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VDC implementation in transport infrastructure projects

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<p>Abstract:</p> <p>Due to the accusation that construction industry have low efficiency levels, relatively poor profit margins, and problems with quality when compared with other manufacturing industries, Virtual Design and Construction (VDC) methodology, which has been mostly developed by the Centre for Integrated Facility Engineering (CIFE) at Stanford University, is seen as a potential tool to overcome such problems.</p> <p>VDC aims to provide effective means of adequately integrate multidisciplinary information required for the project design, planning and construction phases. The contribution of such tolls in construction projects may have different performances and implementations according to the project type and therefore the challenges faced by the project manager as well.</p> <p>By adopting VDC, it may bring to firms benefits regarding project coordination, integration and decision making, planning, review and communication processes during the design and construction life cycle.</p> <p>Full implementation and application of VDC and proper practice is yet to be achieved in Architecture, Engineering and Construction (AEC) industry. The challenges regarding transport infrastructure projects still persist and seem to be bigger when compared to building projects. Some uncertainty remains however within the industry towards VDC and therefore impediments which firms have been facing are assessed in order to allow VDC applicability in their business models.</p>

Keywords:

1. Virtual Design and Construction
2. Transport infrastructure projects
3. Stakeholders integration
4. Project visualization

PREFACE

This master thesis was developed in the spring semester of 2014 at the department of transport and civil engineering, and fulfils the last 30 ECTS for completion of the international master programme in Project Management at NTNU. The study program allows students to choose a study path in their second and last year of studies and therefore specialize in an engineering field. I chose the direction of management of civil and transport engineering projects, since I have previously completed a bachelor and master in civil engineering. Therefore the topic addressed in this thesis should cover management methodologies that suits for civil and transport engineering projects.

Earlier in the master programme, a specialization project was develop with the supervision of Frode Olav Drevland within the same topic. Such project resulted from my will to work with innovative methods and tools within the transport infrastructure project management and it is the starting point for this master thesis. I wanted to do something that could add some advantages when looking for job, and at the same time do something that I wanted, rather than do only one more paper based on literature review.

The boost to work upon such topic was given by Veidekke ASA, which showed the interest to extend the application of Virtual Design and Construction (VDC) in their business to other project types. VDC has already been in used in Veidekke ASA for several years in their building division. However, new demands from the public road administration in Norway regarding 3D modelling in the planning and designing phase of transport infrastructure projects, has raised the opportunity to contractors to improve their project delivery efficiency, by taking construction productivity to a higher level. Veidekke believes that such goal can be reached by transversal implementation of VDC in their projects.

Since I had the chance to get information by means of observation during my summer job at Veidekke along with additional information gathered my means of meetings and e-mails exchange with the contact people at Veidekke as well, some elements from the Norwegian construction industry were introduced in this work, and therefore establishing a connection of the literature review with the reality found in the Norwegian construction industry.

I would like to thank Veidekke for the opportunity to develop this master thesis, and emphasize the availability of some of their staff who help me throughout this semester, especially Svein Gunnar Ornæs, Sverre Longvastøl Flom and Asle Gjøstein Resi.

Finally a special thanks to everybody in the department of transport and civil engineering, since my supervisor Frode Olav Drevland to all my class mates and friends.

ABSTRACT

Due to the accusation that construction industry have low efficiency levels, relatively poor profit margins, and problems with quality when compared with other manufacturing industries, Virtual Design and Construction (VDC) process, which has been mostly developed by the Centre for Integrated Facility Engineering (CIFE) at Stanford University, is seen as a potential tool to overcome such problems.

VDC aims to provide effective means of adequately integrate multidisciplinary information required for the project design, planning and construction phases. The contribution of such tools in construction projects may have different performances and implementations according to the project type and therefore the challenges faced by the project manager as well.

By adopting VDC, it may bring to firms benefits regarding project coordination, integration and decision making, planning, review and communication processes during the design and construction life cycle.

Full implementation and application of VDC and proper practice is yet to be achieved in Architecture, Engineering and Construction (AEC) industry. The challenges regarding transport infrastructure projects still persist and seem to be bigger when compared to building projects. Some uncertainty remains however within the industry towards VDC and therefore impediments which firms have been facing are assessed in order to allow VDC applicability in their business models.

By means of qualitative research, the implementation case of Veidekke Entreprenør ASA in their building projects will be assessed, and supported by theory findings, there will be established guidelines for the VDC implementation assessment in transport infrastructure projects.

The research questions will be tackled in order to appraise how VDC may be implemented and what benefits will that bring to the company and industry.

This study can be seen as a development on an area of VDC implementation where has not been set the main focus yet. Such processes have been mainly towards its applicability in the buildings industry, however here the applicability to the transport infrastructure projects is will be evaluated.

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ACRONYMS

AEC – Architecture, Engineering and Construction

APM – Association for Project Management

ASCE – American Society of Civil Engineers

BIM – Building Information Modelling

CAD – Computer Aided Design

CIFE – Centre for Integrated Facility Engineering

CP – Collaborative Planning

CPM – Critical Path Method

ICT – Information and Communication Technologies

IFC – Industry Foundation Classes

JPL – Jet Propulsion Laboratory

nD, 3D, 4D – n dimensions

NPRA – National Public Road Administration

PERT – Program (or Project) Evaluation and Review Technique

PMI – Project Management Institute

POP – Product, Organization and Process

VDC – Virtual Design and Construction

VIKO – Veien til informasjonskompetanse

VO – Value Optimization

1 INTRODUCTION

1.1 BACKGROUND

The construction industry is one of the biggest industries in Europe, representing about 10% of the GDP. The sector employs directly 12 million European citizens and 26 million others are working dependent on the sector (Guillot, 2010). The industry is divided in many branches which cover a large range of companies that run construction projects usually characterized by short-term partnerships between multidisciplinary teams with varying levels of process maturity and information handling capability. It usually involves the planning, design, and erection of structures of all types, plus a number of stakeholders such as clients, contractors, designers, and material and component suppliers.

Compared with other manufacturing industries, construction companies are accused of having low efficiency levels, relatively poor profit margins, and problems with quality (Woksepp, 2007). A comparison of the productivity index of the construction with all non-farm industries in the United States of America, shows a steady decline of productivity in the construction industry between 1964 and 1998 (Khanzode, 2010). The more recent Norwegian example displays the same tendency of decline, but perhaps at an even lower productivity index (Regionaldepartementet, 2012).

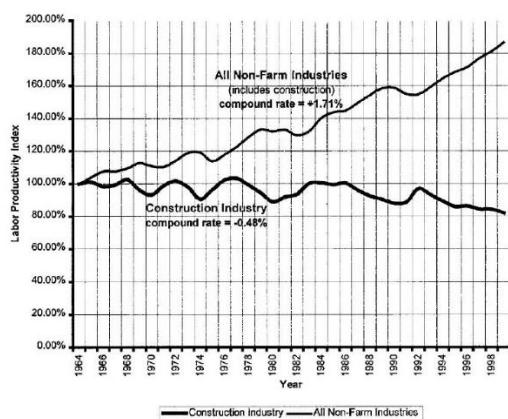


Figure 1 - Construction production index vs all non-farm industries

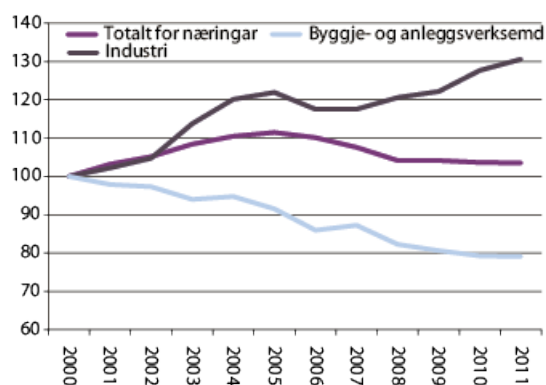


Figure 2 - Construction productivity index vs other industries and total industries

By analysing the figures, it is acknowledge that other industries have improved their productivity indexes in general, when compared with the construction industry.

Additional, construction industry has been criticized for its “widespread problems such as late delivery, escalating projects costs, unsatisfactory performance, among others” (Li et al., 2009). However projects are becoming even more complex and if the current problems are not duly tackled, the issues that nowadays persist may become even more complex.

The fact that other industries have made progress in their productivity levels, may be due to the introduction of information technology and rethinking of the production processes, like lean manufacturing processes for example.

However, over the last couple of decades, improvements in technology and tools have reached the AEC industry also and changed dramatically the process of construction, as well as the quality of construction output. Compared to other industries, exists an old perception that construction industry is a technologically stagnant industry. Data of expenditures on research and development of technology supports the previous statement. According to Goodrum et al. (2009) it is believed that the construction and building industry use to invest less than 0,5% of its profits in research and development, while in other industries invested about 3%. Nevertheless it is believed that in recent years this trend has been changing. Greater demands for more cost-effective and schedule-efficient project have led to new project delivery processes, many of which exploit technologies that serve to either automate or integrate tasks.

1.2MOTIVATION

The construction industry is generally highly fragmented compared to other manufacturing industries. Such fragmentation is entailed to the different specialities and tasks that are involved in a project. Not so long time ago an engineer could totally understand his own discipline. Nowadays, engineering has become much more complex and is divided in many subdisciplines, where every expert is in charge for a certain discipline. They would look at the same problem with a different approach and points of view, and would be impossible for one engineer only to master all specialities within a particular project. This has lead us to a project division into different stages and subsequent activities, each managed by one or more experts. Such fragmentation within a construction project is unparalleled in any other sector, and may have considerable impact on productivity and performance (Gaith et al., 2012).

Every product in the construction industry is unique compared with other industries, but as in any other case, the products must be delivered to the client within their requirements and specifications. Such complexity have been acknowledge as the major cause for performance related problems faced in the industry.

In order to tackle those problems, traditional project management have adopted some computer technology that supports management and processes using a set of traditional tools and methods such as 2D drawings, written specification, tree-view projection, PERT, CPM, bar charts. They have been laid down for decades and fits in an era where the focus was on developing stand-alone tools to assist specific work tasks.

The introduction of technologies that support project planning, implementation and operation have been gradually introduced in the industry, however they demand for a strategy and effective management tools that will improve construction productivity (Gaith et al., 2012).

There are still lack of methods and processes that will take advantage of technological means available to improve collaboration, communication, integration and that at the same is able to manage a considerable amount of information. In addition, introducing new a new process demands for adequate training, effective use of technologies, adaption to new working methods and organization, and entails immediate costs that only some companies are risking to take.

In Norway in particular, but also in many of the new developing countries, there is a huge need for infrastructure development and therefore many new investments will increase the demand for project efficiency and effectiveness. New technology methods and tools are available that can significantly improve project performance, both from the owner's perspective and from the design-contractor's perspective.

Transport infrastructure projects are usually large and expensive. A general view, particularly in the media, suggests that such projects aren't really effective, suggesting that cost and time overruns are predominant in the sector.

Common sense tell us that something needs to be changed in construction project management. Some perspectives have been trying to tackle the current problems existing in such projects. In the mid-1990s some computer-supported management systems were introduced, by using e-mail, the web, among others. Nowadays the focus is not on individual applications or transactions, but on the potential for uniting all of these as a cohesive overall system through integration. Those individual activities have become managed by more than one expert and can therefore get contribution from the expertise of a set of actors, which in another occasions would not work together. However, such process will require more interaction in terms of communication and coordination in order to achieve better project development efficiency, in particular towards interdependent tasks.

One of the most promising approach and potential solution for such problems and many others is VDC, which is claimed as applicable to all kinds of projects. Several studies have concluded that the implementation of information technology management in the construction industry is a realistic way of solving many of these problems, and that VDC may be a model that will possibly take advantage of such technologies to reach a better project productivity rate.

VDC as a project management tool will provide effective means for adequate integration of multidisciplinary information required for the project throughout all the different stages. The contribution of such tolls in construction projects may have different performances and implementations according to the project type and therefore the challenges faced by the project manager as well.

VDC combines and integrates technologies and work processes for optimization of project performance. When properly used, VDC enables engineering designers to better manage and tackle engineering challenges, and furthermore achieve better construction quality and speed.

The three main elements that constitute VDC are the Integrated Concurrent Engineering, Building Information Modelling and Product, Organization and Process models. The adequate use of all elements is fundamental to reach a successful VDC utilization and therefore improve construction productivity levels. The combination of experience with a sustained theoretical foundation is required to reach VDC expertise.

The big majority of the existing literature is concerning building projects and many successful cases are known in particular in such industry. However, its applicability in transport infrastructures projects is still short and are there very few known cases of its successful implementation.

1.3 OBJECTIVE

By studying and evaluating literature available, it is aimed to gather a strong theoretical background that would support the author's findings. In parallel the author intent to address the industry's experience in VDC implementation in the buildings branch, in particular from the firm Veidekke Entreprenør ASA and endorse those learnings in conjunction with the acquired knowledge from scientific research.

Veidekke has successfully implemented VDC in their building projects, and has experienced many of the advantages that such process is able to contribute with. Therefore the author has been granted with privileged information resulted from a cooperation work with the above mentioned firm. The findings from this thesis would possible aid Veidekke and perhaps other Norwegian contractors to lay guidelines towards a successful implementation of VDC in their transport infrastructure projects.

Consequently, the author aspires to investigate the applicability of VDC from the buildings industry to the transport infrastructure projects, and how the previous learnings can be transferred and adapted from one branch to another.

1.4 RESEARCH QUESTIONS

In order to fulfil the major goal and clarify the areas that are intended to cover in this master thesis, the author has defined several steps which are going to be addressed by answering the proposed research questions. Such questions are meant to be answered throughout this paper and according to the order of topics that will be assessed.

Those questions are aimed to be answered based on the comprehension and analysis of the literature researched, along with the information obtained from the Norwegian industry, Veidekke in particular.

1. How is VDC implemented in the buildings division of Veidekke?

This question aims to provide an insight into the way Veidekke and their professionals exploits VDC techniques and takes advantage of it in the building projects.

