CHALMERS
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Implementing Virtual Design and Construction

Challenges of moving towards integrated working methods in the construction phase

Master's thesis in the master's program Design and Construction Project Management

NASKA ABBASSI
NIKOLINA SEKULIC

Department of Architecture and Civil Engineering
Division of Construction Management
CHALMERS UNIVERSITY OF TECHNOLOGY
Master's Thesis ACEX30-19-49
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Examensarbete ACEX30-19-49
Institutionen för arkitektur och samhällsbyggnadsteknik
Chalmers tekniska högskola, 2019

Department of Architecture and Civil Engineering
Division of Division Construction Management
Research Group Name
Chalmers University of Technology
SE-412 96 Göteborg
Sweden
Telephone: + 46 (0)31-772 1000

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ABSTRACT

The low productivity growth in construction industry has been the main topic of several studies over the past decades. As a result, the construction companies have started to investigate methods for improvement inspired by Lean, which has improved productivity in other industries. Virtual Design and Construction, VDC, concept has been developed as a response to this movement. In the current state, there is a rising interest amongst construction companies to implement integrated working methods, for instance the VDC concept. However, there is no consistent definition of the VDC concept along with limited research about its implementation within construction phase. The aim of this thesis is to analyse the potential transition towards the VDC concept in a contracting company, with focus on collaboration between project actors, visualisation aspect and meeting structure, within the construction phase. A qualitative research based on interviews and observations of four building projects was conducted. Based on the empirical findings, building projects reminded of independent organisations due to limited knowledge exchange between the projects. Additionally, the findings indicated resistance towards changes among the older generations due to unfamiliarity and inexperience. Moreover, hurdles and lacking compatibility between the existing technological solutions were recognised as some of the main challenges towards integrated working methods. In order to successfully implement the VDC concept, integrated site meetings, digitised and standardised methods, as well as early involvement of key players, should be embraced.

Key words: VDC, Lean, Lean Construction, traditional delivery, ICE meeting, change management

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List of Abbreviations

AEC - Architecture, Engineering and Construction
BIM - Building Information Modelling
CIFE - Center for Integrated Facility Engineering
DB - Design-Build
DBB - Design-Bid-Build
ICE - Integrated Concurrent Engineering
IPD - Integrated Project Delivery
LCI - Lean Construction Institute
LPD - Lean Project Delivery
POP - Product, Organization and Process
PPC - Planned Percent Completed
VDC - Virtual Design and Construction

PREFACE

We would like to start by thanking our academic supervisor Mikael Johansson, research engineer at Chalmers University, for showing great confidence in our ability to carry out the thesis and being supportive throughout the entire process. Mikael supported our work with his constructive and objective feedback.

Next, we would like to thank our supervisor from the company for his engagement and professional input from the company's perspective. He has been very supportive by providing us with internal data. Additionally, a special thanks to our supporting supervisors from the company's unit in Stockholm, for the thesis proposal. Furthermore, we would like to thank all interviewees for their contributions which resulted in an extensive empirical data that helped answer our research questions. Likewise, we are thankful for the inputs from the company's unit in Gothenburg as well as showing interest in our research.

Lastly, we would like to thank our families and friends for showing faith in our capabilities to deliver this thesis and encouraging us throughout the whole project.

Naska Abbassi
Nikolina Sekulic

1 Introduction

In this chapter, the background to the issue enquiry in this thesis will be presented, with the aim of highlighting the reason of chosen research topic, followed by the aim and purpose of the thesis, summarised and formulated as three research questions. Lastly, delimitations of the study will be presented.

1.1 Background

The low productivity growth as an indicator for measuring the performance in the construction industry (Latham 1994; Egan 1998) has been a main topic in many reports and researches worldwide (Bassioni and Hassan, 2004). In comparison to other industries such as manufacturing, the construction industry has had a lower productivity growth rate which has been identified as an improvement area (Khanzode et al., 2006; Bassioni and Hassan, 2004; Egan, 1998). The relations between the different actors, client-contractor and contractor-subcontractors in terms of common targets and values is one of the improvement aspects. Traditionally, the relation is short lived and limited to the project, yet, according to Egan (1998) and Latham (1994), extended collaboration is a key factor for improving productivity in the construction industry.

The most common delivery methods in construction projects are Design-Bid-Build, DBB and Design-Build, DB. A common feature in these two delivery methods is the lack of extended collaboration aspect between the actors who deliver a building project (Eastman et al. 2011; Hardin and McCool, 2015). Another common feature is the risk factor; in both delivery methods only one actor owns possible outcomes from the risks (Hardin and McCool, 2015). In Sweden, there are two standardised contractual forms for building projects with above mentioned delivery methods that have been used over decades with adjustments for each specific project (Deli, 2017). These contractual forms are used to justify how the project will be carried out and how risks will be handled. However, there is no consideration to collaboration aspect in the project in terms of knowledge and information exchange between the actors (Deli, 2017). In order to improve the outcome of building projects and reduce the potential risks due to lack of communication and cost overruns, new working methods have been developed that focus on improving collaboration aspect (Eastman et al., 2011; Hardin and McCool, 2015).

Several authors mean that reason why conventional project management in construction continuously fail, is that activities are managed in a defective way (Li et al., 2009). For instance, tasks are managed through centrally applied scheduling and controlled by output measures. In contrast to lean thinking, management of workflow and value creation aspect is missed out in conventional project management (Koskela et al., 2002; Johnston and Brennan, 1996).

Further, complexity and uncertainties due to change-orders from clients, new technologies and changes on market along with time pressure, perfectly exemplify the dynamics in construction industry. Koskela et al. (2002) mean that in such dynamic context, activities are unlikely connected to each other in a straightforward sequence. Instead, same authors argue that tasks and activities are linked to other activities by shared resources and/or dependent on the work progress of other activities. Thus, the

significance of accounting for *Transformation-Flow-Value* theory as a set is stressed by Koskela et al. (2002).

Lean Project Delivery System (LPDS) emerged as a response to the ineffective traditional project delivery system. Among first modifications in Lean Project Delivery (LPD) compared to the traditional project delivery is that LPD extends the goal spectrum from solely transformation to *transformation, flow and value*, in accordance with the fundament of production theory. Further, LPD shifts in focus from the traditional emphasis on transaction and contracts, towards the whole production system. Involvement of downstream actors in upstream decisions is another feature contrasting LPD from the traditional delivery systems. Unlike to traditional project delivery, where product design is finished before the start of the production process, LPD allows for simultaneous product and process design. Likewise, aligning the interests among stakeholders to ensure that it is in the interest of participants to enhance the customer's value, is yet another distinction from the traditional project delivery where this issue is disregarded (Koskela et al., 2002; Ballard and Howell, 2003).

Khanzode et al. (2006) point out the fact that despite slow amelioration in construction industry compared to other non-farm industries, improvements have been observed among all individual actors over the past years, primarily owing to technological progress and digitalisation. However, overall productivity in construction industry continuously stays low (Li et al., 2009), which might indicate certain internal waste within the construction delivery process (Khanzode et al., 2006). As an endeavour to resolve the low productivity within construction industry, researchers at Center for Integrated Facility Engineering (CIFE) at Stanford University have developed a model-based and integrated approach, called Virtual Design and Construction, VDC (Ibid).

Li et al. (2009) claims the growth of VDC based on the increasing amount of research that different companies are conducting in the field. According to previous research (Khanzode et al., 2006; Li et al., 2009), VDC is argued to has positive impact on efficiency and productivity in construction projects, alongside improved construction safety and refined design phase processes. However, VDC requires updated information and knowledge sharing both during and between different project phases (Gustafsson et al., 2015). The VDC concept includes numerous tools for improving efficiency and productivity, such as the renowned Last Planner, integrated 3D models, from-to matrix and decision list. These tools can be used as a bundled toolkit or applied separately. Nonetheless, when the tools are being used separately, it might be difficult for the company to see the relation between the project activities and the possibility to extract the full advantage out of the tools (Khanzode et al., 2006). When applying the concept of VDC, these connections become more clear meaning that the final outcome can be further improved (Ibid; Kunz and Fisher 2009).

The development of the technology offers an easier adaptation process of the VDC concept. The meeting techniques within the concept have the common goal of integrating the different phases and actors' work under the same roof. Integrated Concurrent Engineering, ICE, is a prime example of such technique (Kunz and Fisher, 2009). This master thesis is based on a suggestion from a large Swedish construction company that works with diverse civil engineering projects. The company is interested in developing and improving its competence in terms of delivering projects in a more efficient way by improving the collaboration aspect, with special focus on the

construction phase. Currently, the studied company works with digitised and integrated tools, however, the company is interested in further development of these tools for improved outcomes. The discussed tools are frequently applied in the design phase and the company is interested in extended use of these tools in the construction phase. Furthermore, the company has expressed interest in enhanced integration of the different project phases.

The concept Virtual Design and Construction, VDC, is a good example for including both integrated and digitised methods in different phases of a construction project. As stated earlier, the VDC concept includes several tools and methods which can be implemented together as well as separately in order to improve efficiency in terms of collaboration (Kunz and Fisher, 2009). An area of development for the studied company is the meeting structure, including principles and tools used in meetings in the construction phase where multidisciplinary and collocated teams work cooperatively in a traditional manner, in contrast to the design phase where the company has adapted more digitised working methods and tools.

1.2 Aim and Purpose

The thesis aims to evaluate the current working methods applied in the construction phase and to analyse the potential transition towards the VDC concept for the studied company. Special focus is put on the collaboration aspect, both between the actors and different phases of a project, integrated working methods and meeting structure. The expected outcome of the thesis is to be able to answer the following questions:

1. *How does the company currently work in the construction phase?*
2. *What are the differences and similarities between the current concept used by the company and VDC concept in the construction phase?*
3. *What are the barriers and challenges towards more integrated and digitised working methods?*

1.3 Delimitations

This master thesis will only focus on the construction phase of different ongoing housing and commercial projects delivered by the studied company. In order to provide a fair comparison between the different projects the study scope will be limited to Design-Build projects where the company is involved as early as the design phase. Due to high number of involved different actors and disciplines, only projects with an upcoming final inspection will be studied. In this thesis, there will be no consideration to the specific programs and applications within the VDC concept nor technical specifications, such as detail level in the integrated 3D models.

2 Theoretical framework

In this chapter of thesis, the theoretical framework of the study will be presented based on literature research that the authors have conducted. The aim of this chapter is to provide different theories, definitions, concepts and models within the area of research.

The chapter will begin with concepts of traditional working methods in construction industry and their main aspects. Afterwards, the theory of lean construction, which is the supporting theory of the thesis, will be described. Followed by the main focus of this study, the concept of Virtual Design and Construction and its characteristics as well as the definition of concept used within this thesis will be presented. In the last section of this chapter, the challenges and barriers of implementing change is presented with dint of change management theory.

2.1 Traditional working methods

The delivery method chosen by a construction project client determines the responsibility areas and contractually boundaries between the different actors involved in a project (Hardin and McCool, 2015). According to Jackson (2010), until fifteenth century, the responsibility for a project was given to a master builder who had expertise in design and construction. As a result of the Industrial Revolution, this single role was separated into two different functions, design and construction with professionals in one specific area (Jackson, 2010).

The most common traditional delivery method chosen by construction project clients is Design-Bid-Build, DBB, where the client has two separate contracts. The conceptual design which includes detailed plans, drawings and specifications is prepared by the design team during the design phase (Hardin and McCool, 2015; Smith et al., 2010). The results from the design phase make the basis for the bidding phase, where the general contractor with the lowest bid often is awarded and responsible for building the project (Hardin and McCool, 2015; Eastman et al., 2011). Another common delivery method is Design-Build, DB, where the client has one single contract with a contractor who is responsible for both the design and construction (Hardin and McCool, 2015). According to Hardin and McCool (2015), the owner is responsible for preparing requirements about function and performance of the building, a budget and a deadline for completion which is the basis for contractor in the bidding phase. This delivery method is similar to the master builder concept mentioned above.

The fragmentation of different phases is common in traditional delivery methods. As stated above, in DBB projects the design phase is completed before the start of construction phase due to the nature of this delivery method. Nevertheless, in traditional DB projects these two phases often overlap with each other where the construction phase begins after necessary details and plans have been developed during the design phase (Hardin and McCool, 2015; Jackson, 2010). According to Hardin and McCool (2015) and Shrestha and Fernane (2017), this overlapping aspect reduces changes in the project schedule in DB projects compared to DBB projects which results in faster project delivery. In both delivery methods, there are important aspects which can determine the outcome of a project; these aspects are collaboration, visualisation and meetings and are explained below.

2.1.1 Collaboration

According to Hardin and McCool (2015) and Smith et al. (2010), in a DBB project, the design phase is completed without inputs and opinions from a general contractor who has expertise and knowledge that can be useful for the overall outcome. Due to lack of communication between the design team and contractor, delays and additional costs during the construction phase may occur as a result of errors and incomplete information of design. In projects with traditional working methods, the actors will only focus and put effort to areas in accordance with the agreements in the contract which often results in a traditional design process shown in Figure 2.1.

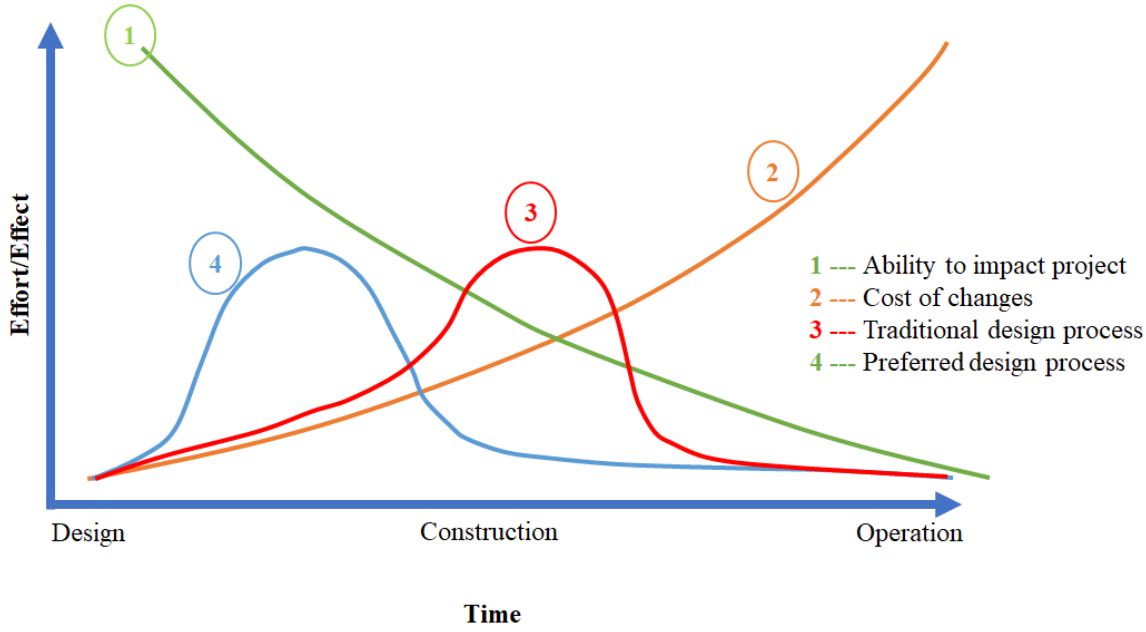

Figure 2.1 Macleamy Effort Curve.

The figure 2.1 shows the increasing costs due to a design change and how it can be avoided by earlier involvement of different actors which can result in the preferred design process. Since, in traditional methods the construction phase often is carried out without any members from design team and vice versa, any redesign on site can be costly and time consuming (Hardin and McCool, 2015; Smith et al., 2010). According to Hardin and McCool (2015), in a DB project redesign issues can be reduced to zero due to the early collaboration between design team and contractor. However, the contractor may take a leading role during design phase rather than a supporting role due to the risk factor. Moreover, the collaboration aspect in the DB projects can only be successful through mutual trust between the actors (Ibid).

According to Kadefors (2004), in the Swedish construction industry DB projects are becoming more common than DBB projects. However, the industry is still conservative as regards to roles and working environment. The contractual agreements used in the Swedish construction industry limit the transparency aspect in a project which can have a negative impact on the trust between the actors. As result, the clients are more apprehensive towards bids and suggestions from contractors due to potential hidden costs. Furthermore, the contractors are apprehensive towards project specifications and details provided by the design team and client due to their limited knowledge in construction phase (Ibid; Kadefors, 2001).

2.1.2 Visualisation

The visualisation aspect includes areas such as design, planning and scheduling of the project. As late as 1980s, computerised programs and software such as CAD became a standard tool for the design of construction projects (Czmoch and Pękala, 2014; Jackson, 2010). As the technology of computerised programs developed, 2D drawings were further advanced to simple 3D objects and later to 3D models. According to Eastman et al. (2011), design errors and miscommunication as well as response latency between actors could be reduced through communication with integrated 3D models and common database services compared to 2D drawings and paper documents. Moreover, an integrated 3D model of the project could reduce the amount of effort put to apply changes in the design, material quantity take-offs and clash detection compared to 2D drawings and other 3D models which only include architectural details or engineering details (Ibid; Cory, 2001).

As a result of these benefits the process of Building Information Modelling (BIM) was developed, integrated 3D models with detailed information about each object, a collaborative working platform for the actors involved in the design phase as well as for actors involved in the other phases of the project (Eastman, 2011). The benefits of using BIM as a collaborative working platform could result in the preferred design process shown in the figure 2.1. However, this requires early involvement of the contractor and as already stated only in the DB projects the contractor is responsible and involved in the early stages (Hardin and McCool, 2015; Eastman, 2011).

