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Preface

This master thesis is a part of the two-year Master of Science (MSc) programme Industrial Economics with a specialization in Project Management at University of Stavanger (UiS). The thesis is written during the spring semester from January to June 2018.

From earlier study, I have acquired a bachelor's in civil engineering, specializing in Construction Technics. During my bachelor studies I gained taste for project management, and this thesis gives me opportunity to combine my interests with my study programme. The topic has been chosen to develop a combination of knowledge to become a good project manager in construction projects after university. The study is an individual project, with generous contribution from Norconsult and AF Gruppen.

I want to start by thanking my supervisor Jan Frick at UiS for the teamwork from thesis beginning to the deadline of this master thesis. Further, I would like to thank my external supervisors at Norconsult; Kathrine Opdahl Sousa and Thomas Bauer Sousa.

Also, thank you to all the people that have showed interest in my master thesis and contributed through interviews and opinions during this period. Additionally, I would like to thank the people that have made me feel welcome at my new work sites at Norconsult and at the Bispevika rig.

Henrik Parnemann

Henrik Parnemann, 14/06-2018

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Abstract

A shift towards a more digitalized construction industry have led to an increased focus on tools as *Building Information Modelling* (BIM), integrated environments, new planning tools and more efficient meeting layouts. The interest for *Virtual Design and Construction* (VDC) is rapidly increasing as construction firms aim to deliver higher quality to shorter scheduled projects. Virtual Design and Construction are considered as a framework of tools and techniques bound to a collaborative system for improved project completion supported through digitalized solutions.

This thesis has been written in collaboration with Norconsult and AF Gruppen and aims to map how Virtual Design and Construction can identify latency and reduce delays in project throughput. In conjunction with the assignment, Project Bispevika, delivered by AF Gruppen has been used as the primary case due to its integration of VDC tools and techniques.

Initially, a literature study has been conducted to form the theoretical foundation of this assignment. In this thesis, mainly qualitative research methods through observations and interviews has been applied to dig deeper into challenges in the design-construction process. Mainly, the VDC aspects *Production and Process Management* (PPM) and *Integrated Concurrent Engineering* (ICE) has been evaluated as these are the less researched parts of VDC and not as commonly used in the construction industry.

Observations and interviews has highlighted the varying degree to which VDC is implemented in organizations, exemplified through Project Bispevika. The thesis is using Project Bispevika as case study. The thesis takes a deeper dive into how metrices are used to continuously improve meeting, planning and coordination. The project is divided into two sub-projects: Bispevika B2 and Bispevika B6a including 1 and 9 constructions respectively. Last Planner System, metrices, BIM level 2 model, ICE sessions, Big Rooms and integrated environment are some of the VDC practices implemented in the project.

Results from the case study, backed by interview participants from several design and construction organizations indicates that the focus on using the VDC framework is improving project delivery. Meetings are optimized, planning are more efficient, latency is reduced, and root causes are not only identified, but categorized and documented for benchmarking in later projects. Metrices is used to identify areas with potential for improvement, where products, organization and processes are continuously improved. This research shows that Virtual Design and Construction in this case study are creating better foundation for collaboration. The

framework also helps detect latency with potential for improvements and benchmarking. This thesis is underlining some of the potential root causes to latency, where further research should be made on reducing latency from the root causes detected.

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Acronyms

AEC – Architecture, Engineering and Construction

BIM – Building Information Modelling

CAD – Computer Aided Design

CII – Construction Industry Institute

CIFE – Centre for Integrated Facility Engineering

IFC – Industry Foundation Classes

IPD – Integrated Concurrent Engineering

KSF – Key Success Factor

LCI – Lean Construction Institute

LOD – Level of Development

LPDS – Lean Project Delivery System

LPS – Last Planner System

MMI – Maturity Model Index

nD – n dimensions (3D, 4D…)

POP – Product, Organization and Process

PPC – Plan Percent Complete

PPM – Process and Production Management

SBD – Set Based Design

TPS – Toyota Production System

TVD – Target Value Design

VDC – Virtual Design and Construction

Chapter 1: Introduction

This chapter will introduce the motivation and reason for the chosen focus and topic for this master thesis.

Criticized efficiency in the construction industry

For several decades, the design and construction industry has faced criticism for low efficiency and lack of innovation. According to Lincoln & Ahmed (2011), improved productivity is related to improved research and development (R&D) in every industry. The design and construction industry have a challenging environment for innovation as design-construction projects are becoming larger and more complex than before (Lincoln & Ahmed, 2011). Parallels to several other industries is underlining a significant potential for improvements in the construction industry (Teicholz, 2001; Thune-Holm & Johansen, 2006; Ingvaldsen & Edvardsen, 2007).

Introduction to Virtual Design and Construction (VDC)

Virtual Design and Construction (VDC) was introduced in 2006 by Center for Integrated Facility Engineering (CIFE) in cooperation with Lean Institute (Khanzode A. , Fischer, Reed, & Ballard, 2006). Virtual Design and Construction is not a new product nor an innovation, but a framework that sets already existing ideas, the use of Building Information Modelling (BIM) and Lean principles in a system. From its introduction, several companies have established its framework to their practices and VDC projects are becoming more commonly used. In Norway, organizations as Veidekke, AF Gruppen, Skanska AS, Kruse Smith, Norconsult, Multiconsult and several others has adapted VDC to their way of delivering projects (see Figure 19). However, the VDC framework and Lean principles are more easily adaptable for the construction phase, where there has been a higher focus on waste over a longer period (EngineeringManagerAF, 2018). This has resulted in adapted VDC courses internally in companies parallel to the increased interest for Stanford's VDC education. Recent research has shown an increased interest from Norwegian companies underlining their belief for potential improved project delivery using VDC (Figure 19).

Thesis focus

The number of tools & techniques implemented in the construction industry has rapidly increased. Lean techniques, different dimensions of BIM and new collaboration tools has been applied. VDC uses these tools to create a framework. This thesis, created in collaboration with

Norconsult and AF Gruppen shall analyse the case Project Bispevika and their use of the VDC framework in terms of coordination, efficiency, latency, communication pathways, and continuous improvement.

