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MASTER THESIS

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Virtual Design and Construction (VDC) in project management	01/05/2022
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IN COLLABORATION WITH	CONTACT PERSON

SUMMARY / SYNOPSIS

Architectural, Engineering, and Construction practitioners are motivated to adopt new methods, such as Virtual Design and Construction (VDC) models. Kunz and Fischer define virtual design and construction (VDC) as follows: "The use of integrated multi-disciplinary performance model and design-construction projects to support explicit and public business objectives." Therefore, there is significant potential to increase the value of the project by using digital models integrated with the proper organizational structure and. The VDC model is used to simulate the complexity of construction projects, identify potential misunderstandings within the project team, and analyze risks before they occur. VDC and Lean construction are also closely linked. A lean construction approach is a production management system that concentrates on delivering value as quickly as possible. This thesis aims to understand how the VDC framework has affected the role of the construction project manager over the last five years and how the role can be further developed thru digitalization. To gain knowledge of how the use of the VDC framework has impacted the project manager's role and what challenges they face. The following three research questions have been formulated to assist in addressing the problem in order to achieve the purpose of your thesis: 1) What changes in the digitalization of project manager work have occurred over the last 5 years? 2) What challenges do construction project managers face when using the VDC framework? 3)How will the client organization benefit when the VDC framework is applied in PM work in the construction project?

The choice of qualitative research methods corresponds to the choice of an intensive research design. Since one are dealing with a new topic and it has not been extensively studied before, a quantitative method is challenging. The research is based on a triangulation of methodologies, including a literature review, interviews, and document analysis, in order to enhance validity and reliability. An important part of this research is the interviews, as they provide a deeper understanding of the topic which is crucial to its success. Qualitative methods differ more from quantitative methods in the sense that they are based more on subjective interpretation.

KEYWORDS
Virtual Design and Construction (VDC)
Project management
Client organization

Innholdsfortegnelse

Figure list

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Abstract

Architectural, Engineering, and Construction practitioners are motivated to adopt new methods, such as Virtual Design and Construction (VDC) models. Kunz and Fischer define virtual design and construction (VDC) as follows: "The use of integrated multi-disciplinary performance model and design-construction projects to support explicit and public business objectives." Therefore, there is significant potential to increase the value of the project by using digital models integrated with the proper organizational structure and. The VDC model is used to simulate the complexity of construction projects, identify potential misunderstandings within the project team, and analyze risks before they occur. VDC and Lean construction are also closely linked. A lean construction approach is a production management system that concentrates on delivering value as quickly as possible.

This thesis aims to understand how the VDC framework has affected the role of the construction project manager over the last five years and how the role can be further developed thru digitalization. To gain knowledge of how the use of the VDC framework has impacted the project manager's role and what challenges they face. The research question for the thesis is:

How has the VDC framework impacted the role of construction project managers in the Norwegian construction industry over the past five years?

The following three research questions have been formulated to assist in addressing the problem in order to achieve the purpose of your thesis:

- What changes in the digitalization of project manager work have occurred over the last 5 years?
- What challenges do construction project managers face when using the VDC framework?
- How will the client organization benefit when the VDC framework is applied in PM work in the construction project?

The choice of qualitative research methods corresponds to the choice of an intensive research design. Since one are dealing with a new topic and it has not been extensively studied before, a quantitative method is challenging. The research is based on a triangulation of methodologies, including a literature review, interviews, and document analysis, in order to enhance validity and reliability. An important part of this research is the interviews, as they provide a deeper understanding of the topic which is crucial to its success. Qualitative methods differ more from quantitative methods in the sense that they are based more on subjective interpretation.

VDC consists of three main elements: Integrated Concurrent Engineering (ICE), Building Information Modeling (BIM), and Product, Organization, and Process (POP) - models and metrics. In order to achieve success with VDC, it is important to use all of the main elements to their maximum effect. In addition, VDC is a dynamic framework that should be used when appropriate. A solid theoretical foundation and expertise are required to successfully apply the concept. By doing so, projects will be better able to tailor the framework to their specific circumstances. To successfully implement the concept in the future, VDC certified key people are crucial.

The concept of ICE meetings is one where relevant actors co-locate in an iRoom over a limited period of time and work together on projects together regularly. Literature has shown that co-located design meetings can have a positive effect on the success of a project. The meetings are attended by all relevant decision-makers, which facilitates the exchange of information among the various parties involved. In general, the interviewees were of the opinion that it would be beneficial to meet together and design and plan thoughtfully. This type of design is particularly useful for large, complex projects. A number of the interviewees emphasized that such interaction meetings would facilitate a more effective decision-

making process allowing problems to be resolved more quickly. During the ICE meetings, they can prepare BIM models and plans together as well as to conduct small meetings and special meetings where the relevant subjects gather when clarification is needed.

In VDC, one of the most important steps is to measure the design process together with the PPM. PPM refers to the application of operations management to the delivery of capital projects. Using PPM, a project is viewed as a production system, where inputs such as raw materials, information, labor, and machines are transformed into outputs, including goods and services. PPM allows participants to see how improvements can be made to the design process to improve efficiency. These measurements are useful for monitoring progress and motivating the design team to maintain a high level of performance. In collaboration meetings, such as iRoom, PPM can be measured in a variety of ways to help designers stay on top of their game.

VDC is a framework that gives project managers and the client organization a real-time idea of the resources, tools, and other costs that will be required to accomplish any task. Leadership can foresee problems before breaking ground on their projects, and they have a better idea of which resources are needed. VDC models can include specialized areas in their simulations so that team members can gain a deeper understanding of ideas and receive the updated information.The implementation of VDC in the concrete industry will result in an increase in collaboration between all stakeholders, resulting in numerous benefits for the industry. In addition, increased coordination will prevent injury accidents, project stalls, and schedule delays. The level of transparency that can be achieved with a project can be highly beneficial throughout the project's various phases, especially during the design and construction phases.

There is still a lot of confusion about what is meant by the term VDC . It is still difficult to agree on a single understanding of this phrase. The VDC methodology and tools are derived from other research environments, such as the aerospace industry, and from other concepts in the construction industry, such as Lean Construction. CIFE does not aim at creating a method that is universal and has a set of tools for its use. Instead, it encourages a step-by-step implementation with individual adaptations.

With VDC, teams can create convincing 3D and fully utilized BIM models of construction projects, along with the necessary costing and scheduling information. VDC also enables construction companies to demonstrate their expertise and accurately plan the project. With VDC, teams can create convincing 3D and fully utilized BIM models of construction projects, along with the necessary costing and scheduling information. VDC is able to provide construction companies with a better understanding of the quantity and cost associated with completing a project. Also, it facilitates greater communication and collaboration, which will help reduce the likelihood of duplicate work and prevent costly rework in the future. VDC's positive effects can be clearly seen on the job site as soon as the project gets underway. A VDC approach uses a comprehensive planning approach to keep the project on schedule, and the design team can use the virtual model to detect and address safety concerns and communicate those risks to the workers.

According to the overall impression that the author got from the interview, VDC is a new framework and is seen as something positive and important for the future success of the construction industry. According to a large number of respondents, the role of VDC managers will grow in importance in the future.

Acknowledgement

This master thesis was conducted in the Department of Structural Engineering and Building Technology of Oslo-metropolitan University (Oslomet). The master thesis is written in the 4th semester and is a concluding assignment that is credited 30 ECTS. This thesis presents my work on understanding how the VDC framework has affected the role of the construction project manager and how the role can be further developed thru digitalization.

I would like to thank my supervisor from Oslomet, professor Allan Tadayon for the helpful guidance through this master thesis. He has provided me with incredible insightful and knowledgeable input. Allan Tadayon has motivated me to push myself further in the work, and it has been a joy to work with such a dedicated and experienced supervisor.

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Oslo, Juni 2022

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Laila Johnsen

Chapter 1. Introduction

This chapter describes the background of the topic. It also presents the objectives and research questions of the study. Additionally, the limitations of the study are discussed.

1.1 Background for selection of assignment

1.1.1 Theoretical background

The construction industry is accused of being inefficient, having relatively low-profit margins, and posing quality-related problems compared to other manufacturing industries. The increasingly complex and time-consuming nature of construction projects, the variability of their quality, and the high cost of their development are causing them to be even more complicated. In addition, the slow adoption of new technologies in construction has led to a lack of improvements in comparison to other industries[1]. When comparing the productivity index of the construction industry with that of all non-farm industries in the United States, it shows a steady decline since 1964[1]. Since the year 2000, Norwegian construction productivity has decreased by 10%. As a result of this problem, several methodologies have been developed to address the issue[2].

Project Management (PM) has been very helpful in delivering construction projects on time, within budget, and to the highest quality standards since it was introduced to the industry. At the same time, the PM has also been criticized for its widespread problems, such as delays in delivery, rising project costs, substandard performance, and uncashed welfare benefits for its community, among others. Therefore, a rethinking of PM has taken place, which examines how the construction industry can better leverage Project Management theory or practice[3].

According to some economists, researchers, and industry observers, technology rarely changes in the construction industry. Unlike other industries, the construction industry has not embraced assembly lines and robotics to the same extent. However, construction methods, machinery, and techniques have significantly advanced. One way to evaluate technological advancements is by looking at the amount of money spent on research and development R&D, and as a sector, construction lags behind its counterparts. Estimates indicate that the construction, building, and housing industry invests less than 0.5% of its sales in research and development when the national average is approximately 3%[4]. This trend, however, has started to change in recent years. A growing need for more efficient and cost-effective project delivery has led to the development of new methods of delivering projects, many of which make use of automation or integration technology.

Architectural, Engineering, and Construction (AEC) practitioners are motivated to adopt new methods, such as Virtual Design and Construction (VDC) models, to overcome several significant challenges. The use of VDC models has increased dramatically over time, changing how the industry designs, builds, operates, and maintains buildings and infrastructure as a whole[5]. Kunz and Fischer define virtual design and construction (VDC) as follows: "The use of integrated multi-disciplinary performance model and design-construction projects to support explicit and public business objectives." Therefore, there is significant potential to increase the value of the project by using digital models integrated with the proper organizational structure

and processes[6]. The VDC model is used to simulate the complexity of construction projects, identify potential misunderstandings within the project team, and analyze risks before they occur. A crucial element of VDC is building information modeling (BIM). VDC and Lean construction are also closely linked. A lean construction approach is a production management system that concentrates on delivering value as quickly as possible. The aim is to maximize value while minimizing waste and to pursue perfection for the benefit of all stakeholders in the process[7].

1.2 Author's motivation

Part of the reason for choosing this thesis is that the authors will start working as project managers for a client company. Building, construction, and real estate (BAE) industry professionals have experienced that there are many opportunities for improvement, as well as the waste of resources and time. Using VDC can help you carry out projects smoothly, get a good flow, save time, and get them done in a timely manner. Nonetheless, without a project manager in place, there is little chance there will be any savings in time, money, and resources.

A project manager is responsible for, among other things, selecting appropriate methods to be used by the team members in order to deliver a product on time and according to specification. During the last year, VDC has been taken seriously by client organizations, and they are contributing more than the contractors. According to a report by the Association of Independent Contractors for the UK Construction Industry, clients will become more active and forward-looking partners in construction. The report states that this will result in more transparent collaboration, greater clarity on tasks, and more comprehensive digital competencies in both project planning and implementation. Despite increasing awareness, there are many different interpretations of what VDC is and is not today. People are still in the transitional phase and trying to figure out how to benefit from VDC fully. NTNU has developed in collaboration with the Stanford Center for Professional Development at Stanford University. This program is designed to teach people about the principles of the VDC model and how they can apply them to their work. It provides the primary source of VDC knowledge in Norway.

1.3 Background

This thesis aims to understand how the VDC framework has affected the role of the construction project manager over the last five years and how the role can be further developed thru digitalization. To gain knowledge of how the use of the VDC framework has impacted the project manager's role and what challenges they face. The research question for the thesis is:

How has the VDC framework impacted the role of construction project managers in the Norwegian construction industry over the past five years?
The following three research questions have been formulated to assist in addressing the problem in order to achieve the purpose of your thesis:

- What changes in the digitalization of project manager work have occurred over the last 5 years?
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- How will the client organization benefit when the VDC framework is applied in PM work in the construction project?

1.4 Scope and Limitations

The master's thesis was written in the spring of 2022 at Oslomet - the metropolitan university, formerly Oslo and Akershus University College. The master's thesis is worth 30 credits and was completed within 21 weeks. Due to the time limit, a number of decisions have been made regarding scope and delimitations. It was decided to use a qualitative approach to study the topic. The data was gathered through semistructured interviews and a literature review.

As a result of this thesis, less emphasis has been placed on the VDC framework than on the implementation of VDC in the project managers' work. The greatest influence on the implementation process has been the association with VDC, so one must gain a full understanding of VDC at this early stage. Throughout the thesis, the researcher sheds light on which elements make up the framework and what its working methods are, but it does not go into depth about how it is implemented.

1.5 Outline

The design of the master's thesis is outlined in this chapter. The following table illustrates the structure of the thesis and provides a brief summary of each chapter within it.

CHAPTER	DESCRIPTION
INTRODUCTION	Chapter 1 is to introduce the concept of VDC and provide a general overview of its background. This chapter will also describe this thesis' aim and research question.
METHODOLOGY	Chapter 2 provides an analysis of how the author has gone about answering the primarily purpose and the corresponding research questions. In addition, the research methods are analyzed in terms of quality and credibility. The methods used are literature study, document study and external interviews.
LITERATURE STUDY	Chapter 3 present the findings of the literature study. By providing an overview of current knowledge, the review helps identify relevant theories, methods, and gaps in the research.
THEORETICAL FRAMEWORK	Chapter 4 purpose is to introduce the theoretical framework for this study to ensure that all relevant topics are covered. The following topics are presented in this chapter:
FINDINGS	Chapter 5, the findings from the empirical data are discussed in relation to the literature already available, as mentioned in Chapter 3 (literature study) and chapter 4 (theoretical framework). Discussion contains the author's personal opinions and views, as well as corresponding contexts, moments, and elements that relate to the study's purpose.
DISCUSSION	Chapter 6 present the final conclusion and is the last Chapter, where a final line is drawn and the major findings are presented.
CONCLUSION	Chapter7, here the readers will find a summary of and a presentation of the conclusions in light of the three research questions in the form of a brief description of the research questions and thus also the purpose of the thesis

Table 1 Structure of the thesis

Chapter 2: Methodology

The methods used in the study are presented in this chapter. There is a method of obtaining quantitative data that is described and justified as a means of answering the research questions. There is a discussion of the validity and reliability of the method of analysis, as well as considerations related to ethics and the selection of respondents.

