs that they have to cover. As of today, I have not experienced that the design planners have delayed workers on a building site. We usually send an invoice for the ones who are delayed (Agreed time).

What are the largest problems/obstacles that occur for you or the project during the time of this project?

-We had to fix it so that we found enough resources to buy our own digital programs and it is hard to work with sub-contractors that don't see the value of the VDC processes. We also have

to find a good architect that can take part in the collaboration process and draw and adjust, make drawings in the BIM actively during the meetings.

How much would you save by solving this?

-We would save a lot of time and see possible collisions sooner in the project, we also increase the value for the customer, but by how much, I would not know, since there is no hard data when it comes to VDC unfortunately.

What could the company do to create more profits?

-Extra income by creating, for example, more parking spaces and more optimized use of area.
-We should mark the components better (more information) in the BIM so that we can use it further in the maintenance
-We should have better KPI's so that we can measure VDC and the improvements.
-We should have more cutouts from the factory (utsparinger).
-We should split work processes to get better utilization, especially when it comes to rig and operation.
-Become better at including things that we can see work well, and not only focus on the things that go badly during a project.
-We should use synchro more detailed and plan the Gantt in synchro so that we can visualize and control the project better This way we also deliver more at the right time.
-We have to digitalize the way we register our hours!!
-We have to have more transfer of experience (an experience bank)
-We also need more training in NCC. We have to be good at using the digital programs to have the most optimal way of doing a project.
-It becomes up to the project leader to decide if any of the budgets he/she gets for the project goes to VDC.
-We should become better at gathering hard data

Do you have any idea of how VDC could improve these problems?

-I can see a great improvement from the traditional projects and the VDC projects that I've been a part of over these years. We see fewer collisions during the construction because we can notice them earlier. We do make it a bit harder for ourselves because we optimize the rooms in a way that makes it more difficult for us to mount different stuff.

-VDC improves the buildability, It gives the customer a better value through the collaboration, we can optimize the area and one can see collisions before they happen.
-Through more collaboration people in the team and project usually feel more satisfaction and fewer conflicts occur.

Any criticism towards VDC?

- It is hard to implement VDC because we lack resources at times and one does not invest enough in VDC.

Other comments?

-I think it is strange that other projects don't use VDC more.

8.4.10 Interview 21.02.18

Jon Sakarias Liknes, Kruse Smith, Prosjektutvikler og VDC fasilitator. Construction

How do you define VDC?

- Very close to the Stanford definition. Project goals, Client goals, ICE, Project and Production Management and BIM.

Does the contract types of your projects support the use of VDC?

-The company initiates the use of VDC, but sometimes the client (usually repeating customers) want to use VDC.
Usually, totalentreprise with focus on the client's goals, but sometimes focus on collaboration. When the focus is on collaboration, the subcontractors are not included, but this is something that might become more common to include.

What have been the difficulties during the implementation of VDC?

-Clearly resistance from some people and the resource time
-At the beginning of projects, one will not have the possibility or time to do the correct or necessary things, and this makes it very difficult to fix later in the projects. The action gets "locked".

-When people get trained in VDC-methods they have to be able to make use of it and see it instantly, not wait half a year, because they would have forgotten everything about it.

What are the largest problems/obstacles that occur for you or the project during the time of your projects?

-Too little planning, quite a few coincidences, things happen in the wrong order, there is a lot of latency. The lack of planning makes it difficult to get an overview so one can not see the consequences of the placement of the order of things, so they become wrong, which creates rework.

-The ones who are involved in the project are not included in the planning, which creates a lot of rework because of the wrong order of things.

-When the cost is essential and one, therefore, hires sub-contractors who are not doing high-quality work.

-Misunderstandings

Do you have any idea of how VDC could improve these problems?

-VDC would structure and organize the planning and a good virtual planning saves a lot of time and money

How much would you estimate that a project would save by fixing these problems?

-It would increase the unproductive time by 25%.

