CHALMERS
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Effects of Implementing Virtual Design and Construction to a Project Organisation

A multiple case study in the construction sector

Master's Thesis in the Master's Programme Design and Construction Project Management

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Chalmers Tekniska Högskola 2017

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Cover:
Virtual Design and Construction.
Department of Architecture and Civil Engineering, Göteborg, Sweden, 2017

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ABSTRACT

The AEC industry is due to its complexity and their multi-dimensional team depending on collaboration and frequent communication between all parties involved. Still, it is here some of the major shortages can be found. Therefore, Virtual Design and Construction has been introduced, which are described as a working method for the design process, developed in order to overbridge the lack of collaboration and existing gap of information in the industry.

This master thesis aims to investigate how an implementation of VDC would affect the project organisation within a Swedish construction company. Moreover, the benefits and shortcomings with an implementation of the VDC concept will be demonstrated as well as the key factors for a successful implementation. In order to answer the research questions a qualitative and abductive study has been conducted, including literature studies, observations and interviews. The literature review was focusing on examining the VDC concept as well as the different key factors used within the concept, such as BIM and ICE. The theory was thereafter put into the context of the construction industry by observations and interviews of projects where both a traditional design process as well as VDC has been used. The different design processes has been compared in order to evaluate how VDC are affecting the design phase of a project.

The study shows that an implementation of the VDC concept would result in changes to the project organisation as well as the different roles within the company organisation. As a result of a changed meeting structure, an increased commitment and participation of the project team are highlighted. Furthermore, the risk of latency will decrease as the correspondence through mail between the different disciplines will decrease, as a result of an advocated collocation of the project team. In order for the implementation of the VDC concept to succeed, the importance of implementing the concept in smaller parts will be highlighted, as well as the benefits of demonstrating the similarities with the current processes within the company.

Key words: *VDC, Virtual design and construction, collocation, BIM, ICE, communication*

Effekter av att implementera Virtual Design and Construction till en projektorganisation
En studie på flera projekt i byggbranschen

Examensarbete inom mastersprogrammet Design and Construction Project Management

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SAMMANFATTNING

Byggindustrin är på grund av dess komplexitet och multidimensionella team beroende av samarbete och frekvent kommunikation mellan samtliga inblandade parter. Tros detta är det här som några utav branschens största brister kan hittas. Som ett verktyg för att överkomma det existerande informationsglappet så har Virtual Design and Construction (VDC) introducerats, vilket beskrivs som ett arbetssätt inom projektering som utvecklat för att kunna överbrygga det bristande samarbetet och existerande informationsglappet i branschen.

Detta examensarbete syftar till att undersöka hur en implementering av VDC skulle påverka projektorganisationen i ett Svenskt byggföretag. Dessutom kommer fördelarna och nackdelarna med en implementering av VDC konceptet att påvisas samt nyckelfaktorer för en lyckad implementering redovisas. För att besvara forskningsfrågorna har en kvalitativ och abduktiv studie gjorts, bestående av litteraturstudier, observationer och intervjuer. Litteraturstudien har fokuserat på att undersöka konceptet VDC, samt de olika nyckelfaktorerna som används inom konceptet så som BIM och ICE. Teorin har därefter verklighetsförankrats genom observationer och intervjuer från projekt där både traditionell projektering samt VDC har används. De olika projekteringsteknikerna har dessutom jämförts för att undersöka hur VDC påverkar projekteringsprocessen.

Studien påvisar att en implementering av VDC konceptet skulle innebära förändringar inom projektorganisationen samt de olika rollerna inom företagsorganisationen. Som ett resultat av en förändrar mötesstruktur, påvisas ett ökat engagemang och deltagande inom projekteringsgruppen. Dessutom minskar risken för fördröjning av information, då mailkorrespondensen mellan olika discipliner minskar som ett resultat av en förespråkad samlokalisering. För att implementeringen av VDC konceptet ska lyckas, belyses även vikten av att implementera konceptet i mindre steg samt att trycka på likheter med de nuvarande processerna inom företaget.

Nyckelord: *VDC, Virtual design and construction, samlokalisering, BIM, ICE, kommunikation*

Contents

Preface

This master's thesis has been conducted at the Department of Architecture and Civil Engineering at Chalmers University of Technology, Sweden, during the spring of 2017. It has additionally been performed at a construction company with the multiple case study taken place in both Sweden and Norway.

First of all we would like to thank our supervisor Mattias Roupé, researcher at the Division for Construction Management at Chalmers for his support and guidance through this master's thesis. Both your input and knowledge have been contributing to the outcome. We would also like to thank Patrik Johansson and Charlotta Cvach for your discussions, time and interest along the whole process during this spring, starting from the very beginning until the very end.

Furthermore, there are a number of persons that through their courtesy and patience deserves a thanks for taking the time to help us out. They have together enabling the case studies of this thesis as well as providing us with knowledge and information enabling the execution of the study. For doing this, we also would like to thank the following Karin Klasén, Roar Fosse, Rupert Hanna, Jonas Thörnqvist and Ulf Thorell for their help. Moreover, we would like to thank everyone else at the case company that have been making this spring an interesting and enjoyable time.

During the development and making of this study numerous of interesting sub-areas, questions and aspects outside the scope of the study have been identified. The field of interacting design approaches are rising a number of questions that the industry is yet to answer but the process in doing so will be very interesting to observe in the years to come. Lastly, thank to everyone involved in any way of this master's thesis.

Göteborg, June 2017

Sara Högberg
Viktor Spargren

Notations

AEC – Architecture, Engineering and Construction

BIM – Building and Information Modelling

CE – Concurrent Engineering

ICE – integrated Concurrent Engineering

VDC – Virtual Design and Construction

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1 Introduction

This chapter aims to provide a basic knowledge of the subject of the master thesis as well as an introduction to the scope of the thesis. Moreover, this chapter will present the purpose and aim of the thesis as well as problem statement, delimitations and method outline.

1.1 Background

To be able to improve and retain competitiveness in the construction sector focus continuously has to be put on both innovation and the improvement of processes (Akintoye et al., 2012). Further, Panuwatwanich et al. (2009) found that it is necessary for a company acting in the construction sector to be innovative in order to stay competitive. Due to the impact from the construction sector on modern society, a highly efficient and functioning construction industry is of importance. However, Li et al. (2009) as well as Eriksson and Westerberg (2010) states that there are a great deal of criticism towards the sector for not leaving the quality required, cost overruns, low productivity and an inadequate customer satisfaction. In order to improve the satisfaction of the customer, improvements needs to be made. According to Syan and Menon (1994), the earlier improvements are being made, the greater are the cost reductions. Therefore, it can be concluded that largest savings can be achieved during the design phase of a project.

The fragmentation within the Architecture, Engineering and Construction (AEC) industry results from being a multi-disciplinary industry, where actors and stakeholders, from different disciplines, are coming together over a period of time to form project-based organisations (Eastman et al., 2011). Garcia et al. (2004) states that it is proven that actors working together in a team are more effective and creative compared to actors working individually. However, the project based approach within the AEC industry, is making it more difficult to implement a long-term relational status within the design team. Mostly because of the gain that could come from contracting each specific project and project team separately, due to variances in requirements (Eastman et al., 2011). Furthermore, Eastman et al. (2011) states that the integrated collaboration within the design team is often limited, resulting in insufficient communication leading to misinterpretations and reworks.

At the same time, the AEC industry is considered highly complex, and the complexity of the construction process has only increased over the past years (Chan et al., 2004, Williams, 2002). Akintoye et al. (2012) states, that the increased complexity within the industry is a result of growing demands from society. Today's demand for low impact buildings with increased standards and to a reduced costs has resulted in a wave of new technologies, processes and materials which in term will make the industry more complex. Within an industry with an increasing complexity and multi-disciplinary project teams, the collaboration as well as the sharing of knowledge and information are crucial for the success of a project (Tjell and Bosch, 2015). However, according to the American Institute of Architects, AIA, (2007), one of the major struggles in the construction industry are due to large gaps within the information flow of the project teams, which is further stated as one of the incapability's of the industry by Li et al. (2009). In order to overcome those gaps, initiatives to address the changing market have been introduced and theories and methodologies supporting collaboration, transparency

and information sharing have been developed; Partnering (Bresnen and Marshall, 2000), BIM Task Group (BIM Task Group, 2017), IPD (AIA, 2007).

As a result of the increased complexity of the industry, the concept of computer-based virtual prototypes has been introduced (Akintoye et al., 2012). Akintoye et al. (2012) further identifies that virtual reality is a result of the growing trend of digitalisation within the industry. The importance of virtual prototypes are further described by Lee and Sexton (2007), stating that the use of virtual prototypes will contribute to solve the gap of communication and reconciliation of diverse stakeholders within the construction industry. The concept of Computer Aided Design (CAD) was for a long time the leading aspect of digital development within the industry (Eastman et al, 2011). Further, the previously frequently used two-dimensional computer drawings changed into visualisations of three or more dimensions (Akintoye et al., 2012). In recent years, the drawing based CAD technologies have been changed into Building Informational Modelling (BIM). Eastman et al. (2011) states that the change into BIM is not only a change in the technology but also a change in the project process, including everything from client requirements to facility operation and maintenance. The development of the computer technology as well as the introduction to the construction industry have according to Eastman et al. (2011) been enabling developments and been a catalyst of new methods and processes.

In 2001, the Centre for Integrated Facility Engineering (CIFE) was introducing the concept of Virtual Design and Construction (VDC), a project design process developed to support collaboration and productivity within a project (CIFE, 2017). Andersson (2016) defines VDC as a process that seeks to apply new technologies to the AEC industry, and at the same time connect all the work performed by the project team into the BIM models. According to Kunz and Fischer (2012), an implementation of the VDC concept to a project organisation aims to create a closer collaboration among the different disciplines involved. The use of BIM within the VDC process, will act as a hub of communication within the project team (Anderson et al., 2016). Li et al (2009) further support this, by stating that the strengths and benefits of VDC is possible to connect to visualisation and integration of people. Moreover, Garcia et al. (2004) stated that processes within VDC results in structured and effective ways to discuss, analyse and explain highly interdependent activities.

1.2 Purpose and Project aim

The purpose of this master thesis is to investigate how an implementation of the VDC concept would affect the processes and roles within a Swedish construction company.

Therefore, this master thesis aims to evaluate the potential benefits and drawbacks of VDC. By comparing the traditional design process and current way of operating with projects at the Case Company with a project where VDC has been implemented, possible solutions on how to develop the organisation will be discussed and evaluated.

1.3 Problem statement

In order to investigate a possible implementation of the VDC characteristics in to an existing organisation the following questions will be answered;

- What roles and organisational changes are required in order to adapt a VDC concept into a project organisation?
- What benefits and drawbacks will an implementation of VDC lead to?
- What is required for a successful implementation of the concept of VDC?

1.4 Delimitations

The master thesis will only be limited to the connections between features of VDC and the design phase, its improvements and development. Further, the thesis will focus on the organisational structure within projects and not the organisational structure of the company, in order to be applicable and to a greater extent comparable onto a project team throughout the industry. In the scope of the design process, no effort nor assessment will be put on specific software and digital hardware, which will be assumed to meet the requirements in the discussion and the conclusion.

Due to limitations of projects applying the features of VDC within the Case Company, as well as in order to be able to analyse the effects of VDC, the non-VDC project had to be chosen from the characteristics of the VDC project. Resulting in, a choice of non-VDC project as a hospital project with comparable complexity and contract structure. Moreover, both cases are having collaborative agreements in their contracts. The limitations will therefore, in the presentation of conclusion and discussions, act within the scope of collaborative contracts. The contract form and specifications of the project and design structure will be briefly described, but no specific details regarding contract and project will be covered with respect to the Case Company.

Moreover, the thesis will only present suggestions for an implementation of VDC. However, no focus will be put on the theoretical aspects of change management that may arise as a consequence of an implementation of the VDC concept.

1.5 Method outline

This thesis is based on multiple case studies on two characteristically similar projects as well as a case study of the Case Company in the Gothenburg region, in order to grasp the status and the difference in terms of the design process. Further, the cases were conducted to acknowledge the key characteristics and the gains from the VDC concept and how to apply these into the current organisation. The cases, together with scope and research questions was identified with the supervisor at Chalmers University of Technology as well as from the Case Company.

In order to reach the projected outcome through the case studies and interviews a literature study had to be conducted. To grasp the concepts there has been a need of evaluating the original sources and the foundation of VDC, resulting in a conceptual point of view from Stanford University. The primary sources for empirical data collection were semi structured interviews and direct observations. Interviews were held with key personnel in the case projects and company as well as experienced

functions in the field of VDC. The selection of interviewees was based on the identification of equivalent parts in each case to get comparable outcome.

Through combining the findings of empirical data with the theoretical data developed in the literature study the research questions were answered. The questions are being discussed and analysed and are further presented in the conclusion, in order to answer the aim of the thesis. Moreover, to be able to ensure that the thesis were conducted properly literature of guidelines in business research methods was used. Further, an extensive description of the methodology is given in Chapter 3, Methodology.

2 Theoretical framework

This chapter aims to provide a theoretical knowledge about the concept of VDC as such. Moreover, the concept of VDC will be presented and the cornerstones and characteristic of the concept further explained in relation to the current industry. Further, components and theories within the concept may be explained in other terminology due to the variances in the meaning of the concept.

2.1 BIM

Over the past years, the construction industry have deviated more and more from paper based two-dimensional models and drawings (Roupé at al., 2014). Nowadays, the use of visual models of three or more dimensions are becoming more commonly used within construction projects (Akintoye et al., 2012). In comparison, the multidimensional models supports analysis and control to a greater extent than manual two-dimensional visualisations (Eastman et al., 2011). The process of using multidimensional information models are not rarely called BIM (Azhar, 2011). However, the current definition of BIM is not unanimously, since the usage of the shortage BIM can refer to both Building Information Model and Building Information Modelling. The Associated General Contractors of America, one of the leading trade associations for the construction industry in the US, are putting the terms of BIM models and BIM modelling in relation by describing them in the following way, cited in Aranda-Mena et al. (2008), page 4:

"Building Information Modeling is the development and use of a computer software model to stimulate the construction and operation of a facility. The resulting model, a Building Information Model, is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analyzed to generate information that can be used to make decisions and improve the process of delivering the facility. The process of using BIM models to improve the planning, design and construction process is increasingly being referred to as Virtual Design and Construction (VDC)".

Azhar (2011) states that a Building Information Model is the digitally constructed, virtual model of a building. Tang et al. (2010) confirms this by describing the BIM model as a semantically rich digital facility model. Further, Eastman et al. (2011) describes BIM models as a technology. In comparison to CAD models, the BIM models are having a higher level of details. In contrast to CAD models, which are only showing a set of single, drawing-based, independent planar surfaces, the BIM models are showing a volumetric object with multiple surfaces as well as the relationship between the different volumes in the model (Tang et al., 2010).

Building Information Modelling, on the other hand, is a process able to change the key processes factors for constructing a building (Eastman et al., 2011). Azhar (2011) page 242, further describes Building Information Modelling as a process by describing is as "*a virtual process that encompasses all aspects, disciplines, and systems of a facility within a single, virtual model […]*".

Eastman et al. (2011) further states the BIM modelling will capture the requirements of the client in order to create drawings and space plans by;

- Help analyse aspects such as: energy, structure, costs, constructability and so on based on early stage design alternatives
- Define how the building is to be constructed
- Analyse how the different materials and fabrications will affect structure
- Evaluate sub-contractors will affect the actual construction
- Connecting actors from different disciplines together in a closer collaboration making it possible to link different models together in order to, in an early stage find and prevent conflicts.

Further, BIM modelling can be described as a "*human activity that ultimately involves broad process change in design, construction and facility management*" (Eastman 2011, page xi)

Eastman et al. (2011) states that implementing the BIM technologies in an early stage of project will bring positive effects on the subsequent activities, including the construction process. One of the benefits of using BIM in the design phase is the ability of using collision controls, a way of discovering clashes between different trades before the construction starts. A BIM-based clash control can be performed at any detail level of the project and across any building systems. This means, that it is also possible to run the collision control across the visualisation models of different disciplines.

The BIM models are not only containing three dimensional visualisations and geometrics of the product model, but also other information supporting the construction process and different procurement activities (Eastman et al., 2011). Within BIM modelling, it is possible to link the construction process plan to the building model, which makes it conceivable to visually plan and communicate activities in relation to both space and time (Akintoye et al., 2012). The usage of BIM, also allows the schedulers to use and review the virtual model more frequently, which has resulted in both better and more reliable schedules (Eastman et al., 2011). Further, all BIM tools provides the benefits of extracting the sum of components, areas, volume of spaces and material quantities, which makes it possible to transform the different components into cost estimations.

In a way of overcoming the issues of interoperability, which is the ability to exchange data between applications, Eastman et al. (2011) describes the different main types of building product data models. Of the different models developed, one is focused on the building planning, design, construction and management being the Industry Foundation Classes (IFC). IFC is developed in order to ease the project collaborative design and operations across different software platforms by providing an open, non-proprietary geometry and information exchange standard (Andersson et al., 2016).

BIM technology further supports a more accurate collaboration within projects (Azhar, 2011). A project using BIM requires that actors from different disciplines are working closely together with the model, which promotes a close collaboration and a strict coordination of the actors involved. A successful use of BIM includes organising of different activities; jointly planning, clash detection, design coordination and validation of space (Building and Construction Authority, 2013, Eastman et al., 2011).

2.2 Concurrent Engineering

Concurrent engineering (CE) is a work methodology for the design and introduction of new products, that aims to shorten lead times and reduce costs by running the development stages in parallel (Oxford University Press, 2016). Akintoye et al. (2012) further explains the method as a systematic way of concurrently designing both the product and its downstream production and support processes, which minimises the total product development time. Syan and Menon (1994) also confirm this systematic, integrated and time saving approach. As mentioned, CE is based on parallelisation of tasks, which means that project phases can start as soon as the right amount of data or feedback, required for optimisation, is provided (Oxford University Press, 2016). For instance, the product design can be performed in parallel with the product planning within CE projects. In contrast, within traditional working methodologies, one phase needs to be completed before the following phase starts.