According to Baldwin and Bordoli (2014), the development in the technology have likewise changed the tools used for planning and scheduling in the construction industry. In late 20th century, computerised software and programs were adopted for different planning and scheduling techniques. Until the beginning of 20th century, bar chart technique, which only shows the start and end date of each activity, was used in construction projects. The critical path planning technique is a further development of this technique with consideration to key activities in the project and relations between all activities. A further development of these two push techniques is Last Planner, which is a pull technique with focus on the end date of each activity rather than start date; Last Planner is further presented in Section 2.2.2. The success of these techniques is dependent on updating the schedule in accordance to changes and delays that occur in a project and communicating the modified schedule to all the actors in the project (Jackson, 2010). Moreover, in order to reduce delays and additional costs due to labour or material shortage, the modified schedule must be communicated timely to subcontractors who often have multiple ongoing projects. In the construction phase, modifications to the schedule can be co-created between contractor and subcontractor through on-site meetings (Ibid), which is another important aspect for the outcome of the project.

2.1.3 Meetings

According to Carlsson et al. (2001), communication between actors in a project is necessary in order to integrate and plan the activities as well as completing the project on time and within the budget frame. The communication methods used in construction projects such as meetings, telephone calls, 2D drawings, emails and other digital tools enable information exchange between the actors (Ibid; Dainty et al., 2006). Results from a research study, which was based on two DBB and two DB projects in the

Swedish construction industry, show that formal meetings followed by telephone calls were the most common communication methods in those projects (Carlsson et al., 2001).

As stated earlier, the development in technology has also impacted the communication methods used in the construction industry by enabling various digital communication tools. However, there is still a necessity for face-to-face interaction in order to discuss and resolve issues by information and knowledge exchange between the actors (Gorse and Emmitt, 2009; Dainty et al., 2006). The reason behind formal meetings as the most common communication method in the traditional delivery projects, is the predetermined roles and responsibility areas of each actor in the project. However, formal meetings can be an obstacle for more integrated working environment and the trust development between the actors (Dainty et al., 2006).

Due to the limited research and previous studies about the meeting aspect in the construction industry (Gorse and Emmitt, 2009), it is difficult to exemplify a traditional meeting and its characteristics. However, there is a common opinion about the importance of progress meetings that occur in design and construction phases (Oke et al., 2016; Gorse and Emmitt 2003; Gorse and Emmitt, 2009), those meetings are scheduled differently depending on the contractual form, size and complexity of the project (Oke et al., 2016). The participants and topics of a meeting are determined through the meeting agenda and invitation which also determines expected contribution of each participant (Gorse and Emmitt, 2009). Decisions, discussion topics and information details can be documented in meeting minutes. According to Mincks and Johnston (2011), minutes from meetings can be useful for the overall project outcome in terms of documented evidence of statements from different actors.

2.2 Lean construction and its concepts

Lean Production evolved over years starting in 1950s (Mastroianni and Abdelhamid, 2003), however the main breakthrough came in early 90s along the Toyota's publication of the book *The machine that changed the world* (Womack et al., 1990). Manufacturing industries quickly adopted to the new thinking of Lean Production as a systematic method for increased value creation by eliminating wastes from the manufacturing process (Wang et al., 2016). Eventually, the construction industry tried to apply Lean Production within construction. In 1993, the concept Lean Construction was formulated by International Group for Lean Construction at the group's foundation and first meeting. Importantly, 'construction' here refers to the entire industry, not only construction phase of a building project (Ibid).

As Lean Construction most frequently is described as a theory-based approach to construction, it is important to understand the main theoretical principles of production which are the fundamental inspiration to Lean Construction. Lean Production is explained by three complementary views, namely transformation, flow and value. The conventional view of production, the transformation view, simplifies the production to a conversive process of transforming inputs to outputs (Koskela and Howell, 2002). The flow view of production was developed as early as in 1920s, however, it was turned into a success in Japanese industry in 1940s and later (Koskela et al., 2002). Flow view represents the ideal uninterrupted flow of work between personnel, or the flow of value as a reaction to the customer's pull (Wang et al., 2016). Thus, elimination of wastes and

optimising the flow processes is the main goal of the flow view. Third view on production is based on perceived value from the customer's perspective. Hence, this view emphasises quality and value creation for the customer (Koskela et al., 2002; Wang et al., 2016).

Wang et al. (2016) explain that despite the same spirit, Lean Construction differentiates from Lean Production in how it views flows. While Lean Production discloses the flow of products and has fixed resources for production, Lean Construction has fixed products, that is buildings, with varying flow of personnel. Since the Lean Construction is derived from Lean Production, Howell (1999) states that it revolves around two main characteristics, namely planning and control. Similar to Lean Production, Lean Construction aims for maximised project results, concurrent design of both end product and process, and full control over the product and process stretching from design to delivery. Howell (1999) further states that Lean Construction is about creating reliable workflow which also is a prerequisite for building trust, and trust can, for instance, be attained through partnering agreements. Reliable workflows are created by repeatedly determining and evaluating how the work is planned and operated (Ibid).

Consequently, one of the main objectives in Lean Construction becomes the matter of bringing the flow of work under control. However, controlling the workflow and production requires a change in the project delivery system, in order to allow a more reliable workflow. Such change involves modification of the work structure in early stages of the design, as well as adjustments in the organisation and overall planning of the process (Howell, 1999). Furthermore, Liker (2005) concludes that involving the employees is crucial in order to reduce time waste and improve quality of work (Liker, 2005). Koskela (1992) described the eleven principles of Lean Production as following:

1. Reduce the share of non-value-adding activities.
2. Increase output value through systematic consideration of customer requirements.
3. Reduce variability.
4. Reduce cycle times.
5. Simplify by minimising the number of steps, parts and linkages.
6. Increase output flexibility.
7. Increase process transparency.
8. Focus control on the complete process.
9. Build continuous improvement into the process.
10. Balance flow improvement with conversion improvement.
11. Benchmark.
(Koskela, 1992, p. 16)

Tzortzopoulos and Formoso (1999) especially emphasised the use of tools for representative models, as an interpretation of the seventh principle, which enhanced and supported communication between involved actors. Finally, Koskela (1992) underlined that these basic principles of Lean Production also indicate different issues of flow process related to transparency, complexity and segmented control.

2.2.1 Delivery systems within Lean Construction

According to Koskela et al. (2002) and Ballard and Howell (2003), Lean Project Delivery System (LPDS) emerged as a response to the ineffective traditional project

delivery system. Among first modifications in Lean Project Delivery (LPD) compared to the traditional project delivery is that LPD extends the goal spectrum from solely transformation to *transformation, flow and value*, in accordance with the fundament of production theory (Koskela et al., 2002). Further, LPD shifts in focus from the traditional emphasis on transaction and contracts, towards the whole production system. Involvement of downstream actors in upstream decisions is another feature contrasting LPD from the traditional delivery systems. Unlike to traditional project delivery, where product design is finished before the start of the process design, LPD allows for simultaneous product and process design (Ibid). Likewise, aligning the interests among stakeholders to ensure that it is in the interest of participants to enhance the customer's value, is yet another distinction from the traditional project delivery where this issue is disregarded (Koskela et al., 2002; Ballard and Howell, 2003).

Integrated Project Delivery (IPD) is an approach within relational contracting, that aims to align the project goals with all key stakeholders in a project. In other words, IPD is a way of establishing an organisation in which Lean Project Delivery System can be practiced (Matthews and Howell, 2005).

2.2.2 Tools in Lean Construction

Mastroianni and Abdelhamid (2003) determine that *"Lean is not a tool, but rather a set of tools and methods"* (p. 11). Accordingly, several tools and methods from Lean Construction are presented in this section.

According to Mastroianni and Abdelhamid (2003), Last Planner System (LPS) a renowned lean method was developed by Lean Construction Institute (LCI) in early 90's, as a way to tackle the issue related to the waste resulting from stakeholders' broken promises to one another and similar misunderstandings. LPS firstly calls for establishment of an overall plan and corresponding milestones. Second step is to develop a rolling schedule of six weeks, that is connected to the project milestones. Third step known as *constraint removal* is simply ensuring that engineering work is finished and that needed resources are available. Next step is developing a weekly plan where the activities are unconstrained. Thereafter, measurement of work effectiveness can be done in terms of plotting the Planned Percent Completed (PPC). Lastly, LPS pushes for identifying reasons behind eventual plan failure, considering each activity not the project as a whole (Mastroianni and Abdelhamid, 2003).

Kanban, meaning 'visual documentation' in Japanese (Murino et al., 2010), is a tool developed for signalling the work that needs to be completed and in which preference, securing the optimised workflow in the lean manner (Mastroianni and Abdelhamid, 2003; Klipp, 2011). In addition to this, Hammarberg and Sunden (2014) extend the definition of this lean tool to a means of involving all project members in the continuous improvement of the working process (Hammarberg and Sunden, 2014). Kanban boards consist of visualised columns of the work process, with the specific tasks or components represented in these columns on small cards (Klipp, 2011). Today, both digital and physical Kanban boards are used (Murino et al., 2010). Klipp (2011) stresses that the advantage of applying Kanban does not necessarily require reconstructing current working processes. Instead Kanban can be incorporated in the existing working processes and they can be improved over time as it becomes clear which elements of the current processes involve waste (Klipp, 2011).

Furthermore, Mastroianni and Abdelhamid (2003) forward 3D drawings and models as visual methods that improve efficiency by enhanced project visualisation and reduced approval time and material ordering. Visual Management, a management strategy with roots from Toyota Production Systems, focuses on increasing transparency with support in visual tools and methods that enhance self-management of the workforce through improved information availability and information flow (Tezel, 2011). Additionally, Tezel (2011) suggests that *"transparent work settings can improve the image of the construction industry"* (Tezel, 2011,p I). Among Visual Management tools, from-to matrix, which can be digital or analogue, is a tool in which questions from and to project members can be raised. Tjell and Bosch-Sijtsema (2015a) argue that this tool increases transparency not only of different actor's workload but also their work routines (Tjell and Bosch-Sijtsema, 2015a). An example of a typical from-to matrix is shown in Figure 2.2. In accordance to Tezel (2011), Tjell and Bosch-Sijtsema (2015a) settled that self-management of work teams is supported by Visual Management. However, Tjell and Bosch-Sijtsema (2015a) also found in their study that Visual Management is dependent on collocation and active participation of the teams. While Parry and Turner (2006) argue that the issue rarely is insufficient information, rather it is the ineffectiveness resulting from the insufficient ways of communicating the existing information. Parry and Turner (2006) further argue that implementation of visual management tools can complement performance measurement in organisations.

From-To	Client	Contractor	Architect	Constructor	Ventilation	Electricity	Fire consultant
Client							
Contractor							
Architect							
Constructor							
Ventilation							
Electricity							
Fire consultant							

Figure 2.2 An illustration of a from-to matrix board for a building project.

Among other methods used in Lean Construction, there are short gathering of the group early in the shift to discuss the work planned for that day as well as the aspect of safety is accounted. The main aim with such daily meetings is to connect and engage team members (Mastroianni and Abdelhamid, 2003).

2.3 Virtual Design and Construction

As stated earlier, Lean Construction have been used in building processes in order to improve the overall project outcome by reducing waste (Wang et al., 2016). However, this methodology, based on the articles and previous studies that have been found, lacks details and suggestions for different digitalisation aspects of these processes. As a solution to this weakness, Virtual Design and Construction has been adapted by the industry in various projects. It should also be noted that VDC has its origin in Lean Construction, thus the intention is still reducing waste in building projects (Kunz and Fisher, 2009). According to Kunz and Fisher (2009), the fragmentation of processes and different phases in construction projects with traditional working methods has adverse impact in terms of long delivery times and low productivity due to long response and decision latency. Consequently, the necessity for alternative working methods such as VDC concept, with focus on improved collaboration and communication methods within and between different phases in a building project has increased (Kunz and Fisher, 2009).

Virtual Design and Construction, VDC, was introduced by Kunz and Fisher at Stanford University in 2001, as a working concept for integrated product delivery in projects through collaboration between multiple actors. There is no universal definition nor agreement of components of this concept (Li et al., 2009). However, in the methodology developed by Kunz and Fisher, the aim of VDC is to reduce latency by focusing on effective information exchange and to improve collaboration between the actors though integrated models and joint project platforms (Kunz and Fisher, 2009). In the VDC concept, the integrated models correspond to an "object-oriented" project model called Product-Organization-Process model, POP model (Ibid; Khanzode et al., 2006). In a POP-model, the product aspect represents a physical element of the project which will be designed and built by teams defined in the organisation aspect with related work activities and completion dates determined in the process aspect (Kunz and Fisher, 2009).

According to Kunz and Fischer (2009), there are three phases of implementation of the VDC, where the first phase is visualisation based on the elements in the POP-model. The success of this phase is dependent on the actors' competencies and resources. The second phase of the implementation is integration, which includes computerised methods and tools for data and information sharing between the actors. This phase can be successful with the condition that the actors have defined standards for data and information exchange. Moreover, these phases also require an integrated and collaborative work environment between the actors, which requires clarification and description in the contractual form used in the project. The last phase is automation, which focuses on fabrication and standardised processes that might reduce construction time and increase productivity (Kunz and Fisher, 2009).

According to Gustafsson et al. (2015), a successful implementation of VDC concept also requires professionals with the knowledge and expertise about the methods and tools used within the concept, since the concept consists of new working methods and tools for information and knowledge sharing between the actors in AEC projects. These VDC professionals could be introduced as new roles in the AEC industry, however, the existing roles in the industry could be further developed and trained into roles who have the required knowledge and skills (Russell et al., 2013; Gustafsson et al., 2015). In current state of the AEC industry, the VDC professionals are involved in design phase,

however, there is a need and requirement for earlier involvement as well as continuity of these professionals throughout the project (Ibid). According to Bosch-Sijtsema (2013), these professionals could be divided into two roles: a "*facilitator*" who is responsible for information and knowledge sharing between actors during meetings by using tools and methods in VDC concept. The second role is a "*coordinator*" who is responsible for integrating visualisation models from different actors and who acts as a supporting role to design manager. However, in addition to the lack of commonly agreed definition of the VDC concept, there is no agreed nor commonly used skills and responsibility areas for describing VDC professionals which is an obstacle for a successful implementation of the concept (Gustafsson et al., 2015).

In this master thesis, the VDC framework developed by Kunz and Fischer (2009) at Center for Integrated Facility Engineering (CIFE), is used due to numerous detailed and evaluated research and case studies of the framework. Moreover, due to the wide application of this framework in practice.

2.3.1 Core stones of VDC

As stated earlier, there are multiple definitions among companies and academics on what exactly VDC is and its characteristics. However, there are three common aspects of the VDC concept which are agreed upon and recurrent in several sources that define VDC. The core stones of VDC, based on multiple articles and reports used in this thesis, are collaboration, visualisation and ICE meetings. These aspects are linked to one another and need to be adopted in order to fulfil the concept chain. In this section, these core stones will be defined and examined in detail.

Collaboration

Construction projects are often delivered by multidisciplinary teams who have different expertise and competences as well as work culture (Kunz and Fisher, 2009). As stated earlier, a successful implementation of the VDC concept requires integrated and collaborative work environment between the actors. The obstacles for reaching full potential of this integrated work concept are the traditional delivery methods and the contractual forms in the construction industry. The conservative view on the roles and their responsibilities in the project as well as actors' focus on their own profitability could be changed through partnering agreements (Ibid; Kadefors, 2004).

In partnering agreements, actors agree upon problem solving methods and have common objectives (Kadefors, 2004) which facilitates the implementation of VDC concept (Kunz and Fisher, 2009). As a result of common objectives, actors focus on the overall profitability of the project and develop trust-based relations with each other which increases knowledge and information exchange (Kadefors, 2004). Furthermore, the VDC concept could be successful by a downstream involvement of key players such as skilled workers and foreman who have knowledge and expertise related to constructability of a project which could be useful during the design phase (Khanzode et al., 2006). This integrated concept focuses on the three elements of the POP-model, the process aspect is dependent on the knowledge and expertise of the organisation that will deliver the product. By early involvement of key players who have the process knowledge in the design phase (Ibid), the preferred design process shown in Figure 2.1 could be achieved where the ability to impact the project is higher. Moreover, costly

modifications to the design and delays in schedule during the construction could be avoided. However, these results could only be achieved with commitment and willingness from all actors in the project. In comparison to traditional working methods, the VDC concept enhances the transparency (Kadefors, 2004) in a project which could improve the trust between the actors and increase their willingness to share their knowledge and expertise (Khanzode et al., 2006; Kunz and Fisher, 2009).

In order to achieve increased cooperation between project teams, there is a need for digital project platforms for information and knowledge sharing between actors within and between different phases of a project (Khanzode et al., 2006), the visualisation aspect of VDC is further explained in the following section. Furthermore, there is a need for collocated teams during ICE meetings where the visualisation tools can be used in order to deliver an integrated project (Ibid); ICE meeting and its characteristics are explained further in this subchapter.

Visualisation

According to the Stanford University coined definition of VDC, *Visualisation and Metrics* are one of the three phases that Kunz and Fisher (2009) distinguish. Metrics account for set objectives that are used to describe, compare and control the performance and efficiency of the processes (CIFE, 2019). However, this thesis will solely focus on the visualisation part, excluding the metrics as it falls outside of the field of research of the thesis.