-The cost would get cut by around 10%

It is also interesting that almost every project has a duration that has a factor of 3 (12, 15,18, 21 or 24 months), this suggests that the industry are not aware of a reasonable progress.
The goal is to create more value for the customer, like if one creates a more optimized production in an industrial building because of the well-thought planning.

What is your thought about VDC in road maintenance?

-One could make use of VDC to control progress and use it during meetings. I believe that they could gain a lot by using it in that way.

There is a lack of lean in the building industry and there is a hard environment to use new

technology in an effective way. This creates a lack of overview among other things. VDC could solve this.

Do you have any criticism towards VDC?

-No, not the method in particular, cause it gives a lot of leeways and does not have strict ways of doing things. One just has to fix problems that occur in the best way and figure out what the best practice is. This makes the use of VDC depend on the person who is using it.

-But one usually shows examples of large projects that use VDC, and that makes it a bit difficult to see exactly how one can use VDC in smaller projects.

-The technology is in some cases not mature enough, and some companies have a monopoly when it comes to some technology.

-The digital programs used in a project are not user-friendly and not everyone has the opportunity to learn them. Like if an sub-entrepreneur has to use a certain app.

8.4.11 Interview 16.04.2018

Siri Heyerdal Augdal, Project director (prosjektdirektør), COWI. Construction

How do you define VDC?

Stanford definition.

What kind of contracts do you usually use?

Engineering contracts (prosjekteringskontrakt) with the client(byggherre) or turnkeys.

What has been the difficulties during the implementation of VDC?

-The client initiates the use of it and adjusts the interpretation to their own needs. The benefits from our perspective could, therefore, be limited. Other elements that make implementation difficult:

- Different clients have different interpretations of VDC and hence we need to adjust to a number of different processes
- In a large number of projects, we are not overall responsible for the engineering process (i.e. the engineering manager is not a part of our deliverables), but delivers just a limited number of disciplines.

- VDC set-up is time-consuming and requires a project of some length
- Rooms suitable for VDC are costly and availability might be a challenge

When it comes to VDC in maintenance, I would believe that there is a lack of knowledge when it comes to this framework. There is also a lack of understanding between the project designers and the operation and maintenance people. Even when we were hired for a project for a large oil company with a professional facility management, who are very high tech and good at processes, there were some issues with dialogue and BIM. The ones doing maintenance use the old fashioned way and are not driven by innovation. They are professional, but their field is very wide and they are usually handymen, not knowledgeable of digital programs.
-We also lack good KPI's

What are the largest problems/obstacles that occur for you or the project during the time of this project?

-In the earliest phases of a project, one of the obstacles are the grounds for decisions, if they are realistic, if the economical estimate is right and if one should go through with the plan.
-It is also hard for the customer to prioritize what they want because they usually want everything, and only a few of them are possible with the price they are paying. This makes us have to wait with decisions and keep possibilities open, which again pushes the costs.
-We have to get better at documenting how hard and costly it is to keep several possibilities open until a decision is made.
-One large problem is to make decisions at the right time.
-We also have a problem when it comes to the maturity of the BIM and where sub-contractors send their information too late.

How much would you save by solving this?

-I think that we could save/gain a lot of time, if we could solve these problems.

What could the company do to create more profits?

-Set in numbers how much time is used on small changes on the 2d drawings, We know that it takes at least 4 hours on a change on a drawing because it needs to be generated and quality checked. This would be useful because we think that contractors have a tactic of asking for

measurements on 2D drawings to increase their deadlines. Basically opportunism.
We should also get some numbers on the use of augmented reality.

Do you have any idea of how VDC could improve these problems?

-It could improve the efficiency and if done right gather more metrics/KPI's to document the improvements.

Any ideas on how VDC could be used in road maintenance?

-There need to be more incentives for people in maintenance to increase the innovation within the field, because there is a lot to gain there. (Statbsbygg could be someone who has the power to do something with this in the construction business)

Any criticism towards VDC?