The purpose of concurrent engineering is to ensure that the decisions taken during the design results in the actual minimum cost of the products life cycle as well as shorten the lead-time and improve the product quality (Syan and Menon, 1994).

According to Akintoye et al. (2012), the first definition of concurrent engineering was put by Winner et al. (1988), whom refers to CE as "*integrated, concurrent design of products and their related processes, including manufacture and support*". Akintoye et al. (2012) further states that concurrent engineering holds two key principles; integration and concurrency. The integration involves the process and the content of information and knowledge in the project phases and of all tools and technologies used in the design process of the product. Integrated concurrent design also holds the requirement analysis by multidisciplinary teams and the early consideration of all life-cycle issues affecting the product. The concurrency involves the scheduling of tasks and interactions of the actors involved in the development of the new product (Akintoye et al. 2013). Syan and Menon (1994) states that concurrent engineering is indispensable to companies that targets improvement of their products and processes continuously and desire to stay competitive as well as ahead of the competition.

2.3 Virtual Design and Construction

The term Virtual Design and Construction, VDC, was first introduced at the Centre for Integrated Facility Engineering (CIFE) at Stanford University in 2001 (Kunz and Fischer, 2012). It was developed as a part of the mission and methods models at CIFE and have been used in both research and teaching ever since. By CIFE a definition of VDC have been put as:

"*[…] the use of such multidisciplinary performance models of design-construction projects, including the product (i.e., facilities), organization of the design-construction-operation team, and work processes, to support explicit and public business objectives"* (CIFE, 2017).

There is not yet an agreed consensus on a clear definition of the concept and it is constantly evolving (Li et al., 2009). Li et al. (2009) further states that the growth of the VDC concept is closely connected to the different research centres and companies that are conducting research with the field. However, there exists several different VDC solutions on the market, where the approach by CIFE is one of them. Other examples of solutions of the concept are Virtual Construction Environment (VCE) (Waly and Thabet, 2002), DIVERCITY (Sarshar et al., 2004) and the approach by Autodesk and the Construction Prototyping Lab (CVPL) developed at the Hong Kong Polytechnic University (Li et al., 2009). According to Li et al. (2009), some of these approaches mutually reinforce each other and some compete in the aspect of theories, technologies and applications.

At CIFE, a large number of the major development of the current practice of VDC for the AEC industry are produced. Being part of introducing the term VDC, Kunz and Fischer (2012) explains that VDC, to a great extent, are performed in an integrated environment. An integrated environment implies that representatives from all involved disciplines are coming together in order to carry out the project in a collaborative way. Described shortly, VDC can be stated to rely on three different concepts: BIM (Andersson, 2016), visual planning (Kunz and Fischer, 2012) and ICE (Chachere, 2009, Garcia et al., 2004, Mark (2002).

VDC in accordance with the approach by the CIFE are consisting of several different features, one of them being the Product, Organisation, Process model which is also known as the POP-model. According to Kunz & Fischer (2012, page 9), a project manager is able to affect three aspects of the project; *"[...] the design of the product to be built, the design of the organization that does the design and construction, and the design and design-construction process that the organization follows*". Therefore, they further state that the POP-models are an important aspect of the VDC process.

The POP-models are beneficial to use as a support to another important tool within the VDC process, the Integrated Concurrent Engineering (ICE) (Garcia et al, 2004). Activities within the construction sector are considered highly interdependent. According to Garcia et al. (2004), interdependent tasks are requiring synchronous communication, preferably performed face-to-face, and therefore ICE is promoted. ICE can be described as a multi-disciplinary process of collocating the project team in order to perform the design phase in a collaborative way (Kunz and Fischer, 2012). The use of ICE has proven beneficial for projects by increasing the productivity within the project team and decreasing the time for the design process (Garcia et al., 2004). Syan and Menon (1994) states the parallel execution of activities of the design leads to improvements in many areas such as communication, quality and profitability. Within a Concurrent Engineering environment, all projects stakeholders can access the integrated project database and individual designers are able to modify and analyse current details in real time (Kunz & Fischer, 2012).

Early conceptualised variances of VDC was originally formed from paper-based visual planning tools, such as two-dimensional maps and drawings. Those visualisation tools have all been developed to be the cornerstones of computer programs that today have changed into different conceptual, multidimensional models and digital variances with the same purpose (Kunz and Fischer, 2012). BIM have through this development

become one of the cornerstones and key concepts of VDC. Kunz and Fischer (2012) states that VDC are mainly focusing on the management issues considering how to work with the models.

Li et al. (2009) concludes that the emergence of VDC provides a promising approach to solve the problems that the construction industry is facing, such as ineffective information and knowledge management, discontinuity in construction processes and creeping managerialism. Rheinlander et al. (2009) states that the VDC approach create a win-win situation for all parties in building and infrastructure construction. Furthermore, through their study Gilligan and Kunz (2007) conclude that VDC has a significant use in practice. According to Li et al. (2009), there are still hurdles to overcome in order to achieve a widespread use such as new and increased costs connected to the design, the risk of changing current processes and need for technical solutions and software capability. Also listed is the aspect of where to put the increased cost of a project. As VDC is targeting integration a problem in achieving a widespread use stands with that different project players still acts as different profit centres.

2.3.1 The Product, Organisation and Process Model

The concept of VDC is possible to divide into three factors, which a project manager are able to manage and that are present in all design-construction processes (Kunz and Fischer, 2012). Those elements are the product, the organisation and the process and described further below:

The Product (P) is the product specifications with detailed information about the project, based on the specifications from the constructor.

The Organisation (O) is the organisation team that are developing the product and process plans as well as carrying out the project.

The Process (P) is the plan on how to carry out the project and completing the product. The actual process of carrying out the project, including both the designing and construction of the building.

According to Kunz and Fischer (2012) the implementation of VDC are performed in phases before developed into a automated process. The first phase are concerning the visualisation and metrics of the project shown in visualisation and planning of the whole project spectre in accordance to the product, organisation and process. The visualisations will provide detailed visualisation of the product, organisation and process including both two- and tree-dimensional models as well as planning and organisational charts. As a supplement, the metrics are used as measurements for performance and requirements needed to achieve the project goals.

According to Garcia et al. (2004), an aggregation of the POP-factors into the VDC concept, will improve quality and reduce rework. Further, they state that it is common to dissociate these factors in the actual practice of the concept.

2.3.2 Visualisations

By developing the fact that a learning process is accomplished through multiple observations and actions, it is possible to state that the human brain is processing information faster from visual illustrations than from texts (Akintoye et. al, 2012). Therefore, visualisation models is initiated to have a great impact on the design process as well as the team-based communication within a project process. In accordance with the elements of the POP model, the POP visualisations consists of three different parts; product visualisations, organisation visualisations and process visualisation (Kunz and Fischer, 2012).

Product visualisations are the visual models showing the design of the product. Instead of the paper-based models in two dimensions, the product visualisations are showing virtual, interactive information models in three or more dimensions (Kunz and Fischer, 2012). Within VDC and the POP model, the product visualisation is stated to decrease the time consumed for explanations and discussions as well as shorten the time for decision-making. Moreover, by combining product visualisations with VDC, the number of design and construction reworks are most likely to decrease, since clashes and errors more easily can be detected (Eastman et al., 2011).

Organisation visualisations are models and charts showing the organisational structure including all actors and disciplines involved in the project, from contractor to the production team (Kunz and Fischer, 2012). The organisation chart is visualising the network and the relations between the disciplines involved in the project process. By creating a visualisation of the project organisation, with names, responsibilities and contact information, the communication will be more effective since whom to contact regarding questions will be clearer.

Process visualisation is the visual schedules and maps showing the different tasks, activities and actions that are going to be performed by the project organisation, in order to successfully complete the project (Kunz and Fischer, 2012). Often the process tasks are illustrated in an activity charts, network diagram, or similar, which are showing the different tasks as well as their relation and their deadlines (Baldwin and Bardoli, 2014). In contrast to paper based visualisations, virtual visualisations are more flexible and interactive with the possibility for data sharing which are creating prerequisites s for a more collaborative environment (Eastman et al., 2011). According to Kunz and Fischer (2012), virtual visualisations are making the information more comprehendible than paper based information.

The POP visualisations are within the VDC concept rather shared on a digital platform, which enables the coordination and sharing of information between the different disciplines within the project organisation. By making the different visual models easily accessible, it is possible to link the product visualisation together with the process visualisation (Kunz and Fischer, 2012). For instance, a 3D model can be used as a foundation for the production time schedule (Baldwin and Bardoli, 2014). Additionally, simulations can be used as a visualisation to ensure the functionality and buildability of a project process (Eastman et al., 2011). Moreover, by using visualisations, an increased understanding between stakeholders can be developed and time consuming discussions and explanations can be reduced. Kunz and Fischer (2012) states that visualisations is the most effective way for different actors to create a common understanding for each

other as well as analyse their own progress and the work of others. Furthermore, Andersson et al. (2016) recommends a use of BIM, as a visualisation process, within the VDC process with the motivation that BIM will act as a hub of communication within the project. This, since BIM are not only containing the visual models, but also the process of working with them.

2.3.3 Metrics

According to Kunz and Fischer (2012) the use of POP metrics are an important tool in measuring performance and progress of the design. The POP metrics are defined as requirements or objectives which are used in order to measure, estimate and forecast the future result and performance of the product, the organisation and the process. Further, they can be used as a steering tool throughout the whole project process.

Clayton et al. (1996) describes a presentation form of the POP metrics where these are placed in a POP model and where tree decision factors are taken into account; form, function and behaviour. The form is described as the geometry of the actual design which describes the physical components. The function is consisting of the client desires and include the needs and requirements of the product. Clayton et al. (1996) further states that the behaviour is the expected performance of the design, as well as how the process corresponds to the function. According to Kunz and Fischer (2009) and Clayton et al. (1996), the function-form-behaviour taxonomy of the design theory, is the most classical way of defining the content of POP-models, visualised in Table 1.

Table 1: The function-form-behavior taxonomy defining the content of POP-models.

	Function	**Form**	**Behaviour**
Product			
Organisation			
Process			

In order to build a POP model Kunz and Fischer (2012) recommend one approach divided into steps in achieving this. This is done by first setting the functions or objectives for the project of product, organisation and process and in response of these, design the form or scope. Further, the next step is to identify the project behaviours to predict or measure the importance of each project functional objective. For each predicted or measured behaviour value, threshold values are identified that defines the levels of quality for each one.

Kunz and Fischer (2012) states that each organisation keep control of their own VDC vision, strategy of implementation and measurable objectives. They further describes, that the presented model is a way of achieving this. Further, it is stated that each company have to identify their unique process metrics and control factors to monitor in order to check and supervise the project process.

2.4 Integrated Concurrent Engineering

One of the main features in the methodology of VDC is the concept of Integrated Concurrent Engineering (ICE), a concept that is based on the previously introduced approach of CE. The organisational theory ICE was developed at the Jet Propulsion Laboratory (JPL) by the NASA project team, Team-X, in 1996, and have been used ever since in designing space missions at an accelerating rate (Garcia et al., 2004, Chachere, 2009). According to Chachere (2009), there are no specific requirement for using ICE at JPL, but the results have been consistently proven the theory to be an effective way of working, providing continuously good results. Originally, the ICE concept was developed for the economy market, but is today possible to apply to most industries including the design process of the construction sector.

The ICE process is described by Chachere (2009), page 1, as: "*[…] a singularly rapid combination of expert designers; advanced modelling, visualization and analysis tools; a set of consistent social processes, and a specialized design facility; to create preliminary designs for complex systems*".

One of the most important features of ICE is to design a project team of multi-disciplinary stakeholders, each of different backgrounds and with spread knowledges that will work closely during the whole design process (Chachere, 2009, Garcia et al., 2004). Garcia et al. (2004) state that such a combination of people will increase the knowledge and experience within the group, which will allow the team to capture more information and together generate a higher process quality (Garcia et al., 2004). In contrast to traditional project organisations, with hierarchal organisation structure, the ICE project team has a flat organisation structure (Kunz and Fischer, 2012, Chachere, 2009). The ICE meetings is run by a team facilitator, who has the task of retaining an overview of the whole process and keeping track of all procedures, that within ICE are performed simultaneously (Garcia et al., 2004).

According to Mark (2002), the ICE process involves a balance between social and electronic networking. Therefore, it is suggested that the project team is provided with right conditions to support those types of networking. In order to reduce the risk of misunderstandings, due to difficulties in communication as well as shorten the lead-time of communication, ICE are advocating a collocation of the project team (Mark, 2002). A case study of the usage of VDC in the AEC industry performed on by Gilligan and Kunz (2007) shows that collocation of project teams results in decrease of lead-time concerning discussions and coordination of problems during the design phase. Moreover, collocation relies on face-to-face interactions between the project team members and according to Chachere (2009), the NASA organisation JPL has not found any substitute for a collocation of the core engineers within an ICE process. Not even the most high technology videoconferencing technologies are stated to be comparable to face-to-face interaction (Chachere, 2009).

Moreover, Chachere (2009) states that higher interdependent work practices have adapted by partially overlapping, previously serial tasks in many industries. In the construction sector the development has been clear. For instance, previous systems where it has been sufficed to complete the buildings framing before installing any electrical system has now changed. Today it has become a routine to begin and proceed with the tasks in parallel; beginning the installations as soon as one area of the framing has been completed. According to Kunz and Fischer (2012), by reducing the serial tasks into partially overlapping tasks the ICE process are able to focus on value-adding processes, visualised in Figure 1.

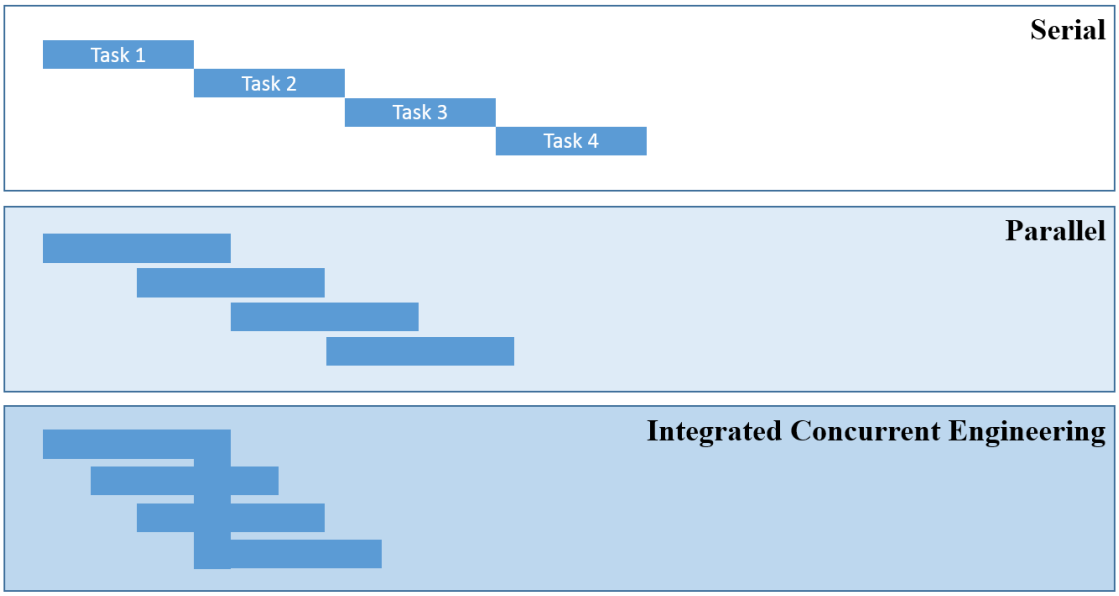

Figure 1: Degree of Parallelism, remodeled (Chachere, 2009)

The ICE process are performed in multiple stages where the first step of pre-sessions where the design team starts with defining the vision and the requirements of the project, considering the aspects from all stakeholders involved in the project (Chachere 2009). Thereafter, the team is gathering for several intense design sessions, where visualisation models are developed in an informally coordinated process (Chachere, 2009, Garcia et al., 2004). Design sessions are to be performed both in large meetings where all project team members participates and in smaller group discussions, so called sidebar conversations (Chachere, 2009). In the same time, project group members not involved in any discussions or meetings, will stay at their own personal space and work with individual tasks within the project (Mark, 2002). According to Mark (2002), smaller groups of the design team can, whenever during the design sessions, break out from the rest of the group in order to solve problems or discuss issues concerning specific areas of expertise. However, all sidebar conversations are aimed to be performed in the same room. According to Mark (2002), this will create a "cocktail party phenomenon", where sidebar conversations can be overheard, and key words can get other members attention. Further, Mark (2002) states that this will make it possible for the participants be aware of what is discussed within the room, and in the same time be able to perform their own work or even participate in other conversations in parallel.

The design sessions are described to be highly intensive and are commonly described to result in a high-pressure environment for the design team (Mark, 2002). The

psychological pressure, described to result from the intense ICE sessions, has also been confirmed by research conducted at Stanford University (Chachere, 2009). As a result, Mark (2002) and Chachere (2009) are recommending to divide the ICE sessions in to smaller sessions of three hours. By shortening the sessions, the participants will be given a fair chance of keeping their minds set throughout the entire sessions.

During those design sessions, the whole project team are gathering in order to, simultaneously, develop the product (Chachere, 2009). According to Gilligan and Kunz (2007) shortening the paths for communication, the processes for decision and analyses will be faster and more effective. Further, Kunz and Fischer (2012) states, that research has shown that project teams working in accordance with ICE, often achieve a more rapid completion with a higher product quality than teams working in a traditional design process. Additionally, by creating a collaboration between multiple disciplines, more knowledge and experiences can be utilised, which in turn will create a higher value of the project process and the final product.

The use of ICE processes within projects will result in increased intensity of the process as well as a higher pressure on the design team (Mark, 2002). Moreover, there will be a higher frequency of the communication. Therefore, Chachere (2009) states that it is of great importance to provide the project team with tools that supports and improves the increased communication within the project team.