2.1 Research Methodology

2.1.1 Qualitative and quantitative methods

According to Busch (2013), qualitative and quantitative research methods are different, and whether to choose a qualitative or quantitative method depends on whether the research is extensive or intensive. A combination of qualitative and quantitative methods is also an option. By using both methods, the researcher will be able to exploit the advantages of both, but on the other hand, this approach will take considerably more time to complete. No matter what approach is taken, the research purpose and the research questions should dictate the method used[8].

Quantitative research is defined as "the numerical representation and manipulation of observations for the purpose of describing and explaining the phenomena that those observations describe", and it is used in a wide range of natural and social sciences, including physics, biology, psychology, sociology, and geology[9]. Extensive research designs are often based on quantitative methods. In quantitative designs, it is easier to handle a huge amount of data. However, to perform advanced analysis, clearly defined limits must be imposed, in some cases at the expense of the quality of the research. On the other hand, a qualitative design makes it easier to investigate a complex problem, but results can be challenging to generalize[10].

Qualitative research is defined as "the study of the nature of phenomena," including "their quality, different manifestations, the context in which they appear or the perspectives from which they can be perceived," but excluding "their range, frequency and place in an objectively determined chain of cause and effect" [11]. In addition to this formal definition, qualitative research generally produces words rather than numbers as data. The use of this method is often combined with an intensive research design since qualitative research is characterized by flexibility, openness, and responsiveness to context. Unlike quantitative research, qualitative research does not have separate and consecutive steps for collecting and analyzing data[8]. Researchers can make informed decisions when choosing methods, their implementation, and the number and type of units to be used in their research. Data collection and analysis can result in the original plan being revised and expanded based on new insights and experiences. It is essential for reasons of transparency that all decisions and their reasoning are well-documented. Several methods are used to collect data in qualitative research, such as document review, observations, semistructured interviews, focus groups, etc[10].

Quantitative research	Qualitative Research
Focuses on testing theories and hypotheses	Focuses on exploring ideas and formulating a theory or hypothesis
Analyzed through math and statistical analysis	Analyzed by summarizing, categorizing, and interpreting
Mainly expressed in numbers, graphs, and tables	Mainly expressed in words
Requires many respondents	Requires few respondents
Closed (multiple choice) questions	Open-ended questions
Key terms: testing, measurement, objectivity, replicability	Key terms: understanding, context, compl

Table 2 Qualitative vs. quantitative research [12]

2.1.2 Triangulation

Generally, the concept of triangulation refers to using and combining several different methodologies with studying the same phenomenon. When the use of multiple method were introduced in the social sciences, it was seen as a bridge between quantitative and qualitative research. This strategy was conceived as a way to help qualitative researchers become more rigorous. It is argued that mixed methods researchers can answer questions that may not be possible to answer using other methodologies alone. Additionally, it allows more diverse views to be incorporated into the findings[13]. There are three possible outcomes when quantitative and qualitative methods are combined in response to a specific research question [14]:

1. The results may converge and produce the same conclusion
2. The results can be related to different phenomena or objects but can be complementary and used to complement each other.
3. The results may differ or be contradictory.

The purpose of triangulation is to examine the subject from several angles, which will increase the validity and reliability of the research in the long run. Methods that are often combined include surveys, case studies, literature reviews, document reviews, interviews, and observations.

2.1.3 Validity, Reliability, and Generalizability

The quality of the results will be influenced by all of the methods that are utilized during the research. Research quality and trustworthiness are determined by the validity, reliability, and generalizability of the results. It is important that research be both valid and reliable.

Validity in qualitative research means "appropriateness" of the tools, processes, and data. Validity can be assessed by considering the ontology and epistemology of the issue being examined, for instance, the concept of "individual" is perceived differently by positive psychologists and humanistic psychologists due to varying philosophical perspectives. In order for a methodology to be valid, the choice of methodology must be able to detect findings or phenomena in the appropriate context. Sampling procedures and methods must be

distinctive between systematic, purposful, and theoretical (adaptive) sampling. The systematic sampling has no a priori theory, whereas purposeful sampling often has a purpose or a framework, and theoretical sampling is shaped by the ongoing process of data collection and theory in evolution[15].

Reliability in quantitative research is generally defined as the reproducibility of processes and results. These definitions of reliability can be challenging and counterintuitive in qualitative research with a variety of paradigms. In qualitative research, results can be tolerated to a degree if the methodology and logistics consistently produce data that bear similar ontological characteristics but differ in terms of richness and ambience within similar dimensions[15].

The generalizability of a study is measured by its ability to apply findings from a sample to the population as a whole. Generalizability and transferability of research are both interrelated characteristics of research. It means that the findings of one study can be applied to another similar situation. The larger the sample size, the better one can generalize the findings[16].

2.2 Choice of method

The choice of qualitative research methods corresponds to the choice of an intensive research design (Busch, 2013). Since you are dealing with a new topic and it has not been extensively studied before, a quantitative method is challenging. The research is based on a triangulation of methodologies, including a literature review, interviews, and document analysis, in order to enhance validity and reliability. An important part of this research is the interviews, as they provide a deeper understanding of the topic which is crucial to its success. Qualitative methods differ more from quantitative methods in the sense that they are based more on subjective interpretation.

1. Literature studies to identify relevant and qualified literature in the field and as a basis for discussing qualitative data analysis.
2. Interviews with Norwegian construction managers to solicit their opinions and experiences regarding VDC in the Norwegian construction industry are then discussed to answer the research question.
3. Document studies give the undersigned access to information that is best communicated in writing and reduce the research participants' burden.

2.2.1 Literature Review

This brief review of the literature provides an overview of the research on whether faculty workload obligations impact faculty job satisfaction and retention in higher education. The literature review primarily focuses on peer-reviewed articles and studies related to higher education. Literature reviews were conducted to understand relevant topics directly related VDC framework. In addition to published reports and online sources, additional references on direct instruction were identified.

2.2.1.1 Identification and collection of literature

Before starting the literature search and identifying the relevant studies, we need to determine the correct keywords and terminology that describe our topic. This was done by first identifying the three primary keywords and then combining them whit all the necessary synonyms or similar phrases that might also be used to describe these concepts. Table (2) below contains all the selected keywords that focus on the main concepts of this review. These keywords are then combined by using Boolean operations such as "AND" and "OR" to generate and develop the search string. The use of the '*' symbol helped to search all variants of a related word, and the keywords were searched within the title, keywords, and abstracts of the papers by using "TITLE-ABS-KEY" at the beginning of the search. Highly relevant research can be found more easily using this search approach among the massive and sometimes overwhelming number of papers available in the databases.

Keywords	Synonyms or similar phrases
VDC-Framework	("Virtual design and construction " OR "vdc framework")
Construction	("construction*" OR "civil*" OR "AEC industry" OR "building information modelling" OR "BIM")
Project Management	("Project Management" OR "Construction management")

Table 3 Keywords and Synonyms or similar phrases

Databases and search engines

Oria is a Norwegian-developed and Norwegian-owned service for digital searches in databases belonging to Norwegian libraries and academic institutions. The tool can be used by anyone who has access to the Internet. However, there is a login module that is only available to BIBSYS employees or institutions who have been given access. Searching the databases of affiliated libraries is made easier by the use of Oria, which provides access to books, published articles, films, music recordings, notes, and other items stored in their databases. This trustworthy Norwegian database also provides access to other databases that ORIA can access.

Scopus is a research journal database that provides summaries and references to articles in academic journals. A Scopus search includes scientific websites via Scirus, another product from Elsevier, as well as patent databases. The Scopus database contains articles from STM journals and the references used to support those articles, allowing the searcher to go back in time as well as forward. Both researchers and collection developers can make use of the database. In addition, Scopus includes comprehensive information about the scientific authors, such as citations, their citation data, references they have used in their work, and the number of times their articles have been cited in other publications[17].

Engineering Village is an online search and discovery tool that makes it easy for engineers to find high-quality information, data, and expertise to answer their real-world questions. With Engineering Village, engineers can perform impactful research efficiently with filters tailored to their needs[18].

In searching for literature, various search engines and search techniques have been used to map literature in the field and to find relevant literature and credible, accurate, and valuable sources. All publications have been assessed according to equal criteria. There are two parts to the assessment process. In the first step, the results were obtained by completing a preliminary review based on the titles of the articles, the abstract, and their keywords in order to eliminate irrelevant articles and ensure that the literature sample was relevant. The next step was to verify the source's credibility by asking a set of questions, more in the nesxt chapter. As a consequence of this process, a total of 12 studies were excluded and ended up with xx studies that were selected. Table x contains an overview of the search strategy.

	Search string	Oria	Scopus	Engineering Village
1	("Virtual design and construction " OR "vdc framework") AND ("construction*" OR "site*" OR "civil*" OR "AEC industry" OR "building information modelling") AND ("Project Management" OR "Construction management" OR "Management")	500	700	113
2	TITLE-ABS-KEY ("Virtual design and construction " OR "vdc framework") AND ("construction*" OR "site*" OR "civil*" OR "AEC industry" OR "building information modelling") AND ("Project Management" OR "Construction management" OR "Management")	56	68	89[1]
3	Limiting the type of literature to Journals and Books	44	27	41
4	limiting the search to a period between 2010 and 2021 and the English language	41	27	40
7	Remove duplicate papers by using Endnote	0[2]	27	40

[1]The Boolean operators search terms "TITLE-ABS-KEY" is changed to subject/title/abstract in Engineering Village
[2]All the article in Oria war found in the other databases.

Table 4 Search strategy

2.2.1.2 Data analysis

After the search process is complete and a substantial amount of literature has been obtained on the topic, it is essential to evaluate the information and evaluate the sources used critically. Internet sites can provide a lot of valuable information, but they can also contain much misinformation and be places where anyone can publish literature without being evaluated by a professional. Even though the library's books and websites have been assessed and are quality assured, one should still be critical of their contents.

When it comes to critically evaluating literature, many different criteria can be utilized. There is no doubt that publications such as journals, books, and government reports have a much higher reputation than websites, for example. Another example is the number of citations. A high number indicates that a source is well-known. However, in this case, a low number of citations does not necessarily mean that the literature is poor. In other cases, sources may be well-cited, but the literature may be outdated, which means it is no longer relevant. The theme of the thesis is relatively new. The number of citations does not necessarily represent a good indicator, however, if the source has many citations, it can be an encouraging sign.

There were some doubts regarding the relevance of some of the sources that were used in this thesis, which led the authors to evaluate them in the form by asking a series of questions (Research Guides, n.d.). The following questions in Table 1 are quite helpful, as they can be used to help determine the relevance of a source[19].

Criteria	Look for
Authority	Who created the information? What are the author's credentials or affiliations? What is their knowledge, experience, or expertise on the topic?
Accuracy	How accurate is the information? Has the information been reviewed by others? Are there spelling mistakes or grammatical errors? Does the author use any references or citations to support the claims? Are the claims factual or subjective?
Argument	What are the author's claims? How does the author justify their position? Is there any flaw in the logic used by the author?
Self-Awareness	Ensure you are seeking information that represents alternative perspectives and worldviews. Ensure you're not favoring sources that only confirm your current belief system (avoid confirmation bias). Get uncomfortable. Read from sources across the spectrum
Relevance	Does the source satisfy your information need? Does the information relate to your topic? Does it help you better understand it? Does the depth and level of the information fit your assignment?
Timeliness	How current is the information? When was the information created, published or updated? Is it recent enough to be relevant to your topic or discipline?

Table 5 How to Evaluate Information Sources: Critical Questions for Evaluating Your Sources [19]

2.2.2 Interviews

A total of 8/nine semistructured interviews were conducted with six/seven project managers. Interviewees are employed at leading consultant organizations and contractors, working on different building and infrastructure projects. Department directors who are certified within VDC were also interviewed, as they are also a critical part of implementing VDC framework in the early stages of development. The interviews were recorded, transcribed, and analyzed in

accordance with the Handbook of interview research, Context, and method[20]. All interviews were conducted in Teams except one.

Interview object no.	Position	Company
1	Department director	Statsbygg
2	Project manager	Statsbygg
3		
4	Project manager	Statsbygg
5	Senior engineer	Statsbygg
6	Project manager	Statsbygg
7	Project manager	Bane Nor
8	Project manager	Bane Nor

2.2.2.1 Structure of interviews

According to Roller and Lavrakas (2015), there are three basic interview designs: structured, semistructured, and unstructured. The interviews were conducted as semistructured in-depth interviews and were operated individually. This technique allowed the interviewer to ask follow-up questions[21].

Semistructured interviews allow all participants to be asked the same questions within a flexible framework. During the interview, all participants were given the same set of questions. However, there was no predetermined order in which the questions were asked. The order of questions in the interview was determined by how participants responded to open-ended questions about their personal experiences during the interview. The open nature of the questions aimed to encourage depth and vitality and to allow new concepts to emerge. Details were obtained by asking for examples. Including various explanations and analyses in the data can enhance the validity of a study[22].