2. *How can VDC be implemented in the transport infrastructure projects at Veidekke?*

According to the current practices in the construction industry, it is intended to assess what would be the challenges (internal and external) faced by the company in order to implement VDC processes in their infrastructure projects, and how would they be overcome.

3. *What will Veidekke's projects benefit with VDC implementation?*

If conditions for VDC implementation are found, how would Veidekke benefit from such working method? It is aimed to appraise the advantages that VDC would bring to the firm and consequently to the project managers.

By answering those questions, the author aims to get a good understanding towards the viability of VDC implementation in transport infrastructure projects, and to assess, acknowledge and suggest actions for VDC implementation in transport infrastructure projects, in particular at Veidekke Entreprenør ASA.

1.5 SCOPE OF WORK

The scope of this work comes from the successful implementation of VDC in the buildings industry. However, VDC is a large concept with several definitions and branches. VDC tools does not have necessarily to be exclusive for such branch. VDC came to affect the methods used, the working procedures and perhaps modify organizational structures.

From a project management perspective, the case of Veidekke Entreprenør ASA in the implementation of VDC in the buildings division, supported by theoretical findings will be base for the analyses of the challenges and needs for VDC implementation in the transport infrastructure projects.

This master thesis is the last element for the fulfilment of the Master in Project Management, and therefore it is important to keep in mind that this research is limited to civil and transport engineering Project Management.

1.6 OUTLINE

Chapter 1 – Introduction

The first chapter aims to give a background to the reader over some the issues in the construction industry, and explain why the author is willing to work in within this topic. Further on the author presents the main goals of this research.

Chapter 2 – Methodology

This chapter aims firstly to introduce the reader to some of the most common research methods, and explain why and how the data in this thesis work was handled and obtained.

Chapter 3 – Theory and Literature

The Theory and Literature chapter is the result of a literature research within Project Management and VDC. Here is laid the bases for results interpretation and discussion.

Chapter 4 – Veidekke Entreprenør ASA

The company Veidekke is introduced in this chapter and the result of their practices assessment is presented. Some industry experiences are additionally given.

Chapter 5 – VDC implementation in transport infrastructures

The chapter 5 addresses the state of the art regarding transport infrastructures in Norway, and it is identified what has been made in the industry that would support VDC implementation and what are the major challenges.

Chapter 6 – Discussion

Regarding the Norwegian industry reality, the competences and objectives of the analysed company, based on the theory it is discussed a possible VDC implementation strategy and its consequent benefits.

Chapter 7 – Conclusion and recommendation

The discussion chapter serve as based for such chapter, where the main findings are summarized and some recommendations are made.

Chapter 8 – References

The chapter where a complete list of the references used in this thesis work is presented.

2 METHODOLOGY

This chapter aims to review the methodology utilized in this research and introduce the most common research methods that are available for the elaboration of scientific papers. Additionally, the author intends to become familiarized with such methods that handle and assess the information properly, in order to response the research question in the best possible way. On the other hand it is wished to get the readers to know how trustworthy the results are and allow them to understand how substantiated the conclusions are.

2.1 RESEARCH METHODS

In this paper, no particular research method was privileged. The chosen method was driven by the set research questions. Firstly, by having an overview over some of the available methods, the goal was to identify which method or methods would support proper research question answering.

The literature available is quite extent regarding research methods. Some of the studied research methods were the quantitative, qualitative and mixed research.

The distinction between the qualitative, quantitative and mixed research method does not lies only in the type of data collected. In quantitative methods, the theory is utilized early in the research to identify hypotheses and to select the appropriated measurements instruments.

The quantitative methods are in general concerned with finding the relationship between the hypotheses and study variables, and generalize the results obtained from surveys, databases, or a series of results, to a larger population through an objective process (Chism et al., 2008). Quantitative methods use to fit well for deductive approaches, in which the theory supports the variables and the defined research questions.

How the data is collected, depends on the theory being tested, as well as the method for statistical analysis of the examined data (Borrego et al., 2009). The purpose of quantitative studies is for the researcher to project his or her findings onto the larger population through an objective process. The type of data collected often allow the researcher to generalize the findings and make assumptions. The results of the statistical analysis will have a considerable weight in the study's conclusion.

The author believes that such method does not fit the current research work. What substantiate such statement is that none of the following theory will be tested neither hypotheses generated. Any instrument for data collecting and treatment was built, and no variables were introduced or manipulated for data collection. No further statistical analysis will neither be performed.

On the other hand, qualitative method is a technique that better fits when examining a particular issue, which seeks to understand a certain phenomena in depth and within specific contexts (Chism et al., 2008). It rather focuses on smaller groups in order to examine a particular context

in greater details. The goal is not to provide a general description, but rather describe a particular situation in enough depth that the full meaning of what is occurring is clearly presented.

Qualitative research is characterized by the collection and analysis of textual data (interviews, observation, conversation analysis, focus group) and by its importance on the context of the research work (Borrego et al., 2009). However, it requires rich and contextual descriptions of the data obtained. It is often conducted from a post-positivist perspective, which supposes the existence of a trustful theory. Qualitative research involves planning the research that covers the study aspects, from the research questions to examination and analysis of the data collected.

The use of theory use to come later when compared to quantitative methods.

The data are examined without preconceptions as to existing theory or pre-determined categories, allowing themes or categories to emerge from the data (Borrego et al., 2009).

In general, the approach is inductive rather than deductive. This means that the approach is exploratory, rather than confirmatory. The concepts are generated rather than tested.

In concern to this paper, the author is from the opinion that qualitative method is the one that best suits the research performed in this paper. It was the chosen method since it is the one that according to the data collected, will facilitate the proper answering of the research questions.

There are two main trustworthy sources due to different factors. This paper is addressed towards a particular example of the Norwegian industry, and as the research questions emphasize, part of the objective is regarding the case of firm within a certain industry.

Therefore, the main data was collected from the actual firm. Such data is assumed to be reliable by the author and seen from a post-positivist perspective. The proximity with the research partner in this master thesis, allowed the author to have direct contact with several actors who granted precise information towards the current practices that also helped defining and answering the research questions.

Qualitative methods additionally support the identification of contexts for transference of the researched theory. When invoking the research questions, such particularity plays a significant important role for fulfilling one of the goals of this thesis.

Furthermore, the fact that the research topic is a fairly recent topic that still has its research focalized at CIFE. It is considered an important and reliable source, and also for many other authors that have made research in this topic, have used CIFE as one of the main references.

Some of these actors have been trained by CIFE and such contractor has also been cooperating with CIFE for several years, and have implemented methods in its buildings' division based on CIFE's framework. Facts that attribute a special importance to the source.

Lastly, to mention that mixed methods involves both quantitative and/or qualitative data in a single study. In this method, the fundamental is the research question. The methods should

follow the needs of the research questions in order to offer the best chance to answer them (Borrego et al., 2009).

2.2 LITERATURE REVIEW

As part of the master program that the candidate aims to complete with this thesis, there was a course over the master that intended to facilitate the students with capabilities for development of a proper literature review. There the candidate got introduced with decent methods for selection and analysis, as well as methods for writing and synthesizing literature. Nowadays information flows throughout many different channel, therefore such skills are extremely important for a successful literature review.

Not less important is where the information come from. The candidate explored several scientific sources, where the most important ones were databases, journals or internet libraries recommended by VIKO (guide to information literacy). Those internet based sources were Science Direct, Engineering Village, Springer, and Scopus mostly. In parallel it was also utilized the online library ASCE – American Society of Civil Engineers Library and Bibsys that enables google scholar search in addition.

All research materials were evaluated according to VIKO's criteria in order assess if the information is whether or not reliable, objective, accurate and relevant.

2.3 DATA COLLECTION METHODS

Data collection is not the simple mechanical act of gathering the information for later analysis. The data collected should be linked to the research questions and scope of the study.

The decision of which method to use for data collection is usually determined by the researcher. A number of factors will influence the decision. These factors include the expected quality of the data, the means available for data collection, the content of the data, and the subject under study. Often, the decision is easily made because the alternatives are unrealistic, not practical or unavailable for a particular study. However, if alternatives exists, then the choice may be difficult (Lyberg and Kasprzyk, 2004).

The most common methods of data collection are interviews, direct observation, surveys, administrative records, and combination of methods.

The author aimed to collect data regarding the working processes of the company. The goal was to get familiarized with the practices within the company and get to know what sort of issues and challenges were faced by the project managers. Therefore, the possibility of collect data by means of surveying was put aside, and the focus was towards data originated from the experts and top managers. In consequence, interviews with specific actors was a priority and considered to be the best way of gathering the most valuable and reliable data.

The possibility for data collection by direct observation was linked to the summer internship that took place in Veidekke. During the summer of 2013, the author had the opportunity to get familiarized with the methods used in a particular infrastructure project in Norway, which was in full implementation phase, by Veidekke. Such project was a road project, which was about 9,6 kilometres long and included 5 bridges of medium/small size.

The data collection methods chosen were also influence by the opportunity factor. If such internship was not possible, possibly another form of observation would have to be arranged.

2.3.1 INTERVIEWS

In qualitative research a common method for data collection is by interviews. “Interviews allow the researcher to collect data from specific participants, focus the participants’ attention on specific items of interest, and obtain the participants’ views on the topic. The research learns about experiences, perceptions, and feelings of those being interviewed” (Chism et al., 2008). Nevertheless, it is important to keep in mind that the interviewed data may not be a real description of the experiences and knowledge. This data collected is filtered by the capability of the interviewer to set the questions, the perception and understanding of the interviewee, and the skills to explain and express his/her point of view.

The interview process may be complex due to the number of elements that may take part in it, along with the different ways that the meeting may be conducted. The interviews that the author took part may be classified as a semi-structured interview. This is the most common type of interview within a qualitative approach. It required the preparation of an agenda to be followed, and the pre-determination of questions. However, there were no limitations regarding exploration of certain topics that emerged during the process. In a way, the interviews were flexible but long, and allowed to cover the topics that the interviewer intended.

The first interview was held at the Headquarters of Veidekke before the start of the specialization project, and it was an exploratory meeting, in order to find common ground for the both actors. There was intended to understand the needs of the company and how the master candidate could contribute towards company’s issues, having in consideration the wishes of both sides. As a result, the main goals of this cooperation towards the master thesis were settled and both entities agreed on what should be done further. Such process was important for setting the scope of the work and its objectives.

Further in February 2014, another interview took place. The interviewer got to know in advance who would be the interviewees and how much time available would he have to conduct the interview. Firstly, and according to the agenda, every person in the room made a short presentation about themselves and in what were they experts. Besides the interviewer, the other actors present were Svein Gunnar Ornæs who is Veidekke’s former project manager for infrastructure projects and current Head Manager of the Infrastructure Division, Sverre Longvastøl Flom who is one of the VDC technicians at Veidekke and finally Asle Gjøstein Resi, Geospacial Manager.

Afterwards, the master candidate presented his ambitions and goals for the master thesis, and how he expected to add expertise to the company, and at the same time acquire knowledge himself and contribute in the field of academic research.

Further, the interviewer started setting the prepared questions. The questions regarding VDC in the buildings industry went towards Sverre Flem, and regarding infrastructure projects went towards Svein Ornæs and Asle Resi. Everybody was present in the room during the whole process, and all were free to intervene, discuss or add any comment towards the topic. The answers were discussed in an opened matter and sometimes it actually worked as a group interview. Such fact can be a powerful tool for gaining information not accessible in individual interviews. That is due to the fact that the interactions between group members may stimulate memories, discuss different points of view, and at some point start a brainstorming of ideas and/or other perceptions.

On the other hand, from the interviewer's standpoint, this interaction may turn the interview harder to conduct, and harder to keep up with all the ideas discussed. This may require great attention during the whole interview and at the same time, the capability to take notes when necessary. However, the interview was audio taped which allows the interviewer to later scrutinize the answers and discussions that took place.

2.3.2 OBSERVATION

During the observation period the author spend time on site and observed how the construction processes took place in many of the project elements. The author noted what sort of problems both the construction manager and project manager struggled during such stage and where was room for improvement.

Additionally, the author observed several meetings between the operations manager and foreman, and how the tasks were planned, controlled and estimated. The observer had access to the software used for those processes and to the documentation handled in the construction site.

The observation process was performed in a natural setting, where the interveners "just" did their job, while being aware at they were observed, but not under judgement.

Later on, the observer visited the main facilities of Veidekke, and observed the room where are hold the collaborative meetings with the project stakeholders, supported by Integrated Concurrent Engineering methods.

The data collected from the observation process bring to the candidate a good understanding over the reality found in the industry and in this contractor in particular. Thereby, the candidate will grasp a better perception over the methods and actions that can be adopted in the future, within the business.

2.3.3 «4-DIMENSIONAL JOURNEY TO THE FUTURE OF THE CONSTRUCTION INDUSTRY»

The aforementioned seminar took place in the early 2013 at the NTNU, and it was organized by Veidekke ASA. Such seminar had as goal to present and acquaint the Norwegian construction industry with the current and emerging VDC practices. Therefore, the director of CIFE, Professor Martin Fischer, was present as the main attraction in the seminar, in order to lead the presentation. Several experiences of the industry were disclosed, and showed how much the industry could earn, and improve processes by implementing VDC. Another actors representing the Norwegian industry also took part in the seminar and exposed the progress that the industry has made and what is yet to achieve in Norway.

Such information was relevant to understand the generality of the VDC perspective. Additionally a good insight over the Norwegian state-of-the-art towards VDC utilization was revealed. Such reality should not be far from Veidekke's situation within the construction industry. This is a good starting point over the assessment of VDC implementation in the building's division at Veidekke.

3 THEORY AND LITERATURE

In the following chapter is presented an overview over the relevant topics for this master thesis covered in the literature review. Such literature review aims to contribute with a strong theoretical background over the research questions, from where the answers should be sustained and based on.

3.1 INFORMATION TECHNOLOGY ON PROJECT MANAGEMENT

New computer based systems are nowadays trendy as a project management tool. However not sufficient to insure project success and therefore it is important to understand some processes, skills and techniques that can have significant impact on project success. This chapter aims mainly to get an insight over some of the most important features within project management theory.