2.5 Tools and facilities

According to Chachere, (2009), the ICE meetings are one of the essential parts of VDC, and therefore also the collocation of the project team. Therefore, Chachere (2009) further states that the shared space for collocation should be designed to facilitate the methods used within ICE as well as support both large, full group meetings and multiple, simultaneously communicating groups. Within VDC projects, it is recommended to dispose a separate room for the collocation of the project team, commonly called VDC room (Garcia et al., 2004). Kunz and Fischer (2012), describes the VDC room as separated space, promoting integration of the project team and with focus on methodology and technology. Further, Garcia et al (2004) defines the VDC room as a space provided with multiple visualisations screens and with personal chairs for each team member. By collocating the team members in a VDC room during the design process, together with high-technological tools, it is possible to utilize and maximize the capacity of the whole project team. Moreover, by pursuing the ICE process in a VDC room, Mark (2002) states that it is possible to double the productivity of the design process.

In order to perform the ICE seminars successfully, it is of great importance that the technology provided supports and streamline the methodologies used within ICE (Chachere, 2009). Thus, technology supporting and help improving communication within the process is crucial for project success. According to Chachere (2009), the ICE process requires high-performing computer modelling and simulation tools to support the visualisation of the project. Further, interactive graphic displays and extensive collaboration systems are required. This is confirmed by Kunz & Fischer (2012) who states that the VDC room commonly includes projectors showing the screen

of a computer on large touch sensitive displays, as well as personal computers provided with shared databases, network connection and visualisation programs. The large interactive screens are making it possible for the involved actors to present solutions and see the impact of their own ideas as well as interpret and review the work of others in an effective way (Garcia et al., 2004). Chachere (2009) and Kunz and Fischer (2012) further states that the computers should be provided with a publish-and-subscribe connection, making it possible to enable time synchronisation of models and other applications on the computers.

Within the VDC process, there is also a need for the appropriate hardware, software and data connection in order to adopt the VDC process to the everyday workflow (Andersson et al., 2016). It is also crucial for the project success to have a shared project platform supporting the communication and information sharing within the project (Andersson et al., 2016, Garcia et al., 2004). According to Andersson et al. (2016) and Akintoye et al. (2012), the success of a VDC project, does not only depend of the tools and technology used, but also the skills and knowledge of the people within the project organisation.

2.6 Implementation of VDC

The growing need of enhancing competitiveness of activities across the industrial spectrum and especially the construction sector results in a heightened case for innovation (Akintoye et al., 2012). This is confirmed by Panuwatwanich et al. (2009) highlighting that a company within construction have to be innovative in order to be competitive. Further, an openness to change through management leads to and organisational knowledge, which is in itself, increases the organisational core competence and organisational knowledge (Stonehouse and Pemberton, 1999). The fragmentation of the construction industry is now acting as a knowledge and learning barrier together with a centralised and hierarchical organisational structure (Akintoye et al., 2012). Akintoye et al. (2012) concludes that the construction industry needs to remove its fragmentation, embrace change and leverage innovation drivers through new business models and strategic trajectories in order to achieve an effective management of change. Further, underlying that the management of change to be effective, the actors in the construction system have to be fully integrated. In order for there to be a free flow of knowledge and information exchange with a top-down adoption and implementation procedure that is synchronised to a bottom-up learning and problem-solving approach.

The construction industry has a tradition of being slow and resistant to change and innovation (Akintoye et al., 2012). Further, through the systems approach towards innovation the importance of social processes and cultural changes is shown underlaying the innovation process. This is strengthened by Xu et al. (2014), that concludes that one of the most significant drivers for potential implementation of BIM is the dimension of attitude. Moreover, Xu et al. (2014) further implies that as well as being a significant driver, the willingness and interest are also the biggest barriers for an implementation. Further, Gilligan and Kunz (2007) concludes that non-users of technologies related to the concept of VDC would overwhelmingly adopt the technologies if they felt that it would help them create process improvements or increase their efficiency.

According to Kunz and Fischer (2012) the implementation of a VDC process is made in three different phases which are taken the shape of the implementing organisations strategies and value proposition. These are the visualisation and metrics, integration and the automation. In order to get the visualisation of a project to work well, there is a need for all stakeholder organisations to develop the competence to both interpret and develop the visual models. This is often connected to a strategic investment of the methods within the organisation. In the first phase of the implementation of VDC, the focus is on the actual design of a specific project. Including implementing the concepts of working in multidimensional models, developing the organisation which is supposed to carry out the design as well as how the requirements and metrics are to be achieved through the entire process. Kunz and Fischer (2012) further states that the stage of visualisation have through the years emerged to be an increasingly easier stage to pull through because of a developing technology.

Kunz and Fischer (2012) describes that when the integration phase picks up after visualisation the projects move on to methods of exchanging data in order to simultaneously affect data among disparate modelling and analysis applications. A factor in order to get the integration phase to work well for multiple stakeholders is to incentivise data sharing through multi-party collaboration contracts. What has changed since the visualisation phase is that Kunz and Fischer (2012) justify the usage of VDC tools with the value proposition. This is supporting the organisation since it is a costly decision and need to be used through multiple projects in order to be economically beneficial. The last phase contains the use of use automated methods to perform routine design tasks or to help designing subassemblies in a factory. An automation construction process often requires that the companies drastically change their processes to enable or perform a design and analysis and spend less time and billable effort to routine design. In order to achieve an automated construction process the strategic commitment from the entire organisation has to be changed from the traditional approaches.

2.6.1 Emerging roles from VDC

According to Gustafsson et al. (2015), the increased use of VDC in the construction industry has resulted in a need for new roles. The introduction of VDC has introduced new ways of working, which has resulted in a changed need for specialized competence (Akintoye et al., 2012). Furthermore, Chachere (2009) argues that the increased technological complexity within the construction industry has caused a higher demand for special competence and technological skills. In contrast, Cho et al. (2014) suggest new techniques instead should be in cooperated within the existing roles (Cho et al., 2014).

As a result of the ICE methodology within the VDC concept, the new role of the VDC facilitator will be introduced. The VDC facilitator will be responsible for monitoring and coordinating the ICE design sessions within the VDC process (Chachere, 2009). Mark (2002) states that the facilitator is responsible for monitoring all networking, both social and electronical, within the ICE process. This includes ensuring that the project team are communicating properly as well as share information and knowledge with each other. Furthermore, the facilitator is responsible for ensuring that the project team

are able to proceed with the design process, as well as keeping project team on schedule (Garcia et al., 2004, Mark, 2002). The importance of a facilitator within teams working with an approach of concurrent design are also highlighted by Bosh-Sijtsema (2013). According to Chachere (2009) the VDC facilitator is not required to have specific technical skills in order to be able to monitor the ICE process. The reason is argued to be the change of distribution of technical skills within the project team, due to the increased complexity of the industry.

In projects using BIM to a larger extent, Akintoye et al. (2012) states that there is a need for a manager that oversees the successful exploitation of BIM and the coordination of the BIM models within multidisciplinary teams. This role is often referred to as the BIM-coordinator (Bosch-Sijtsema, 2013). However, it is not unusual to define the BIM-coordinator role under other names such as; VDC engineer (Mourgues et al., 2007) and BIM-manager (Akintoye et al., 2012).

As stated, the distribution of technical skills has changed within project teams. Nowadays, as a result of the complexity of the industry, the specialist engineers with special competence are having an important role within the project organisation (Chachere, 2009). Chachere (2009) continue to state that this is the reason why the NASA project team Team-X are selecting their team members based on technical skills and experience. Moreover, due to the high work rate, Mark (2002) states that people working in an ICE team need to be able to cope with stress and in the same time be flexible and adaptive. This is further confirmed by Chachere (2009) that describes the members of a project team working in accordance with ICE, needs to be able to work in chaotic, high-pressure environments. Therefore, Mark (2002) further states that one key factor is to create a team consisting of people that are enjoying problem solving in an exceedingly social environment.

2.7 Theoretical Summary

VDC is the use of multidisciplinary performance models for product, project organisation and work process (CIFE, 2017). The approach consists of three key concepts; BIM modelling, visual planning and ICE sessions, and are stated to solve known issues within the AEC industry such as lack of communication, discontinuity in the construction and lack of knowledge management (Li et al., 2009).

The VDC concept is possible to divide into three factors which ate project manager are able to manage during the project process. Those factors is the product, the project organisation and the work process. Those factors are commonly referred to as the POP-factors (Kunz and Fischer, 2012, Garcia et al., 2004). Further, these factors will impregnate the whole design process, by ensuring that all steps within the VDC process focus on those factors (Kunz and Fischer, 2012).

Moreover, the VDC concept are relying heavily on visualisations, such as BIM models. Further, BIM is stated to act as a hub of communication within the VDC process (Andersson et al., 2016). Another core concept within the VDC approach is the concept of ICE. ICE is a meeting structure for the design process and is based on the well-known concept of CE. The ICE process is defined as a combination of experts

designers, advanced modelling, visualisations and analyse tools performed in an integrates, social environment in a specially designed facility (Chachere, 2009).

An implementation of the VDC concept is stated to result in some organisational changes, mostly affecting the different project roles. A new role, the facilitator, emerges as a result of the change of the design meeting structures, which further brings on a change in the tasks of the design manager (Chachere, 2009, Mark, 2002). Moreover, the increased use of BIM leads to an extended need of a BIM-coordinator (Akintoye et al., 2012).

2.8 Research approach and design

The importance of an improving construction sector is of a great importance to the society and along with the criticism that the sector have received in an inadequate customer satisfaction have made it recipient to new approaches in tackling the traditional design (Eriksson and Westerberg, 2010). With VDC coming up, as an increasingly growing trend in the design and the meaning of the concept is diverse, this study aims to conclude in how to extract the concepts of most importance and to characterise how this concept differs from our traditional approach. Further, knowledge gap in existing literature can be found in regard of the effects and implications of an implementation providing validity to the research questions.

It is stated by Dubois and Gadde (2014) that an abductive approach supports a continues interplay between the theory and findings. Further, it is said to enable a systematic combination of theory and reality which goes in line with research that could require changes in the theoretical framework due to new information and the changes the study could take. According to Bryman and Bell (2015) a qualitative research methodology has the aim to show the relationships between theory and practice. The qualitative research design enables the possibilities to explore and interpret the selected circumstances in the development of this master thesis. Further, the qualitative design allows the thesis into adapting and changing in line with findings along the process. Compared to the quantitative design it differs in this regard where the qualitative focus on the outcome rather than quantification (Bryman and Bell, 2015). Therefore, the approach of this study chosen is an abductive research approach with a qualitative research design.

The thesis is based on qualitative case studies combined with a literature review providing an overview of the concepts and laying the foundation for the analysis of the case studies. In order to address the effects and differences of the design approaches in the construction sector multiple case studies were performed. Bryman and Bell (2015) states that the qualitative research approach aligns with a comparative design which is the case of the multiple case study. Other methods used in order to reach the projected outcome and to support the case studies were interviews and direct observations which are described in the following chapters.

3 Methodology

In the following chapter, the methodology used for this study and justification for the choice of methods is presented in order to give the reader an understanding of how the research was performed. The procedures used are described including materials, observations and selection of cases, interviewees and methods.

3.1 Literature

The theoretical framework is established in order to provide a framework in which the result and analysis can be put as well as provide a base for the research to be built from (Bryman and Bell, 2015). In order to create the basis of the analysis and the cases the concept of VDC had to be defined through a literature review creating the theoretical framework. The main literature introducing the concept of VDC are developed by individuals at CIFE at Stanford University resulting in all initial data and understanding had to be based on their definitions and points of view. By initially using literature and articles from one single institute, the theory had to be critically evaluated and verified in order to be presented as relevant.

What has been regarded as sufficient information have been done in accordance to relevance, publication dates and connections to construction industry as criteria's for the chosen literature. Recent publications have been preferred due to the new development and introduction of the concept. All literature have been reviewed critically before being used in the theoretical framework in accordance with Bryman and Bell (2015).The sources were mainly accessed via Scopus, Summon Chalmers Library, Google scholar and consisted of journal articles, books, published case studies. Further the use of complementing sources was used such as organisational web sites such as academic research centres or institutes. Search words included: *VDC, Virtual Design and Construction, Concurrent Engineering, ICE, BIM, VDC implementation, change in construction, Collocation, virtual planning, visual modelling*.

Initial focus in the literature search was put on the broader knowledge of the concept and construction sector at a whole resulting in a base of knowledge for further literature research. This research and knowledge played a vital part in defining the research questions and scope partly changing along the writing of the thesis which is motivated to be the case in an abductive research approach by Dubois and Gadde (2014).

3.2 Case Studies

Being able to handle the procedures and working methods from the case studies there was a need for a deeper understanding of the current organisation and structure. Therefore, this was done in order to map how new procedures could be implemented into the regional housing department and how they would differ from the current operations. To do this, a case study towards the current organisation has been conducted through interviews, direct observations and a look through the documentation and central processes provided in order to conduct the design process. This is further used as a reference point in the Chapter 7, Chapter 8 and Chapter 9.

Given that a VDC project would be found inside the case company a case project of implementing VDC was found and chosen in the form of a hospital outside Oslo, Case B. Through extensive commitment from the client and a new collaboration agreement with Stanford they have been implementing VDC into the design process. In order to be able to make a relevant comparison between the VDC case project a similar non-VDC project had to be chosen. Therefore, the project of Case A, were chosen. It is a hospital project of the same complexity as hospital projects and in comparable extent and size. The reasons of chosen another hospital is shown in the complexity of running the current everyday procedures without risking its operations at the hospital at the same time as building new facilities and rebuilding the old.

In mapping the cases there has been an aim of being able to find comparable data in both case projects in order to highlight the outcomes in relation to the theoretical aspects in line with the qualitative design (Bryman and Bell, 2015).

3.3 Interviews

The semi-structured interview method was chosen as it is considered the most suitable and widely used format for qualitative research since it provides the right balance between flexibility and allows rich data collection (DiCicco-Bloom and Crabtree, 2006). Further, it is stated by DiCocco-Bloom and Crabtree (2006) that qualitative research interviews are to be performed as unstructured or semi-structured since the structured interviews tend to result in quantitative data. The structure of each interview have been adjusted to the interviewee and been dependent on what at the time have been unknown but the focus for each role of the interviewee have remained. This have been done depending on what was needed in order to map the same parameters in both cases in relevance to the position of the interviewee. Prior to each interview, the interviewee had been given the topic and context of the interview. Additionally, due to various possibility to prepare depending on coincidental opportunities in the perspective of geographical locations, complementary questions and exchange of information have been done through emails and phone.

In performing the cases, a number of interviews have been conducted. Both in connections to case projects, and interviews with the aim to get a picture of processes and knowledge transfer from actors within the industry with experience of the processes evaluated, have been conducted. The conducted interviews are presented in **Fel! Hittar inte referenskälla.**. Further, it is to be stated that two interviews were conducted with the digital developer at the Case Company in different phases of the study where the first one was performed to create a knowledge basis on which to develop the study. Initial Facilitator B will be representing as both the initial facilitator at Case B, as well as the person responsible for implementing the VDC concept to the Case Company's office in Norway. Further, the Digital Developer have experience of working with VDC in project organisations. Since the Digital Developer is possessing knowledge on both implementing VDC as well as being one of the individuals responsible for digital development at the Case Company. The interviews performed are presented in Table 2.

Table 2: Performed interviews

Case Company	Case A	Case B
Digital Developer	Design Manager A	Design Manager B
BIM-coordinator		Initial Facilitator B

3.4 Direct observations

During the process of collecting empirical data the authors participated in a number of meetings regarding the design of case projects in order to collect supporting material, confirming the provided data as well as provide an understanding of the process and design. For each project, all meetings were held by the contractor with project representatives from consultants, partly sub-contractors and client representatives from each project. The meetings observed are presented in Table 3.

Table 3: Observed meetings

Case Company	Case A	Case B
Design meeting	Design meeting	ICE session
BIM-coordination meeting		

The empirical outcomes of the direct observations are presented together with other empirical outcomes in Chapter 4, Chapter 5 and Chapter 6, presenting the cases where it is following to be taken into consideration through the cross case-theory analysis as well as into the concluding remarks.

3.5 Analysis of data

According to DiCocco-Bloom and Crabtree (2006) the analysis of qualitative data is preferably done simultaneously as the data selection is done through interviews. Further, DiCocco-Bloom and Crabtree (2006) states that as a result of this iterative process of collection and analysis of data, new categories and themes are generated which, by Bryman and Bell (2015), is stated to be a characteristic of a qualitative design.

In order to analyse the empirical outcome from the case studies a cross case-theory analysis is to be performed in order to highlight the difference between the conceptual theories and practices. This cross case- theory analysis is done in line with the iterative process of an abductive research approach (Dubois and Gadde, 2014). The different parts of the cross case-theory analysis are being visualised in Figure 2.

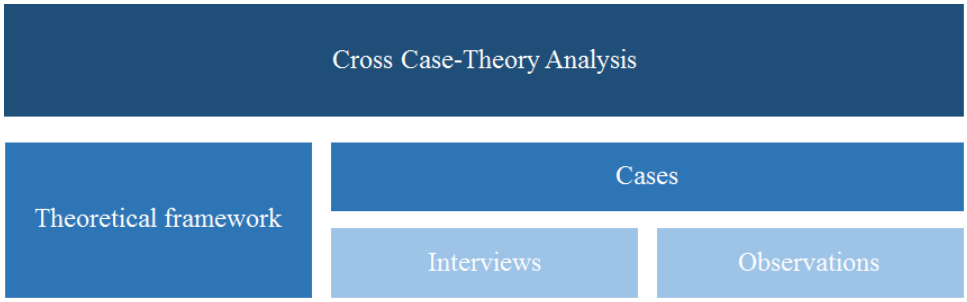

Figure 2: Parts included in the cross case-theory analysis

3.6 Ethical aspects

Bryman and Bell (2015) forwards the ethical principles of conducting business research and divides them into four main areas. These are further confirmed by DiCocco-Bloom and Crabtree (2006) and are consisting of harm to participants, lack of informed consent, invasion of privacy and whether any deception is involved. Kvale et al. (2009) highlights the importance of informing interviewees about the studies purpose and method. Further, it is stated that issues of participation is to be taken into account to address the matter if any consequence due to the study may arise. Therefore, throughout this study the participants have been informed by the study's range and purpose as well as being ensured about an anonymous presentation of data. This is done to achieve a free flow of speech throughout the interviews and to ensure the interviewees to elaborate their answers. Further, all interviewees have given their permission for audio recording of interviews which is only to be used by the authors.