Chapter 2: Background

The second chapter will underline the topic of interest in the perspective of the companies involved. This thesis is written in collaboration with Norconsult with two mentors from their Sandvika office. Additional, the case study used is Project Bispevika with the contractor AF Gruppen. The case study has received close follow up by the project team at Bispevika consisting of AF Gruppen and Norconsult representatives. The chapter will therefore underline the motivation from Norconsult and AF Gruppen for the conducted thesis.

2.1 Integrated Environment

A big part of the Virtual Design and Construction framework is the working methodology. The concept is called Integrated Concurrent Engineering (ICE). ICE is not an innovation in the VDC framework, but has had an increased focus. The ICE concept on workplaces is creating an integrated environment and is providing a common workspace for project participants to reduce barriers for communication and teamwork. The adaption of an integrated environment has helped shifting the workload to an earlier time in the project timeline which is claimed to reduce wastes and improve project delivery.

The process of having more focus on engineering and design before construction phase is shown in the McLeamy curve (Figure 1) (Lu, Fung, Peng, Liang, & Rowlinson, 2014). The integration of ICE aims to improve the communication process that is responsible for:

- Struggling in capturing, structuring, prioritizing and implementing client needs.
- Design, fabrication and construction are done independently. Data from one-stage is transferred, where information is hard to read and lost in the process.
- There is a lack of integration, co-ordination and collaboration between the various functional disciplines involved in the life-cycles (as costing, maintenance etc.).
- Lack of information is resulting in design errors, which results in waste through re-doing design and work-packages.

The McLeamy curve is illustrated in Figure 1. The figure is describing a situation where a project moves from making decisions unnecessary late based on poor knowledge to use more time at an earlier stage in the design phase, working in an integrated environment to make those important decisions. The curve shows the ability to make changes is decreasing throughout project lifetime (shown with blue line and labelled no. 1 in Figure 1) and costs of making changes to the design is rapidly increasing (shown with red line and labelled no. 2 in Figure 1). The criticised design process is illustrated with a black line numbered 3 in Figure 1 named

Traditional design process. With effective meeting philosophy, clearer agenda and better decision points – Fischer & Kunz (2012) believe that design performance can improve, and project schedule and costs can decrease. This could cause an effect shown with the green arrow, resulting in the burgundy line numbered 4 in Figure 1.

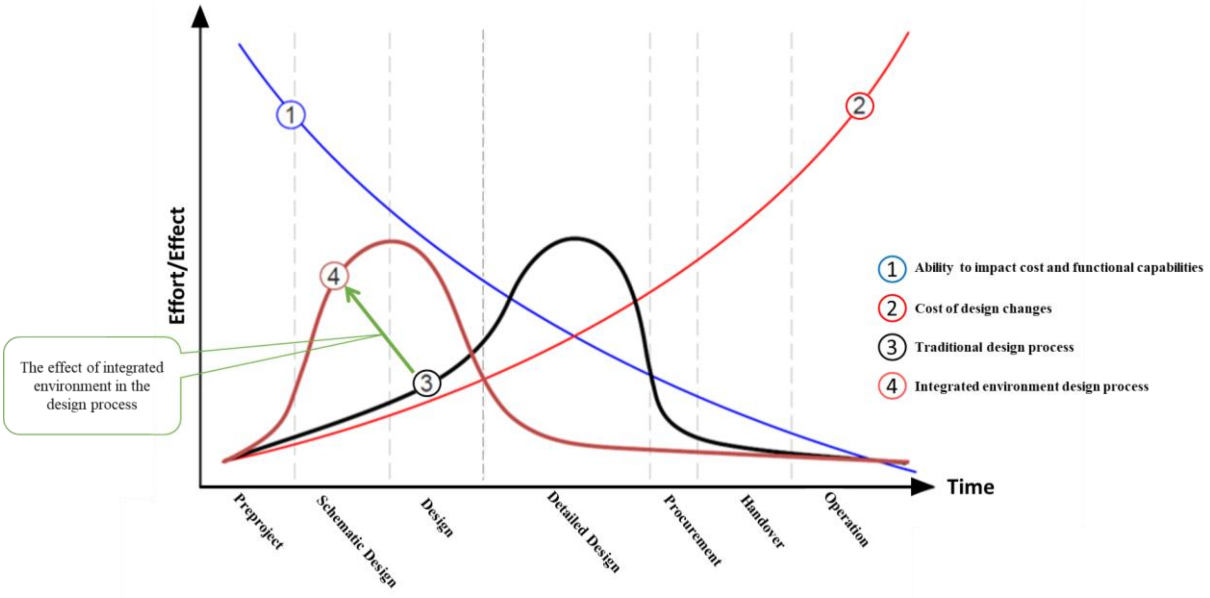


Figure 1: The work effort and effect shift using integrated environment in the design process (Holzer, 2012). The objective to be attained when implementing VDC.

The McLeamy shift shown above is not achievable by only placing a team in an integrated environment. To achieve more effective project planning and project delivery with better quality it is needed to create better processes, using the correct tools, and improve teamwork. These are aspects of the VDC framework, where ICE is creating the environment using these aspects. Companies have shown an increased interest for the framework (numbers presented in Figure 19 in section 6.1 VDC as an emerging framework). Information flow often done through a BIM model presented (KruseSmithVDCcoordinator, 2018). The combination using ICE culture with BIM toolset is emerging as a big part of the foundation of VDC. VDC have had an increasingly interest from contractors and consultants. The VDC framework has so far only been partly integrated in project deliveries. (KruseSmithVDCcoordinator, 2018)

2.2 Involved organizations motivation for master thesis

In collaboration with Norconsult it is interesting to research how VDC is used in practice at Project Bispevika. The Virtual Design and Construction framework is easily adopted to the construction phase, where the framework is more researched and used. Norconsult along with other consultants are interested in adapting the VDC methods to their projects. It is therefore of interest to observe how VDC is used at Project Bispevika where its aspects have been used in all project phases.

According to NorconsultProcessManager (2018) important decisions should be made already in the pre-project phase. Client objectives, project objectives, and client involvement are important topics that should be established from the beginning. Design phase are criticised for design loops where work-packages must be done multiple times because of the above-mentioned topics have not been clearly identified. (NorconsultProcessManager, 2018)

Further, special aspects of the framework are of special interest. BIM and Lean has been well researched before and are aspect inside the VDC framework. Production and Process Management (PPM) is less researched and metrices has shown to be a challenge in VDC projects conducted so far. Metrices is also the least researched area. How metrices are used in Project Bispevika to improve project delivery has therefore become one of the research questions answered in this thesis.