For successful visualisation, all stakeholders need to have the ability of interpreting visual models. Such technical competence might for some stakeholders imply the need for strategic investment. However, the biggest obstacle to overcome in enabling successful visualisation among multiple stakeholders is the matter of openly sharing data between each other. As previously mentioned, Kunz and Fisher (2009) mean that ideally collaboration contracts between multiple stakeholders should incentivise data sharing, which in turn might require strategic change in partnering contracts (Kunz and Fisher, 2009). In general, however, visualisation phase is easily legitimised and enforced in projects (Ibid).

Li et al. (2009) problematised design error detection as a drawback of traditional project management, that on the other hand is well embedded in the VDC concept. Simulations in 3D virtual environments enable efficient detection of possible clashes and errors which can be prevented before the costs for correction drift away (Li et al., 2009). Interactive and integrated 3D models, that only are a part of the visualisation aspect, are argued to bring clarity and better understanding to the stakeholders compared to traditional static 2D drawings (Kunz and Fisher, 2009). Similarly, "*4D product-construction process animations"* are promoted over traditional project schedules in form of Gantt-charts. What differentiates the 4D product-construction process models is that interconnections between different parameters will display even when only highlighting and observing one of them. Having the dependencies between different elements visible can therefore reduce the time needed to discuss the issues that affect several stakeholders and/or disciplines. With this advantage even faster decision-making processes will follow (Ibid).

More specifically, product visualisations can be made with different 3D-modelling software with numerous different objectives. To mention some, it is to help stakeholders visualise the finished product, coordinate the work among different disciplines involved in the construction phase, to perform constructability analysis, to evaluate site logistic plans, to extract quantities of material and components and simplify the estimates (Khanzode et al., 2006). Knotten and Svalestuen, (2014) propose Building Information Modelling (BIM) to be a potent method during early stages of a project, whilst examining several different alternatives. However, Kunz and Fisher (2009) highlight that BIM does not regard the visualisation of the organisation and processes as effectively. Therefore, product and process models, also known as 4D models, which are 3D models of the product amplified with fourth dimension which provides the timeline and deeper understanding of the construction process, were developed (Kunz and Fisher, 2009). Furthermore, there are modelling tools for organisation and process that support simulations of organisational effort needed to finish the project as well as they enable handling potential risks of delay inherent in the project organisation. Collaboration among geographically spread teams is approached with different online collaboration tools that provide team members a shared project model in which they can work together (Ibid). Lastly, Kunz and Fisher (2009) stress the importance of using consistent naming and level of detail in the integrated models, as well as the importance of centralising the content into one place that is easily accessed by all stakeholders (Fisher and Kunz, 2009).

CIFE developed another complement to the above described visualisation tools called iRoom. Integrated Room, or iRoom, aims to provide structure for integrating data between different stakeholders which in turn enables faster and improved collaboration between the stakeholders (Khanzode et al., 2006). Interactive Rooms, equipped with several computers and displays, are argued to facilitate problem solving between different disciplines involved in a project, as they can explain and understand each other's models in a faster way than traditionally (Fisher and Kunz, 2009). In CIFE, this specially designed and equipped room is also used for ICE meetings which is explained in next section. Meeting participants are expected to increase productivity in the meetings by shifting from more descriptive tasks towards more value adding tasks using the VDC tools for sharing information (Khanzode et al., 2006).

The visualisation aspect that VDC promotes, is focused on establishing symbolic models and representations of the product, organisation and process. Such visual representation is known as a Product-Organisation-Process (POP) model, and is supposed to support early planning, negotiating, exploration of alternatives and decision-making regarding the project scope, schedule and organisation, with help of virtual methods (Khanzode et al., 2006). The goal of VDC is thus to make use of these virtual models as a mean to shed light on potential complexities and downsides that project teams might encounter. In that way, project teams have a possibility to analyse potential scenarios in virtual space and prevent problems from occurring in the actual construction process (Ibid).

In conclusion, both simple and advanced visualisations serve as an effective method for stakeholders to communicate more efficiently with one another, explain and understand the interrelations of different issues, and have an opportunity to analyse the integrated work (Fish and Kunz, 2009).

ICE meetings

Integrated Concurrent Engineering (ICE) is a work methodology developed by NASA in 1996 which focuses on high integration and parallelisation of tasks in order to reduce the project time and improve quality (Chachere, 2009). ICE meetings, also known as Big Room meetings, consist of collocated teams in predetermined facilities with tools and equipment for visualisation and collaboration (Ibid).

The success of ICE meetings is dependent on tools and methods used as well as participants who should have knowledge and expertise of these tools and methods. Moreover, a successful ICE meeting also requires short lead times regarding necessary information for completing an activity (Chachere, 2009). ICE meetings require a flat organisation rather than hierarchical, where an elected individual from the team is responsible for ensuring that the agenda is followed and that decisions made in the meeting are available for the team members in a common database. Moreover, this individual should organise "sidebar" conversations between team members in order to solve problems related to their areas of responsibility (Ibid). In order to achieve efficient meetings where decisions are made on scheduled time with reliable information by collocated teams, there is a need for facilities with tools that enable visualisation and collaboration between participants (Ibid; Dave et al., 2015).

A predetermined meeting facility must be equipped with proper software and hardware as well as have a layout that enables efficient use of the tools and improves collaboration and communication between actors. For instance, decision list is a method that is regarded both as an instrument that helps visualise decisions and serves as a meeting protocol (Tjell and Bosch-Sijtsema, 2015b). According to previous case studies based on Europe Space Agency (Curran et al., 2015) and Team X from NASA (Chachere, 2009), these meeting rooms should have a multimedia wall that displays important documents and models, furnished in U-shape were the participants can easily see the display wall. These facilities should also enable space for "sidebar" conversations during the ICE meetings (Chachere, 2009).

According to Kunz and Fisher (2009), ICE meetings reduce the response, information and decision latency between actors in projects as a result of improved communication methods and integrated work environment of collocated teams with essential skills and knowledge. ICE meetings could be seen as a platform to combine collaboration and visualisation aspects of VDC, in other words, a successful VDC implementation also requires new meeting methods and structure such as ICE meetings and predetermined facilities for those meetings (Ibid). On the organisational level, ICE meetings are criticised to generate high stress levels, and working under strict time constraints may result in poor decisions. Furthermore Chachere et al. (2004) and Chachere (2009) illuminated the groupthink and ventured decisions as potential drawbacks of working in ICE meeting setting.

2.3.2 Definition of VDC in this thesis

In this thesis, authors choose to combine existing and presented theories of VDC and Lean Construction to create an own model. The model will be used as the main framework when analysing empirical data and answering the research questions.

In accordance with previously provided definition of VDC by CIFE, VDC is viewed as a concept consisting of techniques and approaches that can be categorised into three groups. These groups are suggested to be people, process and technology (Koskela and Dave, 2008; Pee and Kankanhalli, 2009), in this given order. This threefold view is chosen in order to provide a broader sociotechnical understanding (Viklund Tallgren, 2017) behind the VDC concept, and to underscore that the technology evolves in the organisational environment which is associated with human and social aspects (Coakes, 2002). Thus, the concept of VDC should be approached and developed in the same suggested sequence. As a wide conceptual framework, VDC cannot be applied as a predetermined tool to all projects. Nevertheless, VDC can be adopted to enhance efficiency by focusing on improved collaboration and integrated working between multiple disciplines and stakeholders in all construction projects (Khanzode et al., 2006; Li et al., 2009, Kunz and Fisher, 2009). Based on the literature research, three parameters of VDC are identified as particularly interesting for answering the research questions in this thesis. The three parameters are collaboration, integrated meetings and visualisation, reciprocal to categories of people, work process and technology as shown in Figure 2.3.

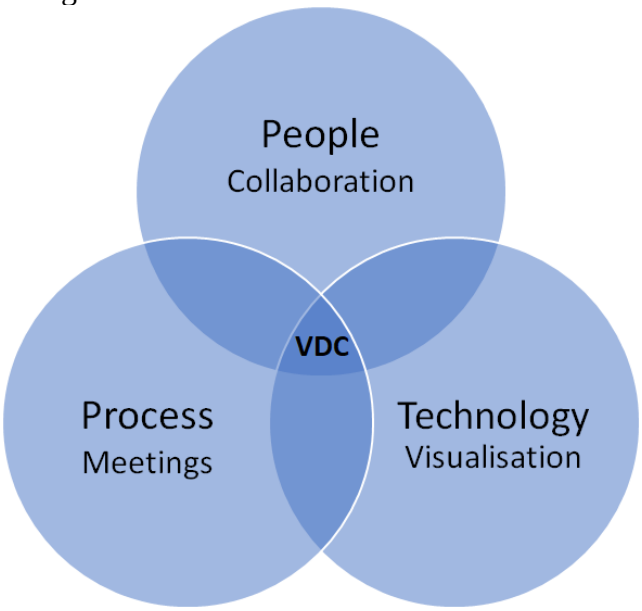

Figure 2.3 The theoretical framework of VDC in the thesis.

Collaboration, being dependent on people and individuals' traits, is especially challenging to manage. Prodan et al. (2015) explain people parameter in terms of their motivation and willingness to improve. According to Prodan et al. (2015), process parameter emphasises modes of modifying processes towards improved work delivery (Prodan et al., 2015). Integrated meetings, ICE-meetings more precisely, make a great example of structuring a process of integrated working aimed to increase effectiveness of multidisciplinary teamwork. Lastly, visualisation including visual representations of the product, process and organisation, along with other visual tools and methods, can be categorised as technology, a collection of mechanical tools and methods that create the foundation on which the collaboration can be built when applying VDC. Technology, in other terms, consist of tools and methods which support people and processes to deliver improved results (Prodan et al., 2015). Especially, authors of this thesis would like to highlight the latitude of the visualisation aspect used in this thesis; technology category and visualisation is not limited to 3D and 4D models, rather it

includes all visual representations used in planning, information sharing and knowledge exchange.

2.4 Barriers to implementing VDC

In this section of the theoretical framework, challenges and barriers of implementing new working methods like VDC will be presented. Firstly, a brief description of change management which is the main theory for this section will be described. Followed by challenges and resistance among employees towards change. Lastly, the attitude and challenges in terms of change and new workings methods in construction industry will be described.

2.4.1 Change management

Change management is defined as the act of managing implementation of changes in business processes, organisational structure and specific business tasks, with the aim to optimally excess the benefits that the change implies. Notable is that change can be approached on different levels, where the most common distinction is individual, team and organisational level (Murthy, 2007). Regarding organisational change management, people are identified as a crucial factor. Thus, change handled on the individual level is of outer importance for a successful organisational change (Ibid). Change itself, however, can be categorised in either structure, technology or people. Technology is the most self-evident of the three categories and includes changes related to work processes, methods and tools, while structure enfolds structural complexity, formalisation and centralisation as well as job redesign. Finally, change in the category of people regards attitudes, expectations, behaviour, and interpersonal work relationships (Murthy, 2007).

Experiential learning, one of the renowned theories on learning, explains the learning as a process in which an individual obtains knowledge through experience and with that new knowledge adapts its behaviour (Kolb et al., 2001; Murthy, 2007). Literature stresses the emphasis on information sharing and achieving shared vision as one of the main differences between individual learning and organisational learning, meaning that organisational learning cannot be compared to the learning of single individuals in the organisation (Murthy, 2007). Furthermore, Murthy (2007) highlights that change cannot be achieved until all the decision makers learn collectively and commit to creating premise for change to occur.

2.4.2 Challenges and resistance

As it is within managers' objectives to improve the organisation's productivity, it becomes natural to expect managers to be willing and motivated to implement change. However, resistance in people and subordinates comes as naturally, as the change for them at first only implies dislodging status quo (Murthy, 2007).

Kotter and Schlesinger (1979) describe and exemplify some common reasons behind resistance to organisational change, whereas low tolerance for change is one of them. They argue that some people will ultimately resist change due to personal fear of not being able to develop the new skills or behaviour that the change requires. While all people are limited in their ability, such limitation varies among the individuals (Kotter

and Schlesinger, 1979). On the other hand, organisational change might push people to change too fast or too much, which undoubtedly is inhibited by previously described resistance due to low tolerance to change (Ibid). Likewise, Kotter and Schlesinger (1979) discuss the resistance due to different assessment of the change. Simply put, resistors might be perceiving the situation differently than those initiating the change, meaning that the former do not share the vision of the change resulting in benefits, instead they might even perceive it as bringing negative results (Kotter and Schlesinger, 1979).

Addressing the resistance, there are several techniques for managing and coping with resistance to change (Murthy, 2007). First method is about offering clear communication and information towards employees about the change and its benefits, and the logic behind it. Second technique is to involve individuals to participate, arguing that participation reduces the resistance. Another technique is offering supportive efforts to those who resist the change. Such supportive and facilitating actions for meeting the resistance can range from providing new skills training sessions, counselling and therapy, or even offering short paid absence to employees if that is necessary for adjustment to change. Negotiation can also be used as a mean to manage resistance to change, by offering something valuable in exchange for reduced resistance. Manipulation and co-optation can also be applied for handling the resistance. Lastly, coercion makes another technique where change agents can use their formal power or direct threats to make the resistors accept the change (Kotter and Schlesinger, 1979). Additional approaches for reducing resistance to change are formulated as building trust and encouraging participation (Murthy, 2007).

2.4.3 Challenges in construction industry

Koskela et al. (2002) argue that the challenge of implementing Lean Construction is not in changing procedures and internal systems, the challenge is instead in changing people's minds. Liker (2004) states that implementing only several lean tools could bring some improvements, however, it could not result in the full benefits of implementing the whole system of lean production. As previous studies from Kadefors (2004) imply, the conservative mindset in the construction industry limits the possibility to implement new working methods and tools that require radical organisation and process changes. In other words, the full potential of new working methodologies has not been seen in the construction industry which could be linked to the low productivity growth.

Howell (1999) explained how Lean Construction Institute (LCI) as a theory seeking institution, tries to approach problems related to the production in construction, starting with the management of "physics" of production. First off, an understanding for the current state of knowledge and practice needs to be collected with the respect to underlying theories and models behind these practices. Howell (1999) underlines that people cannot improve something they do not understand. Thus, to facilitate the introduction of new methods and tools, a common knowledge about the same should first be established (Ibid).

Several researchers have raised the issue of knowledge exchange in multi-generational teams (Bennett et al., 2012; Pitt-Catsouphes and Matz-Costa, 2008). However, most of the research focuses on knowledge transfer from experienced workforce to the newer

generations. Important to note is that multi-generational workforce creates obstacles even for the knowledge transfer that goes the other way, that is from younger to older generations. Although implementing a change affects individuals differently, apart from the generation factor, there is also research showing that some generations do accept the change more easily, or for instance have grown up with certain technologies, thus making some technological change easier to process (Ibid). Millar and Lockett (2014) argue that older individuals may be selective users of new technologies, however, not incapable of using the technology. Furthermore, it is argued that the multi-generational factor should be emphasised in a higher extent as it represents a major hinder in keeping up with technological development and innovation opportunities. Ageing workforce and new client base constitute a social change that organisations need to deal with (Millar and Lockett, 2014).

Li et al. (2009) identified several challenges for broader use of VDC concept. First, Li et al. (2009) point out the technical difficulties due to lacking compatibility between different software which is currently used. Paradoxically, the technology that is supposed to improve interoperability represents one of the main hurdles for communicating efficiently over multidisciplinary borders. Furthermore, matter of cost and investments to overcome the first mentioned hurdle for widespread application of VDC are also pinpointed (Ibid). Lastly, Li et al. (2009) identify the implication of change as a challenging factor, which is the second key aspect of the thesis.

3 Method

The chapter aims to describe and present the research strategy. Firstly, a description of the chosen research approach and design which impacts the outcome of the study will be presented. Followed by a presentation of the chosen data collection method, observations and interviews methods, and a critical evaluation of the chosen method. Lastly the ethical aspects of the study will be presented.

3.1 Research approach and design

In order to answer the research questions of this thesis, mixed approach, combining exploratory and descriptive research (Sreejesh et al., 2014), was adopted. Within the exploratory research, firstly secondary data was used to assess internal information from the studied company. Secondly, qualitative research was applied in form of interviews, providing the main database for the study. Along these two research techniques of exploratory research, observations were also used as a descriptive research method, to systematically assess the rather easily appreciated and quantified data.

In total four projects were observed, three in the West region and one in South region of Sweden. Qualitative interviews were conducted with several different professional roles from the three projects in West. Due to limited time and scope of the thesis only two interviews were conducted in the project in South of Sweden. These four projects were used as the main empirical data. Similarities and differences between the current methods used in practice and the concept of VDC were studied.

The explained research design was adopted to generate needed information from the company, regarding both the internal work processes and the actual application in different projects. Secondary data was obtained through the company's intranet in order to present current working guidelines, while observations and interviews were primarily conducted to present the working methods used in practice. Finally, all empirical data eventually served as a foundation of the analysis and evaluation of the current state, as well as it provided answers to the research questions of the thesis.

3.1.1 Literature research

The theoretical data about traditional working methods, Lean Construction and VDC was obtained from previous theoretical research such as books, reports, journal articles and master theses. Additionally, to the field of research of Virtual Design and Construction, a general investigation has been conducted within the change management field, as the human aspect was identified to be of importance for studying introduction of a new concept in a big organisation. Characteristics such as representativeness, accuracy and precision were used in the process of gathering data from previous studies about the different fields in order to collect relevant data (Sreejesh et al. 2014).