The interviews were all conducted using a prepared interview guide, which is available in appendix x and can be viewed for more information. The guide was developed in collaboration with supervisors through brainstorming questions related to the research questions in autumn 2022. To conduct the interview, the research question was broken down into three main questions, along with a series of more detailed follow-up questions that were used to develop the interview guide. Follow-up questions are aimed at creating a deeper understanding of how the VDC framework will influence project manager work, its challenges, and the client's benefits of using it in construction project PM work. Primarily as a checklist to ensure the most relevant aspects of the interview were addressed.

According to Rubin and Rubin (2011), a good interview structure will elicit depth, detail, vividness, nuance, and richness through a combination of three kinds of questions: main, follow-up, and probes[23].

> The main questions are what gives structure to the interview, they make up its skeleton. The main questions entail thoroughly examining each part of the topic and ensuring that

the research problem is thoroughly investigated. Instead of simply giving a normative answer, company line, or textbook-type answer, participants are encouraged to describe their experiences, perceptions, and understandings. It is recommended that an interviewer prepare a limited number of main questions. Having too many questions prepared can result in the interviewer only asking all of them instead of encouraging the participant to elaborate on their response. If the interviewer rushes through a dozen questions, he or she may not gain sufficient knowledge on any of them. In the event they have too few questions, and one question is inappropriate, the interview may not progress[24].

The follow-up questions must be based on the comments that the participants have made. After listening carefully to what the participant has said, the interviewer can asks additional questions to explore the particular themes, concepts, and ideas he or she has presented. It is not possible to follow up on every interesting topic during an interview. The interview would lose its focus, and you would be rushed. A follow-up is likely to be made on matters that are puzzling or unclear or that suggest concepts, themes, or ideas that you did not anticipate[24].

The purpose of probes is to keep a discussion going while clarifying issues. When using probing techniques, more details are elicited without changing the focus of the question. In order for them to be effective, they have to be simple, and short, and the interviewer have to know what to say in light of what the interviewee has said. The wording of the probes is not problematic, with identical questions used in a wide variety of interviews depending on which are most appropriate at the moment. Generally, probes must be simple, short, routine, and make sense based on the context, and must be appropriate[24].

2.2.2.2 The interview guide

A pilot interview was conducted prior to the first interview in spring 2022. A pilot interview was conducted. The pilot interview was conducted with a department manager from Statsbygg. This interview aimed to test the interview guide and ensure that the questions were relevant and easy to understand. Due to the interviewer's familiarity with the department manager from before, the interview flowed more smoothly and provided insight into what works and what doesn't work in the department. The interview guide was modified based on feedback from the pilot interview with the department manager.

All the interviews conducted during the spring of 2022 followed Tjora's approach (2017). Interviews were composed mainly of questions that contributed to the goals of the research, which provided the core of the discussion. The first questions that were asked were easy and contributed to setting the interviewee at ease. Participants were asked to introduce themselves and talk about their experiences before moving on to more challenging questions. Finally, closing questions were asked in order to normalize the situation by refocusing attention from the reflective level. This approach is followed in Appendix x. The interview was conducted for 45 minutes to one hour, depending on the availability of participants as well as their

preparedness to answer questions related to the topic. The length of the interview was deemed to be short, according to Robert K. Yin [25].

2.2.3 Document analysis

Document analysis is often used in combination with other qualitative research methods in order to verify the validity of the findings. In addition to documents, such sources include interviews, participant or non-participant observations, and physical artifacts. It is expected that the qualitative researcher will draw upon multiple (at least two) sources of evidence, aiming to achieve convergence and corroboration by using different data sources and methodologies.

The process of document analysis involves the systematic review of documents, both printed and electronic. In order to perform a document analysis, one has to examine and interpret data,just as other qualitative analytical methods do. Documents contain text (words) and images that have been recorded without a researcher's intervention. Documents are referred to by Atkinson and Coffey as 'social facts,' which are produced, shared, and used in socially organized ways[26].

2.2.3.1 Selection of data source

Document studies are used primarily as a complement to other types of research, making them a good choice to complement literature reviews and interviews. The documents analyzed are all relevant VDC information that will help you gain a deeper understanding of the framework. In this study, the author analyzed the certifications material from CIFE Stanford, relevant authors, the transcripts of the VDC course at NTNU, and the documents shared by each interviewee.

In collaboration with Stanford University, CIFE and PPI have jointly developed a curriculum about Virtual Design and Construction. As a leading academic research center for Virtual Design, CIFE's mission is to be the world's premier educational institution. Professor Martin Fischer is the Institute's Director and has been serving the institute for 16 years. The Stanford VDC Certificate Program has been designed by PPI and CIFE to deliver this content to more than 1,000 industry practitioners. The center focuses on developing information technologies, tools, and methods that can dramatically improve complex projects[27].

- The Stanford CIFE and the Project Production Institute (PPI) offer VDC Course Certificate Program to teach AEC and Facility Management (F.M.) professionals how to use VDC effectively in their projects and businesses. The first program of this kind was offered in collaboration with NTNU between June 2019-May 2020 for 200 professionals in Norway[28].
- The VDC-Certificate Program Norge NTNU - Professor Martin Fischer has developed Stanford from the Center for Professional Development at Stanford and Professor Eilif Hjelseth from the Department of Civil and Environmental Engineering at NTNU. Both of these professors are considered very credible authors of VDC literature[29].

- One of the supervisors recommended a couple of master's theses. These insights helped the author better understand what the VDC framework can offer to the construction industry and how it could be further explored.

2.3 Summary

The figure below summarizes the research method and strategy for the study described in this chapter.

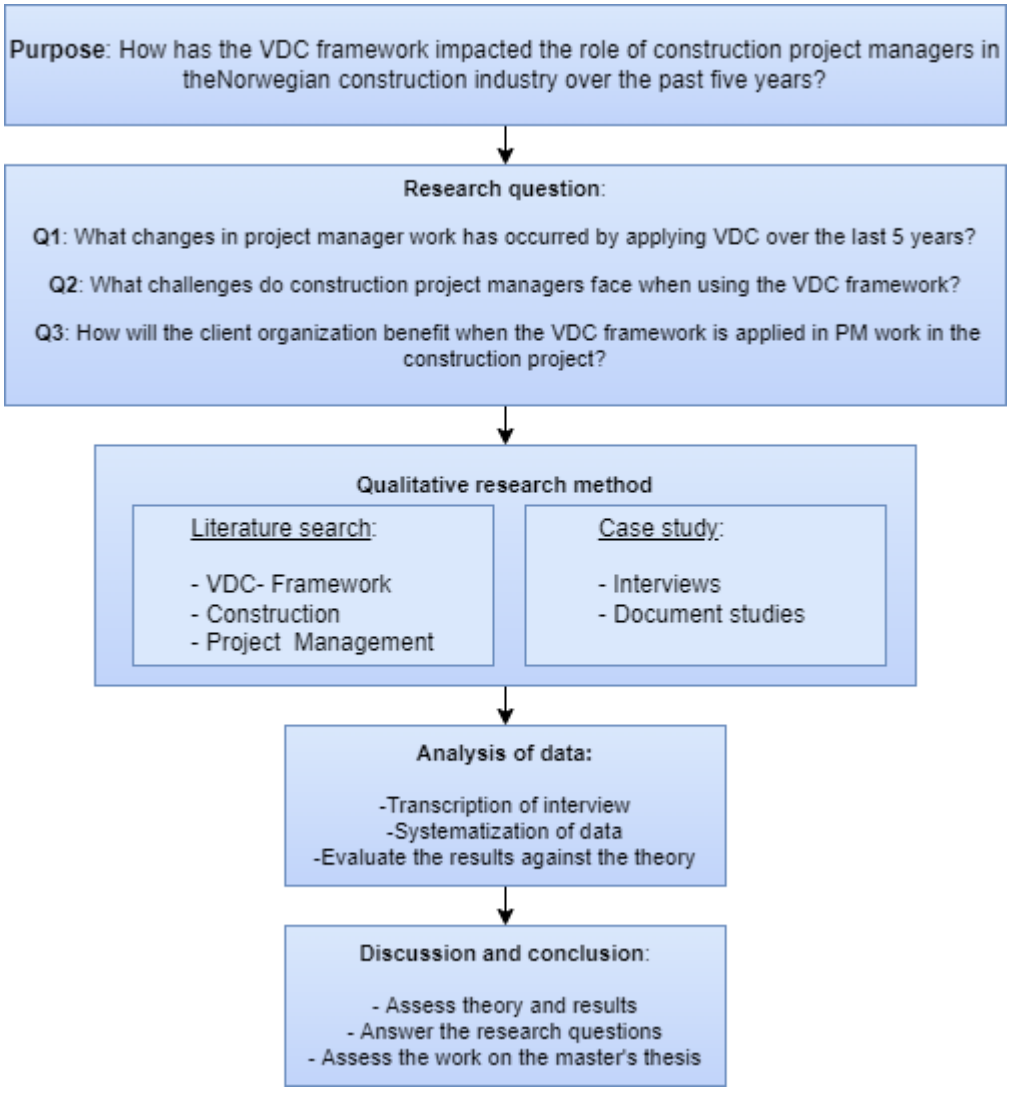

Figure 1 Research method and strategy

Chapter 3: Literature study

The purpose of this chapter is to provide readers with an overview of the existing literature in the field. The goal is to set the groundwork for quantitative research.

3.1 Virtual Design and Construction

3.1.1 Introduksjon til VDC

The Center for Integrated Facility Engineering (CIFE) at Stanford University introduced the term Virtual Design and Construction (VDC) in 2001[1]. Since then, VDC has been researched and developed in several completed projects, both in design and production. The virtual design and construction method involves using and managing multidisciplinary models to support, promote, and implement project goals and success criteria [30]. Kunz and Fischer from CIEF define VDC as "the use of multidisciplinary performance models of design-construction projects, including the Product (i.e., facilities), Work Processes and Organization of the design - construction - operation team in order to support business objectives" [21].

The goal of this framework is to optimize projects by combining time-efficient tools and project procedures, BIM models, and ICE methodology to reach more efficient and shorter management decisions by helping managers better understand the potential difficulties between project team members, analyze risk, and testing solutions in a virtual environment prior to performing any construction in the real world. [2, 5, 31]. For the industry to progress, CIFE believes that an integrated model-based approach based on product, organization, and process (POP) models is what is required to capture and simulate project performance[1]. The term 'product' in this context refers to the building itself, whereas 'organization' refers to the actors who will define, design, produce, and operate the building, and 'process' refers to what the project team follows while working on it. This model allows construction practitioners to develop symbolic models of a building, design organization, and construction processes before making a significant commitment to the client. Hence, this helps design and construction managers describe, evaluate, predict, and make decisions about a project's scope, organization, and schedule using virtual methods[32].

3.2 Main elements of VDC

VDC method is based on four main components: ICE, BIM, POP (Product-Organization-Process) models, and measurements. The four main elements are illustrated in Figure 2. They must all be present in the entire process from the beginning to the end. Furthermore, an explanation follows of how the main elements related to the construction process. According to CIFE, VDC implementation differs from one project to another[33]. VDC processes involve identifying, generating, and certifying the usefulness of information, and identifying the source of the problem is crucial for providing value to the customer[34]. Each of these elements of the VDC indeed relies on technological tools, but their actual use is a social process. The

implementation of VDC can be based on a "plan-do-check-act cycle"[23]. The "Plan" steps are defined as Lean-based production plans. The 'Check' step is designed as a Lean-inspired way to make sure that all work performed in the 'Do' step conforms to the intended specifications. The "Check" step includes measures such as quality conformance of BIMs and installed work, cost conformance with budgets and schedule conformance, as well as planned percent complete (PPC)[34].

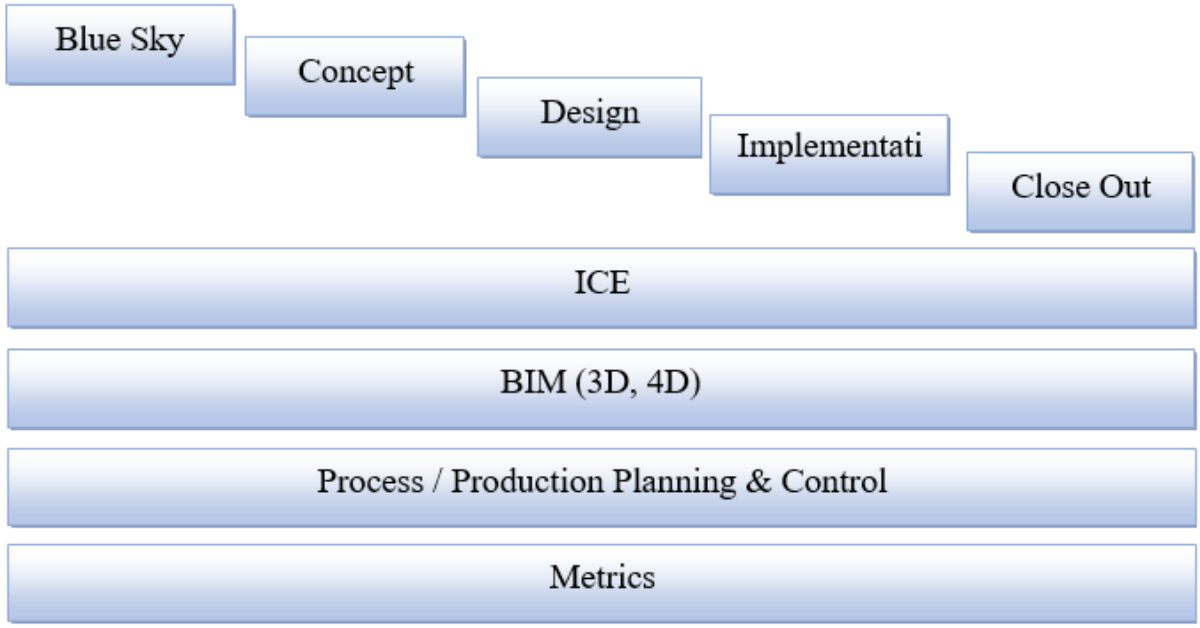

Figure 2 VDC for Reliable Project Execution[35]

3.2.1 POP (Product-Organization-Process)

VDC's Product-Organization-Process framework allows project teams to assess how product, organization, and process changes may affect the overall project. Therefore, the POP model is a tool for planning and controlling processes and products. The model can also help develop the 4D model in BIM[30].