-The contractor owns the concepts and sets the meaning, it is also adapted to the construction process. It is not ideal for the design planning. Advisors have not contributed enough with their views.
-VDC is not used ideally as of today.
-VDC is just a system of things that already existed. A hype word. Stanford owns this concept and earns on selling it. Honestly, we started to work similarly to this at least 10 years ago on the Trondheim hospital.
-Small companies or sub-entrepreneurs don't have enough incentives to work like this.

Is there anything more you want to add?

-There is a lack of expertise, and a large knowledge gap between the design planners and the maintenance people.
-In the industry, it is often said that they use VDC and 3D, but one usually use 2D drawings, just in pdfs. This needs more manual work. This is because clients and contractors still want 2D drawings.

8.4.12 Interview 09.03.18

Tor Alf Høye, Drift og vedikehold, Nye veier, former Vegvesenet. Road maintenance

How do you define VDC?

-I don't know VDC well, but it has BIM and is about work processes and meeting efficiency.

Does the contract types of your projects support the use of VDC?

-We have only started and our first road maintenance project is in 2019.

We usually work with contracts that guaranty the quality of the road when they are building it and for the 20 years after. The warranty includes functional and condition requirements so that, for example, the upper layer of the asphalt must be corrected before the condition requirements are exceeded, or if a fence that no longer functions as required..

-I've usually been working with 5-year road maintenance contracts in my former job at vegvesenet.

-I would believe that BVP contracts and in general collaborative contracts is something that would support VDC and it is also something that we are working towards using more often.

What are the largest problems/obstacles that occur for you or the project during the time of your projects?

-One of the problems is that the there are a lot of short distances, the road network is not uniform, which makes it hard to have design and build contracts where the contractor also maintains the road. This is also the reason why it has not been usual to have the same contractor maintaining the road.

-The cost is a challenge

-It is also a challenge to find 2-3 competent people that have an understanding of the economy and a good understanding of the job and what it takes.

Do you have any idea of how VDC could improve these problems?

-No, I'm sorry. I don't want to comment since I'm not sure about it.

What is your thought about VDC in road maintenance?

-There should be more interaction and collaboration between the client and the contractor.

-One can use AR & BIM models a lot more than what it is used today.

-Find a better way to set a good price on a contract where it does not put pressure on the contractor, so the quality can be better, and where the client does not overpay for the job.

-We are working toward getting everything into one digital system.

Do you have any criticism towards VDC?

I don't feel that I have enough knowledge to comment on this.

8.4.13 Interview 08.03.2018

Professor at the University of Agder, Bo Terje Kalsaas

How do you define VDC?

-BIM and processes in planning/design.

What kind of contract types do you think support the use of VDC?

-Partnering contracts (Samspillskontrakter) like IPD & BVP.

Contracting processes that converse to turnkey contracts and competitive dialogue (konkurransepreget dialog).

What are the difficulties of VDC?

- The design/planning processes are demanding, especially in complex projects. The BIM part is not one of the difficulties.

What are the largest problems/obstacles that occur during projects normally?

-The design/planning phase is one of the largest obstacles, and by that, I mean the process of handling changes, handling the developer, manage processes so that it maintains maturity and that one holds the progress.

How much do you think one would you save by solving this?

-I don't know, but it can be very very large amounts. It's hard to say a percentage..

Do you have any idea of how VDC could improve these problems?

-It has a lot to do with the people, their motivation and the interactions on this part I don't think VDC can do anything, but having good processes and VDC can be favorable.

Do you have any ideas about VDC in road maintenance?

-It is possible to build in a lot of things in the BIM that is needed. Like information in regards to maintenance. That has to be planned during the design stage.

Do you have any criticism towards VDC?

-VDC is, in my opinion, an unnecessary word, kind of like the Emperor's new clothes. BIM has been and is developing. It just links the development of digitalization to processes.
ICE meetings and concurrent engineering have existed for a long time. It just seems like Stanford has taken this and commercialized it. One of Martin Fischer's presentations about VDC in Oslo a few years ago was very sales oriented, only positive sides. Unrealistic.

Anything else you want to add?