Keywords such as traditional construction, Lean Construction, VDC, ICE meeting and change management, were used to gather relevant and appropriate theories. In order to obtain relevant knowledge about different working methods applied in the construction industry, the research strategy and keywords were not only limited to new working

methods. Due to the rapid development in the digital and visual concepts, the prime focus was directed at recent research studies about these aspects of the study. However, despite the intention of using contemporary sources, the theory of traditional working methods was limited to older articles and books. Thereafter the collected theoretical data was compiled to a comprehensive summary representing the theory chapter.

3.1.2 Observations

According to Sreejesh et al. (2014) observations as a technique, can be used in order to gather information and knowledge about a topic without any interruption to the process or dependency on the participants. Schensul et al. (1999) further state that participant observation, as a starting point of ethnographic research, *"gives the researcher an intuitive as well as an intellectual grasp of the way things are organised and prioritised, how people relate to one another, and the ways in which social and technical boundaries are defined"* (Schensul et al., 1999, p. 91). Thus, this research technique was used in order to gain deeper knowledge about the current working methods and tools in different projects delivered by the company, as well as the interrelationships and roles of the different actors, pursuing the sociotechnical aspect of the thesis. The observations were divided into two parts; the first part focused on mapping the current working method according to the internal guidelines. The second part of the observations was obtained through site visits to three projects in West of Sweden at several occasions, and one project visit in South of Sweden. The intention of an additional project in South was to provide a broader perspective of how the company works in different regions.

During the project visits, two different site meetings were observed. The first meeting type was a daily review meeting, which was chosen due to its wide participant range and its impact on the workday in terms of communication and solving issues related to the work activities. The second chosen meeting type was a weekly coordination meeting that processed more complex issues and had leading participants. In contrast to the daily review meetings where a larger number of skilled workers were participating. Overt observations (Pan et al., 2013) were applied, meaning that the meeting participants were familiarised with the aim of the observations. Project observations were carried out with a checklist, developed by the authors, in order to simplify the process on site and create equal comparison between different projects, see Appendix A for an example of the checklist. The checklist was used in each project and considered different aspects of the meeting structure, tools and technology, and team-members' engagement, in order to provide a general description of each project which is an important contribution to the empirical collection. The chosen aspects in the checklist were developed from the theories in Chapter 2, especially inspired by the definition of VDC developed by the authors.

3.1.3 Interviews

Due to the importance of obtaining critical and objective perspective on the current working methods in the company, the interviewee's opinions and answers were considered critical for the study. As Brinkmann and Kvale (2015) suggest, qualitative research interviews are recommended when the subject's own perspective is of interest and when the themes of prevalent world need to be understood. According to Sreejesh et al. (2014) individual depth interviews allow an interactive exploration of a subject

for both the interviewee and the researcher. There are three types of in-depth interviews, unstructured, semi-structured standardised (Sreejesh et al., 2014). In this study semi-structured interviews were chosen due to two reasons. First, to establish a structure covering all three main aspects that study builds upon, and to regulate eventual time matter. Second reason was to keep the interviewee responsive to new questions and follow-up questions that could arise. Interviewing several different roles within each studied project was chosen to obtain a thorough section of the current situation. in the company. Miner metaphor that Brinkmann and Kvale (2015) present, is representative of the interviewing approach adopted in this thesis. The perception among different actors in ongoing projects was revealed by "*mining*" the surface of internal guidelines, through in-depth interviews.

Thirteen interviews were conducted in total, whereof eleven interviewees were employed in the construction phase and two interviewees were engaged in the design phase. At least two interviewees from respective project had the same role, aiming to construct a possibility to compare insights from all projects in the light of partly shared perspective. A more detailed presentation of all interviewees is given in Chapter 4. The basis of interview questions can be found in Appendix B. Transcription of the interviews is based on the audio recordings of the interviews and handwritten notes that were made during the interviews. The recording was chosen as a method of documentation to enable freer dialogue and to simplify the compilation of ensuing transcriptions (Brinkmann and Kvale, 2015). Handwritten notes were used as an additional, albeit brief, source of documenting authors' own reflections and observations of interviewees' mood and the setting that could not be captured in the audio recording.

3.2 Data analysis

Among prevalent methods for analysing qualitative data, Vaismoradi et al. (2013) present descriptive phenomenology, content analysis, thematic analysis, grounded theory and hermeneutic phenomenology (Vaismoradi et al., 2013). Further, Vaismoradi et al., (2013) explain that content and thematic analysis are two similar approaches for analysis of qualitative data where researchers systematically search through the data to detect themes and patterns. Themes are developed by coding the data set, by discovering different keywords within the data related to the research (Javadi and Zarea, 2016). Javadi and Zarea (2016) add that a strength of thematic analysis is the diversity of data sources that can be used, including interviews, field notes, documents, pictures, etc. Due to diversity of data collection in this thesis and partly inbuilt themes in interviews, thematic analysis was adopted as the data analysis approach. The collected empirical findings from the interviews, on site observations and the assessment of company's existing guidelines, were all objectively and systematically compared to the theoretical framework provided in Chapter 2, with respect to the three predetermined themes of people, process and technology, which characterise theoretical thematic analysis according to Javadi and Zarea (2016). Special emphasis in the analysis was put on the human aspect, as an indentation of the holistic approach of the thesis.

3.3 Critical evaluation of the method

A potential weakness of the chosen methodology is that quantitative data is excluded, which could be of interest for the company. However, due to the scope and time limit

of this thesis, only qualitative approach was considered to be valuable for the chosen research questions. The studied concept has a heavy previous research within the design phase, which was used as the starting point of the theoretical framework, this could be considered as limitation of the theoretical foundation used in this thesis. As a response to this weakness, the authors have chosen to develop an own definition of the VDC concept in order to compensate for the lacking theories. Knowledge transfer theories were excluded due to the scope limit; however, such theories are considered to be an important aspect that could be used to create a more profound analysis of implementing new working concepts.

The low number of studied projects could be seen as another weakness in terms of evaluating the company's practice, although the studied projects varied in size, number of involved actors and location, to provide a wider perspective of the current practice used by the company. The project observations were limited to two different types of site meetings with only one observation for each meeting type. The observation results could thus be different if several observations had been carried out and patterns could be easier identified. However, the evaluated aspects from these meetings were general aspects which did not require extensive inputs in order to validate results.

3.4 Ethical aspect

The ethical aspect needs to be considered at all interview research stages (Brinkmann and Kvale, 2015). In this thesis, the authors have therefore been meticulous with early informing the interviewees about their own anonymity in the interviews, and the anonymity of the projects they work in, as well as the company name. Likewise, the interviewees were familiarised with the purpose of the research. Additionally, interviewees were asked for permission to record the interviews in conjunction with introducing them to the purpose of the interview.

Brinkmann and Kvale (2015) bring up the *consequences* aspect of participating in a qualitative study, in addition to already discussed aspects of *informed consent* and *confidentiality*. The authors of the thesis have however not identified any possible harmful consequences for participants in the interviews and left this dilemma to the interviewees themselves to decide on. No clear benefits could be promised on beforehand either, thus leaving it up to the interviewees to appreciate independently.

Last aspect of ethical issues in interviewing is the role of the researcher. Within this aspect, the researcher's integrity and moral responsibility is included (Brinkmann and Kvale, 2015). Brinkmann and Kvale (2015) state that autonomy of research can be distorted from either way, by the research funders or the participants. Due to the interactive aspect of interviewing, Brinkmann and Kvale (2015) mean that interviewers who have personal interplay with the participants are especially inclined to co-opt the research findings. However, the authors of this thesis have not encountered any of the interviewees prior to the study start and have kept a professional relation with all the interviewees, with good faith that they remained unbiased and objective throughout the research. Finally, ethical aspect in form of confidentiality was especially considered during observations of the projects, concerning potential abuse of invasion of privacy (Ibid).

4 Empirical findings

This chapter aims to present the empirical data that is used for analysing the company's working processes with focus on meeting structure and project execution in the construction phase. The starting point is an assessment of the company's current working processes derived from the company's intranet. Thereafter, four observed projects will serve as the main empirical data of company's working processes in practice. Followed by a short introduction and description of each project and significant data from several interviews in these projects will be presented. Lastly, a summary of observations from all projects, based on the results from standardised checklist shown in Appendix A, will be provided in the end of the chapter.

4.1 Assessment of company's internal work processes

This part of the study is based on company's internal guidelines which are available on its intranet. The company is involved in various infrastructure, housing and commercial projects as a contractor primarily in Nordic countries, but also in Europe and US. The company have provided different internal guidelines for different types of projects. For housing and commercial projects, the company have provided documents and guidelines that can be applied in different stages of a project with possibility to adapt these to each specific project. The different phases in those projects with DB as delivery method are illustrated in Figure 4.1.

Figure 4.1 A timeline over different phases of a typical DB project delivered by the company.

In DB projects, the design phase is managed by an internal design manager. Depending on the contractual agreement and project size, this phase is carried out with close collaboration with the client, project manager, installation manager and representatives from construction such as construction manager and foreman. The aim of this phase is to provide plans, details and conditions for an effective construction phase, and visualisation is considered to be the most beneficial method for this phase. The project manager has the responsibility to prepare objectives for the project which should be adapted to the project conditions and communicated to all project members. In a partnering agreement, these objectives are prepared with the client.

Furthermore, the documentation methods and digital tools used in the project could be different in each phase. The documentation method used in the project is determined by client requirements and the project manager has the responsibility to decide which project platform that will be used in order to meet client requirements. Internal guidelines provide three alternatives: an internal project platform, a traditional folder structure on computer and an external joint project platform. In the design phase, the digital tools and methods for the project are chosen by the design manager who has the responsibility for information sharing and the use of these tools and methods in the design phase. This process is carried out in consultation with a digital leader who provides support in regard to digital working methods and tools usage in the project.

In traditional DB projects, the design phase is completed before the construction phase. However, there are projects where these two phases are carried out in parallel, depending on the contractual agreement and client requirements. The construction phase is the main focus in the assessment of the company's current working process and the primary elements in this phase, according to the internal guidelines, are illustrated in Figure 4.2. However, it should be noted that these primarily elements have been chosen by the authors of the thesis with the theoretical framework in mind. The primary elements shown in Figure 4.2, have been divided into four main aspects: *people*, *process*, *technology* and *process & technology*, which are presented in detail further in this section.

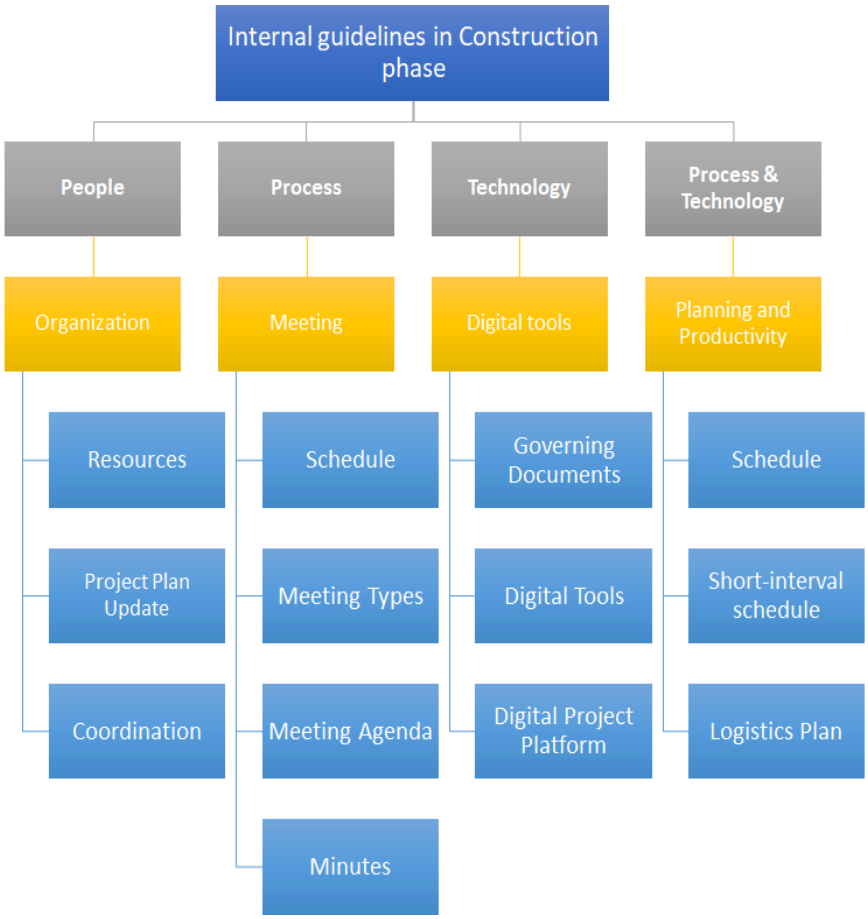

Figure 4.2 An illustration of primary elements in the construction phase assessed by the authors.

4.1.1 Organisation

The construction phase of a project should be carried out in close collaboration between project manager, construction manager, project engineer and foremen. According to internal guidelines, if possible, these roles should be involved in the earlier phases of the project. In order to achieve the project objectives determined in the design phase, the project manager and the construction manager should prepare and perform each element in the Figure 4.2 carefully.

As stated earlier, the project size and contractual agreement affect the involvement stage of different roles in the project. In housing and commercial projects up to 500 million SEK, the construction manager and a digital leader are partly involved in the design phase. The involvement of internal foremen occurs as late as the start of the construction phase. The design manager and project engineer only work as a support function during construction phase for projects over 150 million SEK. These resource related guidelines are used by the region manager and project manager for each project before the start of construction phase. Project manager and construction manager must also update the project plan before the start of construction phase. The project plan is carried out during design phase and after the start up meeting for construction phase it might require adjustments of the activities in terms of time and labour.

Coordination is another important factor that could improve the construction phase and reliable structure of the work. Coordination in projects is divided into weekly structure and meetings, workplace introduction and governing the subcontractors. Weekly structure includes providing a work plan for activities that will occur during the week and communicating the plan to involved actors. The construction manager prepares the weekly structure and has the responsibility to follow up the work by holding construction meetings which will be explained further in the following section. Workplace introduction is mainly focused on workplace security and culture alongside governing the subcontractors in terms of involving everyone in the project. The responsibility for these aspects of coordination relays on the construction manager.

4.1.2 Meetings

Meetings are another important element for construction phase that enable control and plan of work as well as provide a platform to solve work related problems. The construction manager with his/her internal management team must plan these meetings in order to achieve efficient meeting structure. The internal guidelines provide a meeting plan template for planning the typical meetings during construction phase; start-up meeting, client meetings, daily and weekly review meetings, coordination meetings with internal representatives and with subcontractors are a few meeting types in the template. It is also recommended to invite the client to internal meetings which are held on the construction site in order to have a close collaboration and faster decision process.

There are templates for traditional meeting minutes for above mentioned meetings and suggestions for how often each meeting could be scheduled. Construction meetings, which are divided into meetings with internal representatives only and those with subcontractors, should be scheduled once a week. In those, otherwise known as coordination meetings, held by a construction manager, the projects' progress in accordance to its plan is discussed by the participants. The minutes of these meetings should be kept, and important decisions should be communicated to other project actors.

Daily review meetings held by a foreman, where a brief review of the workday is presented, should be scheduled in the morning. Representatives from internal management, subcontractors and skilled workers who will work in the project that specific day should attend this meeting. However, like in all other meetings important decisions must be communicated to all concerned actors. For above mentioned

meetings, the guidelines suggest using minutes templates as the meeting agendas with possible adjustment for the specific project. For daily review meetings, there are two main topics that should be addressed in every meeting, namely information from each participant about what they have done since the last meeting, what they will do that day and any obstacles as well as questions to and from others, information and issues related to safety. Furthermore, there is a well-developed guideline for daily review meetings that describes the space layout, visual tools and their application for an efficient meeting. However, this detailed guideline is limited to the daily review meetings with no further expansion in other types of site meetings.

4.1.3 Digital Tools

Documentation of governing documents, agreements and minutes from different meetings and distribution of these documents to concerned actors are important for the projects' outcome and appropriate methods and tools should be used. The client might require routines regarding incoming and outgoing correspondence for letter and email communication. On site, the responsibility for digital tools relays on the construction manager who must, with the help from an IT coordinator, plan and order digital tools like digital joint project platform, tablets for employees on site and visualisations tools such as BIM 360 Field, Bluebeam etc. In the internal guidelines, there are suggestions for different levels of digitalisation based on previous projects, digital coaches within the company as well as guide documents regarding how to use different digital tools.

A joint project platform can simplify information exchange and documentation aspect between the actors who work in different phases of the project within the company. The joint project platform provides a shared calendar function with possibility to access it on mobile and computer devices. However, as it was mentioned in Section 4.1, depending on the client's requirements the project manager might chose a traditional folder structure on computer. This decision about the project platform is made before the construction phase.

According to the internal guidelines, a digital from-to-matrix board should be used during the design phase in order to answer project related issues in a more efficient manner. However, there is no suggestion for further usage of similar tools, such as from-to-matrix, during the construction phase. Due to the complexity of digital tools for subcontractor representatives and skilled workers who have limited experience with these working methods, it is recommended to have a digital leader on site who is responsible for issues and problems related to digital tools and methods used in the project. This role could be combined with an already existing role, for instance a foreman or a project engineer.