3.1.1 PROJECT MANAGEMENT

Project management is a popular mean for organizations to improve internal operations, respond rapidly to external opportunities, achieve technological breakthroughs, streamline new product development, and manage the challenges arising from their business environment in order to meet the project requirements (Pinto, 2010).

The APM book (Management, 2006) defines project management as:

“the process by which projects are defined, planned, monitored, controlled and delivered such that the agreed benefits are realised. Projects are unique, transient endeavours undertaken to achieve a desired outcome. Project bring about change and project management is recognised as the most efficient way of managing such change.”

In order to successfully deliver a project, the expertise and knowledge found in an organization will essentially be required to (Management, 2006):

- Understand the need, problem or opportunity that the project will address;
- Determine the business case, success criteria and benefits of the proposed project;
- Define what has to be accomplished and delivered, typically stated in terms of scope, time, cost and quality;
- Develop a plan to achieve the deliverables and then implement the plan, ensuring that progress is maintained in the line with objectives;
- Utilise resources as and when required in a team environment, under the direction of a project manager who is accountable for the successful delivery of the project in terms of time, cost and quality;
- Ensure that the sponsor is accountable for achievement of the defined benefits;
- Use appropriate mechanisms, tools and techniques.

Throughout all the project life cycle, there are generic project management processes that may be applied, according to each particular phase they are. Following, the series of phases that all projects pass through are addressed.

3.1.2 PROJECT LIFE CYCLE

Projects will always have a beginning and an end, and will be characterized by different phases. How these phases are defined may be more or less clear. Some actors define three simplified phases, while others define four different phases. According to PMI book and APM book, the last mentioned number of phases are mapped. Regardless how big or small, simple or complex the project is, all go through a life cycle. The phases are defined according to what appears useful, commonly by processes, ownership or responsibilities (Samset, 2010). In line with the APM book, the project life usually follow a sequence from concept, to definition, to implementation and finally handover and closeout.

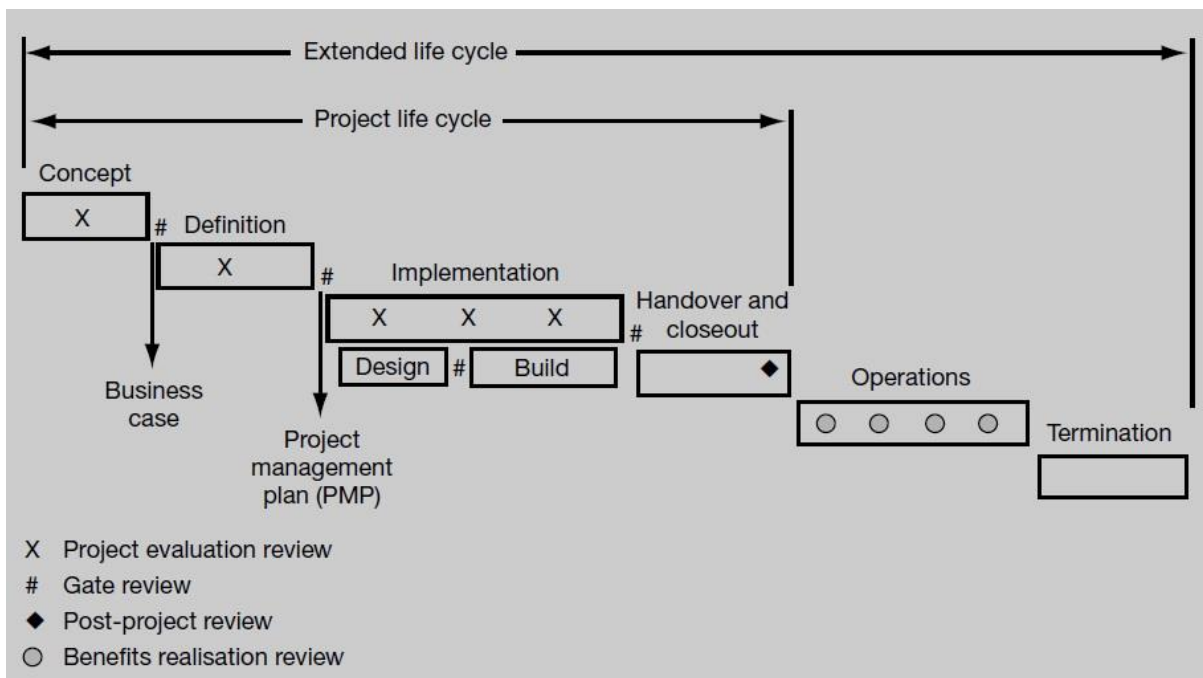


Figure 3 - Project life cycle

In the first phase (concept phase) the need, problem or opportunity for the project is identified. If the project is feasible, possible solutions are studied and the favourite one is chosen. If support is founded, the project should continue further to the definition phase.

The next stage (definition phase) evaluated the chosen solution and assess ways to fulfil the project solution, and therefore prepare the necessary implementation plan.

The implementation phase will then implement the project strategy conform planned. Such implementation may be made in two or more stages.

The project reaches its completion in terms of delivery of a capability that will allow the creation of value, when is delivered to the project sponsor and organization. This is called the handover and closeout phase.

In an extended life cycle project, some other phases may be included, where will be included the operational life of the project.

During the project life cycle, some characteristic features should the taken into account. Following, some of those are described (Management, 2006):

- The potential to add value to the project reduces as the project progresses, and the cost of making changes increases.
- During the implementation phase, the consumption of resources will accumulate at their greatest rate.
- Planning and estimation should be carried out at an appropriate level to suit the phase.
- Resources should be identified early and therefore effectively utilised.
- Risks should be identified and responses targeted at distinct phases.
- Gates should be established to allow effective end of phase reviews and to confirm that sufficient planning and preparation are in place to commence the next phase.
- Early phase successes should be used to reinforce stakeholder commitment.
- Lessons can be learned from earlier phases and applied to improve future performance and future projects.

Such phases may be overlapped, but none should be omitted. All phases of life cycle are important.

3.1.3 TECHNIQUES IN PROJECT MANAGEMENT

Several techniques are used in project management to aid a successful delivery of projects. Some techniques are cross functional and can be applied in a different variety of projects, while other and suitable for more specific projects. Such techniques will enable a project manager to (Management, 2006):

- Fully define users' requirements;
- Take an initial preferred solution and refine it into an optimal solution;
- Estimate the project's cost and time objectives;
- Use technology appropriately through the project life cycle;
- Ensure the continued application of best value;
- Model and test deliverables prior to handover and closeout of the project;
- Ensure that a project's deliverables are developed in such a way that their configuration is clearly controlled.

In order to deeply address the main focus of this thesis, some more enlightening over the use of technology as a project management aid tool is next covered.

3.1.4 TECHNOLOGY MANAGEMENT

“Technology management is the management of the relationship between available and emerging technologies, the organization and the project. It also includes management of the enabling technologies used to deliver the project, technologies used to manage the project and the technology of the project deliverables.” (Management, 2006)

The use of technological tools may create opportunities for new problem solving approaches and product delivering methods, but can also add threats and risks that should be managed.

Nowadays are out there multiple types of technology available that enable business processes, however its introduction should take in consideration the organization’s strategic objective. Therefore, both strategy and technology should be aligned in order to achieve the results expected. Such management may occur at different levels, and may be directed towards different project criteria, as for example to manage tools that enable project planning, designing or monitoring (Management, 2006).

Failing in utilizing the managerial technologies may result in poor manage and put at stake the recognition of the organization towards the innovative technological tools.

3.1.5 INFORMATION TECHNOLOGY MANAGEMENT FOR CONSTRUCTION

Construction firms are currently looking for means to improve their communication, collaboration and information management. Innovative information and communication technologies (ICT) may provide those tools for a continuous process improvement (Stewart, 2007).

Requirements from the clients along with the will to create competitive advantages over other firms has boosted construction firms to look for more efficient processes regarding project information exchange, manipulation and management.

Currently, ITC comprehend several computer-based tools that support not only the construction industry. Those tools are usually associated to building information models (BIM) when it refers to such industry, however it is not the only one (Froese, 2010). ICT systems may experience difficulties fitting into current practices and taking full advantage of the potential of such systems, due to the required high level of integration and collaboration along the project tasks. Froese (2010) suggests “that project management practice, enable by construction ICT, could more explicitly recognize, represent, and manage the interdependencies that are pervasive throughout construction, thereby fully exploiting the potential of the ICT to improve overall project performance”. Technologies such as BIM, VDC, IFCs, and nD demand for changes in the construction projects, in the way project teams come together to find answers towards the design and management of the construction project.

The level of complexity of a construction project is largely affected by the quantity and interdependence of project’s components (Froese, 2010). One approach that the construction industry has developed to deal with such complexity is to decompose the project into well-

defined work tasks and assign each of them to a specialist group. Those tasks are next executed as if they are at a large extent independent from each other. Every specialist understands that their work and actions will certainly affect others' work. Additionally, it is found few individuals that are responsible for project coordination. Therefore, every individual is trying to develop its own work while very few focus on managing the project as a whole, and consequently turn the system more effective and productive.

ICT potentiates and increases integration of data that computer applications manage. Designers and managers form mental models that are connected to the real world, and add inputs to the project by creating information models through computer application and documents. Those models are able to be integrated and improved by the ability of computers, having minor changes in the basic documents and the idea of the project. No computer application, document, or individual's understanding of the project will capture all the project information and its interdependencies, although they can improve their capacity to integrate the different views over the project and its attributes (Froese, 2010).

The information collected pertaining to the construction project and its interdependencies would be supported by ICT tools that enable new consequential functionalities resultant from the common information that all participants would have access to, and to the improved communication/collaboration channels. In the meantime, the changes in the management process would be small, but the impact in the understanding on how each task interact with others within the project could be great.

3.2 VIRTUAL DESIGN AND CONSTRUCTION

The concept of Virtual Design and Construction was introduced in 2001 by the CIFE at Stanford University, and has focused on developing an integrated, model-based approach to address some of the issues that may be affecting the productivity levels in the construction industry. CIFE has identified as one of the issues, a fragmented design and construction process that makes projects last longer until its completion (Khanzode et al., 2006).

The development of a project requires a linkage between the design, construction project management, and product and financial management. Most of this linkage is made nowadays manually and socially, with “greater cost, interaction latency, and confusion.” (Kunz and Fischer, 2012)

The objective of making systems and organizations to work together (interoperability) was motivated by business drivers and technical work in concurrent engineering, which endeavour to integrate product, organization and process modelling and analysis tightly.

CIFE has defined VDC as “the use of multidisciplinary performance models of design-construction project, including the Product (i.e., facilities), Work Processes and Organization of the design-construction-operation team in order to support business objectives” (Khanzode et al., 2006). The scope of definition of VDC is broader than BIM. While both BIM and VDC refer to technologies employed and the process used, VDC is a more comprehensive and holistic methodology that incorporates the use of BIM, and includes all processes over the planning, design, construction, and operation of a project as well as the project organization supporting these processes (Kam et al., 2013).

However, other authors claim that the definition is yet to be agreed and that its concept is still continually evolving (Li et al., 2009), but for the effect of this thesis, the above mentioned definition is the one which guides the author throughout this work.

VDC’s abilities are strongly connected to technological developments and should not be seen as static concept, but as means to constantly integrate new tools and methods for better problem solving solutions.

CIFE has come up with three stages of development of VDC. The first phase is visualization where project teams create “3D models that represent design of the product, models of the organizations that perform design, construction and operations and the process followed by organizational participants to do design, construction and operations and management, based on performance metrics that are predicted from models and tracked in the process” (Kunz and Fischer, 2012). Stakeholders need to be able to interpret the visual models and may require multi-party collaboration contracts to allow and incentivize information sharing. This stage use to be easily justified and implemented by a project, due to the current PC technology that makes available high capable software tools, which however may not be cheap. The visualization is

the most effective way for stakeholders to describe and explain themselves accurately and to analyse in their minds their own and others' work.

In the following stage, integration, “projects develop computer-based automated methods to exchange data among disparate modelling and analysis applications reliably” (Kunz and Fischer, 2012). In order to integration work well, stakeholders need to agree on exchange standards. This would just require one first and only investment in tools that could be used in other several projects.

The last stage is automation, where “projects use automated methods to perform routine design tasks. For automation to improve design, project organizations normally need to dramatically change their processes to enable or perform more high-value design and analysis and spend much less time and billable effort for routine design” (Kunz and Fischer, 2012).

The current focus of VDC is mainly staying on visualization, and it is shifting to the integration of construction (Li et al., 2009).

3.2.1 VDC MODELS

VDC models are computer based project models that are used flexibly, visually and interactively, and are not document or paper based. Discrete paper based documents do not help integration of different disciplines and make even simple changes require hours to days to make a change, print and review the updated documents (Kunz and Fischer, 2012). Additionally, some papers like 2D drawings or charts may be difficult to understand for some stakeholders. Since VDC is designed to support a multi-disciplinary project team, stakeholders may meet in simultaneous and through interactive process models of the product, organization and process, display, explain and update simultaneously the model by the engineers who generated it. In addition VDC models make the content of each model much more accessible than they are in traditional static paper. “Most stakeholders find interactive 3D models are vastly more understandable than static 2D plan and section drawings, and 4D product-construction process animations are much more understandable than traditional project schedule charts.”

VDC creates an integrated framework and set of methods to manage the project, including those aspects of the project that must and can be designed and managed. VDC models involve building, organization and process interactions. In comparison, Building Information Modelling (BIM) technology for instance does “not normally model, visualize or analyse the organization and process accurately and effectively, and methods to manage and communicate multidisciplinary information and processes remain ad-hoc” (Kunz and Fischer, 2012). VDC practices allow stakeholders to “participate effectively in the design models, learn to understand all models as they evolve, and express their perspectives in a timely manner to other stakeholders throughout the project design”.

The decision making processes may be reduced by enabling an interactive behaviour and therefore reducing the time between requesting information and actually get the requested with enough quality that should allow the decision to be made.