Bryman and Bell (2015) discusses the difficulties of ethical decision-making of qualitative studies which is open-minded. This is resulting in the questionable situation of informing the participants about the study, since it may transform along the process. Along with this master's thesis development it have not been considered to be a change in the extent to which the participants involvement and role of the study has changed in order to which, no deception of the participants have occurred.

4 The Case Company

This chapter aims to provide an overview of the Case Company organisation as well as their support and steering guidelines of the design process, provided through central support functions and guidelines within the company database and at a regional level. Furthermore, the chapter will include information based on interviews with a Digital Developer as well as a BIM-coordinator at the Case Company. Additionally, thoughts and comment on VDC from the Digital Developer will be presented.

4.1 Organisation and steering process

The Case Company is a contractor currently active on the national construction market as well as in the complete Nordic region, but also in other parts of the Europe and the US. In order to run the organisation effectively and with consistency steering documents have been developed. Those documents are provided to the company employees through the internal databases. On the internal database, documents regulating the whole project process can be found. The documents are providing guidelines for the employees involved in the different parts of the company operations. For housing projects, and the design phase in specific, the documents are regulating the different phases within the design process as well as the managing of the organisation. Moreover, there are documents providing guidelines for the steering of the project such as the project organisation, management and steering of the project, economy, risks along with others. However, the steering documents are only acting as guidelines and are leaving some space for interpretations resulting in varying steering and management between different regions and projects. This however, is making it possible to regulate and adopt the process to the specific and unique project.

The design process at the Case Company is usually managed by a project chief and a design manager jointly. They are the ones responsible for developing and defining the design process and its execution, based on the guidelines of the internal steering documents. By creating visualisations of the product, plans, problems and different solutions within the project, the right conditions for involvement, engagement and a smooth progress can be created. Further, in projects with large proportions, a BIM-coordination will be involved in the design process of a project. The BIM-coordinator will be responsible for coordinating the models of the different disciplines involved in the project, ensuring that all models are aligned and without any disturbance. Moreover, multiple support functions will be available during process, from project design to construction.

4.2 Current operation process

This section aims to provide knowledge of the traditional structures of the current operations at the case company at regional level in Gothenburg. Through, this section internal steering documents, the methods used within the project process, the internal usage of BIM and visual planning will be presented.

4.2.1 Traditional design process

According to the BIM-coordinator, the design process can differ between projects depending on the project organisation and the extent of the project. The decision of how to steer the design process and what methods and tools to use are allocated to the design manager and the project chief. However, the design process always contains representatives from the contractor, the client as well as different specialist engineers.

During the design process, several meetings are being held. The initial design meeting, called the start-up meeting, are managed by the project manager, but the design manager are expected to participate actively during the meeting. Moreover, other roles within the company organisation are preferable represented during the meeting such as managers from procurement, logistics, calculation and construction team. During this first meeting the requirements, aims and the process of the whole project are being agreed upon. The economic aspects of the particular project are being presented and economic goals are being appointed. The start-up meeting, will be performed before the start of the project and aims create a common understanding of the project, by providing an overview of the design process as well as the project targets. Furthermore, this meeting intend to create a collaborative spirit within the project team.

Within the Case Company, design meetings are commonly held once a week. The number of participants are usually varying, depending on the theme of the meeting. However, generally the meetings are being managed by the project design manager and protocolled by one of the project managers. Moreover, the project chief are preferably present as well as representatives from the client and the different specialists involved in the project. The extent of the project will regulate the representatives from specialist engineering disciplines.

There are several ways of presenting the agenda of the meeting as well as documenting what is being discussed. What are discussed during meetings are being documented, often only by small simple notes that later has to be developed further by the design manager after the meeting. Over the past years, as a result of the digitalisation within the construction industry and the Case Company, the documentation of the design meetings has become more digitalised. The traditional manual protocols has moved towards more digital tools such as visual boards and question matrixes within digital platforms. One tool that is promoted through the internal database is the decision log. When using a decision log, all participants of the meeting are responsible for register their assigned tasks in contrast with traditional protocols where the scoreboard documents all responsibilities and decisions taken. The project log aims to reduce the workload of the design manager and the scoreboard, by avoiding time-consuming rewriting of the documentation after the meeting.

Another varying aspect of the design process is the duration of time for the meetings. Depending on the project extent, the involved parties, tools for the process as well as on which stage the decision process are currently in, the design meetings will proceed over an undisclosed period of time. However, it is not unusual to schedule a half day for project design meetings. Depending on the duration and the topic discussed on the meeting the engagement of the participants will fluctuate. According to the interviewed Digital Developer as well as a BIM-coordinator, it is not unusual that participants' gets

easily distracted during meetings or in some cases; some parties are not involved in the discussions at all. Furthermore, this is stated to be a common issue during the meetings.

4.2.2 Visual design process

The Case Company has been recommending the use of visual design approach in the design process through internal systems for multiple years, in order to create a broader spectrum of alternative methods in the design process. Within the company, the visual design is defined as a decision and steering tool that visualises goals, plans, responsibilities and interfaces between all participants in the project. The concept is stated to increase the profitability and the efficiency as well the engagement of all contributing actors in the design team, which is stated to result in a higher quality of the project.

The visual design process at the Case Company is based on weekly meetings, with the focus on solving key issues and several other aspects of the design. It is recommended to dedicate a room, provided with tables and chairs for each of the team members as well as a number of boards. Further, it is recommended that this room remains available and intact for the duration of the design period unless there is a digital design platform that works in the same way. The visual design process relies heavily on close collaboration between the participants, which according to the Case Company is resulting in an increased engagement of the actors within the design team. An increased participation are further stated to create a committed project team that performs and deliver a higher product quality.

One of the basic elements of the visual design process is the usage of visual boards. There are several different visual boards promoted by the case company, and often those are used in parallel. By using visual boards, it is possible to highlight all the issues that needs to be addressed during the design phase, clarify their relation as well as advocate the responsibilities between the different project disciplines. Moreover, difficult questions and discussions can be marked and pinned as key issues. Another success factor for the visual design process is the visual project plan, a plan visualising the different milestones, activities and deliveries within the project time schedule. The project plan is preferable developed during a workshop, where the whole project team are participating. Based on the project milestones, project activities and deliveries, the team will be developing the project plan.

Instead of documenting the meeting result in a protocol, the visual design process are promoting the usage of a decision log, where both questions and answers are documented. Compared to a traditional meeting protocol, the decision log are not stating the responsibility and task of the different disciplines. Instead, it is up to each discipline and actor to take notes and make sure that their allocated tasks are being performed on time.

4.2.3 Building Information Modelling

Today, the Case Company are promoting a usage of the BIM models in three dimensions. Moreover, for projects that are more complex, there exist a requirement of including a certain amount of modelling and 3D-collsion controls.

According to the BIM-coordinator, the in-house developed residential projects are commonly utilising the models to a substantially higher degree compared to projects developed by other actors, since it is easier to set and control the requirements for in-house developed projects. Based on research within the region, a set of specifications of how to use the models within an early phase has further been developed and adopted into the organisation. Besides those specifications, there are no other requirements on how to use the models within the projects. However, depending on the project and the benefits of using the models, each project organisation can regulate in what extent they will use BIM.

The BIM-coordinator role is responsible for the collision control and merging of models from the different parties in the design phase. According to the interviewed BIM-coordinator, it is currently a role that is fluent in the perspective that it is combined with other roles depending on the project such as design manager. Due to high occasional workload, it is also stated that there are varying opportunities in follow-ups of previous projects. Furthermore, according to the internal support systems the role of the BIM-coordinator involved in large projects also is supposed to support all the 3-dimensional modelling questions that may arise. The BIM-coordinator may also act as a support function during the construction process, assisting if changes to the models will occur. This could accordingly to the BIM-coordinator differ between regional departments in the sense that the BIM-coordinator, depending on region, could have different responsibility towards the construction phase and end product.

4.3 Digital development in accordance with VDC

It is to be stated that the Case Company is currently not working in accordance with VDC on a national level. This section is based on an interview conducted with a Digital Developer at the Case Company, who has previously worked with an implementation of VDC.

According to the Digital Developer, one of the challenges of today's construction market is the loss of knowledge due to gaps between the different disciplines. The developer continues by stating that an increased collaboration and closer coordination of the involved actors will help address this issue. Thus, since one of the core values of VDC is to utilise the knowledge of the whole group, the interviewee consider VDC is to be a solution to this gap. VDC will also reduce the latency of long email conversations between the different disciplines within the project, by promoting collocation and redirecting conversations and discussions to the meetings.

The Digital Developer also highlights the importance of collocating the project team within a VDC project. Collocation of the project team is crucial for the success of a VDC project. However, the experience of the Digital Developer says that collocation might be difficult due to a resistance from the involved disciplines, regarding leaving the personal office. Further, the resistance is experienced particularly strong from the perspective of the consultants. Therefore, the Digital Developer suggest to put a demand for collocation on the team members. However, the disciplines do not have to work actively, to 100%, with the specific project. For instance, specialist consultants are able to work with other projects, the important thing is that they remains on jour

and can separate the hours worked for each project. Further, the interviewee states that full day meetings should not be seen as an extra-long meeting. Instead, since the VDC process and the ICE meetings also contains work meetings, it should be considered as time the engineers already has budgeted for.

Traditional design meetings is according to the interviewee often time consuming and ineffective. Discussions and decisions are often being continuously postponed to the following meeting, which results in irritation within the project team. Moreover, the Digital Developer is expressing an annoyance against traditional protocol writing. Often, the design manager or a separate minute taker are taking smaller notes during the meeting, which later on needs to be rewritten into a real protocol. This is according to the Digital Developer a time consuming process, which can be avoided by implementing a VDC process.

The Digital Developer state that VDC as a concept is revolutionary for the construction sector. However, the Digital Developer argues that one of the issues with VDC is that there exists several internal interpretations of VDC on the market, where only smaller parts of the VDC process are being used. One of the challenges of a successful implementation of VDC is to implement the full concept. However, the POP metrics are stated to be difficult to connect to a real-life construction project, and are therefore recommended to be accepted. According to the Digital Developer, an implementation of VDC is most successful when implemented in smaller parts. Further, it is stated that in order to motivate all involved actors to fully cooperate with VDC, it is beneficial if the requirement of VDC is stated already in the initial design contract.

5 Case A

The following chapter will present basic background information about Case A, as well as present the structure for the organisation and meetings of the design of the project. The information will be based on interviews with project participants, representing the Case Company within the project and the design team. In order to map the design process direct observations of design sessions have been conducted. Further, information will be used from press releases, official sites, articles and internal databases will act as sufficient complement to the interviews.

5.1 Introduction of the project

In 2016, the case company signed a collaborative contract with a real-estate group conducting care properties with a total area of two million square meters within the region of Stockholm. The contract embodies the design of both new facilities and reconstruction of a hospital, located at Kungsholmen in the central parts of Stockholm.

The project is contracted as a partnering collaboration between the client and the contractor, however, all subcontractors and specialists will be contracted traditionally and without partnering collaboration aspects. The project is divided into two different stages; where stage one will contain the collaborative design process and the second part the partnering agreement for the construction. Therefore, two independent contracts will be developed and signed within the project. At the time of the first interview, the first contract containing regulations regarding the design process had been signed. The second contract, for the construction will be based on the schematic design, which the design team is currently developing. However, the second contract does not necessary need to be rewarded the same contractor that is performing the design of the project. The contract if agreed upon will be followed by the construction, where a new contract covering the construction process will be signed before the end of the second quarter of the year.

The construction start is planned to the second quarter of 2017, and the completion is planed to 2020. In total, 29 200 square meters of new facilities will be constructed and close to 4 200 square meters will be reconstructed in order to adapt the hospital into new technologies and operations due to a changing demand of care in the region. The adaption are forced upon the tenant from the county council where the real-estate owner holds the facilities.

One of the main challenges of the project is that, during the whole project process, there will be ongoing business in the hospital. In a complex industry as the healthcare, it is of great importance to not disturb the everyday operations and keep the previous patient care at the same time as the hospital is expanding. Therefore, extra focus will have to be put into the planning and design of the project. Hospital projects are in general containing a high level of technical solutions, which in combination with the high risk connected to disturbance of the ongoing daily operation will be extra crucial. These aspects are making the processes even more complex.

Currently designing and planning the schematic design drawings in parallel with the expected start of the construction works creates a head start for the design towards construction phases which will not interfere with each other. The design of the project is planned to be continued until 2018 and where the construction will be ongoing until 2020 pushing the design team to always be ahead with the design. In the early design phases, the focus will be put on completing the structural designs and rough structures in order to create preconditions to work with for the construction team. From that phase, the design will go on in becoming further more detailed.

5.2 Project design organisation

The project organisation is consisting of representatives from the contractor (the Case Company), the client, the tenants as well as all the disciplines of contracted specialists shown in the organisational chart (Figure 3).

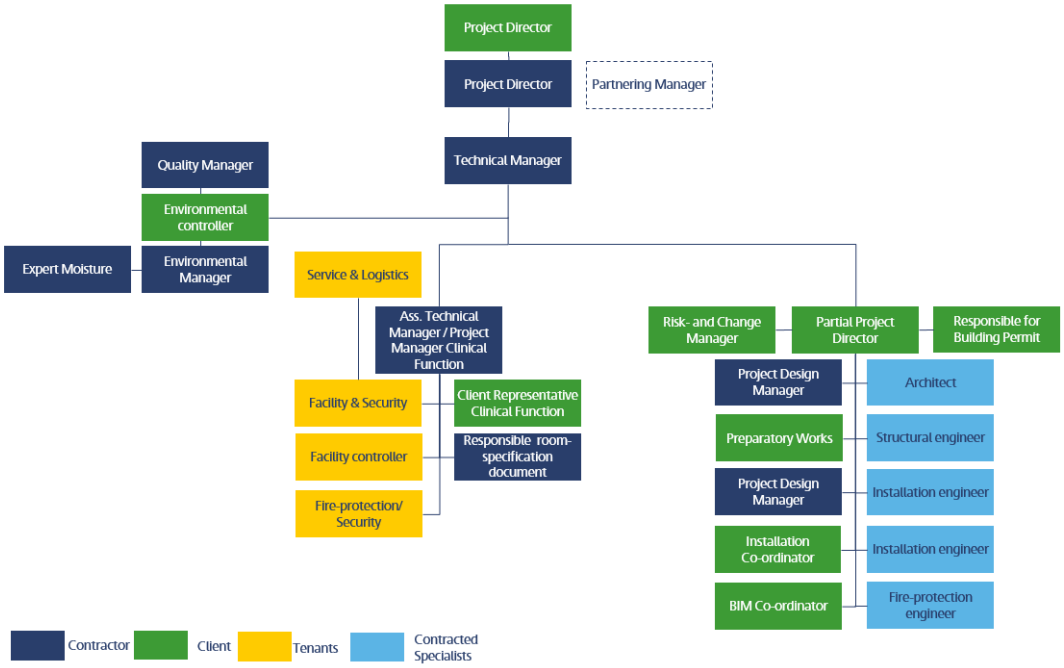

Figure 3: Organisational chart of the design organisation at Case A

Within this project, some of the roles has two representatives. The two project directors are having the overall responsibility of the project, one representing the client and the other the Case Company. Moreover, the design process are being moderated by two design managers. The design team in opposite to the project directory will be resolved after the design phase even though many of the specialist consultants will take part at separate occasions along the projects different phases.

5.2.1 Organisational roles

Within the project, there are many actors involved and each actor plays a particular role for the design process. The design managers are responsible for monitoring the meetings held during the design process, ensuring that the discussions and decision-making are heading forward as well as in the right direction. As stated in Section 4.1 "Organisation and steering process", it is the responsibility of the design manager to

decide the processes, approaches and tools to use within the design of the project, unless any other certain request are made by the client. Until the time for the interview, the design managers had been monitoring all parts of the design phase together. However, during the more detailed design process, the work will be divided between the two design managers. The division of tasks will be based on the contact with the different disciplines within the project. Still, the two design managers will be supporting each other and continue to work closely. A special circumstance for this project, it that none of the design managers are having any specialist competence within the field of construction. Instead, the specialist consultants and the coordinators within the project are submitting the technical competence. According to the Design Manager A, allocating the decision-making concerning technical solutions to the other actors within the project, the design managers are able to focus more on how to make the design meetings run smoother and more efficient.

Besides ensuring that the meetings are heading in the right direction, the two design managers are responsible for the disposition of the time and developing a schedule for the meetings. Moreover, it is the responsibility of the design managers to ensure that the discussions during the meetings do not deviate from the schedule. Another important task for the design managers is to ensure that all members of the design team are engaged during the meetings. Moreover, it is the responsibility of the design manager to ensure that important and extensive questions are being divided into smaller ones in order to be more manageable. However, the design managers are not responsible for solving problems and taking decisions. Instead, the design manger allocates this responsibility to one, or several specialists within the project team.

Within the design organisation, the contractor and the specialist consultants have been contracted in an early stage. This includes consultants representing architects, structural engineers, fire protection, electrical engineers and plumbing and heating engineers. Each actor is responsible for possessing the knowledge and information required in order to contribute effectively to the project design. Moreover, there are actors responsible for coordinating contracted specialists and ensuring that they are taking part of shared information. For instance, contracted specialists concerning fire protection or medical gases will not participate on each meeting, and will therefore need to be notified when information and questions concerning them are being provided. Therefore, coordinators for medical equipment and installations will be active during the design phase of the project.