4.1.4 Planning and productivity

Planning and productivity consist of elements like time and resource planning, workplace planning, work preparation and visualisation. A schedule for construction phase, which is a part of the overall project schedule, consists of activities that will be performed during this phase. In order to achieve the milestones in the schedule, it is critical to continuously adjust and update the schedule with engagement from all concerned actors. The project manager has the responsibility to prepare the overall project schedule. Since it is the point of departure for construction schedule, the overall

project schedule should be updated once a month. The construction schedule should be prepared by the construction manager in collaboration with the project manager and other concerned actors from construction phase. The schedule should be communicated and available in a visual format to these actors, while in complex projects the schedule should be broken down to different disciplines or building floors.

There are different examples of project schedule available on the intranet that show how a typical housing or commercial project schedule could look like. The examples available on the intranet are Gantt charts with and without linked activities. As described above, the construction schedule might be complex with several activities happening months later, therefore there should be short-interval schedules based on at least three upcoming weeks' activities from the construction schedule. The foreman in the project is responsible to prepare short-interval schedules for subcontractors and skilled workers. These schedules should be continuously updated and available to all subcontractors, skilled workers and others, in order to simplify their labour and resource planning.

Logistic plan is another important factor within the area of planning and productivity which could result in an effective and safe workplace. The construction manager has the responsibility for preparation of logistics plan for deliveries to site, location of cranes and elevators, gates for pedestrians and deliveries, safety barriers, coordination with other projects and stakeholders for a safe workplace and minimised impact on the environment. It is also suggested to have a schedule over the deliveries to site and a work deposition plan. The work deposition plan shows where the sheds, large machines, gates, escape routes and transport routes, and other important things, are within the construction site. According to guidelines, a digital tool like Bluebeam should be used for preparing the work deposition plan.

4.2 Project 1

Project 1 is a housing project located in West of Sweden. The project has a contract sum of 210 million SEK. The project includes a new apartment building for a client who is a well-known real estate owner and landlord in West of Sweden. In this project, the Design-Build delivery is used with a partnering agreement. The design phase of Project 1 was completed before the construction phase started. At the time of the observations and visits of Project 1, there were 17 subcontractors and roughly five contractor employees within management who were involved in the project. Introduction to the interviewees from Project 1 follows below.

- Construction Manager 1, who is the construction manager for Project 1 with background as a carpenter and foreman, was interviewed as a central figure for the project with the expectation to provide overall information about the project and its construction phase.
- Foreman 1 is an internal foreman with two years' experience within this role, with previous education in building engineering. An internal foreman was chosen for the interview as a highly involved figure throughout the entire construction phase.
- Subcontractor 1 is a subcontracting foreman for ventilation, with few decades of experience within ventilation systems. An interview with a subcontractor was aspired to provide an objective assessment of the construction process.

4.2.1 Interviews

Meetings

Construction Manager 1 participates in numerous meetings related to the construction phase of the project, such as coordination meetings and daily review meetings. He explains that the person who holds the meeting has the responsibility for the minutes. Both Construction Manager 1 and Foreman 1 declared that they follow the company's internal guideline for meetings, however, with slightly modified agendas to fit the particular project needs. The modification is explained as taking out what they consider *"non-value adding activities"* from the meeting agendas and keeping the essentials of the structure. *Safety* was used as an example of an essential element that is highly ranked and therefore kept. Minutes are distributed to all participants via email but also uploaded to a joint project platform, Foreman 1 conveyed. Foreman 1 added that detailed and direct information is forwarded by email, while major information is announced on posters at the construction site. Subcontractor 1 indicated that he appreciates the safety aspect and finds it very important, however, as it is each subcontracting representative's responsibility to spread safety-related information to their own subordinates, it can be difficult to know if and to what extent that is done.

Technology

In Project 1, representatives from the internal management team, that is a foreman and the construction manager, stated that they have experienced loss of participants' focus when they used TV-screen during meetings. Therefore, they have taken a decision of their own to stop using the TV-screen during coordination meetings which has resulted in a more present group that is forced to actively listen and participate in the meetings.

To solve problems faster, Foreman 1 is convinced that the decision line should be shortened. Furthermore, Foreman 1 shared her opinion that more direct contact should be available, meaning that distinct communication charts should exist to facilitate possibility of having dialogues with the right person faster. However, none of the interviewees in Project 1 has previously used from-to matrix during the construction phase. Although, Construction Manager 1 and Foreman 1 were familiar with the method. Foreman 1 shared her personal perception that emailing questions to concerned actors is a faster way to get answers, rather than using a from-to-matrix during the construction phase. Anyhow, she added that there is also a risk of important information and decisions may *"fall between two stools"*, when the information is exchanged directly between a couple of stakeholders at a time. Subcontractor 1 stated that he believes more in verbal communication and finds daily review meetings successful for getting needed answers and information. Construction Manager 1 disclosed that problems are generally solved fast in Project 1 and usually directly as they arise.

Miscommunication is not prevailing in the project according to interviewees. Although, Foreman 1 added that some unplanned work has occurred since the company has another ongoing building project in the near of Project 1; hence, the unplanned work was caused by lacking communication and coordination between these two projects. Additionally, Construction Manager 1 exemplified one major misunderstanding which was caused by an architect who picked a wrong element, which could only be recognised if looking at the 3D model. As the skilled workers used 2D drawings, the

wrong element was not detected until it was too late, which resulted in rework and increased costs.

Collaboration

Foreman 1 stressed the importance of engaging the participants in meetings and showing empathy. Therefore, the internal management team of Project 1 added an additional matter to their coordination meeting agendas, in respect to the participants well-being; namely, asking all the participants how they feel before they close the meeting. Important to note is that this additional question is also a part of the meeting minutes, and in that way participants' answers are archived and can be used as a follow-up tool during the project. Construction Manager 1 shared that except the individual traits, he believes that the actors who are dissatisfied take more space in meetings and talk more than those who are satisfied. Foreman 1, in contrast, believes that the least active actors during the meetings either are *"honestly not concerned with any issues in their work, or they simply aren't updated and don't know that they might have issues, thusly being quite."* Thus, Foreman 1 underlined the importance of being observant on the work on site and the internal management's duty of being updated on everyone's work and coordination of the schedule.

To bridge the design and construction phase, Construction Manager 1 expressed the need to extend the collaboration internally by involving a construction site foreman in the design phase. Besides, he stated that *"people grow with the assignments; therefore, you need to let everyone get an opportunity to contribute and have trust that they can handle it."* Foreman 1 agreed on the benefit of including foremen earlier on in the process, especially it can be helpful for making accurate purchase appreciations and similar.

4.2.2 Observations

Daily review meeting

In Project 1, the daily review meeting was held by a foreman with the participation of subcontractor representatives, other internal foremen and the construction manager. The daily review meeting was held in the predetermined meeting space, with a fixed agenda that was similar to the agenda suggested in the internal guidelines, where each participant was informing about their work and any obstacles related to it. The meeting space shown in Figure 4.3 was next to an entrance door used by workers which caused loud external noises during the meeting and made it difficult to hear the information given from the participants. The meeting participants were standing in two different groups, the representatives from subcontractors on one side of the room and the company representatives on the other. Some sidebar conversations were also observed between subcontractors after they informed about their work, neglecting the information provided by other subcontractors.

Figure 4.3 Predetermined meeting space for daily review meetings in Project 1.

In the meeting space shown in Figure 4.3, there was a display wall with a short-interval schedule on a whiteboard, 2D work disposition plans and the meeting agenda. These tools were not used during the observed meeting.

Coordination meeting with subcontractors

This meeting was held by a foreman who was also responsible for keeping the minutes for the meeting. The participants were three other foremen and construction manager from the internal management team and subcontractor representatives. The fixed agenda for the meeting was based on the minutes from previous meeting with modification to the current weeks' work activities. This was similar to the agenda from internal guidelines with modifications such as a last question about work related stress amongst the participants. There were different topics discussed during the meeting followed by information rounds and questions related to each topic. The meeting was held in a typical conference room shown in the Figure 4.4, where all the representatives from the company had their own computers and several subcontractor representatives had tablets which they used during the meeting. The atmosphere before and during the meeting was good, however, there were few subcontractors who were only active when asked to provide information or answer a question. The majority of questions were answered during the meeting, however there were a couple of questions to which the construction manager or the foreman promised to get back with answers later. The minutes for the meeting would be communicated via email to participants and uploaded to the joint project platform.

Figure 4.4 A typical conference room used for coordination meetings.

The meeting room was equipped with a TV on one side of the room and a whiteboard on the other side with some printed pictures of the projects. Neither the TV nor the whiteboard were used during the observed meeting.

4.3 Project 2

Project 2 is an extension of an existing shopping mall in West of Sweden, with a project sum of 200 million SEK. The project is procured by a commercial client as a Design-Build project, with a partnering agreement. At the time for observing and analysing this project, 15 subcontractors were involved. The design phase of Project 2 partly continued parallel with the construction phase. The interviewed roles from Project 2 are presented below.

- Construction Manager 2 is the construction manager of Project 2. He has had this role in roughly two years, however, long previous experience as a construction worker and foreman.
- Foreman 2 who along the role of the foreman, also holds the role of the digital leader in the construction phase of Project 2.
- Subcontractor 2 is an experienced subcontracting foreman for electricity.
- Design Manager 2, the design manager for Project 2, was interviewed to provide additional data on the bridging and overlapping of the design and construction phases in practice. Design Manager 2 was responsible for the design phase ever since the Project 2 was initiated and awarded to the company.

Justification for choosing interviewees in Project 2 is identical to the argumentation for corresponding roles interviewed in Project 1, see Section 4.2.

4.3.1 Interviews

Meetings

Project 2 has a very clear meeting schedule that is accessible for everyone, either in the sheds on construction site, or via the joint project platform. This schedule for meetings

has its roots in the internal guidelines with some adjustments that management in Project 2 made to accommodate the project needs.

As a part of his role, Construction Manager 2 should participate in all meetings that have been described in Section 4.1.2. According to the Construction Manager 2, it is a waste to attend certain meetings if his subordinates and the rest of the team can solve it without his inputs, disclosing that he therefore does not attend all the meetings. Despite a clear meeting schedule, Construction Manager 2 pointed out that spontaneous meetings are called when necessary, which approximately occurs once a month. Foreman 2 partakes in numerous meetings; among the most essential meetings he mentions the daily review meetings, coordination meetings with subcontractor representatives which take place once a week, monthly construction meetings, and sporadic meetings that he convenes based on necessity. Foreman 2 gave several clues on what makes an effective meeting based on his working experience. Namely, he stresses that there is a need for having a clear purpose for the meeting, but also being distinct to communicate the purpose to all the participants. Furthermore, Foreman 2 expresses his perception of too detailed or irrelevant information during meetings has negative impact on the efficiency of the meeting. Foreman 2 concludes that meetings work less well when the objective is too broad and discussions tend to drift away from the original objective, hence pointing out that having steady meeting structure is another success factor for improving meeting efficiency.

Foreman 2 clarified that he in the first hand talks to the construction manager if he misses a meeting. He adds that subcontractors who cannot attend a meeting are expected to send another representative and are responsible to get in touch with the management team to take part of important information, which Subcontractor 2 also confirmed. Additionally, Subcontractor 2 expressed that he prefers getting answers verbally via direct communication. Construction Manager 2 primarily looks at the meeting minutes that are forwarded by email in case he did not attend a meeting. Construction Manager 2 explained that meeting agendas have been adjusted internally by the management team to increase productivity. He adds that he noticed a need to follow up meeting structure and agenda more with participants and understand how everyone perceives it in reality. Design Manager 2 stated that they follow meeting agendas from internal guidelines in the design phase. However, he noticed that sometimes there have been too many participants in a meeting despite not being concerned with the subject. He stated, *"It would be more efficient to have bigger design meetings every second week and add more meetings about technical related issues each week"*.

Technology

Various communication tools are used in Project 2, ranging from emails, phone calls, video conferences to online information sharing platforms such as OneNote, Foreman 2 stated. Construction Manager 2 pointed out few software tools such as *BIM 360 Field*, *Build Safe,* and *One List* - an application that they use in Project 2 for sharing lists of work to do, where questions also can be linked to a particular element on the list. This application was discovered by a foreman in the project and accepted as a proposition among the skilled workers and rest of the team.

Foreman 2 hinted at certain difficulties with digital tools and technologies associated to the age and generation issue. However, he acknowledged that initiatives have been taken to involve internal skilled workers more and train them successively in using different digital tools. Starting with simple discussions and introductions whenever there is time to do so, Foreman 2 shared that he could recognise slow but determined will among skilled workers if they could realise the benefit of applying these new methods. Foreman 2 asserted that currently there is several digital tools and platforms, however, too many different tools that are not compatible with one another, which makes them difficult to apply in practice. There is a clear need, Foreman 2 stressed, for an integrated toolkit and a unified platform that supports all software that is used. He also lifted BIM 360 Field as a successful software with potential to overcome the previously discussed issue. In addition, Foreman 2 believes that a tool like this could help link the design and construction phases.

Design Manager 2 explained that he is confident in using the digital tools himself, but there are difficulties in motivating other team members in doing likewise. For instance, many still raise questions during design meetings instead of using from-to matrix via the joint project platform, which results in double work, managing the digital from-to matrix and long written meeting minutes due to many questions that were raised during the meeting. Additionally, he pointed out that there is no possibility to mark priority in the specific digital from-to matrix they use, which he thinks is a drawback of this particular application. Consequently, Design Manager 2 tried a similar visual application in another software which worked better and offered opportunity to visualise the urgency of an issue. As many team members still prefer sending emails over using from-to matrix, Design Manager 2 said he ensures that these individuals post the answers in the from-to matrix afterwards, so that the information becomes accessible for everyone in the design phase. He marked that use of from-to matrix would be equally effective tool to use in the construction phase.

Collaboration

Speaking of visualisation with Construction Manager 2, he presented a small brochure of Project 2 that the contractor management team initiated as a way to engage the most crucial actors. They involved ventilation, electricity, plumbing and sprinkler subcontractors in creation of this simple visual representation of the project early on, as a mean to get everyone realise their own importance for the project as well as being a part of a team with a common goal. Along short project description, the brochure emphasised the aspect of the common project culture, specified measures to support the project culture and contact information of few central management roles in the project.

Design Manager 2 highlighted the complexity of decision making in the design phase, as one decision usually affects several actors and it is not straightforward to decide if not everyone has agreed and approved the matter. Thus concluding that, it is very important to work closely and integrated in order to be efficient. Miscommunication has not been an issue according to the design manager, however, numerous change orders from the client have hampered the process. Lastly, Design Manager 2 discussed the issue of handover phase, pointing out that it could be preferable to let those responsible for construction phase to finish the last part of the design phase, that is, include them into the finish of the design process. In Project 2, Design Manager 2 explained that design phase overlapped quite a lot with the construction phase due to

late design orders from the client. However, he believes that planned overlap between phases would be preferable to have in other projects as well.

Partnering agreements were discussed as lacking compared to common contract types, e.g. contractual agreements used in projects delivered with for instance Design-Build. There is a need to make an official contract for partnering in order to apply its full potential, Foreman 2 said. Design Manager 2 told that active participation in design phase differs and he believes that is connected to individual's personality. He lifted that subcontractors are the least active in the design phase, saying *"They believe that they don't belong in the design phase, that this is something subcontracting project manager takes care of and their competence is making an entrance later in the project, which is completely wrong."* He also shared that a reason behind this attitude is that subcontractors usually are involved in many projects simultaneously and cannot fully commit. Lastly, Design Manager 2 talked about differences among actors, mostly as a qualification to provide a good end product, however, differences at times hinder collaboration if certain actors are not willing to compromise and consider the project as an integrated product.

4.3.2 Observations

Daily review meeting

In this project, the daily review meeting was held in a predetermined room which was mainly used for these meetings. Two foremen from the internal management team held the meeting and the other participants such as the construction manager, subcontractor representatives and skilled workers were sitting facing the two speakers. The meeting room is shown in Figure 4.5. They used a fixed agenda starting with safety and deliveries, followed by information from each participant about their work and any obstacles related to it. There were sidebar conversations between participants. After this meeting which lasted ten minutes, representatives from the company and internal skilled workers had a follow up meeting in the same room. In this meeting, questions that were raised by subcontractor representatives and other questions were discussed and answered.

Figure 4.5 Predetermined meeting space for daily review meetings in Project 2.

There were two display walls, one showed a short-interval schedule, and the work disposition plan and delivery plan for the week on whiteboards. On the other wall, there were 2D drawings of the project on a whiteboard which also showed where in the building each subcontractor would work during that week. There were many chairs and a few tables in the room, as well as a TV which was not used during the observed meeting. The 2D drawings were used during the meeting in order to answer a couple of questions.

Coordination meeting

In this internal coordination meeting only representatives such as construction manager and four foremen from the company participated. The observed meeting was held in a typical conference room which is shown in Figure 4.4. During the first part of the meeting, a foreman informed about unanswered questions and the decision made in the previous meeting. The second part of the meeting focused on the work activities, labour and material related to these. There was no agenda nor minutes for the meeting, the main topic was answering the question "*What will happen next week?*" and modifications to the project schedule and obstacles related to following weeks' activities were discussed.

The room was equipped with a long board and chairs and two display walls. There was a Kanban board for the internal management group and labour schedule for next week on a whiteboard. The labour schedule was used during the meeting to organise where and how much the internal skilled workers would work during the upcoming week. On the second display wall, there was a projector screen which was used during the meeting to show the construction phase schedule in Gantt chart form and a 3D model of the building in order to answer some questions. Moreover, printed 2D drawings and schedule were also used during the meeting.