The P, O, and P elements of the POP model all have a defined meaning (or semantics) to the stakeholders. Building elements such as floors, walls, and beams are defined by the Product model, while organizational groups are defined by the Organization model, and activities and milestones are defined by the Process model[33]. The VDC POP models define the function, designed form, and behavior of the project product, organization, and process. Project elements include the product, typically a facility, the organization that designs, builds and operates the facility, and the process that the organization follows as it does its project work. The generic POP models are shown schematically in Figure x below[35].

	Function: Objectives	Form/Scope: Design choices	Behavior: predictions
Product	spaces, elements and systems	Designed spaces, elements and systems	Predicted cost ($)
	Measurable Objectives	Values	Predictions; Assessed values
Organization	Actors	Selected actors	Predicted cost (hours or $)
	Measurable Objectives	Values	Predictions; Assessed values
Process	Tasks	Designed tasks	Predicted cost (days or $)
	Measurable Objectives	Values	Predictions; Assessed values

Figure 3 The POP model in VDC [35]

3.2.2 ICE – Integrated Concurrent Engineering

Integrated Concurrent Engineering (ICE) is an approach that breaks the decades-old practice of working in isolation and convening meetings to discuss progress and problems. With ICE, rapid design can be done with a level of quality similar to or better than traditional methods at a lower cost. This process increases feedback within the design team, speeds up iterations, and reduces wasted time in the design process. The ICE technique combines engineering analysis with team communication and decision-making to improve feedback and reduce wasted effort [36]. The approach uses a unique combination of expert designers, advanced modeling, visualization, analysis, and communication tools to create preliminary designs for complex systems[37].

NASA's Jet Propulsion Laboratory developed Integrated Concurrent Engineering (ICE) in the mid-90s. As a result of fostering an environment of extreme collaboration, Team X was able to improve the speed and quality of space mission planning. For AEC industries, similar setups are referred to as "ICE" and are based on the theory that a team is more efficient than an individual[35]. When it comes to planning large construction projects, ICE plays a critical role in ensuring well-informed decision-making and facilitating project success. The ability to conduct effective meetings is essential to the success of a project. Key success factors are good preplanning, a clear agenda, and objectives, productive environment[38].

The ICE Method

The structure of ICE design sessions is to have all team members simultaneously develop interdependent models and analyses informally coordinated, but with a strong sense of focus. The sessions are similar to traditional meetings in that a facilitator communicates the agenda and monitors the session's progress. On the other hand, ICE involves the participants continually forming and dissolving "sidebar" conversations to share information. In this

context, the physical orientation and movement of the engineers in the room passively communicate the structure of many discussions to all team members. There have also been cases where participants overhear errors and correct them, although the effect of this phenomenon on performance has not been conclusive[37]. The ICE meets in an open forum, where all the actors within the design team are responsible for it. There is no chair for the ICE meeting. One facilitator helps to shape larger or smaller groups and direct the design team's attention toward important issues. The members of the team are chosen based on their technical knowledge, experience, and ability to work independently and effectively[39]. ICE sessions are limited to three or four hours in part due to the psychological demands involved. During an eight-hour ICE Charrette at Stanford, demonstrating Virtual Design and Construction, one participant felt as if he had been run over by a train[23].

The engineers involved in the ICE process are fully dedicated to one specific project during the session. Engineers in the traditional process often work on more than one project at any given time. Historically, traditional projects require more management oversight, and they rely more on technical experts who are not entirely dedicated to the project [39]. Figure 4 provides an illustration of the differences in timing between ICE and traditional processes. This diagram illustrates a Gantt chart with four tasks arranged in increasing parallelism. When pressed to meet tight deadlines, projects often overlap tasks that were once executed sequentially. Scheduling in this way can be costly, difficult, and risky if teams fail to anticipate the complex interactions among product, organization, process, and technology. Although many industries are parallelizing their design work, there have been few trials with ICE. Compared with other engineering methods, ICE offers a major advantage in its accelerated execution, which gathers and executes the most interdependent tasks across the entire organization[37].

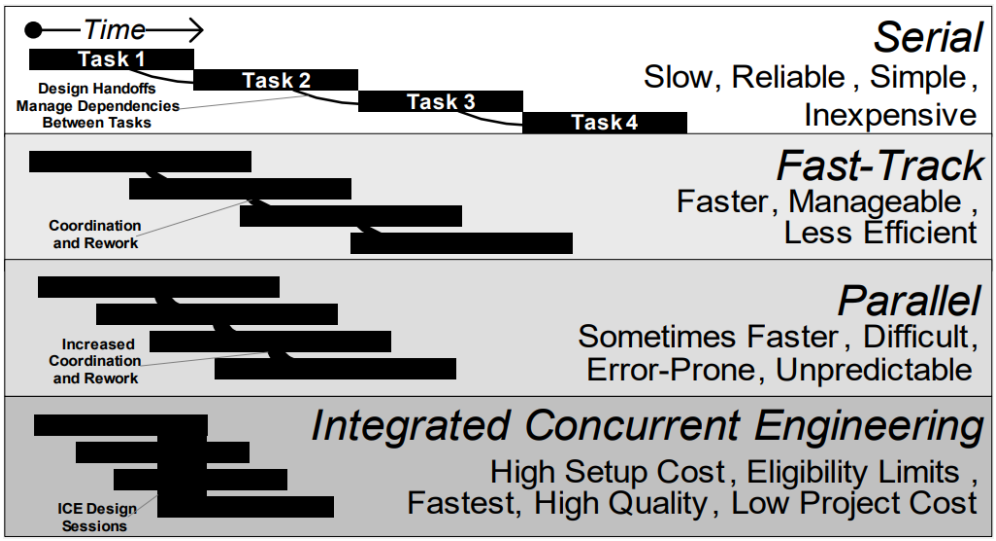

Figure 4 Levels of Parallelism: The ICE approach radically increases parallelism, facilitating effective coordination and reducing waiting and rework

ICE is conducted in sessions, and a key to its successful implementation is that the sessions will be conducted in a iRoom. It is necessary that all relevant decision-makers participate in the meetings. The projects are broken down into manageable tasks for the design team to be able to make quick decisions based on clarity of concept[35]. The iRoom was developed by CIFE and allowed for the integration of data from commonly used engineering applications (such as Microsoft Excel, Microsoft Project, Architectural Desktop, etc.). Users can collaborate quickly and iteratively across multiple stakeholders[1]. iRooms need to be equipped with interactive presentation tools, and P.C.s need to have the necessary software and be linked to an internal I.T. system with a shared database. In this way, all design participants can create their own models and store them on a database utilizing the IFC-based data exchange format[21].

Through ICE, people from different fields can come together to create common solutions to problems. Meetings are conducted in the form of planning meetings, whereby items are discussed in groups or individually. For the remainder of the meeting, everyone gathers to discuss solutions and to review and update the plans. See Table 6 [40].

Description of ICE meeting	**Implementation**	**Participants**	**Frequency**	**Place**	**Goal**
Co-located meetings offer good access to other actors' information to facilitate quick clarifications and decisions Interdisciplinary collaboration	Topics addressed together Work on smartboards A small meeting can be held to solve a problem Independent work	In ICE sessions, all participants who are interested in specific issues should be addressed.	Every week / every 14 days (depending on project size)	iRoom interactive room with smartboards	High-quality project execution with efficiency Reduce the slowness

Table 6 Guidelines for Conducting ICE meetings

3.2.3 BIM

Building Information Modeling (BIM) today is enabling many architectures, engineering, and construction AEC professionals to improve performance. By 2009, more than 80 percent of major AEC firms in the U.S. had adopted (BIM). Throughout the past several years, more and more construction companies have embraced BIM. As a matter of fact, BIM now accounts for nearly three-quarters of the construction industry. Yet, the AEC sector lacks a standardized VDC (or BIM) assessment framework that has comprehensively and continuously captured the VDC implementation for AEC projects [6].

BIM as defined by Eastman et al. (2011) appears to be slightly narrower than VDC, as it focuses on producing a three-dimensional (3-D) intelligent virtual model that represents physical reality, but does not include the process element. On the other hand, VDC seems to focus on an overarching process that includes not only BIM, but also organizational and process modeling tools and collaborative techniques as part of the process[5]. VDC establishes a framework and set of methods for managing the project, including the building and design/construction process, as well as the organizations involved[35]. In terms of the current understanding of this technology, both of these terms could be considered as reflecting the same understanding at the present time[5]. Due to this, the terms VDC and BIM are sometimes used interchangeably, which is not entirely accurate. BIM represents the form and scope of the product, which is essential but is only one piece of the VDC framework. It is important to note that when we refer to VDC, we are referring to the entire framework method (P-O-P), which includes BIM as part of the product definition, illustrated in Figure 5 [34].

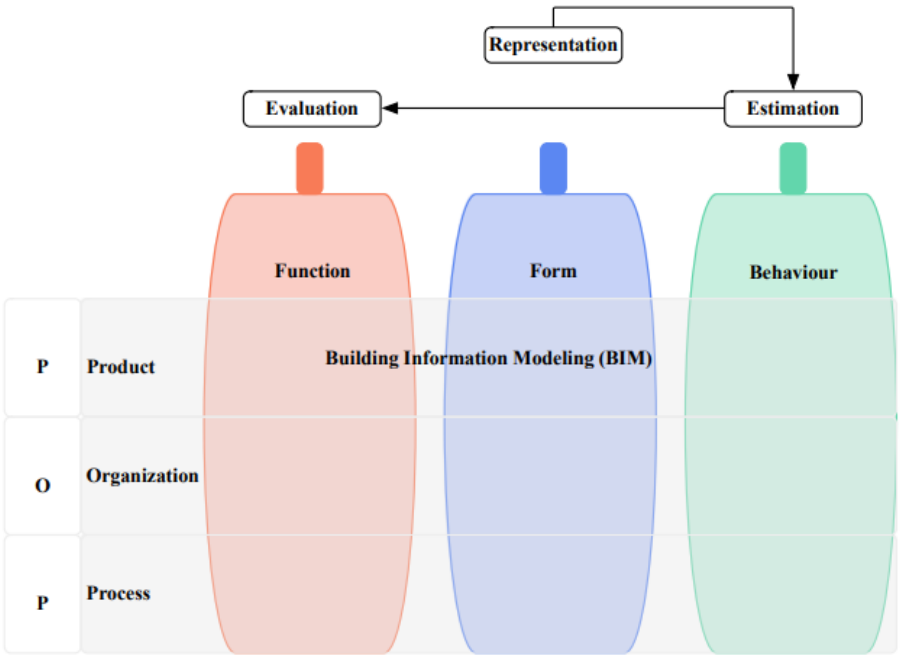

Figure 5 The three components of the P-O-P framework

Today, the term "BIM" means more than just a technology or tool. It represents a brand new approach to addressing the process of building. The inputs of BIM support three-dimensional (3D), four-dimensional (4D), five-dimensional (5D), and six-dimensional (6D) design, where 3D is the object-based parametric modeling and 4D is sequencing, Scheduling, materials, floor, and space and etc. In a 5D design, parts lists and cost estimates are considered, whereas, in a 6D design, facility management, lifecycle costs, and environmental impact are considered. The successful implementation of these concepts depends on software technologies[41]. Research by Kam et al. [42] described five levels of modeling within VDC (Table 7), and found that implementing them all significantly correlates with successful projects. The BIM model

requirements are clarified during the start-up meeting, which leads to a good working relationship and the most efficient utilization of the model[23].

	LEVEL	MODEL USES
1.	**Visualization**: Models are created for visualization purposes (Analysis not required)	Mass model study, 3D rendering, 4D animation, Organizational chart, Scheduling for presentation
2.	**Documentation**: Models are created for documentation with accuracy up to construction tolerance	Design/construction documents, Product/ system specification, 3D laser scanning for an existing condition, Quantity takeoff, RFI, Punchlist
3.	**Model-Based Analysis**: Models are created to support discipline-specific analysis	Spatial validation, Structural analyses, Energy analyses, Thermal comfort, Daylight and interior lighting analyses, Fire & smoke, Life safety/egress, Cost estimating, Acoustics, Security Analyses, GIS, Computational fluid dynamic simulations, Construction safety
4.	**Integrated Analysis**: Models/analyses of multiple stakeholders are interoperated for cross-discipline collaboration	Clash detection, Integrated 4D/5D models, Change order management, Supply Chain Management - RFID, color coded tracking, Facility management
5.	**Automation & Optimization**: Routine analyses or fabrications are automated	Off-site fabrication, Automation of analysis (code check)

Table 7 5 levels for using BIM models within Virtual Design Construction.[43]

3.2.4 Metrics in VDC

The purpose of VDC is to develop a productive workplace where people can maximize their efforts through a smooth working environment. Having the right tools, processes, and people does not matter if one cannot measure the results and how they compare with the client's objectives, therefore VDC uses [31]

VDC maturity model

Fisher and Kunz (2012) found that users implement VDC in three distinct phases, where each has its value and cost-producing strategies. The three phases were described by Fisher and Kunz (2012) as follows:[31]

Visualization and Metrics is the first phase where Project teams create models of their products in 3D, their organizations that perform design, construction, and operations, and the processes they follow to do design, construction, and operations. They use these models called

"performance models" to predict performance metrics for each element. Then, they track the actual performance of each element and compare them to the predictions. An essential requirement for this stage to succeed is that all stakeholder organizations need to be able to interpret the visual models, and for this reason, a strategic investment needs to be made in the methods as well as their implementation is required. In order to facilitate data sharing among multiple parties, it requires multi-party collaboration agreements that allow sharing and ideally incentivize it, which may require adjustments to partnering arrangements. The Visualisation phase is the most time-consuming and cost-prohibitive phase of the project, and it is also the phase where the most mistakes are made. In this phase, projects: [35, 43]

- Analyze and visualize the most expensive elements of the Product, Organization, and Process (POP) on a rare basis.
- Through the use of a social process among the project stakeholders, it is possible to integrate more than one VDC model and its versions.
- Justification of investment in VDC tools and methods is made based on the value they add to the project since this stage is relatively inexpensive, and each project receives a considerable benefit.
- Provide clarity to the project objectives, values, responsibilities, designs, and expectations, as good visualization allows many more stakeholders to participate in the project review in a more meaningful way than is customary in routine practice.