It is naturally expected that the majority of the stakeholders find 3D or 4D models more attractive and understandable than the 2D plan and section drawings. 2D models require reading and understanding of the drawings, which contrasts with 3D and 4D models that are naturally understood.

The interactive models allows that change or highlighting in any of the models will rapidly be updated in all other dependent models. Such fact leads to less needs for explanations, and less time to make decisions. It is additionally expected that the stakeholders will increase their feeling of ownership and influence in the decision-making process and thereby decrease the need for rework in both design and construction process.

3.2.2 PRODUCT, ORGANIZATION AND PROCESS

In order to facilitate means for a project manager to handle the aspects that can be managed, CIFE created the project model so called Product-Organization-Process model, or the POP model. Therefore, CIFE's scientific paper Kunz and Fisher, 2012 is used as the main source for the development of this topic in this master thesis.

A project manager is able to control the design of the product to be built, the design of the organization that designs and builds, and the design and the design-construction process that an organization follows.

There was defined two related types of POP models – generic and instance. The generic model which basically defines the vocabulary used in the project work by the stakeholders involved. This model should allow the professionals to share customized vocabulary towards the project elements and attributes. However, such models lack values for their attributes, or names of individual instance elements. Therefore, instance models will specialize the vocabulary by naming and differentiating every individual element.

POP makes information specifically to be shared among models, not a complete project model with which individual modelling applications send and retrieve information.

“The POP model describes the content of the individual P, O P models, each represents the details of designed conceptual elements with their attributes, attribute values and relationships. The individual P, O and P modelling tools have user interfaces that present the models using natural visual idioms that are appropriate for each relevant discipline perspective.”

The purpose of the shared POP model is to define conceptual elements that are shared and help the stakeholders to assure that the product, organization and process specification are appropriate and mutually consistent. The organization model determine which of the stakeholders will design and build each of the physical elements.

The process model assigns activities and the milestones to the stakeholders so they are all coordinated and able to follow the tasks and fulfil the requirements of the works. The product model represents the components and systems of the deliverable elements.

At a high level, POP models represent the “function, designed form or scope, and behaviour of the project product, organization and process” (Kunz and Fischer, 2012).

The main goal of the POP model is to support stakeholders to identify the elements that require the greatest cost, effort or schedule in the design process, and additionally permit the consistent modelling of such elements throughout the project.

A POP model is satisfactory when its elements are mutually consistent in detail, refer to each other, and for a particular level of detail the most important details are described together. For instance, the product elements should be related to the design and construction activities, and to the organizational parties responsible for those activities.

3.2.3 INTEGRATED CONCURRENT ENGINEERING

VDC facilitate that multiple stakeholders cooperate and provide several different perspectives for a project, even though they have specific business objectives. The different perspectives and experiences may raise some barriers in what concern the collaboration process. Additionally the vocabulary is not usually common for every parties, and the methods and cultures may differ at some level. All these points may contribute for a less effective integration. Other obstacle may be related to “conflicting objectives, such as maximizing profitability of their own organizations and maximizing utilization of their own organization assets” (Kunz and Fischer, 2012).

Of what today researchers call Integrated Concurrent Engineering (ICE), is a method created by a Jet Propulsion Laboratory (JPL) design group. This method “defines the functional objective, design response and makes many predictions about the cost, schedule and performance of the proposed mission project”. It takes in consideration the physical design, the organization of the design, manufacturing and operations, and the process of the manufacturing operation. Such method reduced the costs of the design study, increased its quality standards, and reduced project schedule (Chachere et al., 2004) (Kunz and Fischer, 2012).

ICE uses a “singularly rapid combination of expert designers, advanced modelling, visualization and analysis tools, social processes, and a specialized design facility, to create preliminary designs for complex systems” (Chachere et al., 2004).

CIFE realized that the space mission projects managed by JPL had some similarities with construction projects. Although they are different, both seek for the development of new capabilities, and involve collaboration among multiple disciplines and multiple stakeholders with a mixture of shared and competing objectives and methods. Based on the observation of JPL methods, CIFE implemented the ICE method in their VDC working practices, with the goal of developing a very quickly and collaborative multi-discipline project model that would

support effective multi-stakeholder design review and approval (Kunz and Fischer, 2012) (Khanzode et al., 2006).

The ICE method aims to remove the diversions which will not add any relevance to the project from the attention of the design staff as they participate in an ICE session. In the absence of diversions the design team achieves short response latency, which in comparison with other practices is both very fast and very reliable.

In order to facilitate the process and allow the teams to describe and explain their models and to simplify the interpretation by other present elements, a so called *iRoom* was established. That is a multi-screen interactive environment, which includes multiple touch displays, each showing the projected screen of a computer. Such tools create a common framework for data integration and allows fast and interactive collaboration between the stakeholders involved in the project (Kunz and Fischer, 2012).

3.3 VDC AND PROJECT MANAGEMENT

Projects are naturally a way of bringing stakeholders together that demands for coordination and integration actions. The tools available have the purpose of supporting the project manager to achieve the goals of a certain organization, by responding to external opportunities, exploiting technological appliances, developing new products and handling the most several challenges that may raise within a business environment. In this topic is intended to assess some of the flaws of conventional project management tools and how VDC is able to help overtaking those issues.

3.3.1 CONVENTIONAL TOOLS OF PROJECT MANAGEMENT

The main source for this topic is based on the studies developed by Li et al. (2009). The author conducted interviews with actors that are experienced in Project Management and VDC in wide project areas, analysed data from critical literature review, participated in open debated and did some field work. By analysing all the qualitative data, the author distils the most mentioned shortcomings of traditional Project Management and identified the fundamentally problematic aspects of contemporary project management, which are discussed as follows:

- Cannot try before build
- Discontinuity in construction processes
- Ineffective information/knowledge management
- Creeping managerialism

The first bullet point faces the impossibility of trying different designs and constructions schemes before the actual building process, which leads to two major problems. The first problem is that it harder to effectively identify design errors in the design stage, then in the implementation stage. At this stage, the problem identification may lead to substantial disruption of the construction process and consequential losses. The author does not mean that

project revision is not done and that errors are not detected. However, he means that such revision is not done with the support of technological tools that could increase the effectiveness of error detection and correction. Additionally, construction schemes developed at the planning stage cannot be rehearsed and tried in advance. These factors make construction a “very risky business”. The planned information and the engineering design may have imperfections or mistakes, which make the construction project an experimental process until it reaches its end. Such information is presented in a way that the imperfections and mistakes may not be easily found. A virtual and simulated environment would allow projects to try different schemes before it is actually built.

The following shortcoming in contemporary Project Management is discontinuity in construction processes. For a long period construction theorists or practitioners have not questioned the fact that a project was divided into several stages. On the contrary, this has been perceived as an organizational innovation, and different types of companies, e.g. design firms, contractors, suppliers, have been established purposely for different specialisms. “In view of the poor performance caused by the discontinued construction process, there is a strong stream of thinking that calls for a higher integration of project process”.

Indeed, discontinued project process should be reunited to achieve better performance of a project. Li et al. (2009) has identified some changes in the processes, however still considers that a lot should be done in order to achieve higher project performance.

“Discontinuity is still widely observed in construction, although anecdotal evidence showed that undertaking of some construction projects has been improved by partnering. Discontinuity was caused gaps between what is designed and what is constructed; interoperability is low thus causing poor communication between project parties. A reunion of discontinued construction processes has moved to the forefront of solutions for improving contemporary Project Management” (Li et al., 2009).

The next shortcoming is ineffective management of information/knowledge. “Managing a construction project is essentially making a web of decisions across its process based on the information/knowledge available” and its loss from one stage to another has caused many problems in the sector. In addition, “the continual improvement of performance relies on learning from the past and the creation of new knowledge. Information/knowledge generated from a project was often discarded with the dissolution of a project team”. As a result, similar mistakes recur in different projects.

Project teams are not sharing information/knowledge and neither having and interactive and mutual, which result that construction companies have to come up with particular and individual solutions for similar problems faced in different projects.

The last problem addressed is that over the years the increase of complexity and size of modern projects have created more and more managerial positions. As a result, the size of management teams has been significantly increased. It has led to sophisticated bureaucracy while long-

standing problems such as low productivity, delayed delivery time and cost overrun seemingly remain unsolved.

The “creeping managerialism” adds to management cost. “The cost formula in construction shows that the direct costs account for up to 70% of the overall construction and indirect costs such as overheads, contingencies and profit take up about 30%. Given that contingency costs are unavoidable, management cost escalates, and the margin for labour is then usually squeezed by managerial level.”

Many attribute the importance to management that actually is required, however it is often highlighted the need for reduction of managerialism as a solution.

3.3.2 FACTS OF PROJECTS MANAGED BY CONVENTIONAL TOOLS

As early mentioned, a sizeable proportion of projects are constantly being delivered late, over budget and fail to meet quality expectations. The previous mentioned shortcomings may result in great losses in profit and time throughout the execution of projects in the AEC industry, which are reflexed in the projects by (Rheinlander et al., 2009):

- Rework and delays: up to approximate 30% of construction work is rework (due to issues resulted from poor planning, design, collaboration and quality)
- Poor configuration of design and construction procurement
- Inefficient project scheduling, poor pre-construction planning and construction look-ahead planning
- Poor project coordination between project-wide design disciplines, project design teams and external design firms
- Fragmentation of design disciplines (performing of design work in isolation from other designers)
- Project team members not communicating effectively and “not working together” as thus, collaborative design and planning process including a transparent and cooperative exchange of information does not exist
- Safety incidents and claims: construction workers are exposed to hazards on the construction site causing accidents and injuries
- Inadequate construction sequencing, and insufficient value engineering and constructability reviews
- Ineffective communication across the project teams (off-site including stakeholders and 3rd parties)
- Poor project workforce utilization and inconsistent workflow. Approximately 30 to 40% of the manpower used on construction sites can be wasted due to poor utilization.

3.3.3 VDC AS A TOOL FOR PROJECT MANAGEMENT

Li et al. (2009) mention that the term “Project management” has been expanded from a traditional project management definition. In order to manage today’s projects with increasing

sizes and complexities, emerging project management methods and practices may be adopted. “Their complexity and requirements, together with high uncertainty and rapidly changing environment, the traditional project management approach will become obsolete without the adoption of integral processes and strategic thinking”. The contemporary project management is referred as the usage of core approaches such as scheduling, cost control and quality management that help delivering project goals. However, project management stands nowadays as well for aspects as technology, strategy, finance and so on.

Every project face similar constrains and VDC may allow a project manager to achieve the same goals as traditional methods do. As mentioned earlier, continuously changes create issues for project management and current modelling tools (e.g. BIM) enable creation of multiple versions of design documents, although they have very limited capacity to identify change dependencies among the contents of related methods. However, “VDC adds an integrated project framework to describe, track and manage changes in the product, organization and process over time, which today can be visualized and managed socially”. In addition it offers the opportunity to join efforts from the different actors along the construction industry (Kunz and Fischer, 2012).

In fact, construction projects have been criticised for lack of cooperation among stakeholders. They often have narrow areas of responsibility and they often prioritize to profit individually instead of maximizing the value of the project as a whole (Lahdou and Zetterman, 2011). Setting stakeholders together maximises the efficiency of every participant, by displaying, comparing and managing the project, when potential problems are identified. If changes are required, they can immediately addressed it from all aspects as a team, instead of producing new project versions for each stakeholders that would require further evaluation and discussion. The team can therefore adapt quickly to the changes, predict the performance of project tasks, perform what if analyses, simulate scenarios and create visualisations to provide effective means in optimising the overall design and construction strategies, planning and construction and provide an interactive communication environment (Rheinlander et al., 2009).

3.4 PROJECT VISUALIZATION METHODS

Product models are traditionally composed by a set of lines which the human eye interprets as specific elements. Those models are historically 2D CAD models, although more and more are represented in 3D or even 4D. Such models are extremely important to understand the design of a physical product before its construction. Typically traditional models ignore the relationships of the organizational actors and activities with the elements of the product. More modern 3D CAD models use the set of lines to constitute 3D elements that the computer modelling system recognize as an “object”. The modelling system is able to numerate, locate and assign properties to each modelled element. These models may be set in formats that permits the interchangeability between different applications where they can be interpreted by other actors from different specialities.

3.4.1 FOUR DIMENSIONAL MODELS

A 4D model integrate 3D physical design with the time dimension. The elements in a 4D model will contain its geometric attributes that form its 3D shape, and the time attribute that should specify the starting and finishing construction time of the respective element. Such element will therefore be attached to other elements until the completion of the whole product (Mahalingam et al., 2010). This process may facilitate the understanding of the construction process, since it provides the actors with visual elements that can be used to simulate a sequence of construction tasks.

Moreover, Mahalingam et al. (2010) affirm that 4D models aim to aid the traditional planning methods achieving better performance and integration. Some models may require an important level of expertise and thereby become counter-productive for the companies. Yet, such models are intended to be simple representations of the project and allow its application towards a wide variety of participants as well as towards diverse levels of skills and experiences.

Project planners, designers and engineers have been using 4D models to analyse and visualize construction projects, in order to aid decision making, planning operations and constructability analysis of a project plan. In addition, other processes such cost estimation, resource management, and communication and collaboration among stakeholders may also be facilitated (Mahalingam et al., 2010).

The systematic use of 4D technologies can result in significant benefits regarding time and cost savings, and be especially useful in projects that involve multiple stakeholders. 4D models boost collective decision making, and the development of constructability and execution strategies.

According to Mahalingam et al. (2010) 4D technologies are not widely implemented yet in the construction industry, however continuously more companies are getting benefits in their performance by expediting such technologies. Some companies have claimed for the need to innovation in order to grow in a very competitive business environment, by introducing new project management paradigms, and focusing on tools that will help improving their operational efficiency.

3.4.2 APPLICABILITY OF 4D MODELS IN TRANSPORT INFRASTRUCTURE PROJECTS

The most currently used or under development 4D systems are intended for building and plant projects that use 3D objects consisting of vertical and manufactured elements. However, Kang et al. (2013) claims for the need of development of “systems designed for the graphic expression of schedule data for civil engineering projects derived from horizontal and natural topographical conditions”. Namely methodologies toward projects in the field if transportation construction projects such as highway or railway projects, which would increase the utilization of 4D objects.