Project Bispevika is further described below, where it is described that it consists of two parts (B2 consists of constructing one building and B6a consists of construct nine buildings). This thesis will observe and analyse how VDC is mainly used in Project B2 and what lessons learned from B2 that can be improved and implemented to Project B6a. It is therefore of interest for AF Gruppen to investigate how meetings are conducted, how coordination is at the Team Bispevika rig and what responses team participants are making through questionnaires and interviews to make improvements. The master thesis does also have the opportunity to be integrated in a book project developed by AF Gruppen.

2.3 Case study: Project Bispevika

Bispevika is consisting of two projects: Bispevika B2 and Bispevika B6a. They are including 1 and 9 constructions respectively and are located just by Barcode.

Bispevika is using Virtual Design and Construction throughout the design-construction process. The case is therefore seen as valuable for evaluating the use of VDC in projects. Practices as Big Rooms, The Last Planner System and ICE practices are used in the project and evaluated in the thesis. Metrices are used to measure client satisfaction, meeting efficiency, latency and team performance. At Project Bispevika, there is a high focus for innovation, which is reflected in the case. AF Gruppen are using BIM level 2 at Project Bispevika. (AFgruppenTender, 2016)

PROJECT BOX:

Number of buildings constructed: 10

Number of apartments: 365

Construction time: 3 years

Total money involved: 1150 million NOK

TEAM BISPEVIKA

2.4 Research scope

The main objective of the thesis is to evaluate if Virtual Design and Construction can improve project delivery. This is done by analysing how VDC are used in Project Bispevika. It includes how metrices are used, presented and what to gain from them, how ICE sessions are conducted, how meetings and workspace are coordinated and how team Bispevika continuously works towards optimizing processes. The scope is limited to the construction industry and limited to aspects involved in the case study. The master thesis is a 30 credits study, developed over a 21-week time interval. The time interval has resulted in a limitation to seven interview attendees and one case study. The chosen interview participants have been selected based on their background and variety to include both perspectives from operations- and design & engineering departments at Project Bispevika, as well as input from consultants and contractors from external companies.

It has been chosen to do a deep dive into one project (case study Project Bispevika) rather than several cases. The case study is one of very few projects in Norway of this size focusing to such a high degree at Virtual Design and Construction throughout the project (AFgruppenTender, 2016). Then, it was seen as beneficial to use significant more time on-site to observe behaviours and dive deeper into this case.

Due to the thesis is using one case compared to several cases has presented that the results gained in this thesis, is an indication of what can work, but not an overall answer for the rest of the construction industry. Project Bispevika is used as an example on the design-construction progress, but the general form of construction projects can vary.

Chapter 3: Topic of Master thesis

This thesis aims to identify reasons for latency in the design-construction process. The thesis is looking further into the use of Virtual Design and Construction (VDC) in the design-construction process. VDC is the framework considered as it is one of few practices that is quantifying processes and activities. Latency is arriving from multiple places during the design-construction process. This thesis is therefore evaluating the use of metrices as a VDC tool in Project Bispevika to improve planning, coordination, latency and ICE sessions.

Currently, it is little written information about root causes to latency in design-construction projects. The use of Virtual Design and Construction in projects aim to reduce latency, but are currently relatively new to the industry. Therefore, it is necessary to use case analysis to observe and interviews to gain insights about possible root causes to latency.

The question this master thesis aim to answer is:

Can Virtual Design and Construction improve project delivery?

The topic is having the following four research questions:

- Which VDC implementation is crucial to benefit from its framework?
- What projects will benefit from using VDC?
- What are typical reasons for latency?
- Which reasons for latency can be reduced using VDC?

Chapter 4: Theory – Virtual Design and Construction (VDC)

The theory chapter is mainly based on literature research and been backed by interviews. The chapter is explaining Virtual Design and Construction (VDC) designed by the three pillars *(1) Building Information Modelling (BIM), (2) Production and Process Management (PPM),* and (3) *Integrated Concurrent Engineering (ICE).* PPM is further divided into two areas, lean tools and techniques where the last planner system has been the main focus, and metrices where latency and root cause analysis is included.

4.1 Introduction to VDC

Virtual Design and Construction (VDC) is developed by Center of Integrated Facility Engineering (CIFE), Stanford University. It uses a multi-disciplinary performance model for design and construction with the attributes as illustrated in Figure 2.