Integration is the phase that refers to the process of creating computer-based automated methods for exchanging data between different modeling and analysis applications that take place during projects. Vendors may offer their own proprietary methods for exchanging data between different applications. These usually work well for those applications made by the same vendor. To integrate effectively, vendors must agree on common exchange standards, which may involve a strategic commitment to support interoperability. Moreover, in order for integration to work for multiple stakeholders, multi-party collaboration agreements must at least allow and hopefully encourage the sharing of data, which requires a strategic modification of the partners' agreements. During the Integration phase, projects include[35, 43]:

- Through interoperability, data can be effectively exchanged among Product, Organization, and Process models and analysis programs. This is accomplished by utilizing reliable computerized data exchange.
- Investment in VDC tools, methods, and human resources cannot be justified based on project value propositions. It is essential that the value proposition supports the firm because this phase is relatively expensive, and multiple projects must utilize the same processes so that the investment can produce significant benefits.
- It is often the case that vendors provide families of software applications that interoperate, often using proprietary exchange methods, which limit exchange with other applications that might be useful.
- Integration, in itself, can be a source of incremental value since it can reduce modeling effort and time.

Automated methods are used in this phase, where projects use automated methods to accomplish routine design tasks or to help build subassemblies in a manufacturing facility. For project organizations to improve design quality, considerable changes must be made to their processes. This will enable them to perform a greater number of high-value designs and analyses while spending less time on routine design work. It is critically important that a project commits to a strategic partnership arrangement that includes core partners capable of supporting fabrication. It is essential to have good visualization for automation in order for it to function well. During the Integration phase, projects must do the following[35, 43]:

- The ability to automate some aspects of routine design and manufacture of assemblies for field installation by Computer Numeric Control (CNC)
- A project value proposition cannot justify investment in VDC tools, methods, and human resources. In other words, it must either support a program of projects or the organization as a whole.
- Provides a dramatic increase in design efficiency and effectiveness.
- Allows for the dramatic reduction in construction duration, which in turn leads to breakthrough performance in construction duration, such as the CIFE 2015 target of being able to construct most projects within six months from groundbreaking to high-value use.

Chapter 4: Theoretical framework

The purpose of this chapter is to introduce and explain the theoretical concepts which are used to gain a deep understanding of the theory. Additionally, several other concepts are briefly discussed in order to make sure their relevance to this study can be assessed, as well as to ensure the reader has a clear understanding of the theoretical concepts used in this study. The chapter is divided into three parts.

4.1 Construction project management

During the different stages of a construction project, a vast number of interests will be affected, both positively and negatively. Various stakeholders shared their needs and expectations, and sometimes they contradicted one another. There will be a challenge to satisfy all stakeholder expectations regarding the project. The challenge for the construction project manager is to identify stakeholder needs and expectations and to match those to the main objectives of the project. Successful project managers must understand and handle the often hidden power and influence of various stakeholders, referred to as project stakeholders. In addition to identifying their significant stakeholders and responding to their concerns, managers should listen to their interests and concerns[44]. It is the goal of construction project management to achieve a project's success, which is usually measured by three aspects: cost, time, and quality. The project manager's responsibility is to ensure that the project is delivered on time, expenses are kept within budget, and quality is according to an agreement. This is known as the Iron Triangle[45].

4.1.1 Leadership and management

Management is not the same as leadership, although it is an important aspect of management. Leaders can be defined in many different ways, which makes leadership a complex topic. "Leadership is a part of management, is the ability to convince the others to search to achieve defined targets, gives coherence to a group and motivates it to achieve goals" [46]. The term manager refers to a person who has formal title and authority, while a leader is a person who may or may not be a manager but can influence others. Leaders are not required to hold formal positions such as a manager. Traditional definitions of leadership include the following[47]:

Leader and Follower:	A leader cannot be a leader without followers. Good followers don't just say "yes," but they give input to the leaders they follow and influence them to make better decisions. This is what is meant by the term "follower."
Influence	As an effective leader is able to influence others. Leaders influence others by expressing their ideas, gaining their acceptance, and motivating them to support and support their ideas.
Organizational objectives	Effective leaders develop a shared vision and goal, and they guide their followers to consider organisational objectives.
People	It is evident that being a leader is all about leading people. The best leaders like to work with people, guide them, and have a shared vision
Change	Achieving goals and influencing others are both related to change. When setting objectives and influencing, organizations need to adapt quickly to changes in global environments.

Table 8 Leadership Key Elements

Based on DeRue and Ashford (2010) management leadership skills are defined as interpersonal roles, informational roles, and decisional roles. Having good interpersonal skills means being able to communicate, understand, and work well with individuals and groups. In order to make informed decisions, one must be able to conceptualize situations and take advantage of opportunities. There are a number of managerial roles which fall into the categories of interpersonal, informational, and decision-making roles[47]. A decision-making skill involves solving problems. Leaders should be able to identify problems within their organizations and propose solutions to them, according to Mumford[48].

4.2 Lean

The concept and roots of Lean are based on foundational ideas that date back to W. F. Taylor (1911) and to H. Ford, who put in place an impressive production system in the Highland Park manufacturing plant in 1913. As a result, they were able to turn out products at incredible speeds with incredibly short turnaround times and high consistency thanks to the practices and tools they chose (interchangeable parts, standard processes, and the assembly flow line). However, this system was not very flexible[49].

The Ford manufacturing process was a revolutionary break from the traditional manufacturing approach of producing cars. The manufacturing system consisted of general-purpose machines that could be classified by their processes, and which were used to make parts that ended up in finished products after a bit of fitting through subassemblies and final assemblies. To deliver perfectly fitting components directly to the line-side, Ford arranged fabrication steps where possible in sequence to fabricate and assemble components within a few minutes[50]. During 19 years, the Model T was manufactured virtually unchanged under this system, and there were no setups or changeovers necessary since there was only one product being processed. After World War II, increased market requirements for shorter product cycles and more variety

changed the competitive marketplace to the point that Ford's early "Leanness" was not sustained in the long run[51].

Following World War II, Toyota's leading manufacturing engineers, Taiichi Ohno and Kiichiro Toyoda, a member of Toyota's founding family, visited Ford factories and observed their operations. As a result, they believed that if they had some elements from Ford's system and adapted them to Toyota's scale and reality, they could make Toyota a highly competitive automotive manufacturer. Essentially, the focus was shifted from optimizing machines and workstations to optimizing product flow through the entire process, including the right-sizing of resources and improving the self-monitoring capabilities of the equipment to ensure quality. Additionally, a scheduling system named Kanban was used to coordinate production pulls from and link one workstation to predecessors and successors, as well as to link the company with its suppliers and enable Just-in-time delivery. As a result of these changes, Toyota now produces a wide range of products in a sequence that reflects the market's needs, reducing lead times and eliminating the need for large inventories. Hence, a management system was developed to reflect and support all those changes in emphasis and style, which is now referred to as the Toyota Production System (TPS)

Womack and Jones, with their co-author, presented the results of a benchmarking study of the automotive industry in The machine that changed the world. Based on the study's findings, the Japanese plants in Japan performed far better on all major measures of performance than other plants in the country. Manufacturing executives, in general, were affected by this book profoundly, not just those in the automobile industry but executives from many other industries as well[52]. The five principles of Lean manufacturing are defined by Womack and Jones in their book Lean Manufacturing, which encourages continuous improvement and is based on respect for people. Also the same authors also present the concept of Lean Thinking in ther bok [53]. According to the authors, the concept of "lean" is not just another buzzword or quick fix but a way to run businesses that benefits everyone from the employee to the CEO. In their opinion, the ultimate goal is to reduce waste and eliminate all other activities. There are five stages that are involved in eliminating waste in Japan with lean thinking[54]:

1. Define Value: In order to deliver value, one must first have to discover what the customer is actually interested in, not only what they are looking for but what their actual needs are as well. There are times when customers are not sure what they want or are unable to express it. The use of techniques such as interviews, surveys, demographic data, and web analytics can all be used to decipher and discover what customers find valuable.

2. Map the Value Stream: With Lean Methodology, it is important to identify and map the value stream. The objective is to use the customer's value as a reference and identify all the activities that contribute to this value. Those activities that have no value to customers are considered waste. There are two types of waste: non-value-added but necessary waste and non-value-added and unnecessary waste. The second is pure waste that should be eliminated, while the first should be reduced to the greatest extent possible.

3. Create Flow: Following the removal of waste from the value stream, the next step is to ensure that all of the remaining steps flow seamlessly without any pauses or delays. A number of strategies can be used to ensure value-adding activities flow smoothly, including breaking down steps, reconfiguring the production steps, balancing workloads, creating cross-functional departments, and training employees to be versatile and adaptable.

4. Establish Pull: Pull-based systems aim to reduce inventory and work in progress (WIP) while ensuring the necessary materials and information are available for smooth work flow. Pull-based systems are always developed based on customer requirements. In other words, a pull-based manufacturing system permits just-in-time production, where products are manufactured when they are needed and in the quantities required.

5. Pursue Perfection: In order to pursue perfection, the fifth step is the most important among them all, which makes lean thinking and continuous process improvement a part of an organization's culture. While delivering products that meet the needs of the customer, employees should strive for perfection. An ideal company is one that seeks to improve continuously on a regular basis and that is a learning organization.

Figure 6 The Five Lean Principles

By following the Lean principles, an organization can become efficient and effective. Through lean management, managers can discover inefficiencies within their organization and deliver better value to their customers. An organization that practices all five principles can increase the value delivered to customers, reduce the cost of doing business, and maximize profits. By creating better flow in work processes and developing a continuous improvement culture, an organization can remain competitive[54].

4.2.1 Today

Toyota stands today as one of the strongest examples of how lean can be effective in business, and it is poised to become the largest auto manufacturer in the world. Due to the continued success of lean thinking, there is an enormous demand for more information on the subject. There are literally hundreds of books and papers, not to mention thousands of media articles that explore the subject, and numerous other resources. There are many reasons for Toyota's success in every global market, such as growing sales and market shares in every global market, as well as a clear advantage in hybrid technology. There is a growing interest in lean awareness and methods among leaders and managers of all sectors that are just beginning to penetrate. Over the past few decades, lean thinking and tools have expanded beyond manufacturing to supply chain management, supply chain distribution, retail, health care, construction, maintenance, and even government[51].

International Group for Lean Construction (IGLC) was founded in 2002, marking the beginning of the world's first organization to use lean construction technology to improve the construction industry. In addition to a range of training and certification programs, the IGLC provides tools for operational planning and control, supply, visualization, and continuous improvement[55]. IGLC, is now much larger than when it was founded. In their theory of production, they made the project the most fundamental component of creating things[56]. For the most part, Specific manufacturing techniques can be extended to lean construction, but this is still under debate. Each context conforms to the socio-technological construct, in which both human and technical elements play a crucial role in achieving higher performance levels. In order to achieve better performance outcomes in a construction project, it is critical to identify the tools and processes that can be utilized to achieve better execution in the project[55].

The goal of Lean Construction is to design production systems to minimize waste of materials, time, and effort in order to maximize value creation. During the early stages of a project, the owner, the architect, contractors, facility managers, and the end-users are all working together in order to design the production system in order to meet all stated goals[50]. The issue goes beyond contractual arrangements of design/build or constructability reviews, where contractors, and sometimes facility managers, react to designs instead of informing and influencing them. With its roots in the Master Builder concept, Lean Construction draws upon the principles of project-level management and acknowledges that any successful project undertaking will inevitably involve the interaction between project and production management. In a way, lean construction can be seen in terms of macroeconomics, where Lean construction makes use of both project- and production-level management techniques with the aim of improving productivity and reducing waste[57].

The lean construction research practitioners argue for a shift away from the traditional transformation view to a more holistic view to construction, which includes both the value and flow concepts as well as the transformation concept. The term "transformation view" is used to refer to a conceptualization of construction in which a set of inputs is converted to an output,

and the transformation is kept within limits. The term of "value view" implies that the construction process generates value for the project owner. The "Flow view" refers to the fact that construction is really a set of interacting but distinct activities that must be coordinated so that the project can be completed on time and on budget. Construction is really a series of interrelated but distinct activities that must flow to complete a project on time and within budget.

4.2.2 Lean Project Delivery System (LPDS)

Lean Construction Institute (LCI) focuses on applying the principles of Toyota's Lean Production system to the way construction projects are delivered. LCI argues that construction should be conceptualized as a production system to address the fundamental productivity issues in the industry. They argue that a new conception of construction as a production system is needed in order to address the fundamental productivity issues in the industry. Therefore, LCI has introduced a new method of managing building projects that are based on the principles outlined above regarding lean thinking in the production industry. This new method is called the Lean Project Delivery System (LPDS). This is an innovative project delivery methodology that views design and construction projects as lean production systems[1].