4.4 Project 3

The third project is a commercial building, delivered with Design-Build as the delivery method and a partnering agreement for a small municipality in West of Sweden. This project was the last one in the line of four commercial buildings that the municipality has procured. Thus, relatively same contractor team and subcontractors were involved in the construction of Project 3, that previously delivered the other three projects for the same client. Project 3 has a contract sum of 42 million SEK. The design phase partly run in parallel with the construction phase. Below, a short presentation of the interviewees follows.

- Construction Manager 3, the construction manager for Project 3, has long experience within the role and has had the same role in the previous projects for the same client.
- Foreman 3 is an internal foreman with fair experience of this role, with previous background as a carpenter.
- Project Engineer 3, an internal project engineer for Project 3, was also interviewed as this role was represented during the time for the project visits and considered a good source for forming a broader picture of the construction practice in this project.

- Design Manager 3 has held the same role for the design of the former projects ordered from the same client.

4.4.1 Interviews

Meetings

Construction Manager 3 and Project Engineer 3 explained that minutes from procurement meetings with the client are shared via joint project platform. Furthermore, coordination meetings with subcontractors and coordination meetings with skilled workers are also fixed but are not recorded in minutes. Construction Manager 3 makes notes during the latter; however, he acknowledges that they try to keep the minutes down to only the most important information. Concerning the issue of someone missing a meeting which is not kept in minutes, Construction Manager 3 explained that he tries to distribute the information to that individual personally and as soon as possible. Foreman 3 confirmed that he also verbally communicates the meeting decisions to those who have missed a meeting. Project Engineer 3 added that the team in Project 3 is small and this arrangement works well for them, while Foreman 3 agreed and further commented that for bigger teams there should be differently structured solution for passing on the information. Construction Manager 3 added that important decisions and information that affect many parties are usually distributed via meetings that are scheduled separately when needed.

Generally, Construction Manager 3 and Project Engineer 3 revealed that internal guidelines are used as a directive from which they cull the "*gems*"; they adopt what they find most important and relevant for the project in matter. Foreman 3 agreed and elaborated that the internal guidelines need to be more adapted to the specific project. He said that *"A meeting should not be held just because it says so in the guideline"*, meaning that they many times resolve issues and answer questions throughout the workday and the need for having a meeting disappears. Foreman 3 concluded that the guidelines are good to have but need to be adjustable to projects due to uniqueness of each building project. Foreman 3 also pointed out that he generally finds the meeting procedures work well in Project 3, however, he believes that minimising the number of meetings and making them more effective is a good direction. He lifted the sincere dialogues and devoted team of skilled workers as reasons that meetings function well, by making people feel involved in problems gives the best outcomes, he said. However, he added that it is a bit of a struggle getting subcontractors as involved and open as the internal workers.

In the design phase, Design Manager 3 partakes in numerous meetings where she holds and directs the start-up meeting for design phase, regular design meetings. She is also responsible for keeping the minutes during these meetings. Minutes are distributed by email and/or uploaded to the joint project platform. Design Manager 3 revealed that she got to participate in project meetings for Project 3 a few times when there were questions related to design. She pointed out that it differs between actors and individuals how well they update themselves on meetings that they have missed. Interestingly, she noticed that actors who handle specific technical solutions, such as energy specialist or acousticians, are often better at continuously checking for updates and questions on from-to matrix. She explained that this might be related to the fact that these actors are not invited to meetings unless there is a specific issue that affects their field; however, they are expected to stay updated in the meantime.

Design Manager 3 acknowledged that she in previous projects has not been very good at sending out agendas for meetings in advance, which she therefore actively tried to improve in Project 3. Anyhow, Design Manager 3 shared that design meetings have developed over past years, from being very extensive towards becoming shorter occasions to tune in with other actors and thereafter continue the work either individually or in smaller groups. On the subject of holding meetings, Design Manager 3 added that she would appreciate getting some education related to how meetings should be held and how skills related to this could be developed. She shared that this aspiration exists among design managers in general, they are willing to improve additionally. Furthermore, she explained that it is necessary to put up a framework and jointly decide as a project team if participants should be allowed to use computers during meetings in case the current topic does not affect them, or if participants are allowed to join discussions that are outside their expertise.

Technology

Project Engineer 3 explained that critical and important information usually is shared via emails. In Project 3, they also use few simple software applications and a joint project platform, which all interviewees confirmed works well. Especially, Project Engineer 3 pointed out the digital noticeboard that is a part of the project platform as a great visual tool that is appreciated among the project team.

Construction Manager 3 pointed out that in the design phase, they use the from-to matrix that exists in the joint project platform, where notifications appear for everyone when a project member makes an update. Once again, Construction Manager 3 stressed the user friendliness in such visual matrix that is accessible for everyone, over writing minutes and communicating them to the project team. However, the most important questions and decisions are still preferably done over phone calls, Project Engineer 3 added. Construction Manager 3 also explained that subcontractors are not familiar with from-to matrix and that they prefer to ask questions and get answers directly rather than using a from-to matrix board. Design Manager 3 explained that a digital from-to matrix was used in the design of Project 3, however, mostly for highly technical questions. She especially stressed the importance of formulating questions well in text when using from-to matrix on the joint project platform, as textual formulations might end up minimal and unclear. Other questions are mostly resolved directly in the meetings or allotted to someone who would get back with an answer.

Construction Manager 3 stressed the issue of the sprawling software that is not compatible nor well integrated. He specially criticised the complexity of too many existing software solutions and lacking user friendliness. *"You shouldn't need to switch between 15 different applications to sync everything. It should be automated and linked, so when you work with the time plan, for instance, the economy plan should be updated automatically in accordance to new conditions"*, Construction Manager 3 elaborated. Moreover, he adds that the internet connection not seldom is unsteady on site which further complicates the use of digital tools. Construction Manager 3 and Project Engineer 3 consensually agreed that the internal guidelines are too excessive in information and lack in user friendliness. They concluded that the search function works poorly, which might explain why many project teams make their own solutions instead of searching through the guidelines which is *"too heavy and time consuming"*,

as Construction Manager 3 described it. Interviewee summarised the opinions about the internal guidelines as *"It is a good aid, but it does not work as anticipated".*

Construction Manager 3 highlighted that everything is digitised in this project and that skilled workers use tablets instead of 2D drawings on site. Internal management team in Project 3, claimed that it is easier to solve the problems with the mentioned digital tools; solutions can be achieved faster and more efficiently, finally resulting in reduced costs. Construction Manager 3 shared that there is sufficient competence in using the digital tools and joint project platform among the project members. Since they started implementing digital methods and tools in former projects, dating three years back, Foreman 3 shared that he notices improvements in this area among project members. He stated that all members have at least basic knowledge in the most commonly used software, and they try to teach the workers whenever there is time available.

Visualised representations of scheduled and completed labour hours are one example of how management in Project 3 has worked with a simple analogue method that has showed positive effect on clarity among team members and keeping the project schedule on time, Construction Manager 3 explained. Project Engineer 3 added that these visualisations of hours are also used as some kind of protocol instead of written minutes, while Construction Manager 3 lifted the motivation and reminder effect that these visual representations have on the subcontractors.

Communicating with different actors may require different channels, as Construction Manager 3 and Project Engineer 3 explained. Smaller subcontractors, for instance, may not have the resources to reply to emails fast enough, making phone calls more suitable for getting answers faster. Miscommunication occurs; however, interviewees recognise the solution in involving the actors in planning. *"If you get to own a responsibility you will feel involved and willing to fulfil your assignment"*, Construction Manager 3 argued. Miscommunication is not prevalent in this project, which Foreman 3 thinks is a result of a close team who have carried out three similar projects together prior to this one. However, some minor extra work has occurred due to misunderstandings. Additionally, Foreman 3 stated that from-to matrix on the joint project platform is not used during the construction phase since there are plenty of other digital tools that offer equivalent functions. He suggested that from-to matrix might be a solution for bigger projects, however it is not needed for Project 3 in his opinion.

Collaboration

Construction Manager 3 asserted that he recognised certain improvements resulting from the collaboration and integrated working. Previous three projects carried out by the contractor team for the same client have all been finished before the set finish date, Construction Manager 3 stressed. The success factor according to the Construction Manager 3 is that all team members are highly committed. To further increase commitment, internal management team in Project 3 has payed attention to which skilled workers work best together and used this information to make best possible work teams. Project Engineer 3 highlighted the *"team spirit"* they have established as success factor for the effectiveness of the project team.

According to Foreman 3, solving problems and receiving answers is rather quick. The main reason for solving things fast, he believes, is that he and the construction manager

both have broad experience, are active and direct in their approach. He also said that issues that take longer time, usually depend on subcontractors who were not given clear deadlines. Foreman 3 observed that commitment drops among participants when information is repeated, which occurs in daily review meetings during periods when the same activities are ongoing. In general, Foreman 3 expressed that meeting atmosphere is very good and participants are active in discussions. Lastly, Foreman 3 told that the handover phase should be extended to bridge the design and construction phase more effectively. According to the Foreman 3, there is huge potential in involving foremen from construction in the design phase. Design Manager 3 agreed on seeing immense potential in earlier involvement of construction competent resources in the design phase. *"But also letting design managers stay involved longer in the process is a great way of developing knowledge within design phase"*, Design Manager 3 added.

Design Manager 3 concluded that there is high cooperativeness among all actors, especially since the Project 3 has a partnering agreement. She also highlighted that active participation is very dependent on individual traits. Thus, she lifted that it is of huge importance that meeting leaders know how to properly involve everyone and create opportunity for everyone to freely express themselves. Lastly, embracing everyone's experience, and combining the newer generations' digital competences with seniors' long working experience is crucial for delivering successful projects, Design Manager 3 said.

4.4.2 Observations

Daily review meeting

The daily meeting in this project was held in a dining room on the construction site due to limited space in sheds. A foreman was responsible for the meeting with participation from all workers such as the construction manager, project engineer, skilled workers and subcontractor representatives. The fixed meeting agenda was similar to the agenda suggestion from the internal guidelines that focuses on information about each participant's work and any obstacles related to it, followed by questions from and to other participants. The atmosphere before and during the meeting was good; the participants were open about their issues and any work-related stress.

The meeting room was equipped with chairs and tables, however during the meeting the participants were standing in half circle around a TV which was linked to their shared database with drawings of the project and work deposition plans. The TV was not used during the observed meeting to answer any questions.

Coordination meeting with subcontractors

The observed meeting was held in a typical conference room with the participation of construction manager and representatives from subcontractors, the meeting room is shown in Figure 4.4. The construction manager held the meeting which had a fixed agenda with reconciliation of labour hours as the starting point followed by the work activities that were done during the week and potential improvement suggestions. Afterwards, the upcoming week's work plan, required labour and material resources were discussed. The construction manager also noted decisions that were made during the meeting as well as questions and issues that required further information in order to be solved. The atmosphere during the meeting was good, the participants had sidebar

conversations with each other about topics that considered them. It was also observed that one of the participants who was late to the meeting was less active than the others and focused on his phone.

The meeting room was furnished with a long table and chairs with display walls on each side of the table. The display walls showed several short-interval schedules on whiteboards for different actors such as subcontractors and the company. The short-interval schedules showed contracted labour hours for each activity and the completed labour hours to date. During the meeting, these schedules were updated according to activities carried out during that week and they were also used to answer questions related to labour and material for upcoming week. The meeting room was also equipped with a projector which was not used during the observed meeting.

4.5 Project X

An additional project in South of Sweden has been added to the observations with the aim to broaden the perspective of the assessment of the company's construction processes with respect to the research questions. Due to time limitation and geographical distance, Project X has been observed in a smaller proportion compared to the Project 1-3, thus only being used as a supplementary data. Project X is a commercial project, with a contract sum of 400 million SEK and delivered as DB project. At the time for visiting Project X, 20 subcontractors were involved in the project. The design phase of Project X finished before the construction phase started, with exception for additional design requirements from client about interior.

For the sake of obtaining general data that is comparable with data collected from the three main projects, two interviews were conducted in Project X; the interviewees are introduced below.

- Construction Manager X, the construction and project manager of project X, with previous experience working as a carpenter who has advanced through different roles over the years.
- Foreman X is an internal foreman who in addition to Construction Manager X, was a second source for assessment of the construction processes in Project X.

4.5.1 Interviews

Meetings

The usual meetings such as start-up meeting, coordination meetings, daily and weekly review meetings, and client meetings involve both Construction Manager X and Foreman X. Construction Manager X explained that he lets a foreman take care of minutes during meetings he holds to maximise his own observance and participation in the meeting. Construction Manager X said that they follow the internal guidelines for meeting structure and setting up agendas, while Foreman X elaborated that they use internal guidelines as a main structure and select the elements they find favourable. Meeting minutes that are uploaded on a joint project platform and verbal communication are most commonly used to take part of information and decisions in case a participant misses a meeting. Meeting minutes are also communicated via email to everyone who attended that meeting.

Technology

Several software applications are used in Project 3; Construction Manager X lifted a logistics portal that they show on TV screens which is updated every five minutes. He explained that in daily review meetings, logistics plan and deliveries are displayed on the TV while visualisation of project timeline, safety and risks, decision log, work deposition plan and other common elements are updated manually on a whiteboard.

Foreman X emphasised a possible improvement for 3D models where it would be possible to switch off and on layers in the model in regard to the project timeline. Currently it is only possible to regard model in respect to different categories or disciplines, however, it puts much pressure on management to know exactly in what order and how everything is assembled. Thus, he believes that this could facilitate integrated working between many disciplines and increase everyone's perception and understanding for the interplay in the project.

Collaboration

The collaboration in Project X is said to work very well, which Construction Manager X believes depends on the fact that the project team has worked together previously in other projects and had already established good relationships.

Both interviewees stated that problem solving can range from just a couple of minutes to few months, however, Foreman X shared his opinion that the lengthy problem-solving processes most often depend on high number of stakeholders that are concerned with the question. Overall, interviewees depicted a good collaboration in Project 3 with minimal miscommunication. Construction Manager X explained that they have extensive verbal communication with the client which is their daughter company. Thus, communication is consistent and transparent. Foreman X said that some subcontractors, usually those who are new to the project team, do not see the point in having meetings, while those who understand the aim of the meetings stand out with their engagement. Yet, all the participants are open and honest about their work-related issues in the project group.

4.5.2 Observations

Daily review meeting

In Project X, the daily review meeting was held in a predetermined space with participants from subcontractor representatives, internal foremen and the construction manager as well as skilled workers. The meeting was held by a foreman and the fixed meeting agenda consisted of safety and accidents as the starting subject followed by information about what would happen during the day and questions related to this, deliveries and next weeks' work plan. The meeting space shown in Figure 4.6, was next to the door to construction site and changing room which were used by workers during the meeting. This caused loud external noises and participants who joined the meeting subsequent as well as participants who sat on the stairs to the changing room. The majority of the participants were sitting facing the display wall which the speaker was standing in front of during the meeting. Due to external noises and the space layout it was difficult to hear the information given during the meeting. The atmosphere before

and during the meeting was good, however, one of the internal skilled workers was dissatisfied and brought up issues and possible obstacles related to these.

Figure 4.6 Predetermined meeting space for daily review meetings in Project X.

The meeting space was equipped with one display wall that showed the meeting agenda, previous safety incidents, a 2D work disposition plan, printed 3D drawings of the project, potential risks and upcoming work activities written on a whiteboard. The work disposition plan and schedule for upcoming work activities were used during the observed meeting. There was also a construction phase timeline over the whiteboard and a TV which showed the schedule for deliveries that was updated every five minutes. There were no minutes kept for the meeting, however, new decisions were updated on the whiteboard.

4.6 Summary of observation data

In this section a summary of the observed projects will be presented with dint of the standardised checklist results from the project visits. The focus is given to meetings and meeting structure as well as space and tools used during these meetings.

4.6.1 Site meetings

The observed projects had a fixed schedule for all the meetings and these schedules were available for the workers on site. The daily review meetings were scheduled before the start of the workday, since the information about the work activities, deliveries or safety should be announced before the workers start the workday. A small change of the position of a large machine could be very critical for the safety aspect which should be announced on time. In all four projects, the observed daily meetings had a fixed agenda. However, as described earlier, some topics were not discussed according to the agenda order. Moreover, there were also topics outside the agenda that were discussed in these meetings. The majority of these topics were relevant to work such as questions about deliveries during upcoming week. In Table 4.1, a summary of the observed daily meetings is shown with focus on people, process and technology framework of the study.

Table 4.1 Summary of observed daily review meetings in the four projects.

	Project 1	Project 2	Project 3	Project X
Process				
Fixed agenda for meetings	✔	✔	✔	✔
Minutes for meetings	X	X	X	X
Information is distributed by email	X	X	X	X
Information is available on joint project platform	X	X	X	X
Predetermined roles and responsibilities	✔	✔	✔	✔
People				
Well-informed and prepared participants	✔	✔	✔	✔
Active participants	✔	✔	✔	✔
Cooperative participants	✔	✔	✔	✔
Openness about work-related stress	X	X	X	X
Technology				
Predetermined meeting space	✔	✔	✔	✔
Visual schedule	✔	✔	✔	✔
Digital devices for visualisation	X	✔	✔	X
From-to matrix board	X	X	X	X
Drawings (2D and 3D)	✔	✔	✔	✔
Use of tools during meeting	X	✔	X	✔

In order to have efficient daily review meetings, in all four projects there were predetermined spaces for the meeting and the participants were prepared about their work and questions to other actors in the meeting. These meetings were short, and the information was distributed through verbal communication rather than digital communication tools. In all four projects, in case the person responsible for holding the meeting was absent, another representative from internal management team could hold the meeting.