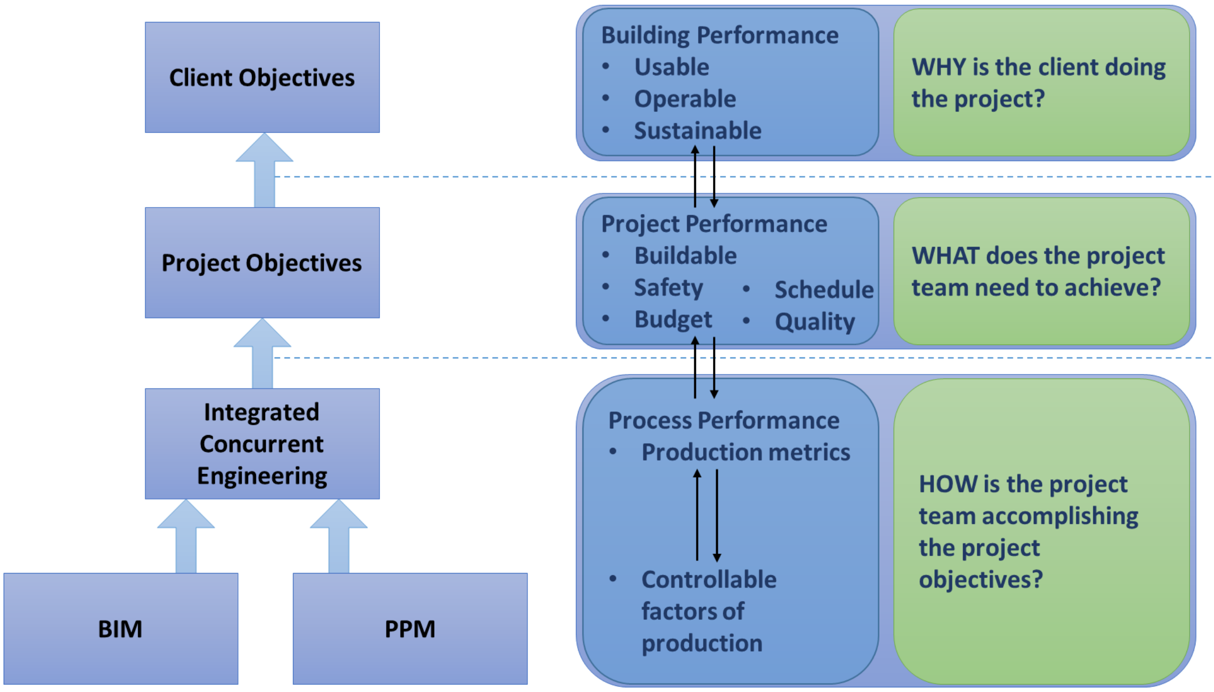


Figure 2: VDC topics with corresponding performance

Figure 2 is illustrating that the VDC phases are aiming to reduce barriers for communication between process-, project- and building performance. Integrated Concurrent Engineering (ICE) are working as a methodology to connect tools and techniques in Process and Project Management (PPM) and BIM, to project- and client objectives. According to Kunz & Fischer (2009) – Virtual Design and Construction is defined as:

"the use of multi-disciplinary performance models of design-construction projects, including the Product (i.e., facilities), Work Processes and Organization of the design – construction – operation team in order to support business objectives"
- Kunz & Fischer (2009)

VDC is based on the three pillars BIM, ICE and PPM referring to products, organization and processes found in all projects. The product delivered can be the BIM model or the finished construction. Organization include how teamwork, coordination and communication are aligned in the company, and PPM is referring to processes of work. These are further described later in the theory chapter. (Khanzode, Fischer, Reed, & Ballard, 2006)

Metrices are introduced in later sections, notable is that Table 8 is addressing project objectives in Figure 2 "WHAT does the project team need to achieve?". Table 6 and 7 introduced later in this chapter is addressing process objectives in Figure 2. This will be further explained later in the chapter.

Innovation was first defined by Joseph Schumpeter: (Schumpeter, 1934)

Innovation is

1. *The introduction of a good (product), which is new to consumers, or one of higher quality than was available in the past;*
2. *Methods of production, which are new to a particular branch of industry. These are not necessarily based on new scientific discoveries and may have, for example, already been used in other industrial sectors;*
3. *The opening of new markets;*
4. *The use of new sources of supply;*
5. *New forms of competition, that leads to the restructuring of an industry.*

According to this definition – Virtual Design and Construction (VDC) cannot be categorized as an innovation. VDC is a system combining already existing ideas and techniques. Tools and techniques have existed for a long time, but in practice they haven't been used this integrated before. VDC is therefore not an innovation, but it is seen as beneficial for organizations to adapt the framework to their project deliveries.

4.2 Process and Production Management (PPM)

PPM is one of the three foundation blocks developing VDC (shown in Figure 2). PPM has several overlaps to Lean Construction where wastes, Lean Design Process and Last Planner System is presented below.

4.2.1 Lean Construction

From the development of Toyotas Production System (TPS), the Lean Construction Institute (LCI) has adapted their principles to the construction industry. LCI claims that a construction project in fact are a production system, which makes it possible to manage using lean production theory and techniques. However, its needed a fundamental shift from Toyota's Lean Production System (TPS) to make it fit the construction industry. Lean Construction is a new way to manage construction projects. Principles and techniques from Lean are brought into the construction industry to form the basis for a new project delivery process. Lean is described by The Construction Industry Institute (CII) as:

> *"the continuous process of eliminating waste, meeting or exceeding all customer requirements, focusing on the entire value, and pursuing perfection in the execution of a constructed project"*
>
> - Diekmann, Krewedl, Balonick, Stewart, & Won (2004)

TPS has adapted to several industries. Tendencies are that firms move away from large production quantities with a narrow range of products and tend to generate a level of defects that they consider to be acceptable. To producers that seek perfection, aiming for close to zero defects (known as six sigma error margin), minimum necessary inventory by using a pull system (known as just-in-time), declining costs, and a wider variety of products. By having a focus on continuous improvement, multiple tools are used to discover non-value-added activities categorized as waste. Wasted materials, wasted time in form of waiting for work or finishing to early, defected products or processes and poor work layouts are some examples that are being targeted and reduced (Teo & Loosemore, 2001). As lean has been further developed, terms that goes across industries has emerged. Muda (waste), Mura (unevenness), and Muri (overburden) has become the three main categories. "The Toyota Way" has emerged four categories that are adopted to most industries as *Lean Thinking*: (presented in Table 1)

Table 1: Toyota Foundations to Lean Thinking adapted from (Gao & Low, 2014)

Toyota Foundations		Principles	
1	**Problem Solving (Continuous Improvement and Learning)**	1.1	Continual organizational learning.
		1.2	View the situation first hand to thoroughly understand it.
2	**People and partners (respect, challenge, and grow them)**	2.1	Grow leaders who live the philosophy respect, develop, and challenge people and teams.
		2.2	Respect, challenge and help suppliers.
3	**Process (eliminate waste)**	3.1	Create process "low" to reveal problems. Use pull system to avoid overproduction
		3.2	Level out workload
		3.3	Stop when there is a quality problem
		3.4	Standardize tasks for continuous improvement
		3.5	Use visual control – transparency
		3.6	Use only reliable, tested technology
4	**Philosophy (Long-Term thinking)**	4.1	Decision-making representing a long-term philosophy, even at the expense of short-term financial goals.

Lean Construction has developed seven categories representing non-value-adding activities. These activities have been named "wastes". The seven categories of waste are presented in Table 2 below.

Table 2: Waste in the construction industry (Gao & Low, 2014)

Waste		Description
1	**Correction**	Re-work and re-doing tasks due to errors in design process discovered after work had begun.
2	**Overproduction**	Performing work ahead of schedule, causing interferences with other planned work or additional material ordered due to inability of suppliers to provide quality.
3	**Motion**	Construction teams returning to "office" to pick up plans, tools, or materials not available on-site.
4	**Material movement**	Moving materials from one place to another or handing off work between crews
5	**Waiting**	People waiting for equipment, plans or instruction on how to proceed. Waiting for material because of ineffective supply chains.
6	**Inventory**	Material staged on site too far in advance of schedule.
7	**Processing**	Redundant or unnecessary reporting, expediting material orders or excessive coordination between suppliers.