Kang et al. (2013) note that in the building projects, the works are mostly vertical and repetitive, which makes a lot simpler the use of 3D objects that many times have standardize shapes, like

columns, walls and slabs. Such facts trend to ease the realization of 4D objects, due to the straightforward link between object and activity. On the other hand, civil engineering projects are often not repetitive nor standardize, which demands for a differentiated 4D modelling. A good example is regarding earth-works. According to the natural topography, the model will require survey techniques and a triangulation with the engineering data. While the work progress, constant changes on the topography will happen aligned to the need of cuts or fills. Because most of the existing systems deal with standardize elements, such particularity in the civil engineering works turns challenging the creation of a 4D model that relates the critical activities with the elements, by exploitation of the existing systems.

These differentiating elements require solutions that enable 4D modelling in both horizontal and vertical dimensions. Therefore, Kang et al. (2013) emphasises for the need of more detailed and useful functions for field engineers and project managers. They have researched some current available techniques, and developed 4D aiding functions that actually have a practical usage. Those functions introduced a link process, between the schedule and 3D object, that uses work breakdown structure as the central concept of information on requirements and occurrence in the 4D system. However, the authors considerer that the current methods available in the civil engineering projects still need some improvements to even the buildings methodologies.

3.5 THE UNCERTAINTY TOWARDS IMPLEMENTATION OF VDC

“Over the past 10 years VDC processes and tools have gain popularity in AEC industry, as that in 2009 more than 80% of the major firms in the United States have adopted VDC applications. The benefits of VDC are widely recognized as enabling more efficient multidisciplinary coordination and adding value to projects over their life cycles. Another relevant fact is that BIM that facilitates VDC has also gained dramatic adoption in the industry in the past years, increasing from 17% to in 2007 to 71% in 2012. The ability to carry on VDC project has also become an important attribute for AEC companies to be ahead of the market competition and undertake modern design and construction projects” (Kam et al., 2013).

These numbers display a huge openness from the industry towards the implementation of technological methods in their businesses. Such figures are result of a research work of CIFE, which is locate in Stanford, USA. Therefore these data does not include numbers of the European current situation. However, by the end of 2012, the CIFE research team has analysed 108 unique AEC projects which had implemented VDC and were reported in a working paper (Kam et al., 2013). Based on those numbers, it was used a statistical approach that aimed to correlate current practices and outcomes as well as to benchmark the current industry’s VDC performance. The evaluated projects were real time AEC projects which covered a wide range of project types in different project stages – from pre-design to close out – and were located in 13 different countries in North America, Europe and Asia, and were design and constructed by AEC firms in various regions. The results of the investigation were not completely satisfying

and lead to the conclusion that full implementation and application of VDC and proper practice is yet to be achieved in AEC industry. Some uncertainty towards the outcome of VDC still remains within the industry. Therefore is important to understand which impediments firms faced, in order to apply VDC in their business models.

Li et al. (2009) have identified four of the main hurdles which are grouped as follows:

- Technical hurdles
- New costs
- Willingness to pay for VDC
- Risk of change

The first point addresses the issue of interoperability. There is a “lack of software compatibility that makes difficult to communicate between different VDC solutions”. In a project, all of those stakeholders that require utilization of software to perform their tasks must agree of the software package and follow the same stream in order to maintain compatibility. The issue is that in construction projects the stakeholders involved are not constant and tend to change from project to project. A software package for one project, may eventually be useless for a subsequent project.

Another technical issue is design speed when using VDC projects. “It takes a long time to create all the detailed 3D models to the desired level of detail and accuracy”.

VDC brings many benefits, but in the meantime also entails extra costs to companies in order to learn VDC and unlearn old approaches. “The cost-benefit relationship of VDC needs to be quantitatively measured”.

But even when the benefits are obvious, controversies over who should pay for VDC are frequently noticed. “VDC aims for integration while the fact is that different projects players are still acting as different profit centres. It is also not a simple matter of “who benefits, who pays” since the benefits cannot be explicitly allocated to different stages or participants”. However, as already mentioned, it is recommended that project owners should be the driving force to promote VDC implementation.

Current construction methods are viewed as of slow response to changes and an implementation of VDC would have big impact if such methods. Therefore, such changes are linked to innovative processes that still entails risks for the business, however it is up to the firms to decide if they are willing to manage the risk of innovate or taking the risk of do not do anything.

3.6 INNOVATION MANAGEMENT

The competition among firms require that they develop best practices in the industry. That require to take financial risks that not all the organizations are willing to take. The risk may be greater or smaller depending on the level of maturity of the technology. However, those who wait too long may miss the opportunity to achieve significant competitive advantages, and meet

the demands of the marketplace. The risk-averse companies tend to innovate their practices and adopt new technologies only when they have already become dominant in the industry. That may seem like a safe strategy, but may also throw them far behind and turn impossible to catch up.

Some simple strategies may help an organization keeping their position at the vanguard and away from the rear of innovation business. Smith and Tardiff (2009) suggest some approaches as follow:

- Continuously evaluate emerging technologies and business practices. There is always something new on the horizon, and by keeping tabs on what is happening you will quickly develop the critical framework that will enable to distinguish truly useful and methods from technological dead ends.
- Continuously seek out opportunities to operate more efficiently, both internally and with external project team members.
- Identify those technologies and practices that will strengthen core competencies, broaden service offerings, streamline workflow, increase the quality of work products or services, lower costs, improve team communication, and enhance electronic information exchange.
- Deploy only those technologies that satisfy one or more of the above criteria.
- Establish metrics at the time of deployment to measure progress toward your goals.
- Deploy only mature, commercially available technologies that require only minimal customization to be productively in your organization.
- Avoid experimental or non-commercial technologies, unless they have demonstrated track record of success and are backed by an organizational infrastructure capable of supporting their continued development.

These strategies may require financial investment, education and training, and a temporarily drop in productivity of the business during the implementation period, but it will help reducing the financial risks and exploit technologies and new business practices at its maximum.

3.6.1 VALUE AND COSTS OF TECHNOLOGY INVESTMENTS

In a literature review are there available several methods that analyse technology investments. Most of them are return on investment analysis that predominantly focus on Building Information Modelling cases. However, Giga Consultants developed the Total Economic Impact model that allows analysis of both the value and the cost of software system investments. Such method “makes the value proposition explicit and quantitative, not just the costs, and it establishes quantitative assumptions and specific measurable objectives for business performance that responsible parties can track and manage to achieve” (Kunz and Fischer, 2012). The anticipated effects on the owner value and costs of investments are considered. Giga Consultants attribute value both for the cost reductions by increase of operation efficiency, and

for the revenues derived from the increase in the market size. On the other hand, costs include immediate and support costs of the investment.

The Total Economic Impact method has been applied by CIFE in order to assess how much value a technology investment, specifically an investment in use of VDC, can contribute to individual projects or companies.

The method is not used to find out how much such investment will cost or how much revenue will generate, but rather to set specific and explicit goals. The method is able to predict the payback period for the investment, by assuming how the investment will be used and how it will impact the business.

Having in consideration several examples and studies made at CIFE, it is acquired that a VDC technology investment may be modest and feasible for a technology leading company inserted in a relatively good market. The results were actually significant. The revenues increased and the savings were also considerable, although it required skilled staff and much commitment in the execution. However, not always a VDC investment is wise. If the market situation is bad, it is unlikely that the investment will be paid off. Additionally, if VDC has been already established in the market, some companies will be investing to catch up their competitors, but their margins may be reduced due to the advantage gap that the others may have already reached.

Many firms do not achieve financial benefits of IT implementation and are largely dissatisfied by their IT investments. In some circumstances, this dissatisfaction has resulted from a lack of strategy IT planning. In others, it is in part due to the difficulty in measuring operational benefits leading to some concerns about the payoff from investments in information technologies. Generally, IT investment appraisal is more difficult than other investment decisions because IT-induced benefits are hard to identify and quantify. (Stewart, 2007).

3.6.2 IMPLEMENTATION OF INNOVATIVE METHODS AND TOOLS IN TRANSPORT INFRASTRUCTURE PROJECTS

The introduction of innovative methods and tools in the construction industry takes place within a complex network of organizations that operate in a “unique, dynamic and continuously evolving environment” (Manley et al., 2010). Other industries typically do not experience the same complexity of project characteristics and technological constrains as the construction industry. Generally these complexities have contributed to difficulties in encouraging innovation uptake, whereby the nature of the constructed product does not align with ideal innovation conditions.

“These unfavourable conditions are based on temporary projects, resulting in knowledge development and transfer discontinuities within and between organizations. These discontinuities can have significant impact on a construction organization’s capacity to identify, integrate and exploit innovative knowledge for the benefit of continuous uptake

across the innovation system. These problems are applied equally to clients, contractors and consultants” (Manley et al., 2010).

Pressures for implementation of innovation in the construction industry are often stronger when there is demand-pull (Ling, 2003). That means that innovation is more likely to take place when clients demand higher requirements. Innovation is required because there are pressures to improve quality, reduce costs and speed up construction processes. The intention of deriving additional benefits, might although associate risks and uncertainties.

According to Ling (2003), the construction industry has not clear boundaries and innovation cannot focus on individual firms. Construction activities project bases, and different firm’s technical competencies are applied in association with technical capabilities from other firms. Construction production is often triggered in response to user need and projects are demand-driven than the result of arm’s length market transaction, which typify consumer-goods industries.

The successful implementation of innovative methods and tools depends on the capacity of the firms, clients and consultancies to work together, erode boundaries between professionals, embrace new roles and develop new aligned capabilities. Collaboration and openness to new ideas can influence the effectiveness for implementing innovator systems. In the construction industry, the type of contracts that bind the project stakeholders dictate the openness to innovative methodologies and collaboration, which can be seen as a barrier for that hinder progress in innovation. However, stakeholder have to necessarily be engaged and committed in order to successfully implement the new methodologies (Ling, 2003). Another barrier is the lack of information on cost savings arising from the implementation of new methods and tools. Moreover, “the effectiveness of the implementation of new methods is influenced by the capacity of the organizations to take advantage of knowledge transactions and on the ability to use it” (Rose and Manley, 2012). In addition, studies found that “organizations that foster innovation have organizational structures that maintained flexibility in unit size and grouping to allow attention to innovation. These organizations made the effort to have special linkages for both internal and external co-ordination” (Ling, 2003). Another important factor is the knowledge intermediaries. They act as a knowledge bridge between interrelated organizations across a network and are critical to an effective innovation system. A project team that includes active knowledge intermediaries will have better outcomes than a team without such players (Rose and Manley, 2012).

With the focus on the previously mentioned factors, which are based on literature review, the “Open Innovation System Model” was developed. The concept is simple and persuasive in its call for greater openness to external ideas, innovations and growth. This model is highly appropriated for examination of knowledge flow in infrastructure projects (Manley et al., 2010).

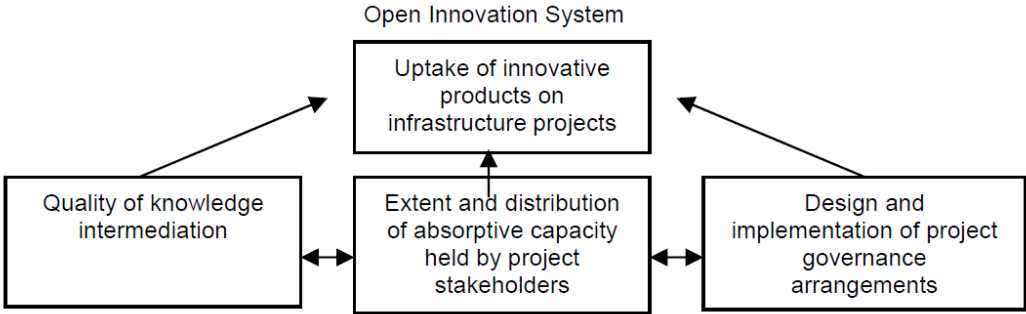


Figure 4 - Open innovation system model

Such model have been applied to large scale study of new product adoption on large scale road and bridge project in Australia. The goal is to maximize the value of Australia’s infrastructure investment plans, by developing methods to increase adoption of innovative products.

4 VEIDEKKE ENTREPRENØR ASA

4.1 INTRODUCTION

Veidekke is one of the biggest civil engineering contractors in Scandinavia and is involved in both building and infrastructure projects development. Their main values are professionalism, honesty, enthusiasm and pioneering. Their products are unique and therefore the processes to achieve its completion are complex. Consequently, Veidekke has been a pioneer in Scandinavia in many on their implemented methods so far. However, the company is always looking forward for new solutions that will improve their performance by supporting and investing in new project management tools, among many others.

Veidekke believes that project management is a central competence and therefore has set a big focus in such area for several years now. In order to achieve a successful delivery of a certain project, it is presupposed that all the project phases are properly addressed, and that all the necessary tools and resources are available. The personnel should have the skills to take advantage of such methods, therefore Veidekke has been cooperating with CIFE where some of its employees have got training. In addition, Veidekke has financed and supported high education institutions in Norway, e.g. NTNU, and has offered possibility to students to cooperate with their master thesis within study topics as VDC, BIM, LEAN Construction, among others.

As one of the main actors involved in the projects, Veidekke must interact with other stakeholders, e.g. project owner, consultancy companies, etc. and aims to cooperate with them towards the best possible project solution to fulfil the project needs, according to the resources available and within the applicable frameworks.

4.2 CURRENT UTILIZATION OF VDC AT VEIDEKKE

4.2.1 GOALS

With the implementation of VDC, Veidekke mainly wish to reduce the project life cycle, reduce the time used handling and transferring information, reach better production levels, reduce production errors, and reduce working related accidents. It is additionally aimed to exploit the available tools for 3D and 4D modelling for better integration of all the stakeholders involved.

Veidekke is continuously looking to improve their working methods, and none of those are static. They are dynamic learning processes that always look for the opportunity to contribute for enhanced methods.