Another coordinating role within the project is the BIM-coordinator, whose responsibility is to collect and merge the different informational models distributed and developed by the specialist consultants. The BIM-coordinator is further responsible for performing collision controls of the distributed models.

In partnering and other collaborative projects, such as Case A, the client is having a larger impact within the design process compared to traditional projects. A committed client are furthermore preferable for complex projects such as hospitals, where it is of great importance that the building are being well conformed to the daily business of the hospital. According to Design Manager A, the client are greatly committed within this project. Moreover, the client are being present and are participating on all design meetings.

5.3 Tools and facilities

Within Case A, all meetings within the design process are being held at the project site office, located in connection to the construction site. The site office is provided by the client and are hosting both meeting rooms of different sizes and multiple personal offices. The design meetings are currently being held in one of the larger meeting rooms within the site office, and is provided with a large projector screen and a whiteboard. According to Design Manager A, the room is usually provided with high desks enabling the participants to hold a standing like position during the meeting, however during the observed meeting, those tables are not available.

All documentation and information sharing within the project are provided throughout a digital, visual platform. The visual platform is used in order to avoid paper based information-carriers supporting document sharing and communication within the project team. Therefore, it is important that all team members are having access to the project platform. According Design Manager A, the platform is highly effective for communicating and sharing important information among the members of the design team. One of the functions of the project platform is the visual question board, which makes it possible to ask and answer questions directly on the digital platform. The question board providing the opportunity of asking questions directly to other team members, as well as posting answers directly under the question, is making it possible to hold discussions visual to all team members. Further, by linking the platform directly to their email addresses, all team members are being notified when that receives some information or when they are asked a specific question.

Within the case project, there is a requirement of using BIM models from the client, which does not differ from the internal requirements regarding these kind of projects from the contractor leading the design. In order to being able to use the different features of the models in the aspects of collision controls, the supportive function of the BIM-coordinator is being present during the collision control meetings. In order to be able to merge the models from the different consultants their models has to be written in the same type of file format, which in this case is the IFC format. During the collision-control meetings, the collisions between the different consultant models are processed in a meeting run by the BIM-coordinator together with the design managers. In this project, they are a part of the process of achieving a complete model of the project. Further, the BIM-coordinator runs the agenda of deliveries of models in the project as well as arranging specific sessions not involving all the design team in order to address certain issues or tasks.

5.4 Design phase meetings

Within Case A, the design process are consisting of several different meetings. Economy meetings are being held once a month, progress and scheduling meetings twice a month with consultants. More commonly held meetings are design meetings, BIM-coordination meetings and work meetings that will be further presented below.

5.4.1 Design meetings

The design meetings are being held once a week, at the project site office, provided by the client. The number of participants and disciplines attending are varying from week to week, depending on the focus and questions to be handled during the session. For instance, the fire-protection engineers among other special consultants are not present on all meetings due to the small range of topics that interferes with their systems.

As previously mentioned, the design meetings within Case A are being monitored by the two design managers, representing the contractor. During the meetings, one design manager is responsible for coordinating the meeting and ensuring that the meeting is heading forward as well as in the right direction. Simultaneously, the second design manager is focusing on taking notes from the meeting, in order to run a protocol. These notes are not being taken into any traditional protocol, but are instead made directly into the project platform.

Each design meeting starts with a check-in, where all participants are asked to mark their mood on a mood-scale. By checking in, all participants are given the opportunity to explain the reason for their current spirit, which has been proven to create a common understanding and better relations within the group. Particularly positive moods are asked to further be presented and explained to the group, in order to spread the positivity within the group. The theory that the check-in is generating a positive spirit within the group can be confirmed by the observations made from the design meeting.

The check-in is followed by discussions regarding coordination and responsibilities of the project activities, following a structure and priority order coordinated and developed by the project managers. In order to simplify this process, a digital, visual platform has been introduced. Further, the question board is utilised for showing the agenda of the meeting, documenting the progress, present disciplines as well as producing a written protocol from the meeting. The visual question board, part of the platform, makes it possible to separate new questions from activities that are already in progress, as well as from problems and questions that has already been solved. This is being made as a routine where the design team members seems to be well in place and prepared in how the routines are followed.

During the meeting, one of the design managers is responsible for coordinating the visual board, including redirecting tasks and taking notes for the activities discussed during the meeting. Moreover, different activities and questions can, on the board, be allocated to specific actors, responsible for providing answers. Making it possible for the different actors to get an overview of their own tasks as well as the activities allocated to others. However, questions not placed on the visual question board, are not to be discussed during the meetings if not being urgent. Such questions has not yet been placed in the meeting schedule, and will therefore disturb the structure of the design meeting if discussed further in order to be solved or handled. Therefore, questions arising during the meetings will be written on the question board, and discussed on the meeting the following week. By doing so, the system of the visual question board will be easier to monitor by the design managers and more easily observed for the design team, which will guarantee the progress of the design process.

Even if the design managers are responsible for operating the design meetings, all team members are being active during those meetings. Each specialist is responsible for presenting his or her own questions. According to Design Manager A, this promotes a higher commitment and involvement during the meetings. The specialists are further responsible for presenting the decisions connected to their questions. By presenting all decisions taken for the whole project design team, all participants are getting an overview of the overall process as well as being able to react if they notice any errors or complications in the design. By allocating the responsibilities of presenting and coordinating specific questions to the specialists, the design managers are not required to have specialist knowledge in the field of construction and installation. Instead, the design managers can focus more on making the design meetings running smoother and more efficient.

At the time of the interviews, the design meetings were said to be approximately three hours long even though the observed design meeting passed right about two hours. Which, according to the Design Manager A are way too long and time consuming leaving the design team unable to stay focus and effective throughout the meetings. According to Design Manager A, the reason for the time consuming meetings are described to be the complexity of the current questions that has to been straightened. When entering the detailed design phase, the complexity and the proportion of the questions will decrease according to Design Manager A. This will in turn result in shorter and more concise meetings.

5.4.2 Work meetings

The interviewed design manager describes work meetings as smaller group meetings where part of the design team is gathering in order to solve problems concerning the design of the project. Depending on the subject of the meeting, different actors and disciplines are participating. The need as well as the extent of the meetings are decided jointly during the design meetings, however, it is up to the concerned actors to coordinate and carry out the meetings. Within Case A, work meetings are suggested to be carried out right after the design meetings. However, the work meetings can be hold up to five times a week, but the number of meetings can wary from week to week depending on the demand for the meetings. Therefore, all participants of the design team are asked to stay and have a cleared schedule after the design meetings.

However, according to Design Manager A, the concept of having a cleared schedule after the design meetings are not working to its full extent. Several of the disciplines often schedules other activities during the time following design meetings related to other projects even though the aim is to schedule design tasks related to this project during these slots.

5.4.3 BIM-coordination meetings

BIM-coordination meetings are focusing on aligning the information models developed by the disciplines of the design team. Before each BIM-coordination meeting, collision controls for the models developed by the special consultants are being conducted. The collision controls are being performed by the BIM-coordinator, who is running clash detections for the different BIM models. The coordination meetings are conducted

when necessary, and are managed by the BIM-coordinator. The need for the BIM-coordination meetings are often being identified during the progress and scheduling meetings. For instance, when the structural engineers are to develop drawings for shafts, a clash detection against installations need to be conducted. Thereafter, the BIM-coordinator collect the accurate models and running them for a collision control. Thereafter, all concerned parts are gathering in order to solve possible collisions and problems. Usually, those meetings are only necessary if any clashes occurs.

5.4.4 Communication

The decision of directing all discussions and decision making to the work meetings has been an active choice from the design managers. According to Design Manager A, by separating the time consuming discussions from the design meetings, focus can instead be put on communicating important information to the team members. Thus, both loss of time and annoyance, due to long discussions not involving all participants, can be avoided.

Communication between the meetings are mainly performed on the visual platform. The platform is providing a simple structured visual board where questions are being posted. Questions can be directed to specific actors, disciplines and work groups within the project. Further, the platform provides the possibility to answer and discuss different questions, directly under the original question. Each time an actor receives a direct question, or a new comment have been posted connected to a discussion followed, the actor automatically receives an email informing them that new information is posted. Moreover, the involved actors can notify each other by the different discussions by addressing them. By using this platform, mail correspondence can be reduced and everyone involved in the design process are able to follow discussions and decisions. Therefore, it is of great importance that all participants in the design team have access to the platform, in order to follow discussions and information digitally. Thus, the visual and virtual platform also enables the possibility to get an easy overview of the project for both current and previous design team members.

5.4.5 Decision making

Within projects with collaborative contracts, such as Case A, the project is being designed and developed jointly by the design team. Therefore, it is important that the decision making is being performed in an integrated environment. Thus, in order to create such an environment it is required that all participants are being forthcoming and open. According to Design Manager A, the project team within Case A have managed to achieve such an environment.

As previously mentioned, even if the design managers are monitoring the meetings, they are not contributing with special competence to the project design meetings. None of the design managers are having any technical expertise within construction, therefore the design managers are focusing more on monitoring the meeting rather than taking actual decisions concerning the technical parts of the project. Instead, the discussions concerning structural design, installations and similar are submitted to the specialist consultants and coordinators.

As mentioned, the main goal of the design meetings, within Case A, is not to solve problems as they occur, but to allocate responsibilities among the participants, as well as sharing information to the whole design team. However, according to Design Manager A, there are still some decisions taken during the meetings. By avoiding to take decisions during the design meetings, discussions are instead being directed to the work meetings. Within those meetings, the group of team members are having a free environment for discussions and problem solving. By only involving the concerned parts in the discussions, the interviewed design manager states that the focus as well as the motivation will increase. Design Manager A further states that a direction of the problem solving and decision making to the work meetings, will make the design process more effective. Thus, gathering involved actors for such meetings will shorten the communication paths and minimise the question asked by email.

Even if most of the decisions are taken in smaller groups, during the work meetings, all decisions will be presented in the design meetings. Further, all decisions will be documented on the visual board on the digital project platform. According to Design Manager A, this will give all actors within the project the chance to react if they notice any issues.

6 Case B

The following chapter will present Case B, as well as present the structure for organisation and meetings of the design of the project. The information will be based on direct observations, interviews with project participants representing the Case Company within the project and the design team. Further, information from press releases, official sites and internal databases will act as sufficient complement to the interviews.

6.1 Introduction of the project

In 2016, the Case Company's regional departments in Norway signed a collaborative contract for constructing a hospital building in Tønsberg, Norway. The contract incorporates a collaboration between the Case Company and a consultant group that will be responsible for all counselling services within the project as well as the design. Moreover, the project will be performed as a jointed venture between different national offices at the Case Company. Thus, this border-crossing collaboration will bring unique competence to the project. The contracts are based on a model of IPD, where all parts are collaborating within the design process in order to find the best solutions possible for the project. This model targets that all involved parties are sharing the pain and gain aspect of the outcome result. The concept of IPD is commonly used in United States, but the Case B project will be the first hospital project in Norway applying IPD model. Moreover, the Case B project will be a pilot project for new contract strategies at this division of the Case Company, where focus will be on BIM and digital coordination.

At the moment the design team are performing the detailed design of the project. The project start is planned to 2017, and the project contains new construction, demolition of existing buildings as well as connection to existing infrastructure and buildings. Approximately, 40 000 square meters will be built, spread on two buildings hosing psychiatric and somatic units. The psychiatric building are planned to be completed in 2019, and the somatic building in 2021. This will bring complexity to the construction process since it is of great importance that the hospital business are not to be disturbed by the construction works.

The project goal is to reduce the construction time with 50%, and to a 10% lower construction costs compared to similar hospital projects. This means a total construction time of 36 months, for both the psychiatric and somatic building, which results in a production pace of 300-320 square meters per week. Thus, a high level of industrialisation of the building process will be required.

6.2 Project design organisation

At Case B, the design team consists of 60 actors representing different disciplines. Included in the design team are both the contractor and the client, but also consultants and sub-contractor. The design team are required to stay collocated at the site office five days a week, due to a request from the client. The collocation of 60 different actors, with the responsibility to represent different actors has resulted in a higher demand for effective communication within the team. However, according to Design Manager B, this is something that the project team needs to improve.

Furthermore, Design Manager B of the project state that there has been a varying response to the collocation among the team members. Design manger B further claims that there is a part of the design team who prefers working in a more isolated environment but that it overall have been a positive response to the collocation.

6.2.1 Organisational roles

Within Case B, the roles within the project organisation holds differences from a traditional project design. This is due to the use of the VDC concept, which results in a changed role and responsibility of the design manager as well as an addition of a new role, the facilitator. The initial initiative to apply the concept of VDC came from the client in line with running this project in a way of the current digital technologies available in the industry. Therefore, the developed concept of VDC, which are frequently used in the Norwegian division, corresponded in a good way with the clients wishes. According to Initial Facilitator B, the client have been taking a great deal of initiatives to invest in both the site office and large, visual screens used within the ICE process.

Traditionally, the design managers are responsible for monitoring and coordinating the design meetings within a project. Within VDC projects, however, those tasks are being allocated to the facilitator, which clearly could be seen at the observed ICE session. However, within Case B, there have been more than one facilitator responsible for monitoring, planning and carry out the design process. By allocating the facilitating tasks to a separate role, the design managers can instead focus on participating in discussions and fully representing the contractor during the ICE sessions. Thus, an increased focus can be put on the actual process and the design of the project. However, the design manager is still responsible for deciding and coordinating the agenda and the subject of the ICE session, in collaboration with the other actors in the design team. At the observed ICE session, all team members had the opportunity to, before the meeting, send in topics for the work meetings. The design manager then incorporated the topics to the ICE session schedule.

Further, within the ICE process the facilitator is responsible for ensuring that the concepts within VDC are being used properly within the project. This mainly includes the ICE sessions, which is monitored by the facilitator or, in as within Case B several facilitators. During those sessions, the facilitators are responsible for ensuring that the meeting is heading in the right direction, keeping the discussion within the subject as well as ensuring that the timeframe is kept. At the observed ICE session, the facilitator was not involved in any project specific discussions, instead the facilitator could focus on monitoring and coordinating the session and the design team. If necessary, the facilitator stops and redirects time-consuming discussions, in order to stay within the strict time limit. As the facilitating role is distributed to specific roles within the project the design managers are having an increased opportunity to focus on the actual design of the project.

During the ICE sessions, it is of great importance that the actors and disciplines are participating actively in discussions. During the work meetings, it is more up to the one

holding the issue or question that initiates the meeting and presents their questions, appropriate solutions or leads the discussion with the disciplines whom it concerns.

During a time of pressure in regard of cutting production costs in order to land inside budget and during a short time produce a lot of design the meeting structure of ICE and the concepts of VDC was dropped and the design team leaped back into the traditional roles. This is something that will be further described in Section 6.4. Due to this the design managers ended up being back in charge of meetings as well as previously comfortable roles for the rest of the design team. However, Design Manager B states that this was not due to any dissatisfaction about the working concepts.

6.3 Tools and facilities

Within Case B, the client has decided to build a new site office for the project team, designed specifically for this project, with the aim to simplify the VDC processes. The site office consists of several meeting rooms, of varying sizes to support the different phases of the project process. However, the core of the office is the BIG room, or VDC room as is also might be called. The BIG room, which are used within the ICE meetings, is provided with a folding wall, which makes it possible to divide the room into two separate parts (Figure 4). Dividing the room into two separated parts, makes it possible work individually in one part of the room, and in the same time holding a group meeting with loud discussions in the other part.

Figure 4: Project site office with VDC room at Case B

The BIG room is being provided with several tools to support the ICE process. Within this project, the client has invested in both a large interactive huddle board, touch screens and projector screens in order to support the ICE process. The Huddle board is connected to a separate hard drive, which according to Design Manager B are making it difficult to reach stored documents from other devices. However, according to Initial Facilitator B, the screens are not completely suitable for the ICE meetings. Further, Design Manager B states that the boards are slightly too technical and complicated for the project. At the observed ICE meeting, however, less complex smart screens where used. According to Initial Facilitator B, the screens used within ICE meetings should be easy to use and connect to personal computers. Besides the large screens, the all seats are provided with a personal computer screen.

In addition to the technical, virtual tools, a paper-based scheduling, called last planner, is being used (Figure 5). Last planner is a, production planning system developed for lean processes. It is further a post-it based scheduling system used for visualising and planning the different activities within the project. At the observed ICE session, the project schedule is divided into two parts, one showing an overview of the whole project process, and the other one visualising one month of the project, starting from the previous ICE session. By separating the schedule in this way, it is possible to plan the project phase in both long- and short terms. All disciplines within the design team are being allocated a specific colour on the post-it notes where their activities can be written down. The post-it activities are thereafter placed on the schedule. Completed tasks are marked with an ok, and are attached permanently on the completing date on the schedule. By doing so, the activities completed and meetings held are being documented. According to interviewed facilitator B, the last planer method is more effective than digital planning tools. Initial Facilitator B means that it is easier for the team members to grasp the schedule if it is being visualised with post-its compared on a digital screen. Further, a paper-based question matrix is used. Just like the last planner board, the question matrix uses post-it notes to write down and document questions. The question matrix is designed as a to-/from matrix where the team members can write down direct questions to representatives from other disciplines. According to Initial Facilitator B, the question matrix is most effective if the participants already before the meeting has prepared questions to ask other disciplines.