The coordination meetings with subcontractors were scheduled in the end of the week, since these meetings focused on work activities that were completed and activities during upcoming week, labour and material requirements for these activities as well as questions related to schedule. As stated earlier, all the observed coordination meetings had fixed agendas and all the topics in those were discussed with some deviation from their position in the agenda. Project 1 was the only project in which meeting minutes were uploaded on the joint project platform. In Project 2 and 3 only important decisions

were noted and distributed to concerned actors by email. In Table 4.2, a summary of all observed coordination meetings is shown similar to the summary of daily review meetings. Since the authors did not have the opportunity to observe a coordination meeting in Project X, this project is excluded from the summary.

Table 4.2 Summary of observed coordination meetings in the three projects.

	Project 1	**Project 2**	**Project 3**
Process			
Fixed agenda for meetings	✔	✔	✔
Minutes for meetings	✔	X	X
Information is distributed by email	✔	✔	✔
Information is available on joint project platform	✔	X	X
Predetermined roles and responsibilities	✔	✔	✔
People			
Well-informed and prepared participants	✔	✔	✔
Active participants	✔	✔	✔
Cooperative participants	✔	✔	✔
Openness about work-related stress	✔	X	✔
Technology			
Predetermined meeting space	X	X	X
Visual schedule	X	✔	✔
Digital devices for visualisation	✔	✔	✔
From-to matrix board	X	X	X
Drawings (2D and 3D)	X	✔	X
Use of tools during meeting	X	✔	✔

In Project 2, the observed coordination meeting was an internal meeting were the decisions and information would be verbally communicated to concerned actors during the upcoming coordination meeting with subcontractors. However, important and critical information would be communicated via email to concerned actors.

4.6.2 Space and tools

As the Table 4.1 shows, all four projects had a predetermined space for their daily review meetings with different equipment and visual tools. In Project 2 and Project X, majority of the participants were sitting during the daily review meeting unlike Project 1 and 3 where the participants were standing in the predetermined meeting space. As it

can be seen in the Table 4.1, in all four projects the meeting spaces were equipped with visualisation tools, however, the use of these tools was only observed in Project 2 and Project X.

In all observed projects, there were numerous conference rooms with different equipment and sizes. These rooms were used for meetings, coordination meetings for instance; depending on the availability and number of participants different rooms could be used during this type of meetings. As stated earlier, the coordination meetings in Project 2 have previously been held in the meeting room for daily reviews due to equipment in that room. In other words, the tools used in a coordination meeting depend on the chosen meeting room and the results in Table 4.2 would be different in terms of technology aspect.

5 Analysis and Discussion

In this chapter, the theoretical framework of thesis will be used in order to analyse the empirical findings in Chapter 4. In order to obtain trustworthy and reliable results, the main aspects of the theoretical framework, collaboration, visualisation and meetings, will be used in the analysis. Firstly, the company's working process according to its internal guidelines presented in Section 4.1 will be analysed by applying the theory of current working methods described in Sections 2.1-2.3. Followed by analysis sections where the findings from interviews and observations from the four projects, representing the working methods used in practice, will be analysed.

The second part of this chapter will consist of a discussion subchapter which is based on the authors' understanding of the concept and opinions about the current state of working methods used by the company in different phases of building projects. Research Question 1 and 2 have mainly been answered in Chapter 4, however, additional discussion of these questions is provided in this chapter, along with the answer to Research Question 3.

5.1 Analysis of company's current working methods

In this section, the primary elements from the construction phase presented in Section 4.1 will be analysed by applying the theoretical framework of the thesis. In Table 5.1, the results from the analysis of these primary elements are shown. These results are explained in detail with regards to similarities and differences between the current working methods within the company and the VDC concept. Elements with partial similarities to both VDC and traditional practices, are marked as *intermixture*. Intermixture can be interpreted as traditional practice with elements close to VDC concept that require further adjustments to be classified as VDC concept. Furthermore, the intermixture should not be considered as a deficient classification, nonetheless it should be considered as an improvement area.

Table 5.1 A summary of the analysis of company's current working methods.

Element	VDC	Intermixture	Traditional
Collaboration			
Project phases		✔	
Partnering agreements	✔		
VDC professionals		✔	
Joint project platform		✔	
Visualisation			
Integrated 3D models		✔	
Construction phase schedule			✔
Short-interval schedules		✔	
From-to matrix			✔
Meetings			
Formal meetings			✔
Integrated site meetings	✔		
Predetermined roles		✔	
Usage of tools		✔	

Collaboration

In a Design-Build project, the design and construction phase overlap which reduces changes in schedule and costs due to close collaboration between actors. The concept of VDC could be more efficient in projects delivered by DB method. According to the company's guidelines, the design phase is often completed before construction phase in these projects, aside from projects with other contractual agreements between the contractor and the client. In VDC concept, the focus lies at developing an integrated work environment for all the actors involved in a project, who have different expertise and knowledge for reducing response, information and decision latency. The company guidelines suggest different involvement alternatives of actors from construction phase in the design phase and vice versa, depending on the project size.

In projects with partnering agreements, the conservative view on roles and actors' focus on their own profitability changes through the common objectives and agreed problem solving methods which simplify the implementation of the VDC concept. According to internal guidelines, the objectives for a partnering project should be developed with the client. Information and knowledge exchange are critical aspects for successful collaboration between actors in a project. In the VDC concept, these aspects are reached through digitised tools and methods where the information and decisions are available for everyone involved in the project. The internal guidelines suggest different digitised methods and tools, such as joint project platform, as well as traditional methods for information and knowledge sharing for different phase of a project.

A successful VDC concept implementation requires professionals that have knowledge and skills about the VDC tools and methods, who should be involved in different phases of a building project as separate role or a supporting function of an existing role. In each project delivered by the company, the guidelines suggest a digital leader in design phase and a second digital leader in construction phase who have the responsibility of digital visualisation tools used in projects, entailing that the responsibility area of those roles is limited to one phase in the project.

Visualisation

The success of visualisation aspect within VDC concept, is dependent on the ability, willingness and agreement among the project actors for open information and knowledge sharing through digital tools. This could entail integrated 3D models with accurate information and relations between different elements delivered by different project actors. In the company guidelines, the suggested level of digitalisation varies depending on project size and client requirements. In the current state, these guidelines suggest VDC professionals, digital leaders and digital coaches, as supporting roles during implementation of digital tools with a lack of clarity and information about integrated models during construction phase. In traditional working methods, the reasons for long response latency and high miscommunication are the usage of 2D drawings and paper documents. The company guidelines suggest a joint project platform as one of the three communication and information exchange tool alternatives for a project.

In traditional working methods, Gantt charts with the critical path is the most common project scheduling method, where the critical activities and relations between them is taken into consideration. A digitised schedule with updates in accordance to changes and modifications in project is an important part of successful visualisation and should be available to all project actors. In the current state of company's' guidelines, Gantt chart is the suggested scheduling method for project schedule with the requirement of continuously updates and its availability to all concerned actors. In Lean Construction and in the VDC concept, the aim is to involve each actor in project scheduling process and focus on each project activity in order to reduce delays and misunderstandings amongst the actors with dint of Last Planner method. The short-interval schedules for projects suggested in the company guidelines, focus on activities during upcoming weeks rather than the whole project schedule.

According to the VDC concept and Lean Construction, another success factor for a project is the use of integrated and digitised communication tools which enable efficient problem solving by transparent information and knowledge sharing. The company guidelines suggest a digital from-to matrix as a communication platform for design related issues and questions during design phase in a project with the lack of information about continuity during construction phase.

Meetings

In projects with traditional work methods, despite the technological development, formal meetings are the most used communication method where the predetermined responsibility area of each actor and their role in the project hinder the integrated project delivery. In the company's guidelines, meetings are suggested as main communication

method for problem solving and information sharing between actors, where participants vary between design and construction phase.

In the VDC concept, ICE meetings are used as a platform where collaboration between collocated teams and the use of visualisation tools are combined in order to reduce latency. Furthermore, in Lean Construction methodology, daily meetings are considered to be a method that could improve the engagement and connection of team members. According to company's guidelines, integrated meetings on site, the daily review meetings and coordination meetings, enable information and knowledge sharing between the collocated team during construction phase.

Due to the complexity of tools and methods used in meetings within VDC concept, there is a need for professionals with user knowledge, since the employees often are unfamiliar with those tools and methods. According to theory, this role should also manage the meeting agenda, enable availability of decisions on joint project platform and encourage sidebar conversations. The current guidelines suggest different roles within the internal management team for holding the integrated meetings on site and communicating the decisions to concerned actors in a project. However, there are no guidelines nor example about the usage of the suggested visualisation tools for scheduling, planning and communication during the integrated meetings. Theory suggests that a successful ICE meeting session is also dependent on the layout of predetermined space, the availability and usage of tools for communication and collaboration. On the other hand, the company's current guidelines lack information and description about these aspects for coordination meetings, nonetheless there is a detailed description of how an efficient daily review meeting should held.

5.2 Analysis of interviews and observations

Collaboration

In all studied projects, it was mentioned that extended collaboration between design and construction phase is desired and seen as beneficial. The concept of VDC emphasises both project phases. Namely, there is a will towards working more integrated, however, the internal working processes and procurement agreements do not always support this seen in terms of distinct phases for instance.

Increasing transparency, being one of the essential lean principles, applies well to the process and integration-oriented idea of Virtual Design and Construction as a working method. Transparency and information sharing are fundamental for enabling the key aspects of the VDC work. Hence, it can be argued for the decisiveness of procurement strategies and project internal information sharing methods. Integrated work is synonymous with collaboration between different parties. Working closely with competitors and in multiprofessional constellations in turn is facilitated by partnering and similar agreement forms which incentivise collaboration, meaning that trust needs to be established between the involved actors. Studied projects were chosen with the criterion of being delivered as DB, additionally all the projects had a partnering agreement. Thus, the aspect of collaboration was mainly positive and constructive in the studied projects.

Theory stresses the significance of collaborative environment between the actors for a successful implementation of VDC. Further, research suggests enhanced knowledge

sharing and overall profitability of the project once the actors work integrated towards common objectives. Previous research also implied improved communication between the actors owing to representative models. In Project 2, a creative way of engaging all actors was introduced by collective preparation of a brochure. Inviting key participants with the aim of early involvement across the multiple disciplines creates transparency and mutual trust that can develop into long term relationships between the actors.

Visualisation

As theory proposed, the main issue lies in finding ways of communicating information transparently and clearly among all actors, thus pushing for development of visual process tools which was witnessed in Project 3. In this project, visual representation of completed labour hours is used and pointed out as a successful method for following up the work, and also used as documentation of work in process. A parallel of this method can be drawn to visualising the performance as Planned Percent Completed (PPC) method suggests, but also it resembles Kanban boards, as a method is used to involve project members in the process. Besides, the usage of regular Kanban boards on whiteboards have been observed in several projects, implying that certain visualisation aspect exists in the current working processes in practice.

Theory proposes from-to matrix as an excellent tool for increased transparency and visualising the current burden of different actors. However, none of the interviewees recognises such potential in applying from-to matrix in the construction phase, despite the tool being used in the design phase. Even in the design phase, interviewed design managers expressed the concern of difficulties to motivate correct usage of this visual communication method due to differences and preferences in communication styles among individuals.

Both Lean Construction theories and VDC concept highly call for the usage of integrated 3D models as means to facilitate the communication and improve the understanding between the actors, envisage and strengthen the common project goals, and visualise the interdependencies as well as enable constructability analysis. Research has already appointed the issue of incompatibility among existing software solutions as one of the main obstacles behind fully applying VDC concept as it was imagined. Several interviewees have illuminated this issue as well, implying that the technical hurdle yet has not been overcome. However, empirical findings implied that work disposition plans and 3D models are frequently used in the studied projects. Although, the indications from the practices call attention to a rather limited use of integrated models during the construction phase between the actors. Moreover, continuity in using the 3D models was also stressed as it can prevent misunderstandings such as it was exemplified in interviews in Project 1.

Meetings

The VDC concept advocates fixed agendas and pre-set responsibilities for holding the meeting. Same could be concluded from the empirical findings, although the responsibility for assessing meeting minutes was possessed by the person responsible for holding the meeting in almost all of the studied projects. Here, a difference can be distinguished between what theory suggests and the company's work in practice. Nevertheless, one construction manager did realise the limitation of having the

responsibility for minutes while holding the meeting and thus adapted the guidelines towards what he believed would improve the meeting quality.

As it was stressed in the empirical findings, the theoretical suggestion of involvement and active participation being crucial for the successful meeting outcomes, is also confirmed in practice. Several interviewees have in addition remarked that meeting agendas that are communicated in advance tend to increase active participation during meetings. Furthermore, with predetermined and well communicated meeting agendas higher expectation can be put on the meeting participants and their contribution during the meetings. In such way, meetings can develop into more integrated working settings where issues are raised and solved in collocated interdisciplinary teams. Furthermore, inclusive daily meetings in the beginning of the shift are highlighted among Lean methods and tools in Lean Construction and the concept of VDC as well. Daily review meetings including the whole project team are well incorporated in the meeting structure, assessed by the same fixed agenda corresponding very well with the internal company recommendations.

ICE meetings and VDC concept in general promote collocated multidisciplinary teams working intensely with joint forces, howbeit, in observed projects this idea was not adopted. At the best, coordination meetings are used to reconcile the work progress and project schedule with all involved subcontractors and contractor internal employees. Furthermore, theory behind successful ICE meetings requires use of certain tools and methods, while it became apparent that in Project 1 potential tools were excluded from use as a part of the internal management's decision. Furthermore, information and meeting minutes are rather limited to being emailed to the participants and other relevant team members in three of the four studied projects, which is opposite to the idea of working integrated and using joint project platforms. Despite joint project platforms being well-known, the empirical findings implied that the use of these was restricted and narrow.

5.3 Discussion

Discussion of company's internal guidelines

The division of different project phases in the guidelines suggest Design-Build projects with no overlap between design and construction phase. The success factor of a DB project is related to the overlapping aspect between different phases where issues and obstacles can easily be resolved without significant changes in schedule and costs during construction phase. The fragmentation of phases is common in DBB projects which is considered to be the delivery method with least integrated work environment. Moreover, the involvement of actors from construction phase in design phase, and vice versa, would be limited in a project with fragmented phases. As the theory suggests, integrated delivery methods, such as DB, are dependent on trust among the actors which can develop if the actors collaborate in order to complete the project as a team rather than two separate teams who work in design phase respective construction phase.

Another observed fragmentation is the lack of continuity of different roles from design phase to construction phase. The guidelines suggest two different digital leaders for a project with similar responsibility areas. As the theory behind VDC suggests, the success of an integrated project is also dependent on the continued involvement of same team members rather than introducing new individuals who often do not have the

required knowledge about the project in comparison to individuals who have been involved since the early stages. Another positive outcome of the involvement of one digital leader in a specific project, is the possible continued use of tools and methods from design phase into construction phase. The lack of information about the use of tools like from-to matrix in construction phase could be overcome through the involvement of roles from design phase, such as digital leaders and design managers, with usage experience from earlier stages.

As stated previously, the internal guidelines are not user friendly nor reflect the methods and tools used in practice. It is suggested to develop and implement methods that would be appropriate for the specific project. The last phase of implementation of the VDC concept is automation which could be interpreted as developing a work method that could be applied in every project. However, the current state of guidelines does not support a change towards standardised processes. As a result, each project delivered by the company has different approaches and methods with no further usage in future projects within the company. The limited continuity in use of successful tools and methods is an obstacle for a concept change within the company. If the company had standards for tools and methods used in every project, the outcome would be successful independent of team who delivered the project. Furthermore, the comparison of completed projects with standardised work methods could be more accurate as the metrics aspect of VDC concept suggests. Additionally, the company consigns the project manager to decide which project platform should be used in a project. Providing the project managers with such freedom and entrusting their competence can be defended and justified in several ways, among other reasons it is an exceptional way to motivate and empower employees. However, with this action follows a risk of experienced project managers not choosing the new digitised methods, assuming that they are not familiar or open to the new technologies, or that they simply avoid trying new methods since they are comfortable with the traditional methodologies.

According to the authors, the lack of information and description of integrated meetings in the internal guidelines is an obstacle towards efficient and productive meetings. The current templates, suggested agendas and distribution of meeting minutes in the guidelines, are similar to traditional formal meetings rather than integrated meetings such as ICE meetings. The aim of daily review meetings is distribution of work-related information and solving problems before hand in order to have a productive workday on site. An efficient meeting is not only dependent on the meeting agenda used during a meeting, equally important aspects such as the layout and equipment in the predetermined meeting space should be considered. The current detailed guidelines provided by the company only focus on the daily review meetings, however equal attention should be put on the other site meetings such as coordination meetings.

Discussion of observed working methods in practice

In Project 2, the construction manager stated that he exclusively attends meetings that are important and where he can contribute with information and knowledge. However, it might be difficult to foresee issues and questions that may occur in a meeting. Moreover, the absence from a key player such as the construction manager might result in phone calls and email conversations in order to get the required information. According to the construction manager, other representatives from internal management team have the required knowledge about the project, in other words his

absence would not be a critical aspect in a meeting. However, a foreman does not have the same authority as a construction manager which limits their ability to make important decision in a meeting without the construction manager which would increase the decision latency. A successful integrated meeting has low decision latency.