4.2.2 Lean Design Process

Virtual Design and Construction is developing more efficient teams on construction sites, more efficient product handling, and more efficient supply chains in the construction phase. However, the design process has been under criticism for going over budget, over schedule, and be one of the causes to re-worked work-packages (mentioned in Table 2 as waste no. 1). It has been identified as a major factor in reducing overall performance and efficiency of total design and construction project performances. (Gao & Low, 2014)

Lean Design is an adopted tool from Lean Construction, where Lean principles and methods are adapted to fit the design process of construction projects. The Lean design methods focus on; early costumer involvement, maximizing value by defining customer needs, minimizing waste by establish clear objectives between the involved disciplines, establish both product and process design from the beginning, and design decisions should be made on the last responsible moment (Ko & Chung, 0214). Further, lean design management should use model tools and techniques as Building Information Modelling (BIM), Set Based Design (SBD), Target Value Design (TVD) and Last Planner System (LPS) to reach project objectives. (Zimina, 2012)

Lean Project Delivery System (LPDS), a tool system emerged from the Lean Design adaption aim to reduce shortcomings and improve overall quality in the design process. LPDS includes five phases;

- Project definition,
- Lean design,
- Lean supply,
- Lean assembly, and
- Use/Completion

Each phase is illustrated as a triangle, where each triangle overlaps with one or two other triangles as they are influencing each other. *"A conversation is necessary among the various stakeholders"* is one of the key success factors (KSF) for smooth project throughput according to Ballard & Howell (2002). The work structure is providing a foundation of work process and provides a reasonable way to practice production control. The LPDS is providing a way to work with proactive planning rather than reactive planning, where companies actively use the LPDS for planning ahead rather than looking backwards. (Ballard, 2008)

From the original LPDS, it has improved to include lean toolsets from the Toyota Production System as SBD and target costing. The toolsets have been adapted to the construction industry and integrated in tools as computer modelling and contracts (Ballard, 2008). The flow of the LPDS is illustrated in Figure 3 and aim to improve project delivery through the following characteristics:

1. Front-end planning is done by cross-functional teams including relevant stakeholders.
2. Project control should practice execution instead of reliance on after-the-fact variance detection.
3. Information comes from a network of cooperating specialists, and pull techniques are executed for material and information flow.
4. Variability is absorbed by capacity and inventory buffers.
5. Every level should have feedback loops to continuously improve delivery, and implementation for a system created for rapid adjustments is necessary.

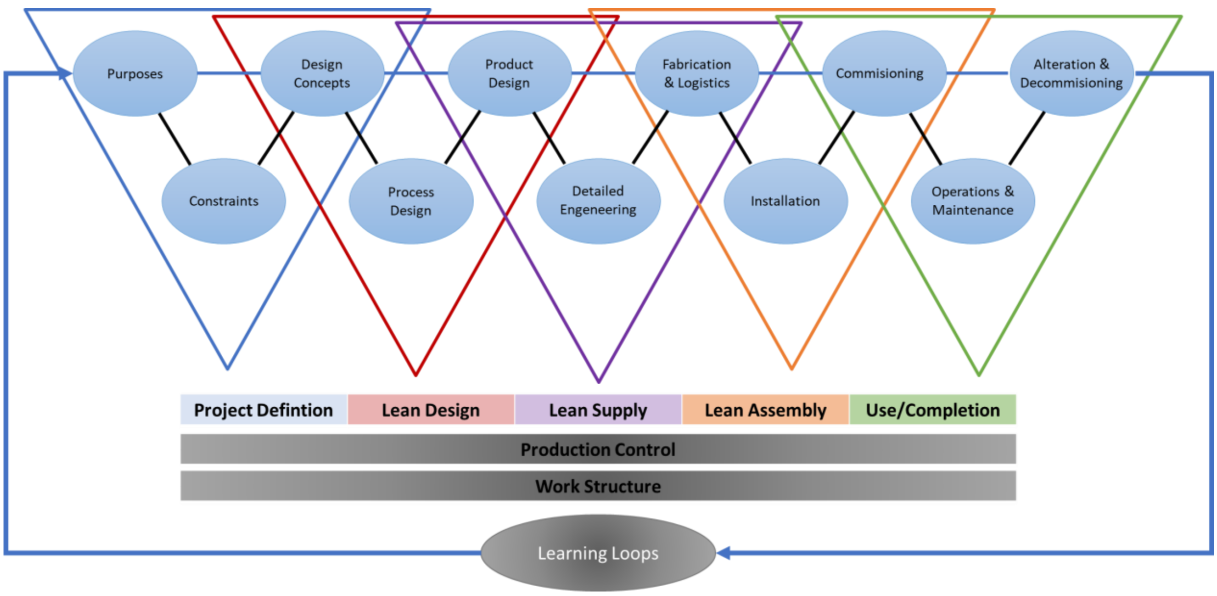


Figure 3: Lean Project Delivery System adapted from Ballard (2008)

4.2.3 Last Planner System (LPS)

The Last Planner System has been used in the construction industry for several years and been a central part of Lean Construction (Ballard, 2000). It is one of the tools that has been given most attention after implementing VDC. It is commonly used in the construction phase, but recently, there has been highlighted its possibilities to move from construction areas to design management and create a more efficient process in early design phase (Khanzode, Fischer, Reed, & Ballard, 2006). Traditional Design Management are being redefined by using lean principles. The Last Planner System pursuit several components and is being effective countermeasures to the traditional way of design management (Ballard, 2000; Mossman, 2013). Last Planner System is a big part of the PPM block of VDC and is further described and showed in context use in the analysis chapter.

In early phase, it is important to combine all relevant stakeholders so expertise within the different sectors are enhanced and the number of surprises arriving later in the project can be minimized to reduce number of days delayed. LPS focuses on creating tasks that are possible to accomplish, within a reasonable time. LPS is focusing on pull planning, meaning that the first work-package planned is the output of the last work-package delivered and work it ways backwards until project start. The activity will only be set in motion and arrive at the next station after all necessary preparations are ready (work-package is healthy). An activity is healthy when the seven below-mentioned characteristics are accomplished: (H. Forbes & Syed, 2010)

1. Enough **labour force** with the necessary expertise to do the work-packages.
2. The correct **equipment** for efficiency and safety.
3. The correct amount and quality of **materials.**
4. Workspace has the necessary **space** to undertake activities.
5. **External environment** as weather and legal permissions are permitting the activity.
6. The **foundation of design** should be available with the correct information. Drawings, decisions, and preferences should be precise and described.
7. **Earlier necessary activities** should be finished and delivered with necessary quality to continue with work packages.