4.2.2 THE ORGANIZATION

In Veidekke, the organization is characterized by its flat structure. That means that there are very few management levels between the staff and the executives. Consequently, the most skilled personnel may be directly involved in the decision making process. That means also that

the managers have a clear knowledge of what capabilities the company possesses. In that extent, the personnel will have direct influence in choosing the project methodology. In the case of the buildings division, the company may be responsible for all project phases. Since the design phase until the delivery, the project can be executed by the company, and therefore the working methods would be adapted to the available skills and to needs of the project and client, if applicable. There are also cases, where the company is only responsible for the construction phase, and will have to cooperate with clients. In those cases, VDC may be exploited at its maximum, although the challenges will also be greater.

In some other cases, VDC may not be used. It does not have to necessarily be used in every project, but its utilization should be evaluated regarding the project goals, needs and characteristics.

Veidekke has several BIM/VDC experts, whom are highly educated and have additionally received education within the company or through external entities, as CIFE for instance.

Those experts do not necessary follow the projects in its total extent. They are allocated in the early phases and are involved in the design, planning, estimation, preparation process, among others. Right before project's kick-off, important meetings take place with designers, architects, BIM/VDC experts, builders, and project/construction managers. There will be defined how the project will be developed with the support of VDC. Once the project starts, the project/construction manager should be able to perform the project with their teams only. Naturally, the BIM/VDC experts will guide and advice when and if necessary.

4.2.3 THE PROCESS

The VDC process implemented at Veidekke was formulated mainly for the building projects. This process is divided in two main areas. The two elements represented in yellow are named as Value Optimization (VO) and Collaborative Planning (CP), and constitute the project planning and management area.

The following area is the Method and Tools area, and is represented by the blue elements for BIM and ICE.

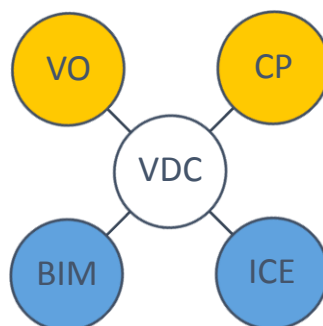


Figure 5 - VDC's implementation model

Although Veidekke has been collaborating with CIFE, the VDC process implemented does not totally follow CIFE's directives. Veidekke has clearly separated designing – in the BIM element - from collaborative planning. Kunz and Fischer (2012) have defined an integrated framework and a set of methods to involve design and process interactions with the so called VDC model. However, while CIFE set its focus in the design phase, Veidekke pretend to have a process that would not only tackle the collaboration needs in the design stage, but also be useful in the planning and production phase.

Additionally, the CIFE's creation of POP model is not denominated in the same way. That does not mean that identical goals and purposes are not aimed by Veidekke with their own processes through different methods. Value Optimization and Collaborative Planning, cover at some extent some of the main points of POP models. These two point are further discussed.

Value Optimization

The VO section intends for the continuously seek of values by defining clear goals along the project. That will guide project participants by having them all in the same page at the same time, and consequently contribute for the motivation and for the learning process of the working tasks, resulting in a higher project efficiency. This is in part coincident with the purpose of POP model, which however set a particular focus towards the use of idioms, but also assigns activities and milestones so that the stakeholders are coordinated from the early start.

By having clearly set goals and milestones, the activities are easily supervised and will support the identification of elements that will add or reduce the creation of value in the construction process. Thus, such elements may be analysed and consequently learn lessons out of it. Such process will support the creation of guidelines for similar future works, in order to boost those elements that create value and repress those that destroy value.

Collaborative Planning

The next point being addressed is CP. It is based on information provided by the company and on a release made by Veidekke (2011). Such concept focus on how planning and control of production will happen in every construction project. The focus is shared towards both the structure and culture, it can be described as a unique working method, which includes management, controlling systems, relationship between individuals, communication and information flow, and the social process. Nowadays CP is conducted in most of Veidekke's projects.

CP is mainly a planning method that may boost the production levels. In order to improve those levels several principles have been followed. Firstly, the working tasks are precisely defined and adapted so that they are executed as planned. The high level of detail of the working tasks, will help the workers to develop their work faster and with more quality. Constant meetings and supervision over the activities are done to insure that the plan is being followed.

Such meetings are assisted by visualization tools, where the plans, charts and other information are projected in interactive boards that facilitate information exchange and ease understandings and explanations. In addition was created a technique, where a board is used as a time plan and the “post its” simulate each task. That allows to move the activities easily and in the meantime facilitate an overview of the plan to every participant.



Figure 6 - The "post-it" board



Figure 7 - Interactive room

Everybody is free to participate in a regular basis, and if necessary even ground workers can join the meeting when some information or experience is required. Thereby, every participant will get a good insight over others' work and understand if and how their own work can be affected or affect others' tasks.

According to Kunz and Fischer (2012) the POP model is only satisfactory when the elements are enough detailed, the relation between activities is established and all the project activities constitute more than individual tasks, but an integrated plan. Veidekke aims for the same, by emphasizing the collaboration between them, sub-contractors and other stakeholders. That will attribute a bigger tolerance and flexibility in the cooperation process. Additional focus is added on making always interaction available with the design and construction activities, throughout the different phases of the project and organization levels.

Veidekke aims to increase the involvement of participants and therefore reach a higher engagement of them.

In order to execute the activities as planned in an optimal way, some prerequisites should be fulfilled. They are divided in seven main categories and are illustrated in the figure 8.

1. The previous activity must be terminated and have the expected quality.
2. The information about decisions taken, design, and description of further activities must be clear and assure quality of the product as well as health and safety conditions.
3. The material should be placed in the right amount and with the proper quality.
4. The man power must be competent enough and have capacity to execute the tasks. The need for variation in the work activities must be assured.

5. The necessary equipment with acceptable conditions to execute the work efficiently and safely must be available.
6. There should be enough space to execute the activities. That includes the cleaning and preparation of the area.
7. The different external conditions must be considered. They may heavily influence and condition the works.

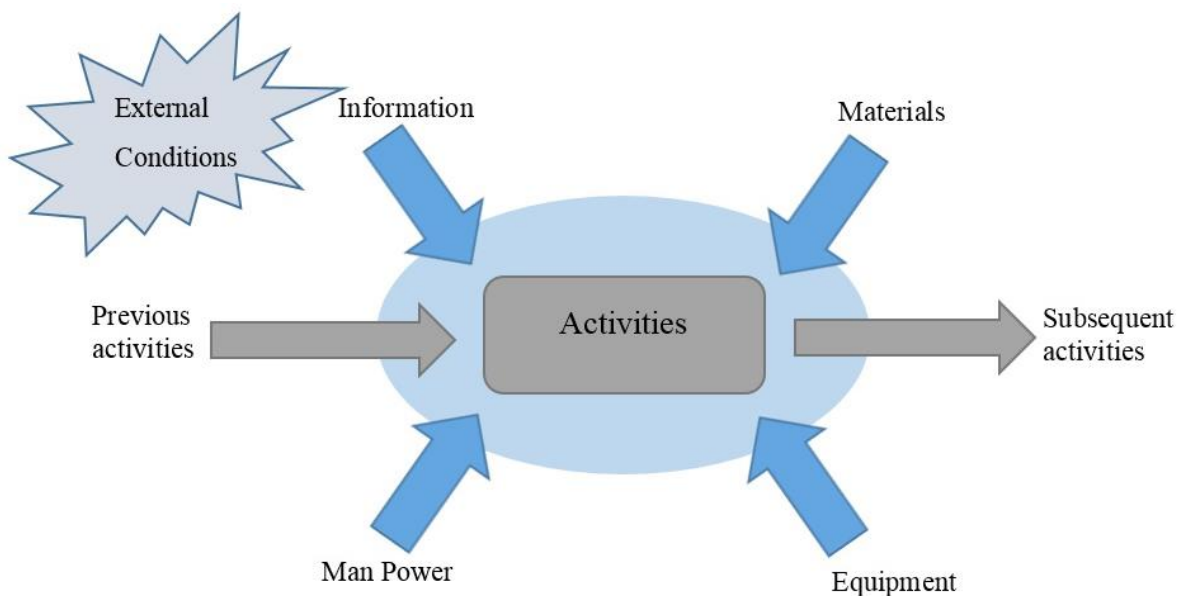


Figure 8 - Prerequisites for an optimal activity execution

If one or more of these prerequisites are not available, so that will constitute an obstacle that can jeopardize the work to be performed.

Another particularity of CP is that the different management levels get extra responsibility regarding activity planning. Most commonly the focus was on activity allocation and delegation, responsibility for personnel, et cetera, and less focus for short and long time planning.

With CP, a distribution of activity planning is made throughout all management levels, with different time period focus, according to the responsibility that each individual has. Higher the level, longer the period in the future that the activities should be planned.

Additionally, the planning system is divided in two levels: The strategic level plan and the operative level plan. The strategic plan is made only once in the start-up phase. On the other hand, the operative plan is made along the project, and a high level of detail is required along with content of the task, recommendations, and responsible person.

The planning meetings at Veidekke follow a pre-structured format. They are meant to be adapted to the project phase and plans.

The CP meeting process starts with a base meeting, where all the managers from all different levels share information, create general understandings, and converge towards the common

goals for the product and process. The project is presented and everybody gets to know what CP is. Such procedure is important to engage and motivate all the project parties. Further, phase-plan meetings take place in the beginning of every new project phase. There, the main activities are analysed and located and organized in the schedule in the correct sequence. The guidelines for the phase-plan are set at this stage.

Moreover, every Monday a team-meeting takes place. The weekly activities are planned in the site. The week-plan, work-plan and drawings get available in advance for those that will take part in the meeting, in order that they can come with questions, or discussion points. After team-meetings, construction managers, foremen, and ground works from Veidekke and possible sub-contractors, discuss the week-plan and go through each activity.

In order to evaluate and control the working progress, evaluation meeting take place by the end of every phase. There the challenges faced during the works are analysed as a part of a desired continuous improvement.

Integrated Concurrent Engineering

Moving on to the methods and tools area, the first element being addressed is ICE. Veidekke has based its operation process on the CIFE's directives, and as Kunz and Fischer (2012), Veidekke defines ICE as method that has a main function to align project design, perform design quality insurance and control. The interdisciplinary integration of elements permit to explore a greater diversity of solutions reaching more efficient problem resolution. The different parties have the possibility to bring new considerations, criteria and priorities to the table. However, such process will demand for higher coordination efforts, higher the interdisciplinary of the team is. The process takes place in a common location where all actors are represented, and is based on a flat organization structure, similar objectives, technical competence, and decision making skills. In an ICE session, all the project participants will work as if they were in their own office. The idea is to gather relevant competence and decision makers in the same location in order to achieve better design integration and to enhance project development.

Several different tools are made available that support such way of working. BIM technology plays a central role and may be connected to scheduling and budgeting.

Although ICE has not been adopted in all the projects in Veidekke, those that use ICE are mostly VDC projects. In such projects participate up to two dozens of people in the process. So far, all the ICE sessions are held in the headquarters of the company, where all the infrastructure is installed.

Recently Veidekke has upgraded its facilities with a brand new *iroom*, consisting of two smartboards, individual internet, screen and electricity connection for every meeting participant, and a white board. The room has the capacity to receive up to 20 people.

Previously there were already two *iRooms* in use, which have been adapted to ICE. Those were smaller, and its disposition has not the most propitious for personal interaction.



Figure 9 - *iRoom* at Veidekke's headquarters



Figure 10 - A participant's equipment

ICE meetings have not a central agenda, but a focus on the circumstances of the project. Therefore it is important to have permanent framework that considers the meeting process as a whole. Such framework is divided in three main points, as follows:

1. Core meeting, start-up

Initially the meeting should follow a common status report, where the different planning levels are processed based on the previous meetings or previous activities, along with the update on the activities performed at that point. Conflict areas are identified for further discussion. The basis for decision making are set by assessing possible solutions. The plan for the rest of the meeting is executed.

2. Interaction time

Interaction among the project actors. Everybody should have prepared in advance the work that will be performed. Project designing will take place individually or in group. Pertinent disciplines representatives may discuss specific matters when required.

3. Core meeting, Summing up

Summary and evaluation of the meeting. Address future progress to be done until the next meeting. Review the status report that has been processed. Review the activities from the project schedule. Every meeting participant highlights what they will need regarding others work, and each of them should inform what will be further worked until the next meeting.

Building Information Modelling

The last point being focused at Veidekke's process is BIM. By implementing BIM technologies, it grants a closer and a more including working method, which supports ICE and consequently VDC. BIM allows the actors to input their competences in a shared and interactive 3D based

model, and therefore transfer learnings among project authors. This will lead to a more efficient and with higher quality project design.

The software that will be used, is defined in advance as well as the delivery file format. All organizations involved in the design process plan their activities relating to the BIM model that guides all parties. That means that all the works performed will be connected to one model only. Therefore the responsibilities are shared between all participants, since all works are dependent from each other. However, everybody have to agree on who will input and what will be input in the model. That should be clearly assigned in the project plan.

In the design itself, only what is necessary should be represented. The model should be structured and do not be over designed.

The design process becomes less sequential and many tasks are made in parallel, even though they are from different specialities. In addition it enhances the communication process and aids problem solving solutions. On the other hand, it destroy walls regarding protection of their own work and open designers for cooperation.

4.3 VEIDEKKE'S EXPERIENCES

Following, an overview of some experiences of VDC's implementation at Veidekke will be presented. They all regard building projects, however the projects were developed at different timelines, and all have unique characteristics. Individual projects that required for different methodologies were picked for this point.

4.3.1 ST. OLAVS HOSPITAL – KNOWLEDGE CENTRE EXPERIENCE

The Knowledge Centre is part of the University Hospital in Trondheim. It was built from August 2010 to September 2013 as the first passive house concept hospital in Norway. The contract form use for this project is a partnering contract, with a fixed after agreement price. Such contract model boost cooperation between contractor and client, and that favours VDC methodologies. Veidekke is responsible for construction and YIT responsible for the technical installation.



Figure 11 - The Knowledge centre in Trondheim – nordiaarch.com – 17.04.2014

Cooperation is carried out from the start-up phase in order to set up frameworks and the guidelines for the project work. The focus on value optimization by cooperation is implemented since the very beginning of the project.