Verbal communication is the most preferable method among the workers on site in order to solve issues. According to the interviewed subcontractor representative in Project 2, this is due to the reduced response latency in comparison to an email conversation. However, the internal management team stressed the importance of reduced unplanned conversations with workers in sheds due to unresolved issues or questions. The productivity of the workday for the internal management team would be reduced if every worker knocked on the construction manager's door in order to get questions answered. Nevertheless, the authors believe that the use of a digitised from-to matrix could solve this issue. Moreover, due to the transparency of this visual communication tool, the same question would not be asked by multiple actors on different occasions. Additionally, the possibility of own decisions taken internally in the project, regarding exclusion of certain tools in the project based on what the project management team considers non-value adding, presents a hurdle to wide application of the VDC concept within the company. Project 1 might have made the right decision for the project from their own organisational perspective; however, these decisions affect the entire company in the long run and prevent potential concept change towards VDC.

Theory highlighted the issue of communicating clearly when using visual management tools. Furthermore, the importance of clear and concise formulation in words when using from-to matrix to avoid potential misunderstandings was problematised by one of the interviewees. Hence, a need to introduce general education for project teams related to the specific tools, but also education in effective communication is detected. This aspect was highlighted by interviewees from Project 3, who provided basic training sessions about the digital tools used in projects for skilled workers and subcontractor representatives with limited experience with these tools.

In Project 3, the response and decision latency were low due to the size of the project where the actors and internal management team had worked in previous projects. As it was stated by interviewees from construction phase in this project, that verbal communication is used to resolve issues. However, in a more complex and bigger project delivered by teams who do not have previous work experience with each other, the response and decision latency would be higher. In a project with a greater number of actors involved, this method of verbal communication would not be an optimal communication method to solve issues. In Project X, due to the higher number of actors involved in the project in comparison to Project 3, the verbal communication would be less efficient and productive for the internal management team. As stated earlier, the workers prefer verbal communication due to low response latency. However, the internal management team of a complex project, Project 2 and Project X, prefer less unplanned verbal communication during a workday.

Another advantage of the project size of Project 3 is the success of the short-interval schedules over labour hours. Those physical boards would be time consuming for a more complex project, for instance Project X and Project 2. The involved actors in Project 3 had previous work experience with each other, in other words this was not a new working method which would require time to adapt and attain user knowledge. As

a result, any mismanagement or errors in this short-interval schedule method from previous projects delivered by the same team would not be repeated. Moreover, decisions made in a coordination meeting in Project 3 are easier to verbally communicate due to the low number of workers on site. Regardless the lack of observation during a coordination meeting in Project X, based on the remarks from interviewees, coordination meetings in this project were better structured and could be adapted to complex projects with higher number of involved actors. Since the meetings were kept in minutes by one participant while another was holding the meeting, unlike Project 1 where the participant was both holding the meeting and keeping the minutes.

Discussion of barriers and challenges

As it was discussed earlier, company's internal guidelines allow project teams and management staff of the project to choose methods and specific tools and adapt them to the specific project. Consequently, the use of tools and methods varies among the studied projects. Additionally, the empirical findings indicated difficulties related to motivating subcontractors to adopt the same solutions that the company uses. All this contributes to aggravating the common use of same and compatible solutions, which in turn diminishes the potential of visual and collaborative aspects of the integrated working methodology. Moreover, application of tools such as from-to matrix requires all actors to engage in active use and to master proper usage of the tool in order to gain efficiency benefits. Again, integrated multidisciplinary effort towards the common goal is stressed as a crucial factor in advantageous implementation of new working methods.

Empirical findings implied differences in individual human attitudes towards integrated working. Despite AEC industry being highly dependent on cooperation, there are plenty of individuals and companies who do not understand the potential and benefits of early joint planning and integrated problem solving. For instance, in one of the interviews it was discussed how self-willed actors can impede the work in meetings by not being aware of the common goals and regarding the project only from their own standing point. The VDC concept presents tools and methods that can be applied to overcome this issue. However, theory highlights that individual attitudes towards change are decisive for organisational change as people are the crucial factor. Thus, change management is necessary when it comes to reforming deeply rooted patterns and structures that exist in the industry to overcome these barriers. Likewise, if there is pessimism towards the change even only on the individual level, how engaged are then these individuals in implementing the change? Evidently not engaged, which leads back to the importance of regarding the organisation as a socioemotional system, where the people aspect is essential not at least when changes are introduced.

Both the contemporary research in the field of knowledge transfer and multigenerational workforce, and some of the interviewees, indicated difficulties in using digital tools and new methods. According to several interviewees, the younger generations are more willing to adapt and use new methods and tools in their work life. However, they often lack the authority to implement changes in a project that could improve the productivity, consequently these changes that might require time and additional costs as well as user knowledge. The experienced workers and employees, who have the authority to implement changes, are not willing to adapt methods and tools due to unfamiliarity and lack of user knowledge. In other words, there is a risk of continued use of traditional working methods in future projects. This resistance towards

change was observed during the interviews, majority of the interviewees were reluctant of implementing from-to matrix board as a communication tool during the construction phase, despite the lack of previous experiences of this method during construction phase in projects. Several of the observed projects had however adopted a digitised from-to matrix board during the design phase with no continuity in construction phase.

Furthermore, several interviewees with previous experiences of integrated communication methods stated that due to the complexity of these methods the implementation in construction phase would not be as efficient. The issues and obstacles that might occur during construction phase often require immediate solutions, low response and short decision latency. The optimal communication method for those issues and obstacles is verbal communication according to interviewees and preferences among skilled workers. However, several interviewees mentioned that rework and delays have occurred due to miscommunication and late response from different actors. Moreover, an interviewee mentioned that in some cases subcontractors have to be reminded to answer a question. This could have been avoided if visual and integrated communication methods were used, from-to matrix for instance, where questions and answers between the actors are transparent for everyone and where clear deadlines for latest response can be set to ensure faster communication.

The authors believe the VDC concept could be used as a framework by construction companies that are interested in improving their project outcomes by adapting integrated working methods. Due to the widespread resistance in the industry towards changes, the implementation process could be divided into stages with minor changes to the existing methods. However, implementing or using limited VDC methods or tools might only cover some aspects of the whole concept, resulting in possible partial improvement, howbeit the full effect could never be achieved due to previously explained dependency between the different aspects.

6 Recommendations

In this chapter, a number of recommendations considering changes towards a more integrated work environment for the studied company will be presented. However, these recommendations could also be applied by another construction company with comparable work methods and similar issues. The chapter ends with recommendations for future studies within the same area of research.

6.1 Standardised work methods

The implementation of an integrated working concept like VDC requires standardised processes and work methods that could be applied in every project delivered by the company. In the current state, projects delivered by the company have developed own processes and methods, since the internal guidelines give general suggestions for these aspects. As it was observed by the authors and mentioned by several interviewees, the complex layout of the guidelines on the company's intranet makes the information hard to collect. The user friendliness could increase by improved search function and relevant information for a specific project, for instance a selection based on project size, contractual agreement etc.

Another advantage of standardised work methods is the successful project outcomes regardless the project team. It might be rather challenging to have the same organisation in each project delivered by the company due to project size, time and location. As a result of standardised work methods, tools and user-friendly internal guidelines, a project delivered by an inexperienced team could be as successful as a project delivered by a team with several previous project experiences with each other or a team with several years of work experience in the industry.

6.2 Early involvement of key players

As the theory suggests, an integrated work environment results in successful projects due to information and knowledge exchange between actors with expertise in different areas. As several interviewees pointed out, many of the schedule changes and additional costs could be avoided if several roles from construction phase were involved in the design phase and vice versa. It is recommended to have a construction manager and a foreman from each project involved in the design phase, on the other hand the design manager and the digital leader from the design phase should be involved throughout the construction phase. This recommendation could be more beneficial if the project phases, particularly design and construction, are overlapping since it enables interaction between players with responsibilities for different project phases.

In order to implement changes without resistance from employees, it is recommended to involve them in the implementation process and give the workers opportunity to develop work methods and tools that could simplify the activity which they carry out. Workshops about these changes with all concerned actors could give successful outcomes. Due to different work methods used by different companies in construction industry and within same company, it is recommended to inform about processes and methods used in the specific project. This could be carried out during workplace introduction, if the project has a from-to matrix or only digitised drawings on site, workers should be informed and educated about these tools.

6.3 Integrated site meetings

The current state of site meetings requires change towards more integrated and efficient meeting structure. The internal guidelines should have more detailed and relevant information about meetings which should be a standard method that could easily be applied in every project delivered by the company. A fixed agenda, minutes for important decisions and information uploaded on joint project platform, and rolling secretary schedule, are the main suggestions for more efficient coordination meetings. For daily review meetings, a fixed agenda with focus on questions and issues related to work activities, a decision list uploaded on joint project platform would make these meetings more efficient. Moreover, the integrated meetings on site and the purpose of these as well as the expected contribution from each actor should be informed during the workplace introduction. This could increase the engagement and inputs from participants during those meetings and reduce decision latency.

The guidelines should also suggest continuous usage of communication tools like from-to matrix in later phases of a project. A standardised meeting structure, suggestion for placement and layout of space for daily review meetings, and a list of visualisation tools and their possible use in meetings should be available on the intranet. As it was observed by the authors, in projects with predetermined meeting space for daily review meetings without disruption from external factors, the meetings were more structured and efficient. In coordination meetings in which project schedule and drawings were used, questions and issues were easier to solve.

6.4 Digitised and integrated communication methods

With the recommendation of integrated site meetings, introduction and continuous use of digitised and integrated communication methods also follows. For efficient information sharing in project teams, both in meetings and throughout the project, proper use of suitable tools and methods needs to be included. However, in order to overcome eventual misunderstanding, misinterpretation and misuse of the tools, a constitutive training should be provided. The training would, besides increasing technical competence among employees, serve as way to allay the fear and aversion towards what previously has been unfamiliar and new. Considering the benefits and efficiency improvements that can be attained, the company is recommended to provide basic training to all of its subcontractor representatives who are involved in the projects. To specify, the authors suggest continued use of from-to matrix in the construction phase, which demands that the company puts higher requirements on subcontractors and their collaboration. From-to matrix is already a familiar tool among most of the internal employees which should favour its implementation. This visual communication tool would be especially advantageous in complex projects with a high number involved actors. Since it facilitates faster answers to questions, increases transparency, creates clarity in responsibilities and serves as documentation of the work in process. Furthermore, extended use of joint platforms is recommended to facilitate information sharing.

Based on the issues identified in practice, the company has a high potential in employing more digitised and integrated communication means within the construction phase. This change needs to be done on a strategic level and commanded top-down in the organisations in order to reform the internal practices. In line with change

management theory, it is important that the change is communicated clearly to everyone in the organisation. The employees must understand the benefits that the change would imply for each and one of them. Thus, an open dialogue about the new integrated methods and tools should be initiated, including the long-term partners and subcontractors in this conversation. Furthermore, exemplifying and bringing forward the facts of efficiency improvement could help with increasing the understanding for the benefit of the change, and in that way ease the resistance. The authors also recommend the company to involve its employees in the process of implementation and development of the new tools and methods, as the theory behind change management suggests that engaged participants accept the change more easily.

6.5 Future research

This thesis focused solely on projects delivered as Design-Build with partnering agreements, where it was possible to follow the contractor's role and involvement during both the design and construction phase. However, it might be of huge interest for the contractor to evaluate benefits of VDC-like methods in Design-Bid-Build projects as well. There are several aspects to be considered in other delivery methods connected to possible change of working methods towards the VDC concept, not the least the bridging phase and collaboration between design and construction phase grows in significance.

Another important aspect for a successful VDC concept implementation, is the willingness and resources for adopting an integrated and digitised work method, from client and subcontractors. The client aspect could be examined through client interviews in future research. Opinions from other key players, such as subcontractors who are involved from early stages, and skilled workers who deliver the end product according to details and plans developed during design phase, should also be further researched. Since an integrated work environment can only be successful with the information and knowledge exchange from each player. The company might develop internal guidelines towards more integrated and digitised work methods; however, they are not the only player who delivers the project and the opinions from other key actors should also be take in consideration.

The digital tools used in the project is another critical aspect for the implementation of an integrated project delivery. BIM models and LOD levels are two key aspects that could be further researched in order to get a better picture of the current state of digitalisation within a company and possible future direction towards a more integrated work environment. Lastly, metrics aspect would be of interest for the company to investigate in order to compare and evaluate the performance and efficiency improvements that the VDC concept contributes with in different projects and phases.

7 Conclusion

This study has focused on productivity improvements in construction phases in Design-Build projects delivered by a Swedish contractor through integrated working methods and tools within the VDC concept. The study has showed, the current state of the company's management practices is an intermixture, which lies between traditional and integrated work methods, with potential improvements by dint of integrated site meetings and early involvement of key players, digitised communication methods as well as standardised working methods.

The empirical findings showed that the internal guidelines are not user friendly and do not reflect the methods and tools used in practice, due to indeterminate suggestions for implementation of different methods and tools. The guidelines lack suggestions and description of concrete examples of these. Consequently, each project reminds of an independent organisation, weakening the knowledge exchange within the company. In regard to findings from observed projects and internal guidelines, the company has well-structured and planned integrated work environment within the design phase, however, the continuity lacks in further phases. Furthermore, the empirical findings showed a widespread resistance amongst the company's employees and skilled workers, towards adaptation and implementation of new communication methods and tools in the construction phase. Despite these methods and tools being applied in the earlier phases of the same project.

Additionally, the empirical findings indicated hurdles and lacking compatibility between the existing technological solutions as some of the main challenges towards integrated working methods. Furthermore, the reason behind widespread resistance towards the VDC methods and tools, is the unfamiliarity and inexperience among the older generations. However, the younger generations are more willing to adapt and employ these methods and tools. Albeit, the younger generations often do not have authority to implement changes in working methods. This responsibility remains with leading roles that require several years of experience in the industry, meaning that these roles often are possessed by older generations.

Lastly, the lack of research within construction phase regarding integrated working methods was found as another barrier towards adapting these working methods in the construction phase. Hence, the full potential of VDC is being lost in the transition between the project phases.

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9 Appendix A - Checklist

Project		Observation Date
	Observation People and Process	**Comments**
Yes/No	**Meeting type?**	
	Who is responsible for holding the meeting?	
	Who is participating at the meeting?	
	Is there a fixed room or space for the meeting?	
	Is there a fixed agenda for the meeting?	
	Does everyone get the opportunity to talk or ask questions?	
	Does everyone get answer for their questions?	
	Do they follow the internal guidelines?	
	How is the atmosphere during the meeting? (Happy and active participants)	
	Is the division of workload even between the participants during the meeting?	
	Are the participants open about their problems and/or job-related stress?	
	Is there minutes or decision list for the meeting?	
	Observation Technology	**Comments**
Yes/No	**Is there any meeting room/space?**	
	More than one meeting room or space?	
	Do we have a picture of the meeting room/spaces?	
Yes/No	**Are the meeting rooms furnished?**	
	How does the furniture look? (long table or bar tables?)	
	Fixed furniture?	
	Is there a coffee machine in the room?	
Yes/No	**Tools and aids?**	
	Is there a projector?	
	Do they use it during the meeting?	
	Is there a TV?	
	Do they use it during the meeting?	
	IS there a Touchscreen?	
	Do they use it during the meeting?	
	Visual schedule (digital or tangible?)	
	From-to-matrix board (digital or tangible?)	
	Drawings (3D models or 2D?)	
	Do they use it during the meeting?	
	Is there a minutes or decision list for the meeting?	
	Do they use it during the meeting?	

10 Appendix B - Interview Questions

Introduction

- A brief introduction of us and the thesis
- Explain the anonymous interviews and ask if we can record the interview

Part 1 - The interviewee

- What is your earlier education and experience in the construction?
- What is your role in this project?
- How long how you been working in the company and in this project?

Part 2 - Meeting structure

- What are the meetings you participate in and what is your role in those meetings?
  - If you miss a meeting, how do you get information about the decisions made in that meeting?
- Do you follow internal guidelines for meetings in this project?
  -If not, why?
- What do think about the arrangements/agenda for the meetings?
  - Do you have any improvement suggestions?
- What are the pros and cons of the current the arrangements/agenda for the meetings?
  - Can you give some examples?

Part 3 - Tools and method for communication

- What kind of communications tools do you use in this project? (Some examples: phone, mail, conference call, Digital project platform etc.)
- Do you have any earlier education about communication and collaboration?
  - What was the education about?
  - Do you wish another education in those areas for yourself or others in this project?
- How fast do you solve a problem or answer a question between different actors in this project?
  - What do you do to solve the problems fast?
  - What are the reasons for problems that take a long time to solve?
  - Do you have any improvement suggestions for solving problems faster?
- How common is miscommunication in this project?
  - What do you do to reduce miscommunication between actors?
- Do you use tools such as From-to-matrix, KanBan-board or other tools for communication?
  - If not, why?
  - Would you be open for trying any of these tools in this project?

Part 4 - Collaboration

- Which actors tend to be most active or less active during the meetings?
  -What do you think the reason for that?
  - What can you do to make all the participants more active?
- How is the atmosphere in the meetings?
  - Which actors are least cooperative-minded? Why?
- Do you see any benefits of having people from design phase that continue in the production phase or vice versa?