In summary, the LPDS is a philosophy, it is a set of interconnected functions that are part of a broader system, a set of rules and guidelines for decision-making, step-by-step instructions for executing functions as well as the creation of implementation aids, tools, and software. Within LPDS, the system is defined by an intersection between projects and production systems, commonly referred to as project-based production systems[58]. The LPDS model consists of five interconnected phases that are: (1) Project Definition (2) Lean Design, (3) Lean Supply, (4) Lean Assembly, and (5) Use. As it is illustrated in figure 2, each phase is represented by a triangle, containing the essential steps that lead to the completion of projects. Additionally, there are two production control modules and a work structuring module that extend through all phases of a project. Learning loops, also known as post-occupancy evaluations, are a way of transferring skills from one project to another when one ends and another begins. [1].

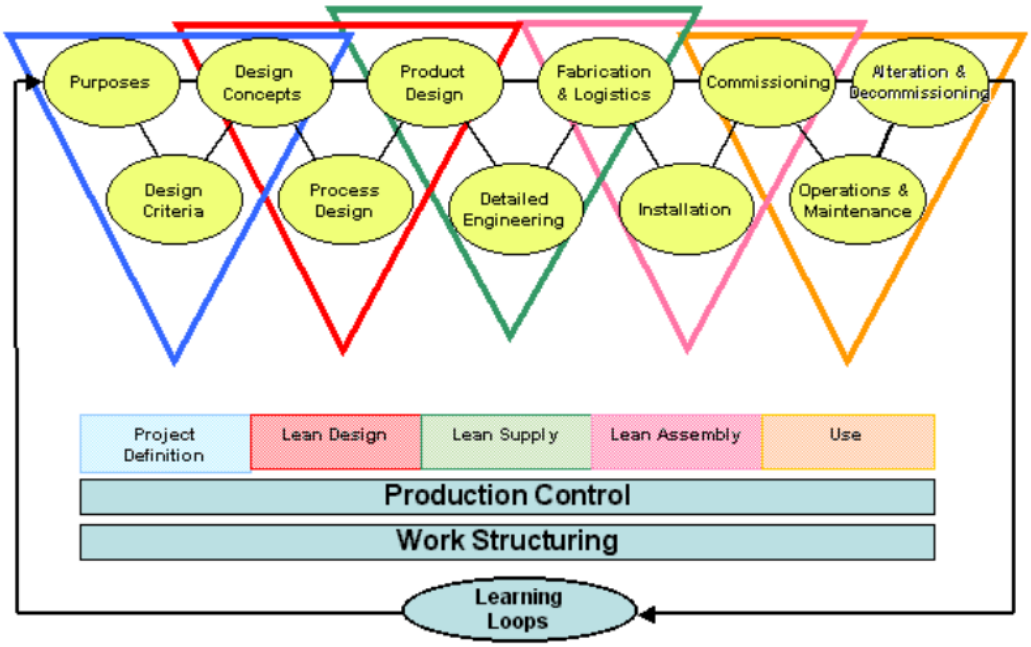

Figure 7 LPDS system[1]

The LPDS provides a framework for understanding how to structure the project delivery process in order to achieve the ideal of a lean production system, but the LPDS does not provide specific tools or methods to accomplish the objectives of a lean production system. In many ways, the LPDS approach can be considered more of a process-based approach. To improve performance on their projects, practitioners are being asked to try these and other approaches.

Chapter 5: Results

This chapter presents the results of the interviews that were conducted as part of this study. In the following paragraphs, the authors provide an overview of the most important findings related to the study's purpose, as they were gathered from the transcripts of the interviews.

5.1 How the project manager's role has changed since the implementation of the VDC.

As part of the interviews, questions were asked related to how the implementation of VDC has affected the project manager's role. The first part of the interview is intended to document any changes in the project manager's role resulting from the implementation of the VDC.

VDC is a more specific term but also a lot more difficult to explain. Several interviewees said that while there is a clear definition of VDC in the literature and theory, different organizations, different teams, and different people do not always have the same definition. Although the term is slightly different from one to another, all agree on the key elements. However, it is important to mention that this is because it is still in the early stages of implementation, and the goal is to have a common definition and terminology within the industry to avoid confusion.

VDC is not just a tool, software, or technology, it is a methodology for aligning construction project management among the various stakeholders of the project. The BIM model is used to plan the entire construction process from beginning to end. During construction planning, features such as budgeting, cost estimation, and scheduling, as well as other important information, are incorporated into the BIM model. Another VDC component that has been mentioned a lot and has given good results is ICE. The purpose of ICE meetings is to be able to make decisions, find the right solutions, and save time. It is a tool to make sure that all stakeholders are involved in the decision-making process.

"*It took some time before many of our project managers realized that VDC is not just a "design thing," that they realized that it was a "project thing."*

"The VDC is a collection of tools that are not new, and therefore, none of the elements are unfamiliar to the project manager. All it is that it is put in a framework and put in a system. In my opinion, VDC influences the role of the project manager to become more of a facilitator, yes, in order to bring about better processes and optimize the way the project management process is done."

Several interviewees expressed the opinion that VDC is a very promising framework with considerable potential. However, its implementation has not significantly altered the role of the project manager. The vast majority of project managers have a very difficult time pinpointing what specific tasks within their day-to-day responsibilities have changed because of the VDC framework. Project managers have not been given a new task, nor have they been asked to

perform something that they haven't already performed. VDC's framework has simply changed how they perform the tasks that they already do. It's not a new way of doing things, but rather a different way of doing them. In that sense, it has a lot more to do with the message they carry with them and how they set up interaction in the team that is a little different.

"The first project managers who were actively involved in setting the level of ambition were involved early in the VDC process. Which VDC methodologies and how far should we extend the implementation in my project was sort of the first thing they got involved in. They also became involved in the design process and planning and digital tools that should be used throughout all phases of construction."

There is no question that the VDC has changed the way the teams work together, and it has made certain elements more visible than they were before. The VDC has not only facilitated communication between departments but has made it easier to solve problems before they arise due to the greater visibility it provides. Through this, I was able to clarify communication between those involved in the process a little better, establish customer goals and project goals, and set up an implementation process for everyone involved. As a result, it has been possible to clarify expectations, which in turn has resulted in a more positive outcome. In addition to improving collaboration and time management, the framework also assists in improving the quality and efficiency of consultation and planning processes. As it is stated earlier, it is more efficient and effective to collaborate with others than to work independently and wait for each other before one can start their own work. There are pretty significant process losses in production on the construction site.

"When building, it is important to build correctly the first time to avoid having to tear down and rebuild afterward, thereby reducing the loss. Working together by using the digital model, such as building an entire project digitally, is one way you can detect problems and correct them before building begins. Using this method allows us to do things correctly the first time, which makes it less likely for errors to occur, reduces costs, and saves time. This will significantly improve efficiency."

In general, it can be said that the primary motivation for using and implementing VDC is that the current methods do not provide enough interaction for the contracting industry. There is a perception that the actors are not well coordinated enough, information flows poorly, and there is a lack of transparency. In addition, there is a need for a more efficient and effective way of managing contracts. VDC can be seen as an attempt to solve these problems. Therefore, the motivation is to create an environment that encourages better interaction between people and organizations.

The project manager role is very much about holding meetings, running around after things, and about having a much more structured week and a structured self. Using VDC, teams can spend more time and create a more efficient structure to get things done right the first time and focus more on individual cases rather than wasting time on things that don't matter. Status

meetings, follow-up meetings, or other forms of communication in which someone has a long list of questions that are answered one by one are no longer necessary. This can be accomplished by replacing traditional meeting methods with ICE meetings.

"*Time savings and having a little more time can make a big difference in a project. In everyday life, there has been a better structure established, and a more consistent focus has been given to what matters, what is the priority now, what we need to clarify for next week, etc. This way, we can work towards a common goal."*

Meetings of the ICE are held to address a wide range of issues in a short period of time. The meeting should be well planned. The facilitator should be able to facilitate the session well. Every person should be prepared. Each task should be specifically formulated so that everyone understands what it is and how to accomplish it to make it a success. This is the most important part of the meeting. The meeting should not be a free-for-all. It should be a structured meeting. It is the core value of ICE to plan well-structured meetings, have a very clear agenda, use participants' time effectively, ensure there is good facilitation, control the agenda as problems are solved, evaluate the meeting, and continuously improve. Instead of traditional design meetings, these types of meetings use 3D models and digital touch screens in order to facilitate interdisciplinary and collaborative collaboration, co-location, and visual interaction.

"An ICE session is better than a traditional meeting. You have higher confidence when you enter such a room. As a result of an ICE session, we will be able to solve issues and have a proper environment to collaborate with the actors."

5.1.1 Providing support and enough training time

The majority of the interview candidates had experience working with the VDC framework for only one or two years. In recent years, their companies have sponsored project managers to attend the VDC classes at NTNU in order to obtain certifications and learn how to use the framework on a more practical level. These courses have also been linked to CIFE. Only two of the interviewees had more than five years' experience with VDC.

All of the interviewees responded positively when asked if they received enough support and training in order to learn VDC. It is recommended that some of the project group members have completed VDC training. Because of the practical focus of the course, it has had a positive impact on implementation. Consequently, it is recommended that a number of the project group members complete VDC training, which should have a pragmatic approach to implementation. According to a project manager, it is intended that those who have completed external VDC courses will train employees in their respective firms. The company should arrange internal training for employees who have not gone through this program in order to make sure this can have a positive impact on implementation.

5.2 What challenges do construction project managers face when using the VDC framework

"So I believe, if you do not have time, money or time, and you do not have personnel who are interested, you do not have the expertise, or the management is not interested, there will be so much resistance that it will be incredibly hard to succeed. In a way, you must act like an anchor, signaling to the actors who come in that we will implement VDC and also demand the framework for them, so if you do not act as an anchor upward, then it will be difficult, so I might say that is the biggest obstacle."

There were several responses to the question of what the interviewees believe are the challenges of implementing VDC, but three of them came up more than once. In order for construction organizations to begin the process of using VDCs, they are going to have many challenges and difficulties in dealing with them. The first challenge or obstacle is that there is nothing in the contract about VDC, the second is the absence of mutual understanding between the team and all of the stakeholders, especially in the beginning stages, and the third is the lack of leadership support.

According to some of the interviews and from our perspective, the first challenge was the absence of any mention of VDC in the contract. There are those who will say that the biggest issue is that there is no mention of VDC in the contract. In many cases, the way a construction contract is written can encourage or discourage the use of new technologies or innovative solutions. If the client has not requested VDC in the contract, or if the contractor has not requested it further down to the designers, it may make the process of implementing VDC more difficult. A widely held opinion is that if a contract requirement or contract offer fails to mention VDC explicitly, then this is a weak starting point, to begin with. If the parties to the contract have not clearly communicated and agreed upon their intention to utilize VDC in a construction project, then it may be difficult to move forward with the use of VDC.

"The reason why I do not completely agree or do not think it is the biggest is that we have seen several examples of projects that have succeeded very well with VDC without saying a word about it in the contract."

There have been several successful projects that were managed with VDC without any mention in the contract, so some people may not fully agree with this or may not perceive it as the biggest issue with regard to implementing this in construction projects. There are cases when the contractor asserts that even though VDC is not mentioned in the contract, it is the way they work, and therefore, they will deliver a better project than if they did not use VDC. However, if the contract states it, then that would have at least eliminated this obstacle and contributed to a better implementation of VDC.

The second major barrier preventing VDC from being effectively implemented was "lack of knowledge of VDC" and "lack of experience with" the framework. Considering VDC is a relatively new concept in Norway, the lack of familiarity or lack of experience with it could

make it difficult to explain how it can integrate into their workflow since everyone has a different way of doing things. As a result of construction managers and employees not fully understanding and being unaware of new technologies, the adoption of new technologies is not as widespread as it could be. Unless enough knowledge and support are provided, VDC might be implemented halfway, which might not allow it to reach its full potential, which is bad for the project. In addition to the lack of knowledge, VDC could be difficult to implement since some employees might view it as an unnecessary effort that won't yield any results. It is illogical to expect an organization to adopt a new way of working without having employees who are familiar with what it is, how it should be done, and what it will look like. Without knowing what it is, it will also be hard to get people excited about it in the first place.

"*There is a major challenge in getting the participants to understand why it makes sense for them to change their working practices. Therefore, management must deliver a clear and concise message explaining why VDC is important and what will result from it*."

The challenge lies in the level of competence of the participants as well as whether or not they are new to the project. There is a strong likelihood that a change within an organization will take much longer than what was initially expected if it does not resonate with the people involved. A major challenge is getting participants to recognize the benefits of changing their working style. When working with external partners in the project who wasn't familiar with VDC and hadn't spent much time experiencing the benefits themselves, it proved challenging to convince them of the value of learning the new paradigm. Once they realize the benefits of learning the new framework, more has been accomplished, and the framework will be used more frequently in the future, contributing to successful VDC implementation. Having sorted out the problem, implemented it, and made it ready, the participants were able to see how such an approach would help them.

A key goal of learning is to provide positive outcomes through enhanced efficiency in the process of learning and through effective adaptation to environmental changes. In terms of a practical understanding of adaptation, it involves taking advantage of technological innovations and adopting the best practices from other organizations. Additionally, efficiency can also be improved through the process of "learning by doing," which involves the accumulation of knowledge through the interaction of cross-functional groups. In order for this to happen, it is important that the leadership and management of the organization take the initiative, as many interviewees pointed out. Without the leadership's backing, it will be nearly impossible to implement new tools and ideas. In order to implement VDC in a project, the upper management must take the initiative to implement it and should also require VDC from each actor who joins the project. If upper management does not embrace VDC as a useful and efficient system, it will be difficult to achieve the same level of commitment from the other actors involved in the project. With no initiative from the top, it will be difficult to meet the goals that have been set.

"I believe that the first step is to have a backup from your management. Here said so you have we I said that. Our project manager and I have been working very closely together for a very long time, and he agrees with me on the importance of transparency and good communication.

And then we had a director here who supported us very much and encouraged us to try out new things, so it is very important if you are just starting out or wanting to do things in a new way that you have that support because otherwise, you quickly meet the wall in terms of reporting and other things. In the first phase, it takes backing from management, and then it takes patience. It's also important to show that results are being achieved, so it's important to establish specific targets for how we plan to achieve our goals and how we intend to use VDC."