The BIM model did not lead to early availability of the project bases. The designing process was not mature enough and lacked knowledge and expertise to perform the work efficiently regarding the design model. However, the design model did support the coordination between designers and aided crash detection. At the same time allowed a proper and timely project visualization.

In the Knowledge Centre project, it took place every week or every other week a two days ICE meetings. A high degree of effectiveness in such meetings was not always achieved in what concern involving all participants. The level of involvement depended on meeting theme. ICE meetings worked mostly better for technical, than for architectural or consultancy representatives. The parties had the will to meet and their capability were developed along the way. Although, it was hard to plan the process or to take decisions regarding the design. After a while, it was clear that more time should have been allocated to update the design progress.

Regarding the IP method, the “post it” technique was used quite a lot and was a very efficient technique to clarify the dependency between activities and the critical path of the project.

Ultimately, VDC did not lead to shorter design time neither less project cost. That was not the main goal though. The focus was on the value creation and on project quality, and those were very good, notwithstanding that the control and monitoring of the project was not the optimal.

Yet, there is definitely learnings taken from such experience. Veidekke was able to gather values in form of knowledge and experience that will certainly improve VDC’s implementation in further projects.

4.3.2 CITY LADE

The following project is an expansion project of a shopping centre in Trondheim city. The contract consists of two parking lots, new shops and a new building that will be built in two phases. The 10 000 square meters building has pre-fabricated concrete elements and a brick façade. The project owner is Trondos AS, Veidekke is the contractor and ARC Arkitekter AS is the architect and counsellor.



Figure 12 - Shopping centre City Lade – ARC Arkitekter AS – www.adressa.no – 17.04.2014

The old area has been refurbished while the expansion project takes place. The total project area is about 45 000 square meters for a total cost of 350 million Norwegian crowns. The contract type agreed for this project was a turn-key model with cooperation.

Veidekke executed a start-up meeting with all project actors before project kick off with focus on the development of a common process work. Such process was based on Veidekke's process (4.2.2). A big mid-term evaluation of the planning process was performed in order to adjust the processes and the utilization of the tools. By the end of this phase a collection of experiences was made and used to develop guidelines for future projects.

Following, the project design bases were made available earlier than usually, resulting in an earlier conclusion of works, although not for all design disciplines. VDC forced all design disciplines to work alongside and work accurately, however two disciplines were behind schedule. Even though they informed other parties, this fact rose the need to re-design and adopt some design features. The project base was a simple BIM model that allowed good coordination and visual crash control throughout all design process. It proved to be a quite effective process. As the design changes and adaptations were necessary, the BIM model offered a support method that permitted good coordination and fast execution of tasks.

Nonetheless, the design phase experienced some IT problems which led to some task delay and reflexed in the project. By the end of the designing phase it was noticed that only 50% of the tasks were completely executed as planned. However, such numbers could have been higher if were not those problems.

Regarding design revision, it always came before the product was actually executed. VDC has proved to be a good tool for assuring high quality standards, punctual delivery, and decrease need for reworks.

The production rates have been marginally better than usually, and has not been found reasons for such fact. Yet the cost allocated for rectifications has been substantially lower than usual. Such fact could be attributed to the reason that the workers understand easily the tasks due to the availability to visualize before build, even in the site.

VDC has been used in many other projects. Here was stressed two different experiences that Veidekke and other project stakeholders have been through. Veidekke has been amending and improving their VDC exploitation over the time and has used such working VDC to tackle the most challenging projects in the construction industry.

4.4 TRANSPORT INFRASTRUCTURE PROJECTS AT VEIDEKKE

Currently, Veidekke Norway has not implemented VDC in their business model. In Veidekke Sweden, VDC has been used out of the buildings sphere already, however not in transport infrastructure projects. Therefore, in order to understand what will be the challenges in order to possibly implement VDC at Veidekke's transport infrastructure projects, it is important to

assess how those projects are currently developed, and compare with the buildings' projects at some extent.

Based on the information collected by the means referred in the methodology (meeting and observation), the present chapter is going to be developed.

4.4.1 ORGANIZATION

The infrastructure division in Veidekke, usually deals with different contract forms, when comparing with the buildings division. The big majority of the transport infrastructure projects are required from public clients, and should follow the national regulation. This particularity will add different parameters that are not always found in the building projects.

In such projects, the power of the contractor to influence decision makers in the early phase of the project is absent. Veidekke is a contractor regarding infrastructure projects and will only build it and eventually maintain the infrastructure after its delivery to the client. Such fact may limit VDC applicability, because the choice of methodology to be used will depend on the contract form, and how it is regulated. This context has forced the companies in Norway to adapt to those requirements, in order to be able to bid for some projects, but at the same time, take advantage of that experience to update their methods and reach a more efficient business process.

4.4.2 EXECUTING PROJECTS

The transport infrastructure projects are usually meant to fulfil population's needs. That may be from a simple two lanes road to a high-speed railway track. Most of the projects are publicly funded, and therefore their development should follow the public directives.

The execution of such infrastructures entail the design and construction of tunnels, bridges, drainage systems, pavements, traffic signalization, electric systems, and should be guaranteed the adaptation to the external factors as landscape and environment. The particular orography of Norway, results in many complex projects, which challenges even the best companies.

In the concept phase, the need is identified and alternatives to fulfil such need is studied. Once chosen, the project is defined and a public tendering for designing the infrastructure is open. According to the public requirements and after the necessary procedures, an institution will be awarded with a service contract. When the design phase is completed, another public tender will award one or several contractors to build the infrastructure. This is usually when contractors as Veidekke come into scene. If the company decides to bid for a certain project, there will be a limited period of time to present the tender. The documentation received from the client will depend on the contract form, and therefore the bases for the estimation as well.

The previously mentioned process is usually based on project models called VIPS. They are the models form that a contractor receives from the project owner. In it, is represented what will be built and how the elements will fit in the terrain, according to the different physical conditions. It facilitates planning, designing, and documentation. VIPS is in practice a standard model for

the development of many transport infrastructures in Norway. The model may cover many of the project disciplines and can be used from the project start until its end.

The cost estimation will then be based in such model. It facilitates material and mass calculation, as well as it represents the road design. In Veidekke it is used MAP software to aid the calculation process and come out with a final bidding price. Every activity must be priced and described, and a final bid is delivered to the project owner. In this stage, the experience and competence plays an important role in pricing the activities, as well as the full understanding of the scope of the work.

Veidekke commonly bases their cost estimations on VIPS road models that could be 3D or 2D plus the height entry from survey. Working with 3D based models was considered a good way of working, and it allowed discussions about the project, and how would the activities be built. The 3D models gave a much better overview of the project as whole, but also aided the understanding of particular elements and disciplines, by “unwrapping” them, and analyse them individually.

Regarding the planning of the construction phase, MSProject is the tool used. The activities should be firstly properly defined and structured. Further, the duration of activities are assigned based on previous experiences and the capacity of the company to execute the respective work. The capabilities of those who defined task durations to understand the natures of the activities, the dependency between activities and their complexity, may also be crucial to materialize a good plan.

For critical activities, which their level of complexity is high, a stochastic estimation based on empirical data, may also be performed.

If the construction plan is rich and well-structured, that will reduce the need and probabilities of changes to happen. Those changes are not welcome, because it may require additional work and, in some cases, approval from the client.

When it applies to the building phase, all the road models are printed out to 2D paper drawings. Those papers must be constantly updated and if changes in the design happen, the drawings would have to be printed out again. In the construction site GEMINI software facilitates basic 3D visualization over some elements, and is the software used to manipulate the VIPS model.

Regarding machinery guidance, the model attributes reference points/lines, so that the driver gets the required orientation to locate or build the required elements. Such referencing is granted by GPS equipment associates the model coordinates to the physical space. Those models have to be manually installed in the machinery equipment, and also updated if changes happen.

5 VDC IMPLEMENTATION IN TRANSPORT INFRASTRUCTURES

In the following chapter it is meant to assess what have been done by the authorities and the industry in order to facilitate the implementation of VDC in transport infrastructure projects. It is additionally intended to have an overview of what have been the challenges and needs for such implementation in the industry.

5.1 THE NATIONAL ROAD ADMINISTRATION

The Norwegian Public Road Administration (NPRA) (Statens Vegvesen) is responsible for the planning, construction and operation of the national and county road network among other driving related subjects in Norway. They are under the direction of the Ministry of Transport and Communications, and under the leadership of the Directorate of Public Roads, which is an autonomous agency.

Such organization is also responsible for the regulation and control of the road projects in Norway, representing the Project Owner in what roads concerns. The NPRA publishes handbooks that set requirements and establish laws to every public road. Additionally, it guides and supports counsellors and contractors executing projects.

The NPRA is not accountable for every transport infrastructure project in Norway, but it is undoubtedly the main public client for Veidekke.

As already mentioned, 3D models are crucial for VDC implementation, and regarding such matter, NPRA has published the “handbook 138 – Model basis”, which sets the requirements for how the fundamental data and project models should be ordered, developed and delivered.

In the eyes of the NPRA, the 3D models can be developed in association between the planning, designing or construction phases. Such models are able to provide more detailed information throughout the different project phases.

3D models based scheduling, designing and construction can be applied to every project type, independently of the size, location or degree of complexity of the project.

The NPRA has not abolish the 2D drawings based projects. However, in the public procurement to counsellors and contractors, it may be required to execute the project in a 3D model project based. Such fact has been more and more common, and most of the Norwegian companies have been adapting to such requires.

The handbook 138 is part of the NPRA’s quality system and contributes to the:

- Clarification of quality requirements regarding fundamental data
- 3D design in all disciplines
- Standardized description of models
- Standardized description of objects
- Usage of open and standardized formats

- Usage of models as a working base in the construction phase
- Standardization of final documentation of the project phases

According to the handbook, all project documentation will develop and deliver in a digital format, will use collaborative methods that allows documentation exchange, will deliver documentation in an open and original format.

The models will be used for cross-disciplinary quality control in the design phase, set the bases for technical analysis, and allow representation of projects for public presentations and decision makers. Furthermore, the model's data will deploy and manage machinery works in the construction phase and can be later used for administration, operation and maintenance systems.

Some of the benefits identified by the NPRA for 3D model project based execution are:

- The model visualization can lead to easier understanding of project plan and faster decision making process
- Cross-functional quality control can be made visually or automatically
- Contractor can use the models to execute phase planning and mass calculation
- Road reference lines and points can be visually controlled in the model
- Contractor export road references for machinery guiding from the models
- Project owner can control contractor's measurements in the model
- Project owner can use cross-disciplinary model for project management and monitoring
- Data from the model can be transferred to administrative systems and reuse in the operation of the construction site

There are defined two different model types, and the combination of these will defined the respective project phase. The fundamental model will represent the terrain model, the soil conditions and the existing objects. This will in fact describe the real situation before project implementation.

The technical model designs and plans the different project disciplines. It regards structural elements, safety equipment, machinery, environment, among others. Such model will also allow the visual presentation of the project and will be base for contractors' works. The model will be divided in disciplines and should not be overlapped. The model will have continuity in its borders, so that the different objects can be connected in one model.

The models' format is also regulated by the handbook, as well as the accuracy levels of the designed objects. Such levels of accuracy are depend on the equipment that the project providers will use.

5.2 THE NORWEGIAN INDUSTRY

In the Norwegian industry, not only Veidekke looks towards new IT technologies as a mean of reaching competitive advantage. Some other companies have publicly stated their will to take

advantage of tools as VDC, BIM, LEAN or ICE with the goal to improve their working processes and consequently, their results.

The BA2015 initiative claim for the need to the actors involved in the transport infrastructure industry to master the above mentioned tools, in order to compete in the industry.

The requirements from the regulatory agencies, make that the businesses have to daily deal with new challenges. Those challenges are mainly regarding public offer description, execution processes and delivery of technical projects.

Hæhre, Skanska and Implenia for instance, have been rapidly adapting and trying to take advantage of the available tools.

Arve Krogseth, who is Project Manager for Hæhre Entreprenør has stated that with the support of 3D models, it was possible to execute a much better working schedule for the E6 - Highway project. It contributed with a better overview of the project when compared with 2D models that allowed to deliver a public offer in a much safer way concerning price and time. The 3D model provide to the project reader a bigger understanding of what the work entails. Therefore, the prices will be more precise and make easier to come up with the right working schedule and safety plan. In addition, the models are used to export surveying information and to discuss and follow the progress of the works.

Nonetheless, ICE technology was also implemented in order to discuss available solutions when changes were required as well as to plan further work activities.

In Skanska, Bård Olav Aune supports Hæhre's experiences. They have also used 3D models to aid the understanding of what will be built. The model give the possibility to get a more detailed overview over the tasks in an early stage and therefore reach more precise calculations.

In Norway, most of the 3D models for infrastructures and are based in the NovapointDMC module software. It is a software developed and owned by Vianova Systems and consists of 19 different components that are adapted to every project phase, user or end. Such tool is costumed made to fit the Norwegian industry requirements.

Such tools can be used by for example project owners, designers, contractors, architects, project managers, surveyors or public authorities, and has an infinity of features available.

Contractors could have full control over the calculated road geometry, by having access to the 3D geometry, cross-sections or plans from just one model. Will have access to all information that have been added during the design phase, and that will be necessary during the road construction. Many other features as exportation and importation of surveying data and terrain are also available and may be used in construction equipment. Many other features are available from the design phase until the operation phase, and are not addressed here.

5.3 IMPLEMENTATION CHALLENGES

In Veidekke and other firms, VDC has been exploited in building projects with satisfactory results for such a considerably new process. However, regarding the transport infrastructure projects, the changing process has been more resilient. There are surely some reasons that support that fact. One fact is that most of the software available in the market specifically address building modelling and are correlated to BIM technology. Just the BIM acronym itself is a challenge, because it causes that many contractors look at the initial “B” of building and assume that the technology is exclusive to building projects. Recently the term of BIM for infrastructures has been introduced in the branch, and somehow has helped to put an end to that idea. The range of software available in the market is still lower for infrastructures in general than for buildings. VDC modelling and analysis tools are at some extent considered difficult to use and do not integrate easily or well with other tools that the project needs to use.