In the beginning – *planning the work* is established by combining the project objectives with what information is available. The planned work-package output is what *should* be done. Next step has the focus of what *can* be done (illustrated with the blue arrow in Figure 4). The last planner is understood as the mechanism for transforming what *can* be done into what *will* be done. This is done by removing bottlenecks found when creating healthy work-packages as described in seven bullet-points above. Weekly work plans are formed, which has the output of activities that *will* be done. These work packages are combined with the available resources, and provides a healthy activity described above. The result is the activities the project team *did*. The process is shown in Figure 4 below. The Last Planner System is helping project teams create healthy work packages and set realistic goals for delivery. (Aslesen & Tommelen, 2016)

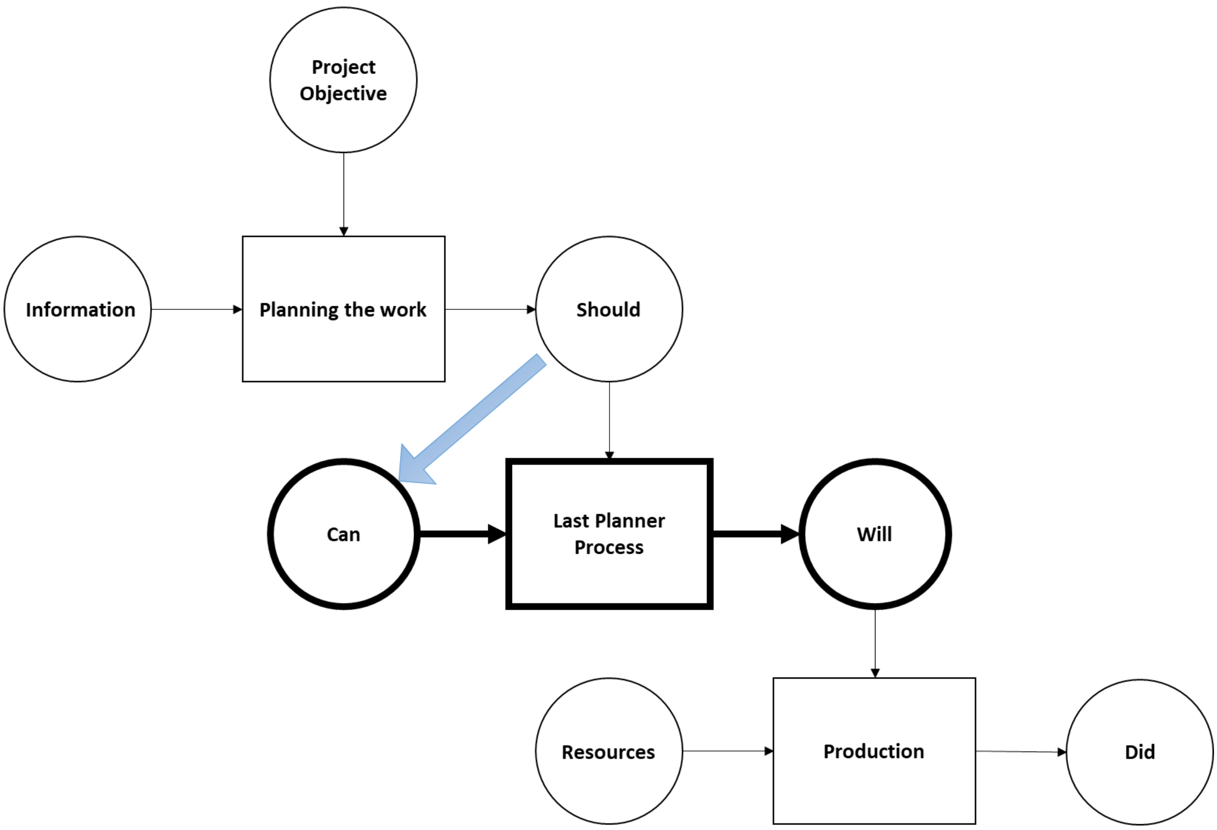


Figure 4: The Last Planner System adapted from TheLeanConstructionInstitute (2016)

When all participants together have determined all work package that has to be done throughout project life, they are to be assigned specific times. LPS works with time-elapses at four different levels: *Master schedule*, *phase "pull" plan*, *forward-ahead planning*, and *weekly work planning*. Additional, there is also a *learning phase*.

Firstly, **Master scheduling** is the overall plan that is describing milestones throughout the project life. It is the first estimate in the planning phase and is therefore usually an optimistic version of the project timeline (H. Forbes & Syed, 2010). The **phase "pull" plan** is broken down from the master scheduling plan. It is more detailed and includes work packages in the plan which determines the outputs from each project stage (Ballard & Howell, 2003). The third level in plan detailing is commonly named **looking-ahead planning schedule**. It normally has the duration between six and eight weeks. This plan should shape work flow sequences, match work flow and capacity, decompose the phase “pull” plan activities into work packages and operations, develop detailed methods for executing work, maintain a backlog of finished work as well as ready to begin work, update and revise higher level schedules as needed. The most detailed plan system is the **weekly plan**. The weekly plan should contain all work packages for a week and be updated from week to week. It is decomposed from the looking-ahead plan where each activity should be healthy. All work packages at this stage should finish within the week. (H. Forbes & Syed, 2010)

The forming of each plan is done in meetings containing all relevant stakeholders. It has been shown by research that LPS is providing specific advantages in managing the design process (Kunz & Fischer, 2012). When continuously coming back to the board and re-planning is showing that activities with high uncertainty, often representing activities far ahead needs rescheduling as the scheduled plan often are too optimistic. A combination between the LPS working method and LPS time elapses show that *should* activities are most uncertain (shown in Figure 5). Thereby uncertainty is reduced as the planning are evolving into weekly schedules. (Kunz & Fischer, 2012)