-Yes, it might be that the same thing that is preventing maintenance in BIM in construction is the same for road maintenance, the developers are not requiring it.

8.4.14 Interview 17.04.2018

University lecturer at the University of Agder, John Skaar. (former contractor, client and consultant)

How do you define VDC?

-Stanford definition. Other than the Stanford definition I would define it as; general needs on how to structure and plan towards digitalization. BIM changes the traditional processes.

What kind of contract types do you think support the use of VDC?

-All contracts could use VDC, one usually adds an extra part to the contract. There is a trend using partnering contracts (Samspillskontrakter), or involved planning. Norwegian partnering contracts are very different from IPD contracts.
-OPS (Offentlig privat samarbeid) contracts give more incentives to improve work and focus on maintenance.

What are the difficulties of VDC?

- It is only used a little bit here and there and is according to IGLC(International Group for Lean Construction) it is very conceptualized. The will to share and make it into a product is a bit

problematic. VDC is one of many possible solutions to an improved construction industry. It needs to be adapted to the situation and it is a bit dangerous when clients start asking for an exact system, cause if some have good experiences with Lean Project Delivery and Have used ICE in addition to it, it can in some situations give better results.

What are the largest problems/obstacles that occur during projects normally?

-The understanding of digital programs. Usually, the training is not good enough and handbooks are outdated fast.

-The design planning has not reached the same level of development as BIM.

-The coordination of workers is a challenge, to get the right order. In design, the level of development is different within the participants.

-The availability of the model is another challenge.

-There is a lot of conflicting interest and one usually has to take some unpopular decisions in some situations.

-There are a lot of iterations (rework) because of surprises.

-Finding solutions during the design planning stage.

How much do you think one would you save by solving this?

-A pilot project in SKANSKA showed that the use of ICE increased flow and reduced latency, compared to a traditional way of holding meetings. ICE meetings gave clearer goals.

Do you have any idea of how VDC could improve these problems?

-I think that one should plan before meetings, like in ICE, but there should be even more planning than what is done in VDC projects today.

-The main strength of VDC is the time aspect, one creates a better flow and reduces latency. One avoids misunderstandings and it is clear what people have done or what they haven't done throughout the project.

Do you have any ideas about VDC in road maintenance?

-The most professional would be to include management, operation and maintenance (FDV=MOM) and the client in meetings to get their opinions and do the work at the same time. Most contracts in the construction business require the MOM plan before the final settlement or before the contractor leaves the building site. The industry(client) still often want information both on paper and digital versions. There are no standard quality requirements for this

information, and often lower quality is handed in. It is normal that the paper version gives too little information, while the digital gives too much. The task is to give the customer something that they can use well and maintenance people are too little in the planning phase.
-One should get more input from the people working in road maintenance, a more bottom-up process.

Do you have any criticism towards VDC?

-There might be some bad development because of the competition when it comes to VDC. Too many words and expressions and many ways to solve problems. They should not introduce many new terms and concepts, but challenge the ones that already exist
-There is a use of many English terms, and that is understandable because they want to make a product, but completely unnecessary to make two different terms for the same thing. They should rather work towards making VDC and the existing frameworks more user-friendly.
-The result depends too much on the project manager and the situation.
-It is too conceptualized and has become too much business. And the fact that it is a university that sells this, is not accepted by many.
-There are some logical shortcomings with VDC that are not challenged. Stanford should be more open to discuss it and open it to the world of science. Specifically IGLC, which is the leading network for Lean Construction. It is possible that there is going to be too many networks if this competition keeps ongoing at the same rate. IGLC works very well as of today.
-VDC uses a lot of concepts that already exist, but has made a system out of them.
-Everything is not told by Stanford, they keep some parts secret. Lack of transparency.
-There should be more openness when it comes to VDC, just because one takes the certification, it does not mean that one supports the framework or are good at performing it Some have the tendencies to set VDC on the same level as Lean Construction, and that is a misunderstanding. VDC is an answer for Lean Constructions principles and is, therefore, a conceptualization or framework that facilitate the use of it.