The availability of more and more IT technologies that support design and construction for infrastructures has boosted the will of private and public companies, and increased the requirements of its utilization in public works.

But in fact such technology was boosted by the mechanical, plumbing and steel subcontractors, because owners realized for the benefits that BIM brought into projects. Those evidences of benefits of VDC from other business areas has forced clients to push software vendors to focus their development efforts on the vertical infrastructure projects, but also in the additional development of IT solutions to be applied in horizontal infrastructure projects.

Transport infrastructure projects are predominant owned by government agencies. Therefore the contractual framework in which the distribution of responsibility, remuneration and cooperation model is determined plays a significantly important role, and they are mostly decided by the public authorities. In the traditional contracts, the transaction form is based in a fixed price model (Olofsson et al., 2007).

Nonetheless, other contract models support collaboration and has incentives to reach common objectives in the project. Yet, most of public works use to utilize as the predominant contractual method, design-bid-build type which do not boost project collaboration – which is key factor for success of any VDC project. It is actually the least collaborative delivery contract method and, more often than not, creates an adversarial relationship between the owner/designer and contractor. Any change in the project will be resisted by the stakeholders since it entails control and approval from the project owner as the need to negotiate remuneration. That requires resources allocation that every stakeholder will avoid to use.

The public agencies that set the requirements have not been keen for VDC adoption, due to reasons as e.g.: ignorance about VDC and their benefits; avoidance of implementation costs; utilization of a non-suitable contract strategy; lack of skilled technicians; fear of the change (Russell et al., 2014). Nevertheless, an effort has been made at some level, and it is supported by the introduction of new requirements regarding the utilization of 3D models since the design

phase, the employment of an “open file format” and the usage of paper form documentation. All these features address some of the current issues and may be the base for the development of collaborative methods.

Another issue is that most of the contractors are not involved in the design process, and that may create the feeling that the investment and changes are not worthy enough. Such IT technology tools are primarily for design purposes, but are also able to aid many other functions that may be relegated by the builders.

Moreover, and according to Russell et al. (2014) transport infrastructure industry do not have the same dependencies on prefabrication that building industry has. Horizontal construction costs are predominantly controlled by earthwork associated with grading and placing utilities. As modelling technology has grown and the ability to link model data to survey and automated machine guidance systems has emerged, infrastructure contractors can realize the benefits of technology with reduced survey costs, reduced equipment and labour costs and enhanced safety with reduced number of personnel on the ground during equipment operation.

Another significant particularity in the transport infrastructure projects is that the main contractors usually subcontract a large number of small other firms to take part in the construction works. Such firms may be involved in the execution of important tasks of the project and therefore they should have a direct link to the methods and processes of the main contractor. That may be a challenge for such builders that may struggle with the perceived costs for adoption the necessary tools for full VDC integration.

However, in the eyes of Russell et al. (2014), firms can minimize these costs by only focusing in one or two specific uses of technology, leasing equipment for each project and potentially outsource tasks.

In order to overcome those challenges and stick to the created VDC model, Veidekke will have adapt their methods regarding transport infrastructure projects’ execution, if they are willing to make VDC applicable beyond building projects.

6 DISCUSSION

6.1 IMPLEMENTATION IN PRACTICE

As we have seen in this paper, some steps have been taken by the public agencies and the industry that would facilitate VDC implementation in the branch. The particular challenges have been identified, so supported in the theoretical findings and in the previous experiences, practical actions will be following suggested.

Veidekke as one of the biggest and most important contractor firms in Norway, may play an important role in the Norwegian or Scandinavian industry by creating drivers for VDC utilization.

6.1.1 CONTRACT FORM

I am from the opinion that VDC would have some limitations regarding its exploitation in the transport infrastructure projects. The main reason for such opinion is due to the current applicable contract forms. Some contract forms are more collaborative than others, as for instance “design-build”, which may contribute for collaboration since the early start. The usual contract form “design-big-build” limits at a great extent VDC exploitation.

Such opinion is seconded by the theory background, which states that the break of the bridge between design and construction is the main achievement of VDC. Such accomplishment would increase profits, reduce latency and confusion (Kunz and Fischer, 2012). Therefore would be important to develop other contract forms that enhance the linkage between the design and construction, and that will integrate parties involved in the project from the early start. When using the traditional contract forms, the contractor is not be able to participate and follow up the design phase, as the designer is not be in the building phase.

In that sense, the public agencies have the potential to adapt the public projects to more collaborative working methods, as has already happened in the building industry in both private and public projects. It would not be necessarily applicable to every project size, but only for the projects that would carry more risk and level of complexity. For those, discussion and search towards the best possible design solution or construction methods could be facilitated, since the designer would directly collaborate with the builder and vice-versa. In addition, the cost models would be more realistic and transparent, since it would make available a non-official supervision from one party to another.

Furthermore, the project owner’s tasks of project progress monitoring and billing control would be eased. There would be available a constant and updated progress, and would not be limited to the project control milestones.

In what concern to project changes, approval gates could be dismissed, by involving everybody in the process and reduce the amount of bureaucracy.

However, if the public agencies do no incentive information sharing between stakeholders, then is meaningful to introduce VDC process.

Nevertheless, the contractors may be able to influence those agencies by exhibiting the capabilities and the will to improve their working methods.

6.1.2 VDC AT VEIDEKKE'S INFRASTRUCTURE DIVISION

In order to introduce a VDC model in the infrastructure division at Veidekke, in resemblance to the buildings division, the current model adopted by the company could be seen as a starting point. That model is still in development and has experienced different levels of satisfaction regarding its utilization and results. It is not probable a very mature model, but it has undoubtedly improved since its first implementation.

Such working methods have developed skills over the time in the buildings division that could support a new implementation in another division. However, it is not expected that their competences are in road infrastructure projects, therefore this skilled personnel would assist regarding the working process itself, but not interfere either with the design or construction practices.

For such reason, it would be inevitable to educate and train employees that run the infrastructure projects. They could either be trainee by internally or externally by taking advance from the cooperation with CIFE. The possibility of hiring skilled and experienced personnel should not also be set aside.

Many do not still really realize what is VDC, since it is at some extent a new method, but it is also an evidence from our society that nowadays the majority are very open minded regarding technologies. That could be seen as an advantage regarding work motivation and satisfaction.

Making a comparison between the VDC process proposed by CIFE and the one established in the buildings division of Veidekke, a question regarding which one is a better suit for the infrastructures division at Veidekke could be raised. CIFE's directives would demand greater change within the firm, but mostly a big change in the public procedures for execution of transport infrastructure projects in Norway. Veidekke VDC's process has a higher focus in the construction phase, and as mainly a contractor in what regards transport infrastructures, such fact could be a breakthrough regarding the choice of the most proper process. Additionally, the firm has developed knowledge based in many directives of CIFE, as well as experiences that lead to the process currently in usage. To implement a CIFE based process, could be seen as a retrogression, after working upon the present process for several years.

If we look upon how such VDC process would fit the road infrastructure projects at Veidekke, it is obvious that the *Value Optimization* element is transversal and its fundamentals would fit most types of projects.

In a "design-build" or other collaborative contract form, *Collaborative Planning* concept could be applicable in its essence. However, even in a "design-bid-build" contract form, such method

could represent an important way of dealing with all the sub-contractors (if applicable) and reach a more effective construction plan. Identical working techniques would be required to properly plan and follow up the project. In the planning stage, the existing facilities at the headquarters of the company could be shared by both divisions, since it would not demand for more or less of what exists already. However, if the projects take place in an isolate or distant location, it should not be assumed that IP is out of reach. As seen, the “post-it” board is a very useful and easy method that can be utilized in the site facilities as well as screens or projectors may be installed.

Regarding *Integrated Concurrent Engineering*, we have seen that such function is applied in the design phase. Considering punctual exceptions, Veidekke does not design road infrastructures. The current public procurement processes do not incentive that the contractors design and build, and the firm does not have the competence for it, because such tasks have not been in the business scope.

The so called BIM for infrastructures or the 3D open models, would take the place of the element BIM. The coordination with project owner and designers from the early stage and the regulation for model usage plays a significant role in this point. Nevertheless, Veidekke should be capable of using the technology and exploit it in order to achieve better planning and estimations.

6.1.3 IMPLEMENTATION COSTS

The implementation of such methods will naturally represent costs, but also offer a bigger portfolio of solving approaches for better product delivery. Notwithstanding, the methods and strategy used should be aligned with the public agencies that regulates the industry, in order to attain the aimed results (Management, 2006). Although some discussion upon who should assume the cost has risen in much of the literature review, I am of the opinion that the firm would rather assume the initial investment costs. Such costs could be later on charged as a project element, and perhaps divided by several projects, depending on the size of the investment.

The client that in most of the cases are the government, should accept such fact, because the firms will improve their performances and it will be reflected in benefits to the general population, by building faster and cheaper.

The public agencies that are regulating the activity, should set the requirements in order to regulate and standardize the activity, however it is up to the industry to adapt. Such requirements may have the consequence that only the companies that are able to fulfil them will be the only ones legible to present bids. The companies that do not upgrade, won't be able to compete for the projects.

6.2 IMPLEMENTATION BENEFITS

Mainly working as a contractor in road infrastructure projects, Veidekke may potentially benefit from VDC implementation. According to Veidekke's practices and based on theoretical findings, it will further be addressed what the company can potentially gain by introducing new working methods.

By adopting VDC, project coordination, integration and decision making may greatly facilitate tools to improve the planning, review and communication processes during the construction life cycle.

According to Froese (2010), by conducting 3D models, a firm could initially experience some problems into adapting practices and taking full advantage of it, however would potentially be in better to position to easily understand project requirements and better to execute construction schemes. The way that 3D models allow to project teams to come together, would ease finding multiple alternatives and allow to study them early in the process to make better-informed decisions. That would lead to a more effective use of energy, water, materials and land.

However, project managers would have to realize that the workflow with 3D modelling is rather different than in 2D. There will not be any longer reference files, but only model data, where all the design is contained and labelled.

The unsafe areas would potentially be identified more effectively, and result as improved safety measures.

Additionally, the construction strategies may be optimized, by having a better overview of the project, as well a better manipulation of the viewports towards project details.

It would facilitate error detection before the actual construction and speed up the correction, before they need rework. It would additionally represent possible cost savings. In case of necessary change in the design, the contractor would be able to quickly adapt its construction plans and schemes.

Furthermore, the 3D data could be used to create 4D environment. The model allows to plan the progress of the work in time and space. The planner could move around, look inside, outside and under the roads or pipes networks or bridges and control the progress of the project (Romandi and Vallas, 2013). The model could also be integrated with human resources, materials and equipment availability/need. Ground work and underground work may also become easier and more accurate, by equipping machinery at the construction site with appliances that enable 3D visualization of the project. This would at some extent guide machinery like excavators to reach an improved accuracy, faster execution and understanding of the works, leading to a higher working performance.

The project would run with greater collaboration among the contractor, sub-contractors and project owner, and the goals would be easily aligned. It would additionally attribute a bigger sense of ownership of the project to every party.

Currently, a considerable amount of paper drawings and documentation are used. That amount could be reduced and ease documentation exchange between stakeholders. It would be also possible to reach a bigger and better quality distribution.

The communication environment would change, but would lay ground for improved relationship with stakeholders, by providing a more interactive and frequent contact.

More accuracy regarding time and cost estimation, would result in a more profitable and sustainable business. Consequently would support the image of Veidekke as a top company in the construction business.

The project visualization is seen as the driving force that brings stakeholders together, however there should be a clear strategic thinking regarding the whole VDC process. Veidekke has, for instance, all the facilities for ICE exploitation, but if they are not able to take advantage from the designing tools or from the interchangeability of models, and at some point eliminate the project discontinuities, then would not make sense to do further investments in such method.

VDC will offer Veidekke an additional form for managing projects, which will perhaps reach the same goals as other methods. However, VDC has shown the potential to tackle issues in a manner that other methods will not do, along with the possible cost and time savings that will be proportionated.

7 CONCLUSION AND RECOMMENDATIONS

The focus of this study was towards a revolutionary project management tool and methods that will allow the increase of transport infrastructure projects productivity of an important construction contractor in Norway. It should help project managers as the company to improve their current practices in a particularly change averse industry.

The theoretical research and the experiences in the buildings sector, have clearly identified advantages of VDC as a project management tool, but it is also an evidence that it is an instrument that is still under development. This is seconded by the current implemented process at the buildings division of Veidekke. It is an evidence that throughout the last few years, the process has been improving and reaching a higher maturity. The company has shown that is worth insisting and investing in the improvement of the process by the enhancement of certain aspects in project development. However the results have not been totally satisfactory and that exposes the need for further advancements.

We have seen that VDC implementation in transport infrastructure projects could be based on the same internal process, but faces challenges that the building industry does not. The branch seems not totally prepared to take the step of full implementation, but it is also an evidence that small steps have been taken in that direction. Therefore, the public agencies will have big influence and be the drives for boosting and setting requirements for the whole industry in Norway.

Those changes that are suggested to happen in the transport infrastructure business, although may not confirm that VDC is actually reliable in the industry, has proved from other industries that the contract forms along with cost allocation are very important factors, and they could be key elements for openness towards other project management methods as VDC.

Even though VDC may not be ready for full implementation in every type of infrastructure projects at Veidekke, there are some moves that the firm is able to do in order to improve their current processes and create value for competitive advantage. The benefits will not be substantial as in the building projects, however it will benefit for instance in stakeholder integration, cost estimation and time planning processes.

As a recommendation, a future suggesting step would be to run a pilot project, where VDC could be fully exploited. According to the results of a first VDC utilization in transport infrastructure project in Norway, it would be assessed its reliability and if there is any room for improvement.

In a real case study, it would be found out what sort and in what form the information would be required. If results are satisfying, the real size project would have an even stronger background for success.

There is still a big focus in the design stage in what concerns VDC. It should be looked upon as a management tool for all project stages and contribute for a more fluent project execution.

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