"There is a lot of steel and concrete in this industry. Things are more or less the same as they have always been, and the traditional ways of doing things are still prevalent. There's a lot of conservatism in the industry, so those who have worked in the industry for many years will recognize similar acronyms that don't exactly mean VDC but do mean similar concepts and approaches. This is a bit of an attitude now. We have heard this before, haven't we? We have a little culture that has developed over time, and it is all about saying, "Well, that's how we do things here."

It is frequently emphasized that the leadership and commitment of management are crucial to the implementation of VDC in a project. It is highly unlikely that the implementation of VDC would succeed without this support. However, there are times when the manager's leadership and commitment do not correspond with the degree of support offered. In reality, a lack of appropriate commitment from management undermines the potential benefits that could result from the implementation of VDC. Thus, the management team must be aware of the amount of effort, the amount of time, and the resources necessary to cover the needed actions in order to implement VDC within the organization successfully. The lack of leadership support has been reported to be one of the most challenging factors in VDC implementation, and good leadership is essential for the success of VDC implementation. It is important to realize that any attempt to change or create a new method of working will not succeed without the support of the leadership of the organization. Moreover, leadership is a role that should be shared by all managers, and, as a result, leadership will positively influence knowledge creation as well as skills development for all employees.

5.3 How will the client organization benefit when the VDC framework is applied in PM work in the construction project?

There has been an increase in interest in VDC from Clinen's organizations, and it is no longer just a contractors thing. Clients will set requirements for real formal VDC competence in future projects, and the client role will change to become a more active and forward-looking partner. Some interviewees have commented that this will improve communication and understanding of tasks, as well as provide a more comprehensive digital competency in both planning and implementing projects. It has been reported that the most significant benefit for client organizations has been enhanced control over the project, improved transparency, and better results in terms of time, cost, and quality, as well as reduced errors during the project. VDC will become a competitive advantage for the client organization since more value will be created with fewer resources. Ultimately, VDC aims to provide buildings that will give their clients the best return on investment.

The VDC method aims to help organizations resolve problems and improve the quality of their projects as one of its goals. Identifying the essential elements of the project can lead to a clear understanding of the client's needs, which should be supported by the project objectives. To achieve sustainability and lower the cost of ownership over the life of the product, stakeholders must work together to achieve the same goals.

VDC, in principle, gives the client organization and the project manager a lot more control over their project. When things aren't going as they should, they are able to implement measures as quickly as possible. It is very common for projects to develop too far before additional resources are invested, or action is taken to change the direction. With VDC, the team has a measure and control over the right things, but more importantly, it gives them a basis to manage the project more efficiently. Therefore, clients benefit from reduced project implementation costs and have improved control over both progress and finances. Due to the transparency of the information, VDC allows for more control over a project than the traditional way.

"Many of the VDC methods are based on this principle that the information must be transparent. It should be easy to read, it should be easier to understand, and it should be quick to understand. There are many of these planning methods in VDC that often use these Lean plans, these patch plans with a lot of colors and swimming lanes, and it is very easy to read a plan."

"*An ICE session is far more visual than a traditional meeting. Instead of sitting waving your arms, it is often the case that you like to stand in front of a screen, you like to point to a BIM model. So it is much easier for someone to go into a project and understand what is happening in five minutes than traditional methods. The plans are easier to read, the meetings are easier to understand, the information is more accessible, and I think it is a great advantage for a project manager to be able to show the client quickly and transparently what is happening in the project".*

Amongst all the interviewees, there was no disagreement over the fact that ICE sessions are the most beneficial element of the VDC for the client organization and the project manager. However, since the VDC framework is still in its early implementation phases here in Norway, it is not yet possible to determine what exactly will be the most significant benefits for the client's companies. Meetings of the ICE are interdisciplinary in nature since they aim to demonstrate, explain, and develop products, processes, POPs, and 4D models in a clear and comprehensive manner. Projects can be carried out in an efficient and flexible manner by taking advantage of ICE meetings, a method that promotes interdisciplinary collaboration and sound decision-making. This type of meeting uses modern technologies for visualization and allows multiple designers to work simultaneously. In this way, the need for back-and-forth emails between departments and teams is eliminated, resulting in a faster introduction and approval of changes. When conducting an ICE session, it is crucial to include the right stakeholders. This will enable the actors to reach appropriate decisions, in an effective manner, with the goal of ensuring that these decisions take effect in time.

The visual elements of ICE sessions make them so successful and why the interviewees are so satisfied with them. Most traditional meetings are less visual than ICE sessions. Instead of sitting and waving one's arms around, it is more common to stand in front of a screen, pointing to the BIM model and explaining. In this way, it is easier for someone to go into a project and understand what is happening in five minutes as opposed to traditional methods. There is more clarity in the plans, a better understanding of the meetings, and easier access to the information. There are fewer misunderstandings as a result, and more thorough planning of the project is performed involving all the stakeholders so that defects will be discovered during the planning phase rather than on the construction site, resulting in higher construction costs.

''In our projects, we have three performance goals: time, cost, and quality. Then it is shuffled in different orders depending on the type of project, so it must support one or more of the performance targets, which is, in a way, the entire purpose of the VDC. Basically, it means lowering costs, accelerating quality, and reducing time''.

The focus of a project is usually on three performance objectives, which are time, cost, and quality. The three objectives can be assigned in a different order based on the type of project, so it should support one or more of the performance targets, depending on the project type. By implementing the VDC framework in PM work in the construction project, the client organization would benefit by reducing the time, cost, and quality at every level of planning and control. In addition to reducing construction costs and increasing efficiency, client organizations wish to lower their lifecycle operation costs, including building maintenance, building management, and company operations. The whole purpose of VDC, in a way, is to improve efficiency, which in turn means lowered costs, faster performance, and higher quality of the construction project. The tool benefits client organizations in a wide variety of ways, including decreasing time, cost, and quality at each level of planning and control. The traditional approach, on the other hand, focuses more on planning a construction so that a structure will have the lowest construction cost and be able to be delivered as soon as possible. It turns out that the project goals and the client's goals are not in sync, and VDC has been able to fix that to a certain extent.

5.4 Differences in the use of digital technology

During the last few years, interviewees have seen an increase in the use of digital meetings in their work. Meetings are held more and more digitally. One interviewee pointed out that digital meetings using software such as Microsoft Teams and Skype have been growing slowly until a few months after the COVID-19 outbreak when the use of these programs really increased. It can be argued that as a consequence of COVID-19 forcing people to become more familiar with digital platforms and as a result of them becoming more confident at using them, the use of digital meetings is becoming more common. Meetings that are held digitally are proving to be a significant time-saver since participants no longer need to travel to physical locations for a meeting.

The fact that digital meetings are often more structured has many advantages, for instance, there is less time wasted, and people are more efficient. The absence of causal communication during

digital meetings resulted in less confusion and misunderstandings between the teams. With digital meetings, participants can schedule shorter, more productive virtual meetings. The elimination of face-to-face meetings allows companies to hold shorter, more efficient, and more concise meetings on demand. Therefore, decision-making is accelerated, and time is better utilized. Prior to Covid, meetings held at the central office could run endlessly, covering a myriad of topics and information that most attendees were not interested in.

"*Digital meetings cannot capture some of the human element here, as they are only captured through physical encounters."*

All the interviewees agreed that digital meetings have a few downsides, despite their advantages. Face-to-face communication involves much more than just the spoken word. Facial expressions and body language convey significant information, and unconscious cues contribute to productive discussions. When a meeting is held virtually, these cues can be lost or missed altogether, decreasing the energy of the participants and may cause some misunderstandings. Meetings that are digital can prove difficult to run since the facilitator cannot be sure all attendees have the same technology or resources. Digital meetings are plagued by technology issues - whether they be audio, visual, or internet-related. As a result, they waste a great deal of time, reduce the impact of the content, and reduce engagement with it.

The final question in the interview was whether they would use VDC in their next project, and if they would recommend it to others. Everyone responds the same way and in a very positive manner. Those in the industry believe that the VDC is the future of how the industry will interact and interact with one another. Those in the industry believe that the VDC is here to stay.

"Yes, my answer is yes. I do it in all projects, but again you have to find the right level of ambition and you have to adapt to the project. In addition, one should not think that VDC is a miracle recipe. So as long as you do VDC, the project will go well. It's not like that. This is a framework that offers us some methods to replace some more traditional methods that will help us become a little better communicators."

"Absolutely. Probably that is why I am making a guide now, because I think that this is the right thing to do."

Chapter 6: Discussion

In this chapter, the theoretical framework, literature review, and findings are combined to answer the reachers' questions. In other words, in this study, the author will be comparing and analyzing the theoretical and practical components to create a basis for drawing conclusions. The author also discusses the results and presents his own reflections.

6.1 The VDC concept

There is still a lot of confusion about what is meant by the term Virtual Design and Construction, or VDC for short. All the interviewees were in agreement that even though they all took the same course and had the same understanding of what VDC is, in practice, there are still significant differences in how it is actually defined. This contributes to difficulty in specific understanding of the term VDC. Depending on the people and location, the term can be used in a variety of ways. The VDC methodology and tools are derived from other research environments, such as the aerospace industry, and from other concepts in the construction industry, such as Lean Construction. CIFE does not aim at creating a method that is universal and has a set of tools for its use. Instead, it encourages a step-by-step implementation with individual adaptations.

Due to the widespread use of VDC, there have been a number of studies conducted using case studies and survey results from VDC projects, which have contributed to several new recommendations. There have also been studies conducted regarding adaptations in the different phases of the project. The literature on VDC describes the method in a number of different ways, and in addition, it is now widely acknowledged that new research has contributed to the development and improvement of the VDC methodology over the last two decades. According to one interviewee, the people in charge of the certification cores and education have a very specific understanding of what VDC is and one common definition. This concept is very similar to the terminology that has become so popular in recent years and is used in most of the available literature. However, if one asks three or four different project managers or other individuals who are familiar with VDC, they are most likely to have different perspectives on the term. Thus, VDC relies on several pillars that one must, in a sense, depending on if one wants to call it VDC. The project is, by definition, a new task and different from the private project every time with a new set of stakeholders, so no two projects tend to be the same.

It may be misleading to use the term 'virtual' here because it implies that VDC is some sort of digital software. It is important to note that just like BIM, VDC is a process and way of working that requires managing integrated multidisciplinary performance models, although information technology will almost certainly be involved. Incorporating the correct people and technology into a project, it can be a way of formulating an ideal strategy. VDC emphasized collaboration and integrated working, and BIM is frequently a valuable part of VDC. Generally, BIM and VDC should not be considered analogous. However, VDC does not need to encompass BIM, and BIM can be performed without being considered part of virtual design and construction. BIM is a much more specific process than VDC, but both are essentially methods of planning and managing a project collaboratively.

For the implementation of VDC, the Lean philosophy can be used as a conceptual framework because the impacts of VDC can be directly correlated with Lean Principles. Implementing VDC from a Lean perspective offers many solutions to radically improve the AEC industry. It is important to note that VDC, unlike Lean, is a framework that was created specifically for the construction industry. Manufacturing industry differs from the construction industry in the sense that they can duplicate the same production strategy and use it in multiple factories with the same success. At the same time, VDC recognizes that this cannot be done in the construction industry due to the nature of construction being different from one project to another. Furthermore, one must follow 'guidelines' if they are going to complete their project to a certain standard, and the VDC is based on these guidelines, so it can be compared to alternatives, such as Lean. A key objective for VDC is to facilitate the LPDS in Lean Construction, as the design process in LPDS includes design concepts, product design, and process design, both of which affect the other, and it follows that changes in product design have a reciprocal effect on process design, and vice versa. VDC provides a way to understand these changes to a project by using the POP framework.

6.2 VDC implementation in the construction industry

According to some interviewees, the concept of VDC can assist with the implementation of new and existing technology, such as BIM, in a more comprehensive way. In VDC, the focus is on products, organizations, and processes and enables the development of these models in the early stages of the project before a large portion of resources are used, and this results in a company meeting the project goals. The relevant actors are involved at an early stage, and this improves the interdisciplinary collaboration between the actors in the design process. In terms of findings, there is a general consensus within the design group that the VDC project form is on the rise and that opportunities may exist to use it early on in a project.

Researchers have found that by implementing the project method of VDC, companies are able to improve their results significantly. Through the implementation of VDC, project participants can work together, communicate more effectively, and implement projects efficiently and with high quality. The interviewees emphasize that it is still too early to fully understand exactly how VDC has impacted their work in the most beneficial way. However, it is important to note that there are two aspects of VCD that frequently come up in conversation, both of which have a positive impact on their work in the long run when discussed. The two elements of VDC that have had the most impact on client organizations and project managers are ICE and measurement and follow-up. The implementation of a new design model must be shown to have measurable effects if it is to be adopted.

6.2.1 ICE

The concept of ICE meetings is one where relevant actors co-locate in an iRoom over a limited period of time and work together on projects together regularly. Literature has shown that co-located design meetings can have a positive effect on the success of a project. The meetings are attended by all relevant decision-makers, which facilitates the exchange of information among the various parties involved. In general, the interviewees were of the opinion that it would be beneficial to meet together and design and plan thoughtfully. This type of design is particularly useful for large, complex projects. A number of the interviewees emphasized that such

interaction meetings would facilitate a more effective decision-making process allowing problems to be resolved more quickly. During the ICE meetings, they can prepare BIM models and plans together as well as to conduct small meetings and special meetings where the relevant subjects gather when clarification is needed.