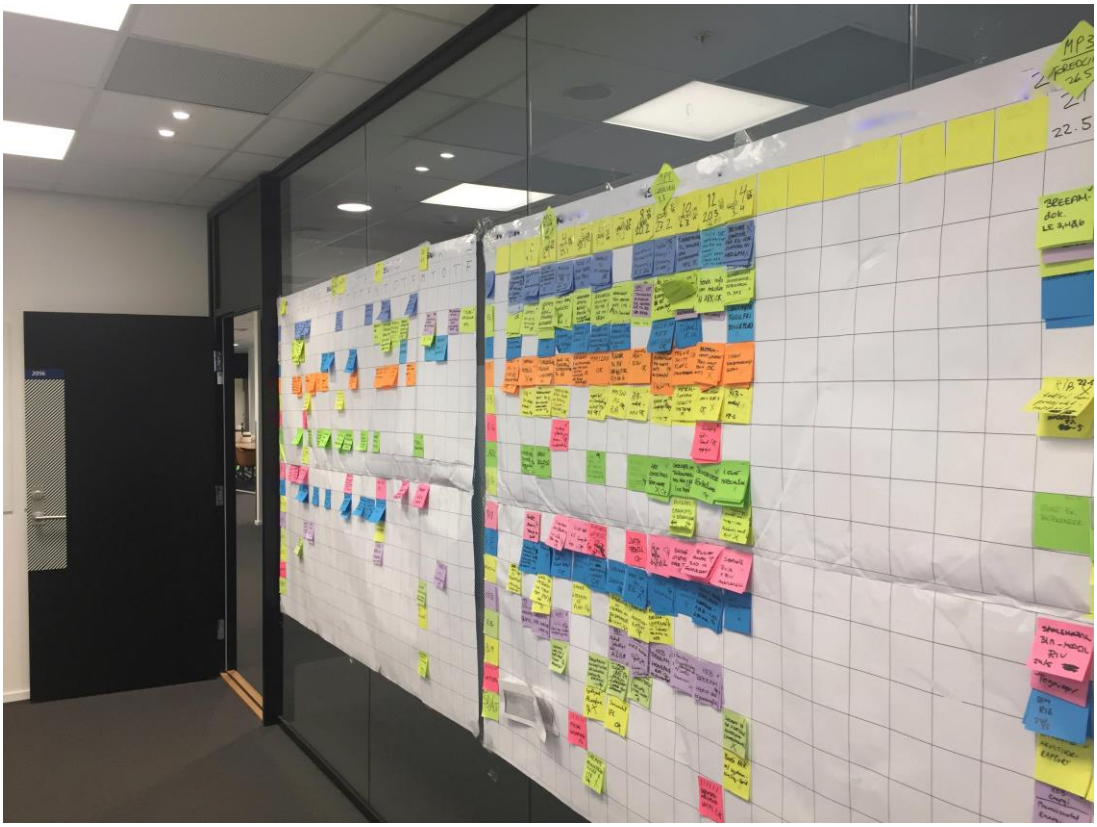

Figure 5: Last planner board at the observed ICE session

In Case B, a last planner system has been used as well. However, according to Design Manager B, the project has been too big to apply on one single plan. Instead, the project plan should have been divided into smaller parts. For instance, according to Design Manager B, the project plan would have been easier to grasp if different buildings would have had separated last planner boards. The documentation within Case B, are being shared to all members in the design tem through a digital platform. According to Design Manager B, the initial plan was to use a digital platform suggested by the client. However, during the design phase the project team has decided to change into a SharePoint based platform software suggested by the contractor. Moreover, a virtual desktop infrastructure (VDI) is used for storing all discipline models.

Within the Case B project, there is a requirement of using BIM in six dimensions. This is not only including a frequent usage of the BIM models, but also the linkage to project plan and costs. The models are used both during ICE-meeting and in order to perform clash controls of the different disciplines models.

6.4 Design phase meetings

The design meetings at Case B, are to be performed in accordance with VDC concept. However, the project design organisation has partly fallen back into a convenient and traditional design approach. According to Design Manager B, this is due to the stress and pressure that arose from cutting and staying within the budget limit of the project. This pressure, forced the client and the contractor to take an active decision to deviate from their original contracts by overriding the VDC process. During the interview, it is further stated that stress is a common reason for fall-backs within implementations of

new working methods, which has been witnessed by Design Manager B in several previous projects.

Another issue, which according to Design Manager B is considered to be one of the reasons for the fall-back are shortcomings in the organisation. The ICE sessions were monitored by five different coordinator, which resulted in five different and inconsistent meeting structures. Furthermore, Design Manager B states that the project has both the technology and the roles required in order to implement the VDC processes successfully. However, they are lacking the organisational culture needed. Design Manager B continues by stating that the meetings needs to be more focused and that there is a need for an increased commitment within the project team. Moreover, the need for clearer and more detailed role descriptions are being highlighted. Unclear role descriptions are further described as one of the reasons for the fall-back of the working methods.

The project organisation is aware of the problem and knows the reason for the fall-back. Since the ICE sessions, is one of the most essential parts of the VDC process, the design team is currently working on a reimplementation of the VDC and the ICE process. When, in the current state trying to reintroduce the concept of ICE and VDC, a number of changes in comparison to the initial phase are to be made. According to Design Manager B, the size of the design organisation became a hinder of the new approaches. Not due to a resistance, accordingly there was a great interest in the processes but in reaching all participants it became somewhat complex. One of the learnings that are changed in this edition of the introduction of the concepts is the size of the groups which is included. By dividing the design process into stages, as for example design and plan one building at the time, the complexity is heavily reduced and it is a lot easier to grasp as a new approach to the design. Further, to avoid the same result as the previous attempt the definition of what responsibility each role holds will be developed to a greater extent.

In the following section the process of the meetings held within a VDC project, monitored by Initial Facilitator B, from the contractor in Case B, will be presented. The observed session, will represent the ICE process in this thesis.

6.4.1 ICE sessions

The ICE sessions are being held within the BIG room. If necessary, starting with a presentation, where each participants gets to present their name, company and their role in the project. Thereafter, the facilitator goes through the agenda of the meeting. The activities of the meetings are being presented and a list of the participants called to the meeting are shown. Moreover, the goals of the session are being presented. Further, comments from previous ICE session are gone through in order to establish a mind-set and bring learnings from previously. By visualising the comments from previous meeting, on what was performed well and what can be improved, the group are being reminded on how to approach certain issues. Moreover, the design manager are getting the chance to present the current state of the design process including deliveries and information regarding the whole design team.

After the introducing part of the ICE session has been conducted, the facilitator will do a plan check of the project plan. The project plan is visualised through last planner, where the post-it notes from last sessions until todays are run through, with the aim to check if all planned activities have been completed. The notes are gone through discipline by discipline, where each discipline are asked to answer if the tasks are completed or not. Tasks that have not yet been completed are marked and the responsible discipline are asked to present the reason for the delay. When all post-it notes with activities has been checked, the non-completed tasks are moved forward on the schedule, shown in (Figure 6), given a new deadline for completion. By editing the schedule when concerned parties are present, all parts are given the opportunity to respond to the changes made to the project plan creating an interactive environment with short communication lead times.

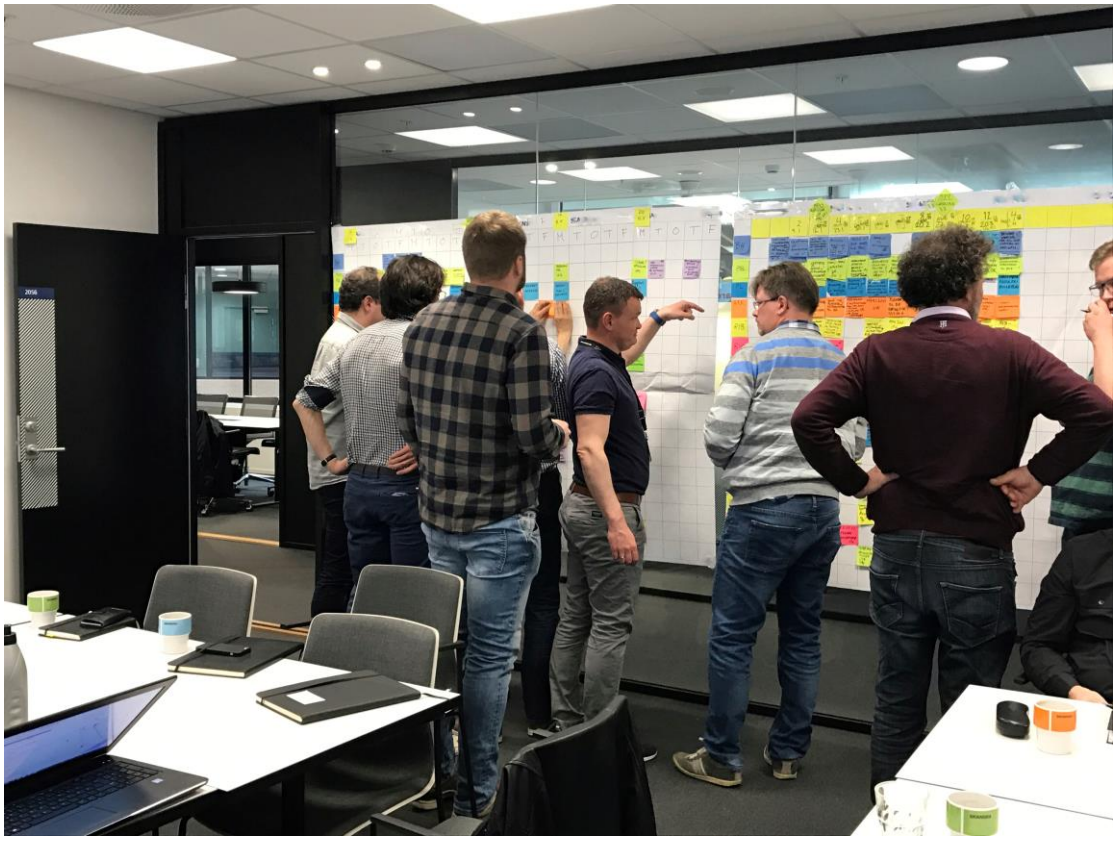

Figure 6: Plan check at the observed ICE session

When all activities have been checked, and the project plan has been updated the facilitator asks the participants to write down questions to other disciplines on post-it notes. The post-its are thereafter placed on the question matrix, under the column of the concerned discipline. The questions are brought up one by one by the facilitator, and the actor responsible for the question is asked to present it further. Thereafter, there will be a brief discussion concerning the question, before a decision of how to proceed are taken. If there is a need to discuss the question further, a new note on a post-it will be written with a comment to call for a work meeting with the aim to solve the issue. The post-it will then be placed on the project plan. The use of the question matrix makes it possible to bring up questions to one specific or several concerned disciplines, and in the same time keep all the other disciplines informed about the question or issue.

The next activity on the agenda of the ICE sessions is to perform one or more work meetings, visualised in Figure 7. On the observed ICE session, the group was divided into two smaller groups, in order to discuss two different issues on an, by the facilitator, set period of time. The discussions was conducted in parallel, on two different large, digital screens. Moreover, both discussions are being held in the same room, which gives the participants the possibility to be active in both discussions. The discussions were led by the initiative taker for the discussion, however all disciplines concerned was participating in order to contribute with their opinion and expertise.

Figure 7: Simultaneously performed work meetings at the observed ICE session

During the observed work meetings, the efficiency within the group could be considered to be high. The participants are through this supposed to stay involved and to use the screens frequently as a support for their discussions and arguments. However, the documentation during the observed work meetings could have been more distinct and fully developed. During the work meetings, the facilitator act as a support function for both the technical aspects of the screens and the more practical aspect concerning the flow of the work meetings. The meetings are summed up by a check of the meeting, monitored by the facilitator. The facilitator asks the group if they have succeed to accomplish the goals of the meetings or if they need to schedule another meeting. Regardless the outcome, all decisions regarding new meetings and delivery deadlines needs to be written on new post-its and be placed on the project plan. When the new activities has been adopted to the project plan, the facilitator closes the work meeting.

The ICE sessions is ended by sum up the session, where the facilitator performs a check-up of the entire session, asking for the opinions of the participants. On the observed session, the check-up is performed digitally throughout a anonymous,

evaluation software where all participating actors are asked to rank their performance and level participation, the rate of preparation of the other participants, commitment within the entire group as well as their own level satisfaction of the session. Furthermore, the group are asked to state what went well with the session as well as what can be improved to the next.

6.4.2 Communication

At the observed ICE meeting, the communication is considered to be frequent. The meeting is monitored by the facilitator, who keeps the meeting structured and effective. When necessary, the facilitator can interrupt discussions that are not considered to relate to the topic or when the disposed time is passed.

During the plan check, the facilitator continuously asks the design team why certain tasks has not been completed. By doing so, the rest of the project team are being informed by the reason for the delay. Moreover, this will give the rest of the team a fair chance to react to the delay. When the project plan is to be edited, with regard to the delayed tasks, all disciplines affected by the delay is gathering in front of the last planer board. On the observed meeting, several disciplines was gathering in front of the visual project plan in order to frequently discuss the changes to the schedule.

The work meetings performed during the observed ICE meeting was conducted in smaller groups. The topic of the meetings was presented by the actor responsible for bringing up the topic for discussion. Participating on those meetings was only the actors concerned by the decisions taken during the specific meeting. This resulted in a high frequency of participation and commitment during the meeting. All group members was frequently being involved in the discussions. Furthermore, since the two work meetings was being performed in parallel, in the same room, some of the actors within the design team were able to participate in both of the meetings. During the work meetings the BIM models were frequently used for communication exceeding disciplines.

According to Design Manager B, the collocation of the project team has resulted in improved communication as well as a shortage of latency. However, Design Manager B states that collocating the project team might result in some stress for some of the team members. It is not rarely actors become stressed when they are allocated tasks with the same deadline as they already have other deliveries. Therefore, Design Manager B further state that an environment and organisational culture supporting communication, even between meetings, is crucial. Especially when the project team are under pressure. Further, Design Manager B states that ensuring such an environment falls under the tasks of the design manager.

7 Cross case-theory analysis

The cross case-theory analysis provides an overview of the possibilities to apply the VDC concept into current organisation as well as identifying benefits and characteristics of applying VDC to real-life hospital projects.

7.1 Organisation and roles

The implementation of VDC has effects on both how the actual design is carried out as well as the roles within the project organisation, where existing roles are changing as well as new roles emerging (Gustafsson et al., 2015). The changes of roles can clearly be visualised in the structure of the different design processes. The VDC concept results not only in a different structural and organisational aspect compared to traditional design processes, but does also highlight a collocation of the design participants. The concept of collocating the design team is a result of the usage of the ICE concept, where collocation of the design team is considered to be beneficial for the communication and the latency within the team (Mark, 2004). At Case B, the project team is collocated five days a week, which according to the Design Manager B, has shortened the latency within the project.

The emerging roles of the VDC facilitator (Chachere, 2009, Bosch-Sijtsema, 2013) and the BIM-coordinator (Akintoye et al., 2012, Bosch-Sijtsema, 2013) is such emerging roles which is exemplified and are to be seen in various extent in the case projects. The VDC-coordinator on the other hand, called facilitator in Case B project is an emerging role due to the use of ICE and the concept of VDC (Bosch-Sijtsema, 2013).

The role of the facilitator is a clear difference in the aspects of divide of responsibilities during meetings between the two projects. Apart from being the responsible representatives from the contractor, leading the design face, the design managers in Case A had the role of facilitating the meeting. This management process is aligned with the internal steering documents at the Case Company, where the design manager is stated to be responsible for defining and developing the design process. However, the steering documents are leaving out details of how to monitor the design process, leaving this choice to the individual design managers. In contrast, the design manager at Case B are not supposed to act as a facilitator during the ICE meetings. Instead, because of the ICE process the facilitator role emerges. The facilitator is, according to Mark (2002), responsible for monitoring the ICE sessions, including keeping the process structured ensuring that the design team are moving towards the next project phase. At the studied ICE session, the role of the facilitator was limited to controlling the agenda and timeframe of the meeting. Moreover, Mark (2002) argues that the facilitator role includes monitoring all networking within the design process. This could clearly be seen at the observed ICE session, where the facilitator was controlling the discussions by distributing the tasks in order to reach a conclusion or end to the question.

According Mark (2002) and Chachere (2009), the facilitator is only responsible for monitoring the ICE sessions. This is differing from the more traditional approach in Case A where, apart from trying to facilitate the meeting, the design managers also had

the tasks of being the representatives of the contractor. In contrast, the design managers at Case B were only responsible for representing the contractor. As the Design Manager at Case B were initially intended to content only a role of being the contractor representative for the design manager, leaving the facilitative role to the facilitators. However, due to the fallback to a traditional design approach in Case B, the Design Manager A picked up the facilitative role during the meetings.

According to Design Manager B, one factor responsible for the recess of the design process, was that there were five facilitating roles within the project. Further, Design Manager B means that this resulted in leaving the design team with an inconsistency regarding the way of conducting the sessions. Akintoye et al. (2012) stated that the construction industry has a tradition of being generally slow and resistant to change. This in itself brings problems related to the inconsistency of having multiple facilitative roles where this may lead to a defensive approach towards a new way of approaching traditional processes.

Within the Case Company, the organisational structure is not varying depending on the method chosen for the design process. The design managers are considered to have a large impact on the design process and the decisions taken. From observations made of a traditional design process, it can be concluded that the participating actors did not stay active during the whole meeting. Some actors did not contribute at all during the meeting. Within an ICE session, the design team participants do have a greater role to play in interacting during meetings. This is confirmed by Mark (2002), but also observed during the attended ICE session. According to Design Manager A, the design managers at Case A strives to create a more integrating environment during the meeting, by implementing methods for activating the participating actors.

According to Kunz and Fischer (2012) the process of ICE promotes a flat organisational structure compared to traditional hierarchical organisation structures. Further, as Akintoye et al. (2012) states that in order for a successful implementation of change the actors have to be fully integrated which is easier achieved in a flat organisation structure as well as to achieve a free flow of knowledge and information exchange. This is shown in the structure of the observed ICE sessions, enabling all design participants to be able to set the agenda of the meetings. Moreover, the increased involvement of the participating actors, compared to a traditional project at the Case Company, will support this. Even though the structure differs between the two case projects, the target values are the similar. Thus, the way of implementing the target values are differing. In accordance with working in a flatter organisational structure and in achieving a free flow of knowledge and information exchange the importance of social processes is highlighted by Akintoye et al. (2012) as well as strengthened by Xu et al. (2014). Therefore, a change in the approaches of design will be easier to implement when aiming for a more integrated design approach, which the design team at Case B now are striving to achieve. Further, based on the importance of social processes Case A, the organisaiton also aims for a collaborative and integrated environment for its design participants, would be an easy recipient for innovation and change.