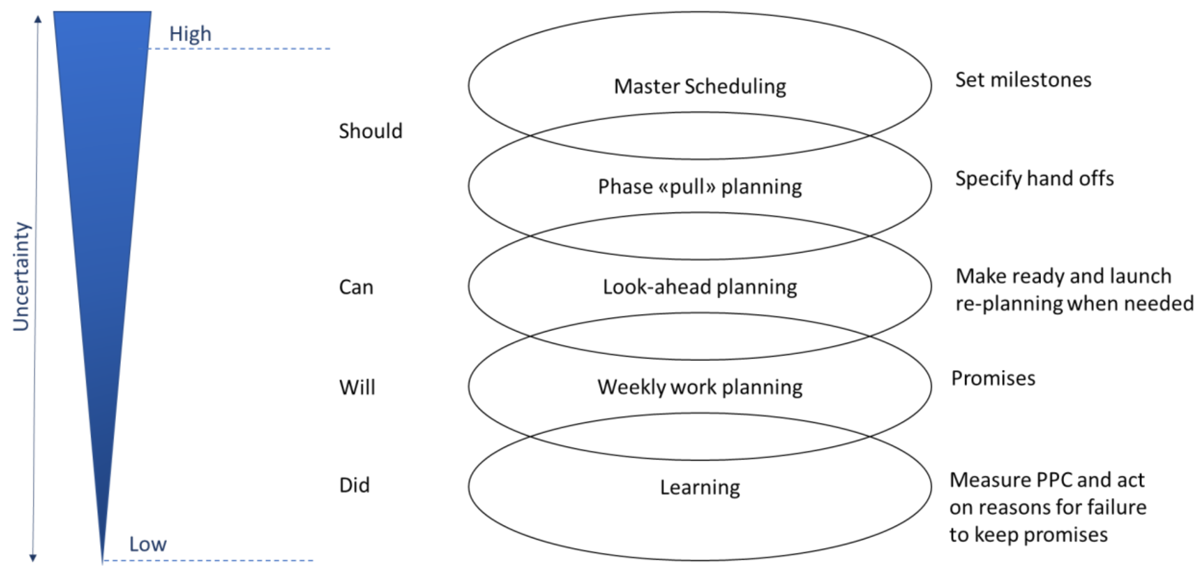


Figure 5: The Last Planner System planning levels compared to work-package uncertainty

4.3 Building Information Modelling (BIM)

BIM is one of three (BIM, ICE & PPM) building blocks creating the foundation of VDC. It is a multi-dimensional modelling program where physical and functional preferences of the facility is described (Forbes & Ahmed, 2011). It has been shown that projects using BIM has provided higher quality of projects (Bryde, Broquetas, & Volm, 2013). BIM is defined in multiple different manners and nailing down one common definition is near to impossible. Krygiel & Nies (2008) is underlining that in addition to be a software, BIM creates a mindset, a process, and a methodology within the firm that creates more precision and quality to the work-packages conducted. Lean Construction Institute (2016) and Krygiel & Nies (2008) is defining BIM as:

" BIM is the creation and use of coordinated, consistent, computable information about building project in design-parametric information used for design decision making, production of high-quality construction documents, prediction of building performance, cost estimating, and construction planning"

- Krygiel & Nies (2008)

"BIM - the process of generating and managing building data during the life cycle of a building"

- LeanConstructionInstitute (2016)

BIM is improving productivity, schedule, safety, cost and quality of construction projects (Zuppa, Issa, & Suermann, 2017). BIM has helped with a shift from delivery by drawings to delivery by models presenting preferences and information needed to the model. An example could be a door (see Figure 6). The 3D model presented on the left side is representing a Level 1 BIM model. A Level 1 BIM model can be described as a "lonely BIM model" where only the 3D representation is shown. An evolved model, a Level 2 BIM model is showed to the right in Figure 6, the 3D model is coordinated with additional information as required resources and material information (Moriwaki, 2014). Normally, BIM level 1 is integrated in most deliveries. The transition to level 2 shown by the below example is not uncommon but should be established as a standard delivery method. Further, information from subcontractors and entrepreneur as guidelines for installation, health, safety, and environmental impact is added to the BIM model.

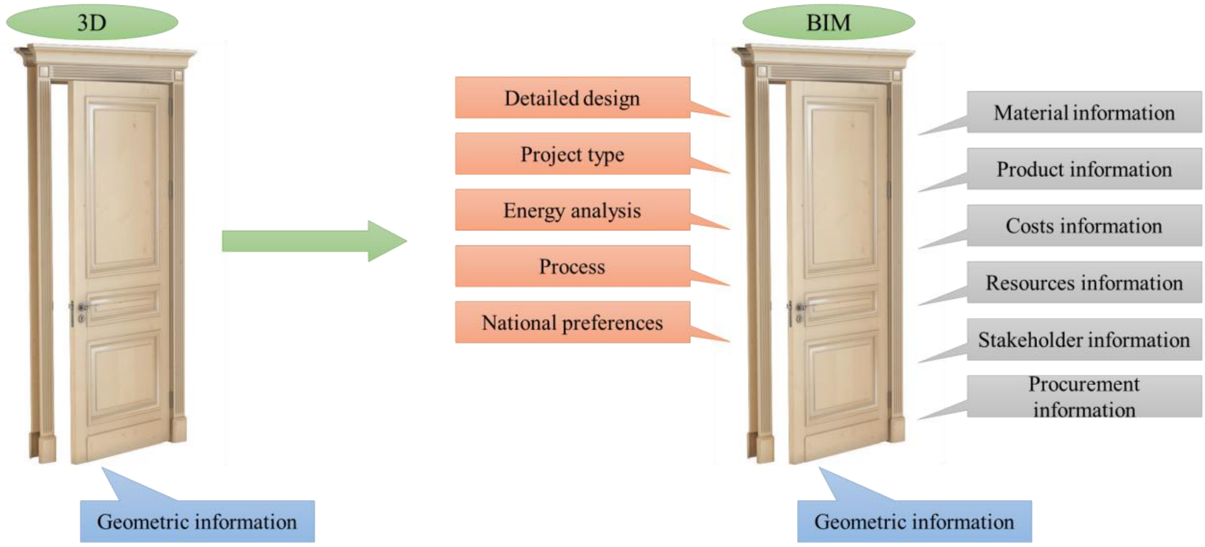


Figure 6: 3D model at left-hand compared to BIM model at right-hand of a door – the BIM model is commonly required in VDC projects

Table 3 is representing the different model dimensions. 3D, 4D and 5D is already implemented in larger and more complex projects where 6D is estimated to be fully integrated somewhere in the 2020's as shown in Figure 7 (Moriwaki, 2014). BIM is commonly described in levels from 0 to 3 where the different dimensions are integrated in the BIM model described in Figure 7 adapted from Moriwaki (2014) & The Stroma Group (2018).