In order for an ICE meeting to be effective, it is important that the right people with the right skills be present at the meeting. While ICE is a new concept to most interviewees, it is definitely the one element of VDC that has made the biggest impression on them. Findings indicate that using ICE in conjunction with VDC will make it easier to find the right solutions for various projects, make better and faster decisions, help to uncover errors more accurately, and enable better communication and planning. There are a number of factors that affect which approach of ICE will be most effective, including the size, complexity, type of products, and the organization of projects. Participants will have to go through a learning process before ICE can reach its full theoretical potential. In the beginning, ICE has been perceived as a challenge to ensure the right people are included at the right time and with frequency. The interviews mentioned that a number of individuals attended ice meetings without really understanding what they meant at the beginning, which led to a number of unsuccessful meetings. ICE needs to be implemented so efficiently in practice as described in the theory before a better production basis can be expected.

6.2.2 Measurement and follow-up

As a part of VDC, one of the most important steps is to measure the design process together with the PPM, which provides the process of pushing the project towards its target. According to the definition of capital projects from Investopedia, PPM refers to the application of operations management to the delivery of capital projects. Using PPM, a project is viewed as a production system, where inputs such as raw materials, information, labor, and machines are transformed into outputs, including goods and services. In the design phase, PPM allows participants to see how improvements can be made to the design process to improve efficiency. These measurements are useful for monitoring progress and motivating the design team to maintain a high level of performance. In collaboration meetings, such as iRoom, PPM can be measured, and improvements can be shared at the same time. The project managers involved in the project do not administer any specific measurements, and when they check on the progress plan, they do so themselves and adjust the schedule accordingly[1].

There is no doubt that the interviewees believe it is important to take measurements and that it would have been advantageous to take measurements in order to gain a better perspective and control over the overall process of the design and planning process. Cause-and-effect analyses can be used by the design team to determine why activities weren't carried out in the planned manner and to analyze the measurements. As a result, these analyses contribute to continuous improvement. An overview of the reasons why tasks are not completed can be hung next to the overview of the measurements of the PPM.

The cost of a construction project can be very high due to the fact that any error can have large consequences for both the client and the contractor. It is quite possible that an error may manifest itself as an oversight in safety protocol as a result of a miscommunication or an

underestimation of how much of a specific material will be required. The use of VDC in complex projects has been adopted by many engineers, contractors, and architects in an effort to prevent issues like these.

6.3 Benefits of VDC

VDC is a framework that gives project managers and the client organization a real-time idea of the resources, tools, and other costs that will be required to accomplish any specific task. Leadership can foresee problems before breaking ground on their projects, and they have a better idea of which resources are needed. Moreover, it makes communication and collaboration between team members much easier since everyone can see the same project overview.

The problem with having a team of people who are of varying backgrounds is that there are a lot of potential channels of miscommunication that can arise. The VDC models can include these specialized areas in their simulations so that team members can gain a deeper understanding of ideas and receive the updated information. As a result, the project runs smoothly on and off the worksite with improved coordination. In addition, increased coordination will prevent injury accidents, project stalls, and schedule delays. In so many ways, the level of transparency that can be achieved with a project can be highly beneficial throughout the project's various phases, especially during the design and construction phases. In conclusion, the implementation of VDC in the concrete industry will result in an increase in collaboration between all stakeholders, resulting in numerous benefits for the industry. Some are as follows:

6.3.1 Fewer mistakes

VDC is the process of developing a strategy using various performance models to simulate complex projects before they are put into action. With the help of BIM, the VDC is able to visualize, organize, and plan construction and design activities in order to minimize costs, waste, risk, and schedule delays while maximizing quality, value, and performance at the same time. Identifying and avoiding unforeseen challenges and errors in the construction process can be achieved by modeling the project with key leaders and specialists first.

6.3.2 Lower costs

Management of the cost of large projects is one of the most challenging aspects of working in the construction industry. When it comes to generating cost estimates from spreadsheets and shop drawings, it can be a challenging and labor-intensive process, but accurate estimates could mean the difference between a project losing money and making a substantial profit. As a result of VDC technology, project managers are able to budget effectively, as it details everything they need to complete a project, this enables them to keep production on schedule, which is one of the top performance objectives managers strive for. It is a fact that when there is a delay, as a matter of course, there will also be additional costs as well. For this reason, VDC helps to eliminate the possibility of schedule delays and late deliveries of the projects.

The VDC can provide building managers with valuable insights and information that will enable them to run their projects more efficiently and at their optimum level. As a result of the

collaborative nature of VDC software, a construction company can use it to create detailed models for their projects that can be used with BIM software to estimate costs more accurately. The accuracy of cost estimation is improved because important components aren't overlooked during the modeling process. VDC's detailed and in-depth 3D models help building managers to make more informed decisions about the maintenance of their equipment. When all stakeholders, engineers, architects, and other technical experts work together on a collaborative model, this ensures that all components and details of a project are taken into account in the cost estimates. This helps to avoid the need to provide updates or repairs in the future that can be delayed further into the future, which can prove to be quite costly.

It is worth mentioning that VDC's benefits go beyond the initial groundbreaking and will provide the best return on investment for contractors, designers, and building operators alike. Managers, leaders, and organizations who strive to bring efficiency to the construction industry should utilize VDC both during the design phase as well as during the construction phase of the project. With every step of the process, VDC can provide the most eco-friendly and economical solutions.

6.3.3 Reduced time and improvs scheduling

The completion of construction projects on time is usually at the top of the list of construction project managers' performance objectives. Projects that fall behind schedule and are delayed will result in disgruntled customers, high costs, and legal liabilities that can completely eliminate the possibility of profiting from the project. By using VDC, stakeholders are able to create more accurate visual representations of the project, and by using BIM software, the team can incorporate project schedules and cost forecasts into the design phase of the project. A framework of this nature makes it easier to handle problems and gives project managers more time to identify potential delays and deal with them in advance. There are many potential negative consequences to delays, including disappointed clients, budgets that spiral out of control, and legal ramifications that could result.

6.3.4 Increasing Safety and Quality

Using VDC, building systems can be coordinated in such a way that off-site prefabrication or modularization is possible, visualizing the construction process while minimizing the risk of oversight of site logistics obstacles. Safety, quality, and productivity are greatly improved when operating in controlled environments, and VDC is a particularly effective tool for spotting site logistics challenges or potentially hazardous activities that are not evident through traditional planning and scheduling. Project managers can gain better insight into the project environment at any time, assess potentially dangerous areas of the site, and implement safety measures to mitigate the risk.

6.4 Challenges in the VDC implementation

During the interview process, the author identified and prioritized several key factors that were considered crucial to the successful implementation of the VDC framework in the Norwegian construction industry. It has been determined that the three most important challenges to the implementation of VDCs are the lack of leadership support, inexperience, and lack of

awareness. VDC frameworks are still a new concept in Norway, therefore, there are still not enough studies and data to conclude that these represent the most important obstacles to a successful implementation of the framework.

There is no doubt that change requires leadership support and endorsement, and unfortunately, the construction industry is known for its resistance to change. Historically, the industry has been conservative and dominated by individuals who are reluctant to change. Perhaps one of the reasons for this may be that change is risky. It requires personnel, time, and money, all of which are resources the industry cannot afford to waste. In order for change to take place, it is necessary to have patience. Resistance to change occurs when organizational members have incorrect expectations of change or do not understand the implementation properly. This is most likely to occur when the leadership is the responsible party. Instead of expecting changes to be simple and quick, organizations need to view them as a long-term and strategic undertaking that will ultimately benefit them in the future. It is important for organizations to be patient with change and understand that they cannot force it to go faster than their members are comfortable with. For the implementation of VDC to be successful, leaders have to provide support and the right resources. In order for the change to occur, they must also seek it so that their employees will follow suit. They need to be able to provide the right education and support to their employees in order to equip them with the necessary skills and secure successful implantation. Additionally, they must also enforce the requirement for VDC among their employees and external stakeholders by, for example, including it as a part of their project contracts.

One of our interviewees mentioned that he recently learned that there are some managers out there that have to sneak in the implementation of VDC and elements of it behind the scenes. It is important that they avoid using the correct terminology for it and instead provide a vague explanation that will also provide plans and the kind of results they can expect to achieve from it. To summarize, they need to show the leaders, the client organization, as well as all other stakeholders what benefits they can achieve by implementing these changes, without mentioning that this is a VDC. Further, it is said that employers also have a responsibility to provide the right information to their leaders in order for them to be able to influence and motivate them to make the right changes and implement new practices.

Another challenge in implementing VDC successfully is that it is still not well known, and organizations are in the early stages of implementation. Despite its benefits, the adoption of the framework is still not widely spread, as well as there is still not enough awareness of it. During the last couple of years, companies have gradually begun to adapt it to their practices. VDC still remains a mystery to many people as to what VDC is and what it provides. Without being aware of the benefits it offers, it is nearly impossible to want to change and make an investment in it. Given that VDC is a relatively new concept for most people adopting the framework for some businesses or organizations might not be worth the risk.

Chapter 7: conclusion

Here, in this final chapter, readers will find a summary of and a presentation of the conclusions in light of the three research questions in the form of a brief description of the research questions and thus also the purpose of the thesis.

"One should not think that VDC is a miracle recipe. So as long as you do VDC, the project will go well. It's not like that. This is a framework that offers us some methods to replace some more traditional methods that will help us become a little better communicators."

There are many companies around the world that are embracing Virtual Design and Construction, or VDC, as a way to gain business performance objectives, such as keeping projects on time and on schedule, reducing waste, lowering costs, and improving efficiency. With VDC, teams can create convincing 3D and fully utilized BIM models of construction projects, along with the necessary costing and scheduling information that enables construction companies to demonstrate their expertise and accurately plan the project. Moreover, VDC is able to provide construction companies with a better understanding of the quantity and cost associated with completing a project. Also, it facilitates greater communication and collaboration, which will help reduce the likelihood of duplicate work and prevent costly rework in the future. VDC's positive effects can be clearly seen on the job site as soon as the project gets underway. A VDC approach uses a comprehensive planning approach to keep the project on schedule, and the design team can use the virtual model to detect and address safety concerns and communicate those risks to the workers.

According to the overall impression that the author got from the interview, VDC is a new framework and is seen as something positive and important for the future success of the construction industry. According to a large number of respondents, the role of VDC managers will grow in importance in the future.

- What changes in the digitalization of project manager work have occurred over the last five years?

The project management tasks haven't necessarily changed. The VDC has neither assigned new tasks to them nor has it removed any of their old tasks from their workload. As a matter of fact, project managers are affiliated to some extent with the VDC components, but VDC combines them into one common framework and optimizes them, so they become more applicable to the construction industry. The VDC did, however, change the way in which project managers performed their tasks, resulting in their work becoming more efficient as a consequence. The tools and methods provided by VDC, like ICE, PMM, BIM, and metrics, have received a very positive impression and are advised to be used in the projects. Currently, VDC implementation is just getting started, and there will probably be some changes to be made in the near future.

- What challenges do construction project managers face when using the VDC framework?

After interviewing several industry professionals, the author prioritized several key factors that were considered critical to VDC implementation in the Norwegian construction industry. The implementation of VDC faces three challenges: leadership support, inexperience, and lack of awareness. There are still not enough studies and data to conclude that these represent the most significant obstacles to using the frameworks in Norway. VDC is still a mystery to many as to what they are and what they can provide. Despite their benefits, the framework isn't widely adopted because of a lack of awareness and skepticism. In order to increase awareness and provide solutions to the obstacles, the industry will need a comprehensive and sustained approach that includes three key components: 1) educating current and future leaders, 2) better informing leaders about VDC's benefits, and 3) creating an overarching vision or initiative.

- How will the client organization benefit when the VDC framework is applied in PM work in the construction project?

A VDC provides client organizations with a visual representation of how the hundreds of moving parts of a construction project will fit together to form a finished building before construction begins. By using this method, it allows for early detection of potential problems, and it makes it easier to test and develop solutions. In particular, it is important to reduce the likelihood that the client or other stakeholders will change minor or even substantial aspects of the design during construction. In addition to allowing team members to estimate more accurately the materials and services you need from vendors and subcontractors, this process reduces wasteful processes like rework and lengthy decision-making processes. The detailed information provided by VDC is invaluable to clients organization and construction project teams, allowing them to deliver a higher level of quality to clients. Ultimately, it gets down to the fact that project teams need to have all the information they need in order to be able to make quick, informed decisions that will result in the best possible outcomes.

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Attachments

Interview Questions

start

1. Tell us about yourself, your educational background and what position you hold the company.
    a. What is your role in the project? How long have you been in your role?

What changes in digitalization of the project manager work has occurred over the last 5 years?

2. How do you think the project management role has been affected by digitalization? recent (≈5, depending on experience) years?
    a. Have there been any differences in tasks and division of responsibilities?
    b. What changes have taken place?
3. What do you think is the main driver to adopt digital tools in construction projects?
4. How has your work changes when you integrate digital platform into your projects/workday?
    a. Do you see any differences in communication? How?
5. How has the collaboration in the various projects been affected by the digitalization?

What challenges do construction project managers face when using the VDC framework?

6. What do you consider to be the biggest obstacle/risk to implementing VDC framework in the construction process?
7. Do you feel that you get enough time and support to use VDC framework properly?
8. What are the challenges/risks you experienced/aware considering digital collaboration and Digital meetings?
9. In what ways digitalization / VDC framework place new demands on you as a project manager?

How does the construction project manager benefits by using vdc framework in the construction project, and what are the benefits?

10. What do you consider to be the biggest advantage of implementing digital tools in the construction project considering project managers role and tasks?
    a. What benefits do you think can arise from implementing the use of VDC framework (considering PM job)?
11. What types of mistakes do you think can be minimized with the use of VDC framework, or where can you save time?
12. In which subject areas do you think VDC framework have the greatest potential? Who gets the most out of which technology?

Corona

13. How do you explain the role of covid 19 in recent development in project manager ’s practice?
    a. Has it impacted the use of digital tools by PM?

End

14. Is there anything you thought I should ask, which I may have missed?
15. What is your opinion about the future of the digitalization in project management ?
16. Do you have any other reflections / something to add?