7.2 Tools and facilities

One of the key concepts of VDC is the VDC room, which therefore is recommended to be provided to the design team (Kunz and Fischer, 2012, Garcia et al., 2004, Mark,

2002). At Case B, the client has provided the project organisation with a large site office, including a large VDC room, in this case called the BIG room. This room will remain available throughout the whole project process, and act as a hub for the VDC process at the Case B project. Dedicating a room for the design of a project is further supported by the internal documents at the case company, where it is advocated to fully devote a room for meetings throughout the whole design process.

According to Chachere (2009) the VDC-room should be designed in a way that makes it possible to run both large group meetings and several smaller discussions in parallel. At Case B, this has been solved with a foldable wall that makes it possible to divide the large room into two separate parts. However, this solution inhibits the so-called "cocktail party phenomenon" described by Mark (2002). This phenomenon arises when several sidebar conversations simultaneously are being held, and when members of the team can overhear, notify or even join those discussions. By separating the large meeting room from the working area, this phenomenon are being blocked. However, the foldable wall makes it possible for actors to stay focused at their own tasks, instead of being disturbed by an ongoing meeting.

Both Case A and Case B are using large screens in order to visualise the design process. According to Atkintoye et al. (2012), visualisations are improving the communication within project teams. This has been observed at both case projects, where visual boards have been used to visualise drawings and models in order to support discussions during the meetings. During the observed design meeting at Case B, the projector screen where used for visualising both the question board and the drawings discussed. Furthermore, the whiteboard were used for check-in and for explaining issues during discussions However, in VDC projects such as Case B, visualisations are often used to a higher extent compared to traditional design processes. According to Garcia et al. (2004), the VDC room should be provided with multiple interactive screens to support the VDC process. At Case B, the client has taken the initiative to provide the VDC-room with several large, visual screens. In contrast to Case A where the design team is only using a projector screen and a simple white board, the design team in Case B are using the projector screens in combination with smart boards and a large, interactive huddle board. However, according to the Design Manager B, it is important to use the appropriate technology for the project. This is further stated by Andersson et al. (2016) stating that within VDC processes there is a need for the appropriate hardware and software to support the everyday workflow of a project. At Case B, the client have invested in a large, interactive huddle board, which according to both Initial Facilitator B and Design Manager B is considered to be too complex for the project.

At Case B, a paper-based method called last planner, which is used in combination to the large, interactive screens. The last planner is used to visualise deadlines and scheduled meetings and deliveries within the design process of the project. Last planner is, due to the simplicity of the product, according Initial Facilitator B, the easiest way to visualise the project plan. At the observed ICE session, the design team where all gathering in front of the last planner board, in order to together discuss and edit the project plan. In contrast, the project team in Case A are using their virtual platform for scheduling meetings, deadlines and deliveries. Further, the project plan is developed within a digital planning tool.

According to Andersson et al. (2016) and Garcia et al. (2004) it is crucial for the project success to have a shared project platform for documentation sharing within the project. Both cases observed are using digital platforms for documentation and information sharing. However, the design team within Case A are using their project platform to a greater extent. In contrast to the internal steering documents where a decision log is promoted for protocoling during the design process, the design managers at Case A has decided to do all documentation directly in the digital platform. The documentation is written directly during the meetings, as the discussions are ongoing. This, will according to Design Manager A, save time since they do not need to rewrite their notes after the design sessions. Instead, all disciplines participating on the meeting can follow the documentation in real-time and give feedback if something needs to be adjusted. Moreover, the documentation is easy to find for all actors, even if they were not participating at the meeting. Furthermore, the documentation platform is used for discussions and documentation of decisions. In Case B, the project platform is mainly used for storage of documentation. Moreover, the project organisation in Case B is using a virtual desktop infrastructure for storage of the BIM models.

Within VDC projects, a frequent use of visualisation models and BIM are described to be one of the success factors for a project (Andersson et al., 2016, Li et al., 2009). At the Case Company, BIM is a requirement for larger projects. For those projects, the BIM model is not only used for clash detection, but is also proven to be a beneficial tool when different actors and disciplines are communicating with each other. Azhar (2011) further confirms this, by stating that BIM requires the actors to increase their level of collaboration. Using product visualisations within the design of a project will according to Eastman et al. (2011) improve the communication within the design team. The Digital Developer at the Case Company further supports this, by stating that communication between actors representing different disciplines will be improved when using visualisations. An improvement of communication and an increased understanding between the stakeholders was also confirmed during the observations made of both Case A and Case B, where the product visualisations were frequently used during the meetings. The models were used to support discussions and arguments as well as for avoiding costly conflicts and collisions in the design process of the project. According to Azhar (2011) and Xu et al. (2014), the BIM models are a useful tool for improving the performance of the professionals within the AEC industry.

The CIFE-version of VDC are strongly promoting the usage of visualisations and metrics based on the basic factors within VDC; product, organisation and process (Kunz and Fischer, 2012). However, both the interviewed Digital Developer at the Case Company and Initial Facilitator B are expressing a scepticism towards the POP models. The POP model is argued to be a theoretical concept that is difficult to apply to a real-life construction project and often disassociated to the actual practice (Garcia et al. 2004). From the observations of both cases, it can be concluded that visualisations are used within all of the three factors. Even if the product visualisations are most frequently used. However, the last planner board, used at the observed ICE session, is also considered a visual tool for the project process. At the observed ICE session, the goals and visions of the meetings as well as possible improvements discussed.

7.3 Design phase meetings

Originally, the design meetings at the two case projects are widely different. Due to the fall-back within Case B, the project organisation has performed the design process in accordance with a traditional approach. However, VDC projects are, in contrast to traditional design processes, supposed to perform the design meetings within an integrating environment. Therefore, the ICE sessions are one of the more central parts of the VDC concept. Mark (2002) and Chachere (2009) describes the ICE meetings within VDC projects to be highly intense and demanding for the participating actors, which further can be confirmed by the observations made of the ICE session. From the observations, it can be concluded that the design team are participating more actively in the ICE process compared to within a traditional design meeting. Therefore, the meetings are not recommended to be too long, where Chachere (2009) recommends the ICE sessions to be no longer that three hours. This is also followed at the observed ICE session, where the meeting is scheduled after this recommendation.

Traditional design processes at the Case Company consists of both traditional design meetings and work meetings that are performed separately. In contrast, the ICE session observed is merging those two meeting forms under one meeting. Instead, the meeting is possible to divide into two parts, where the large group meeting was separated from the work meeting. Where the first part, including information and specifying the aims of the meeting as well as the collective plan check, were performed in large group. According to Chachere (2009) this proses resembles the process of a traditional design meeting. The second part of the observed ICE session consisted of two in parallel performed work meetings, performed in smaller groups where only parties concerned by the topic participated.

According to Chachere (2009), design sessions within VDC can be performed throughout a combination of both large, full group meetings and smaller sidebar meetings. Often those type of meetings are performed in parallel (Chachere, 2009). At the observed ICE session, sidebar conversations occurred when the facilitator directed the team to edit the last planner board. During this process, the participants of the design team gathered in smaller groups in front of the board to discuss effects of changes to the activities in the project plan. Glimpses of this phenomenon was also observed during a design meeting at Case A, where several discussions were being held at the same time during the meeting. According to Mark (2002), it is beneficial to perform several discussions in parallel, since this makes it possible for team members to overhear, or participate to more than one discussion. At the observed ICE session, this phenomenon not only occurred during the editing of the last planner, but also during the work meetings. During those work meetings, some of the team members were participating in both discussions, which was possible only since they were performed in the same room.

At Case A, the project team are not yet working in accordance with VDC and ICE, but according to Design Manager A, they strive to perform the design meetings in a more ICE and VDC like way. According to Design Manager A, the design managers at Case A are trying to make the design meetings shorter by avoiding time-consuming discussions during the actual meetings. Instead, decision making regarding activities or processes is redirected, and asked to be performed after the design meeting in smaller

groups where only concerned parties will participate. From observations of a design meeting at Case A, it can be concluded that the design meeting is rather focusing on allocating tasks to the group members instead of having long discussions in order to find a solution the team can agree upon.

Compared to a traditional project organisation, ICE is advocating a flatter project organisation. Even if a facilitator monitors the meetings, the facilitator does not make any technical decisions (Mark, 2002). Instead, the facilitator is responsible for ensuring that the design process is moving forward and in accordance with the schedule (Garcia et al., 2004). This process can further be identified at the observed ICE session, where the facilitator monitored every step within the session, without being involved in any project specific discussions. With the base in that, the facilitator does not have to make any technical decisions, Chachere (2009) states that the facilitator is not required to have any technical skills in order to monitor the design process in a successful way. Even if the project in Case A is not performed in accordance with VDC, the case proves that the role responsible for monitoring the meeting does not have to have any technical competence in order to run the process successfully. This can be stated, since none of the design managers at Case A are having any technical background in construction. Still, the design managers succeeds to monitor the design process by assigning all technical discussions and problem solving to the team members, with specific technical expertise.

According to Mark (2002), the ICE process includes networking from both an electronical and a social perspective. At the observed ICE session, however, only the aspects of social networking were shown. The ICE processes are to a great extent relying on face-to-face interactions and collocation of the team members (Mark, 2002, Chachere, 2009), which further can be acknowledge by the observed ICE session. Therefore, a VDC room is promoted to be utilised for the ICE sessions. By collocating the project team, the lead-time for communication and discussions will be shorter. The Design Manager B, who states that the collocation results in a faster process, also confirms the shortage of lead-time. At the Case A, the design managers have tried to collocate the design team at the site office once a week, by asking all team members to have a cleared schedule after the design meeting. However, even if the ambition is to get all participants to stay, this is not the case. In contrast to Case A, the requirement of collocation within Case B derives from the client. Moreover, the requirement of collocation of the project team, five days a week, is stated in the project contract. This is considered the reason for the success of the collocation at Case B. However, Design Manager B states that collocation does not suit everyone. Both the Digital Developer at the Case Company as well as Mark (2002) further confirms this.

At Case A, the design managers have decided to involve the other team members to a higher extent that they traditionally do within the Case Company. Traditionally, at the Case Company, the design managers exclusively presents and coordinate the agenda of the meeting. At Case A, the design managers have decided to let actors within the design team present their own questions and discussion topics. Design Manager A argues that, by letting all actors present their own question, the participants of the meeting will be more alert. This was also confirmed at observations from a design meeting at Case A. The interviewed Digital Developer as well as a BIM-coordinator, both representatives from the Case Company, states that one of the problems of a

traditional design meeting is the commitment and energy of the participants. Keeping the actors more active during the meeting, may therefore be a solution to this issue.

7.4 Implementation

According to Akintoye et al. (2012), the fragmentation of the industry is currently working as a knowledge and learning barrier. As traditional approaches to the industry holds, a distributed approach location wise the collocated approach presented in Case B as well Case A, to some extent, will contribute to solve these problems. Akintoye et al. (2012) further claims that in order for a management change to be effective the actors have to be fully integrated and with a free flow of knowledge and information exchange. These are two factors, which are partly covered by a collocated design team and complete information sharing through a design process by enabling a shared platform even though the extent of use of such platform defines the flow of information rather than its existence as such.

Kunz and Fischer (2012) claims that the strategic implementation of VDC into a project organisation is possible to divide in to three steps. If applying this theory to the fall-back in Case B, it is possible to state that they have not fully succeeded with the first step of the implementation, the visualisation. According to Kunz and Fischer (2012), the first step includes establishing a way of working with the models as well as develop and define the organisation working with the design as well as how requirements will be achieved. At Case B, the project organisation has been defined and they are working with the BIM model. However, it can be discussed whether they have defined how to reach the goals and requirements within the project. From start, it was stated that the design team were to work in accordance with VDC. However, during the fall-back the design team deviated from the VDC process. According to Design Manager B, the different descriptions of the roles have not been clear enough, which also are stated to have affected the implementation.

8 Discussion

Based on the theoretical framework, empirical findings and outcome of the comparison as well as the cross-case theory analysis the outcomes will be further evaluated in relation to each other put into the context of the research questions.

How does the organisation and roles change if the studied organisation implement the concept of VDC?

There are multiple aspects to take into consideration considering the effects of an implementation of the VDC concept. For instance, an implementation of the VDC concept will have an impact on the project organisation as well as the different roles within it. Moreover, an introduction of the VDC concept will result in the introduction of new roles to the project organisation.

As a result of an introduction of the ICE sessions, the organisational structure within the design team are recommended to be flat (Kunz and Fischer, 2012, Chachere, 2009). By achieving a flat organisational structure, all members of the project team will be able to communicate on another level compared to a hierarchal organisation. Since the communication is one of the essentials within the VDC concept, a flat organisation structure is hence to be recommended. At the observed ICE session, the organisation structure is considered flatter than a traditional approach. Different team members were leading discussions and presenting their own questions. However, the facilitator is having the mandate to solidly monitor and control the structure of the ICE session. On the other hand, the facilitator are not empowered to participate or contribute to any project decisions (Chachere, 2009, Mark, 2002, Garcia et al., 2004).

According to Kunz and Fischer (2012), Garcia et al. (2004) and Chachere (2009), the role of the facilitator possesses a vital part of the VDC concept. Therefore, the facilitating role can be argued to be required for an implementation of VDC. This can further be confirmed through the interviews conducted and the observation of the ICE session. Through both interviews and literature (Chachere, 2009, Mark, 2002, Garcia et al., 2004) there exists an expressed need for the facilitator to be objective. Moreover, the facilitator is stated to put effort into administrating the sessions in order to free time for the design managers to participate actively in the discussions. However, the level of organisational changes as a result of the new role of the facilitator, are depending on the existing organisational structure as well as decisions of how to introduce a new role to the organisation.

The facilitator role is according to the Digital Developer at the Case Company as well as both Initial Facilitator B and design manger B, an individual role that is separated from all project specific decisions. This is further confirmed by Mark (2002), Chachere (2009), Garcia et al. (2004) and Kunz, and Fischer (2012). At the observed ICE session, it can further be stated that the facilitator is having a separated role, from the rest of the project team. According to Initial Facilitator B, the facilitator is monitoring ICE sessions at several projects, instead of only running the session in one specific project at the same time. The decision of having one or more facilitators working in the company organisation, are recommended to be based on the number of projects using VDC. However, the number of facilitators are not recommended to be more than one

until the project organisation are experiencing an extended need for the role. With the fall-back in Case B in mind, keeping the number of facilitators' down will result in a consistency of the sessions, which is considered preferable.

Another question that needs to be addressed is whom to assign the facilitating role. One option is to combine the facilitating role with another, already existing role within the Case Company. One suggestion is to allocate the facilitator role to a BIM-coordinator. The advantage of giving the BIM-coordinator the role of a facilitator is that the coordinator already possess a technological knowledge. Moreover, the BIM-coordinators are often monitoring the BIM collision controls, and are therefore partly familiar with facilitating. However, according to the interviewed BIM-coordinator at the Case Company, the role is already having a lot of work on their table. The facilitator can also be allocated to a design manager at the Case Company. However, the design manager should be able to reject project specific decisions and focus on coordinating the meetings and the design team. Another option is assigning the role to someone that works singularly as a facilitator. However, having one person working entirely as a facilitator may not be a full time job in the introduction phase of the VDC implementation.

What organisational changes and roles that is needed in order to apply the concept of VDC it is, to a great extent, depending on where this role of the facilitator ends up as it can be distributed in a number of different ways. In the ICE session studied as well as in Case B, the facilitator role is incorporated as a separate function, which if applied into the current and studied organisation would need to be put as a change or add on into the current organisation.

The effect of introducing a role of a facilitator, whether a new job function is adapted or if the responsibility is allocated on an already existing character, it will affect the tasks of the design managers. At the Case Company, the design managers are currently responsible for the progress and meeting design in the studied organisation. When applying the facilitator role to the project organisation, the design manager will be given the opportunity to fully focus on the design process. At the observed ICE session, the design manager were able to participate and contribute to discussions without having to focus on monitoring a meeting. As it is mentioned by Initial Facilitator B, the role of the design manager gets more focused on representing the contractor in the project. According to the Digital Developer at the Case Company, a large amount of time is traditionally put on documentation, both under and after the meeting. Brief notes are being taken during the meeting, rewritten into full context sentences after the meeting and then being sent out to the rest of the design team. According to the Digital Developer, this process can take hours. By introducing the VDC concept, or a digital platform as seen at Case A, the design manager could be released from this task.

Which possible benefits and drawbacks could an implementation of the concept of VDC lead to?

Based on the conducted interviews, the observed cases as well as the analysed theory, VDC can be considered to have a positive effect on the construction sector. Tjell and Bosch (2015) states that collaboration is crucial for the success of a construction project. According to the interviewed Digital Developer at the Case Company and Initial Facilitator B, the tools and methodologies used within the VDC helps to improve the collaboration within the project team. Furthermore, Eastman et al. (2011) states that the collaboration within a design team is depending on the sharing of knowledge and information within the team. Knowledge and information sharing is relying on interactive communication, which are stated to be one of the benefits of VDC (Chachere, 2009). The combination of ICE and collocation of the project team can therefore be seen as one of the success factors for improved communication and collaboration within the design team.

According to Li et al. (2009) and Erikson and Westerberg (2010), the construction sector has been criticised for cost and time overruns as well as not delivering the quality required. Li et al. (2009) further states that VDC could be a solution for those problems. Mark (2002) goes as far as stating that performing an ICE session within a proper VDC room, the productivity of the design team can be doubled. This is also confirmed by the Digital Developer at the Case Company, that further argues that VDC therefore will be beneficial for construction projects. The improved efficiency of the project, can also be confirmed by the observed ICE session. However, even at Case A, an improvement of efficiency compared to traditional design processes can be seen. Moreover, there is no documentation of achieving any doubled efficiency just by implementing ICE sessions onto the design phase. It should be stated that the cases have only been studied for a limited amount of time, which is resulting in a limitation of reaching conclusions what the full effects of an implementation of VDC.

Theory stating that product visualisations improves the commitment within the project team as well as increases the profitability of the project, is something that is also stated within the internal documents of the Case Company. Furthermore, the quality of the product is stated to be improved. Therefore, a visual design process is promoted at the Case Company. According to Akintoye et al. (2012), the human brain is considered to process visual information faster than texts. From the observations made, no data can prove that visualisations improves the processing of information. However, within both observed cases, the involvement within the design team have increased when visual tools have been used. At the observed ICE session, the visual project plan created intense discussions where all team members participated. The same observations are made within both projects, occurring when the project team used the visual models for discussions.

By combining product visualisations, such as BIM, with the concept of ICE sessions, Eastman et al. (2011) states that the number of construction rework will decrease. This is further supported by the Digital Developer, saying that by implementing the VDC concept, the project organisation can assure the buildability of the project by discovering construction errors and clashes already in the design phase. However, as the current use of BIM models have become more common to use within the

construction sector, it may be difficult to motivate the benefits of BIM models as a result of the implementation and use of VDC. It is stated by both Kunz and Fischer (2012) as well as by interviewees that the visualisation aspect of VDC including the modelling is a less influential aspect of the concept because of the development of the industry. Based on that most construction firms are already using BIM, it can be debated that it is not in the aspect of modelling where the greatest benefits is to be found in the VDC concept. Thus, the differences in the aspect of multidimensional models between the VDC concept and a more traditional approach lays in how the models are used in the process as well as in how they are developed. Therefore, it can be discussed if the actual benefits of VDC is a result of the ICE sessions, rather than the use of BIM.

Looking at Case A, an implementation of VDC may lead to some improvement of the design process. The ICE sessions are considered to make the design sessions more effective, even if the Case A project, today have a relatively high commitment and involvement of the design team. Moreover, following the same meeting structure as the observed ICE session is considered to shorten the time for the full group meetings, making it possible for actors not concerned by the topic discussed during the work meetings, to leave after the information and plan check. Which is considered to make the actors more willing to stay on work meetings that requires their performances. Additionally, a collocation of the design team are considered to have high effects on the design process, even if the collocation will be only one day a week. Even though the design managers at Case A, have managed to shorten the latency due to the digital platform used, the collocation of the design team is considered to shorten the latency even more. However, the digital platform is considered effective, and is appreciated to be able to combine with the rest of the VDC tools. The design managers at Case A, are today working in a way not completely different from the facilitator role. One option could therefore be to assign one of the design managers the facilitator role, while the other one is focusing exclusively on representing the contractor.

What is required for a successful implementation of VDC?

By interviewing Design Manager B and Initial Facilitator B, as well as the Digital Developer at the Case Company, it can be argued that the process of implementing a new concept to a project organisation have an effect on the success of the concept. For concepts where the implementation have not been conducted properly, the risks of a fall-back to traditional working methods are high. According to Design Manager B, the implementation phase was one of the reasons for the fall-back to a traditional design process.

However, the success factors for a well turned out implementation can be discussed. According to both Initial Facilitator B and the Digital Developer at the Case Company, one factor that contributes to a successful implementation of the project is to visualise the benefits that derives from the new concept. However, convincing a project organisation of those benefits may be a difficult task. The Digital Developer at the Case Company state that it is not rarely that a project organisation is resistant to change. This is further confirmed by Design Manager B, stating that it is difficult to convince actors to leave concepts that they are well familiar with, behind. Akintoye et al. (2012), further strengthens this, by arguing that there exists a common resistance to change within the

whole construction sector. The resistance towards change can further be traced back to the organisational culture, both in project and company organisations. According to Xu et al. (2014), one of the main barriers for implementation of new concepts is the attitude within the organisation. According to Design Manager B, the organisational culture is something that they need to work with Case B. Further, Design Manager B highlights that the meetings need to be more focused and the design organisation more committed to the task, which is considered a matter of attitude.

Stating that one of the issues for not succeeding with the implementation of a new concept may be caused by a resistance to change within the project organisation. Further, it can be stated that there is a need to address such an issue in case of occurring. According to the Digital Developer at the Case Company, it is most beneficial to implement new concepts, such as VDC, are small steps. This is further confirmed by Design Manager A, that states that within Case A the design managers started of their design process by introducing new tools and method step by step and managed to commit the whole project organisation to the change. Similarly, Initial Facilitator B state that it is important that the similarities between the new concept and the current working methods are highlighted. By pointing out the similarities, the step of implementing the new concept would not feel too big for the organisation. At the Case Company, their work with BIM in complex projects is already established. Therefore, the part regarding visualisations within the VDC process would not be unfamiliar for the company organisation. Moreover, the concept of visual planning is widely known at the case company, even if different design managers are applying the concept to varying extents. Some design managers at the Case Company, even strive to work in a more concurrent environment. Therefore, the step of moving towards an implementation of the VDC concept is not to be considered too big.

Another factor possible to connect to the recommendation of implementing the VDC concept in small steps is the complexity and size of the project. According to Design Manager B, another reason for the fall-back to the traditional design process was the stress within the project team. The stress can be assumed to issue from the complexity of the project as well as the high goals of reducing costs and time. Moreover, requirements for using technology have been stated by the client. Therefore, one recommendation can be to start by implementing the VDC process to a less complex project. However, large, complex projects may gain the most from an implementation of the VDC approach. Still, introducing the VDC concept and all the tools needed to the project organisation might be most beneficial if the projects are not as complex as Case B.

The Digital Developer at the Case Company indicates that there are several concepts, similar to VDC on the market. Moreover, some companies have applied small parts of the tools and methods used within VDC to their organisation. The Digital Developer continues by stating that VDC will only be beneficial if the whole concept is implemented. However, both the Digital Developer and Initial Facilitator B are sceptical to the POP-model. The POP metrics are considered disassociated to the construction sector in reality (Garcia et al., 2004), and can therefore be suggested to be left out during an implementation of VDC.

In order to successfully implement the VDC concept, it is also necessary that the project team is provided with the appropriate tools. One of the most important tools within VDC is a shared space for collocation of the project organisation (Chachere, 2009). Moreover, Garcia et al. (2004) states that it is proven that actors working together are more effective than actors working individually. A collocation of the design team can therefore be argued to be more effective than a project team working in individual offices. However, the collocation can be performed in different ways. At the observed ICE meeting, the session were performed in a VDC room at the regional office of the Contractor. In contrast, the VDC room at Case B project is located in the project site office provided by the client. Having a fully dedicated room at the project site office is considered preferable, since it more likely will be available during the whole design process. However, providing several VDC rooms with the right technology may me costly, even if the screens does not have to be as high-tech as the ones at Case B. According to Design Manager B and Initial Facilitator B, the technology should be easy to use. Therefore, touchscreens with a simple plug and play technology are being suggested. One option is to start performing the ICE sessions at the regional office of the Case Company and when the VDC concept has been more acknowledged within the company, it would be necessary to move the VDC room to the specific project site offices.

9 Conclusion

By analysing the theory behind VDC and putting it in relation to Case B and observed ICE sessions as well as interviews with persons with experience of VDC, it can be stated than an implementation of the VDC concept will result in organisational changes due to changes and supervening in the matter of roles. However, depending on how the roles are decided to be arranged, the changes to the company organisation may differ. The facilitator will be a new role emerging, which depending on strategic decisions within the company will have varying effect on the organisational structure. If the VDC implementation will be applied on a pilot project, the facilitator role may preferable be merged with another existing role within the project organisation. However, due to the emergence of a facilitative role within the project design organisation there will be a change in the role of the design managers. Through a long-term commitment to the VDC concept, the possibility of assigning the facilitative role to one person will emerge, focusing on singularly on the facilitating tasks.

Based on both the theory and the observed effects of VDC, it can be stated that the VDC concept is having a positive impact on the project and the design team. Through the cases studied, it is possible to conclude that the processes of ICE involve the team members to a higher extent compared to a traditional design process. Moreover, the collocation is stated to result in a better collaboration as well as shorten the latency within the project team. From the observed cases it can be concluded that the visualisations are used as a supportive tool for communication between different disciplines. This includes visualisations of the product, the process and the organisation. Visualisations are therefore considered to increase the understanding between the project team members.

In order to achieve a successful result of the VDC process, the way of implement and introduce the concept to the project organisation will be significant for the outcome of the VDC process. Introducing the new concept by highlighting the similarities to the current operation processes are considered to be beneficial. Moreover, by looking at the current organisation of the Case Company, an implementation of the VDC concept are not considered too unacquainted. At the Case Company, the main difference will be to perform the design meeting in accordance with ICE. As a result of implementing the ICE concept, some new tools will be required. The VDC room is considered to be one of the essentials for the ICE process and is therefore recommended to provide to the project organisation. However, different solutions to the VDC room will result in different benefits. Arranging a VDC room at the regional office, will be less costly since it can be used for several VDC projects. In contrast, a dedicated VDC room at the site office will be easier to use and visual boards with notes can be left intact between the meetings. Regardless, solution chosen for the VDC room, it is important that the room is provided with the right tools. However, the tools should be easy to use. Therefore, touchscreens with a simple plug and play technology are being suggested.

As one of the cornerstones of VDC is highlighted to be the visualisation and BIM models in theory there could be concluded that in the size and complexity of the projects studied, there is no further development of the models in connection to VDC to be seen. Further, interviews and observations strengthens the case of no direct link between the models of how they are conducted but rather a difference in how they are used, strongly

connected to the structure and meeting design. As the indications provided through this thesis implies that the development of the modelling in the industry has achieved a consensus on the use and relevance of the use of models, it is rather a question of how to use these in connection to the development of design. However, it should be stated that the extent of the study towards the general application of BIM models is strictly limited. What is clearly seen in terms of the use of the models though, is that it is in whichever approach a project work in the models are still bridging disciplines as a material for communication.

10 Recommendations for further research

In further research, it is suggested to evaluate how the implementation of the specific concept correlates to learning within the design team. Since this thesis highlights the effects of an implementation and covering the result of the same in a current project, the actual implementation and its processes is to be studied in order to maximise the outcome. This is an aspect, which is closely connected to change management and how a change could be implemented in order to maximise the outcome as well.

Indicated through literature is that the concept of VDC would speed up the processes of design. This is something that through this study have not been possible to conclude, more than the hint of the result based on observations of the case study. In order to conclude a faster process, there is a need to conduct a longer study and to follow a project through its end in order to evaluate it as such. Overall, observations and conclusions made within this thesis is based on a specific phase of the design and the results of the findings is yet to be evaluated.

11 References

The American Institute of Architects, AIA National, AIA California Council. 2007, "Integrated Project Delivery: A Guide"

Akintoye, A., Goulding, J.S. & Zawdie, G. 2012, Construction Innovation and Process Improvement in Wiley-Blackwell, Oxford, UK

Andersson, L., Farrell, K., Moshkovich, O. & Cranbourne, C. 2016, Implementing Virtual Design and Construction using BIM: Current and future practices, Routledge Ltd.

Aranda-Mena, G., Crawford, J., Chevez, A. & Froese, T. 2009, "Building information modelling demystified: does it make business sense to adopt BIM?", International Journal of Managing Projects in Business, vol. 2, no. 3, pp. 419-434.

Azhar, S. 2011, "Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry", Leadership and Management in Engineering, vol. 11, no. 3, pp. 241-252.

Baldwin & Bardoli, ABD 2014, Handbook for Construction Planning and Scheduling, Wiley, Somerset. Available from: ProQuest Ebook Central. [21 February 2017].

BIM Task group (2017) *About BIM Task group* http://www.bimtaskgroup.org/about/ [2017-05-30]

Bosch-Sijtsema, P. (2013), "New ICT changes working routines in construction design projects". Nordic Academy of Management (NFF) Iceland, August 2013.

Bresnen, M. & Marshall, N. 2000, "Partnering in construction: a critical review of issues, problems and dilemmas", Construction Management and Economics, vol. 18, no. 2, pp. 229-237.

Bryman, A. & Bell, E. 2015, Business research methods, 4.th edn, Oxford Univ. Press, Oxford.

Building and Construction Authority. 2013 "Singapore BIM Guide Version 2"

Chachere, J. 2009 Obeservation, Theory and Simulation of Integrated Concurrent Engineering: Grounded Theoretical Factors and Risk Analysis Using Formal Models. Stanford University.

Chan, A.P.C., Chan, A.P.L. & Scott, D. 2004, "Factors Affecting the Success of a Construction Project", Journal of Construction Engineering and Management, vol. 130, no. 1, pp. 153-155.

Cho, Y.K., Cylwik, E. & Russell, D. 2014, "Learning Opportunities and Career Implications of Experience with BIM/VDC", Practice Periodical on Structural Design and Construction, vol. 19, no. 1, pp. 111-121.

CIFE (2017) *About CIFE, Mission* https://cife.stanford.edu/mission [2017-02-15]

Clayton, M.J., Kunz, J.C. and Fischer, M.A. (1996) Rapid Conceptual Design Evaluation Using a Virtual Product Model, Engng Applic. Artif. Intell. Vol. 9, no. 4, pp 439-451.

DiCicco-Bloom, B. & Crabtree, B.F. 2006, "The qualitative research interview", Medical Education, vol. 40, no. 4, pp. 314-321.

Dubois, A. & Gadde, L. 2014, "Systematic combining: One decade later". Journal of Business Research, vol. 67, no. 6, pp. 1277

Eastman, C., Teicholz, P., Sacks, R., Liston, K. (2011) BIM handbook: a guide to building information modeling for owners, managers, designers, engineers and contractors, 2nd; 2;edn, Wiley, Hoboken, NJ.

Eriksson, P.E., Westerberg, M., Luleå tekniska universitet, Innovation och Design & Institutionen för ekonomi, teknik och samhälle 2011, "Effects of cooperative procurement procedures on construction project performance: A conceptual framework", International Journal of Project Management, vol. 29, no. 2, pp. 197-208.

Garcia, A.C. B., Kunz, J, Ekstrom, M, Kiviniemi, A. 2004, "Building a project ontology with extreme collaboration and virtual design and construction", Advanced Engineering Informatics, vol. 18, no. 2, pp 71-83.

Gilligan, B., Kunz, J. 2007, "VDC Use in 207: Significant Value, Dramatic Growth, and Apparent Business Opportunity", CIFE Technical Report #TR171. December 2007. Stanford University.

Gustafsson, M., Gluch, P., HEINKE, K., Gunnemark, S. & Engström, D. 2015, "The role of VDC professionals in the construction industry", .

Kunz, J., and Fischer, M. 2012, Virtual Design and Construction: Themes, Case Studies and Implementation Suggestions. CIFE Working Paper #97. Version 14 Januari 2012. Stanford University.

Kvale, S., Brinkmann, S. & Torhell, S. 2009, Den kvalitativa forskningsintervjun, 2. uppl. edn, Studentlitteratur, Lund.

Lee, A. & Sexton, M.G. 2007, "nD modelling: industry uptake considerations", Construction Innovation, vol. 7, no. 3, pp. 288-302.

Li, H., Lu, W. & Huang, T. 2009, "Rethinking project management and exploring virtual design and construction as a potential solution", Construction Management and Economics, vol. 27, no. 4, pp. 363-371.

Mark, G. 2002, Extreme collaboration, ACM, New York.

Mourgues, C., Fischer, M., & Hudgens, D. (2007). Using 3D and 4D models to improve jobsite communication–virtual huddles case study. In Proceedings of CIB 24th W78 Conference & 14th EG-ICE Workshop & 5th ITC@ EDU Workshop, Maribor (Slovenia) (pp. 91-97).

Oxford University Press. (2013) Concurrent engineering. 1st edn, Oxford University Press.

Panuwatwanich, K., Stewart, R.A. & Mohamed, S. 2009, "Validation of an empirical model for innovation diffusion in Australian design firms", Construction Innovation, vol. 9, no. 4, pp. 449-467.

Rheinlander, M., Arulraj, R., Hobson A., Grahan, C. 2009, "31. An Introduction to Virtual Design and Construction (VDC)" in Society for Mining, Metallurgy, and Exploration (SME), pp. 1-1.

Roupé M., Viklund-Tallgren M., Johansson M., Andersson R, 2014, Virtuell produktionsplanering med BIM och visualisering, Chalmers University of Technology, Göteborg.

Sarshar, M., Christiansson, P. and Winter, J. (2004) "Towards virtual prototyping in the construction industry: the case study of the DIVERCITY project", in Proceedings of the World IT Conference for Design and Construction, Langkawi, Malaysia, 18–24 February, pp. 581–8.

Stonehouse, G.H. & Pemberton, J.D. 1999, "Learning and knowledge management in the intelligent organisation", Participation and Empowerment: An International Journal, vol. 7, no. 5, pp. 131-144.

Syan, C.S., Menon, U., SpringerLink (Online service) & SpringerLink Archive (e-book collection) 1994;2012;, Concurrent Engineering: Concepts, implementation and practice, Springer Netherlands, Dordrecht.

Tang, P., Huber, D., Akinci, B., Lipman, R. & Lytle, A. 2010, "Automatic reconstruction of as-built building information models from laser-scanned point clouds: A review of related techniques", Automation in Construction, vol. 19, no. 7, pp. 829-843.

Tjell, J. & Bosch-Sijtsema, P. 2015, "Visual Management in Mid-sized Construction Design Projects". Procedia Economics and Finance. Vol. 21 (2015), p 193-200. Williams, T. 2002, Modelling complex projects, Wiley, Chichester.

Waly, A.F. and Thabet, W.Y. (2002) A virtual construction environment for preconstruction planning. Automation in Construction, 12(2), 139–54.

Xu, H., Feng, J. & Li, S. 2014, "Users-orientated evaluation of building information model in the Chinese construction industry", Automation in Construction, vol. 39, pp. 32-46.