Table 3: BIM dimensions with descriptions

Dimension	**Description**
3D	Virtual copy of the facility/product that should be built
4D	3D-model + the aspect of time which shows the project progress
5D	4D-model + costs of materials, labour and so on
6D	5D-model + environmental affection and project life cycle information
7D	6D-model + facility management applications

Research shows that the projects rapidly have increased in terms of what dimension the BIM model is created in. As projects evolve in size and complexity, it is required for certain information and more detailed information (Moriwaki, 2014). In VDC projects 4D model or above are commonly required. (Fischer, 2017)

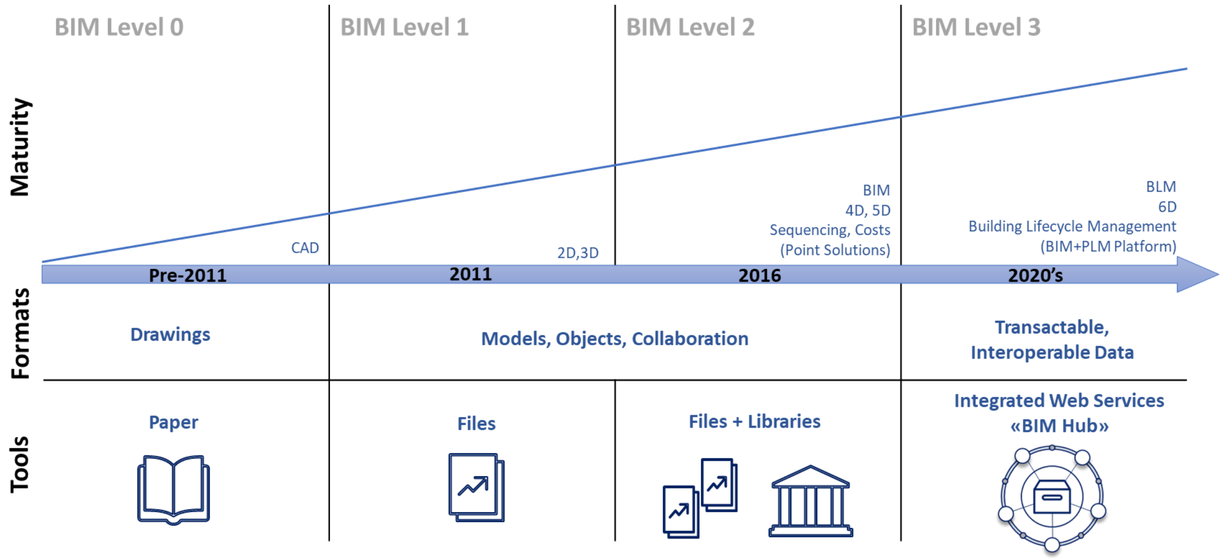


Figure 7: BIM Levels with descriptions adopted from Moriwaki (2014) & The Stroma Group (2018) – VDC normally requires BIM level 2 or above

Coordination is implemented from the beginning of the planning process, through design and onto construction phase. According to Eastman et al. (2011) is coordination between entrepreneur and subcontractor through a BIM model providing a more precise collision control, as well as early detection of errors. BIM provides a platform for communication and information related to the design of the product and delivery process (Lincoln & Ahmed, 2011). When using a 3D model early in project life, all relevant stakeholders can see the development of the model and can provide input in the development of the facility. The model makes sure all stakeholders have the same vision for objectives and functions of the final product. In non-BIM projects, a lot of time is used on communication due to no central spot with all information. When using BIM as a communication channel and information centre, it produces a reference point. This is illustrated in Figure 8. According to Chen et al (2004) will a BIM model enhance communication between all participants due to the information available. This is claimed to produce better quality of the overall product.

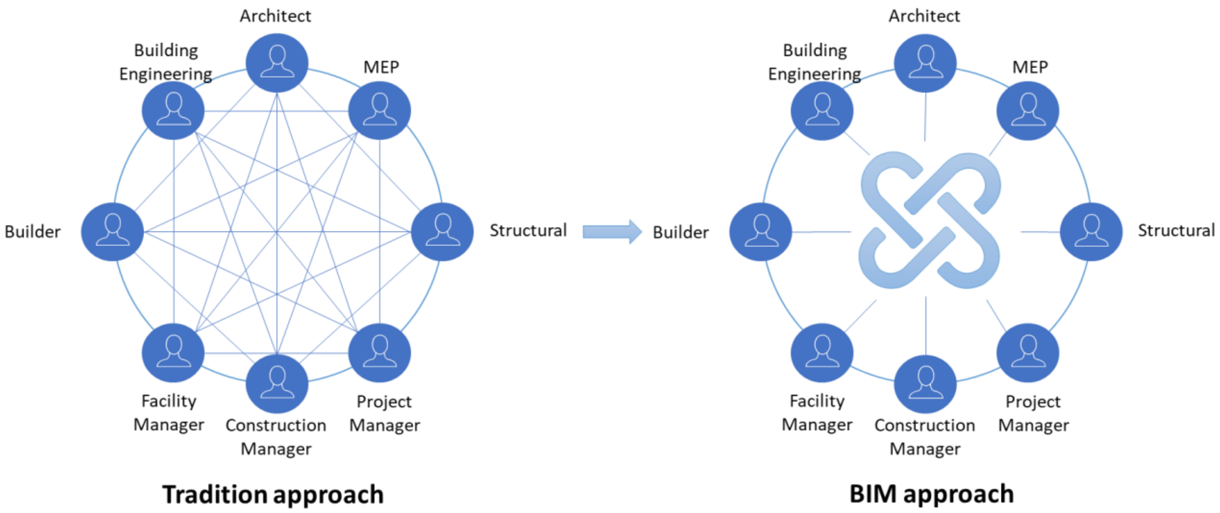


Figure 8: Communication routes with and without BIM model. BIM integrated in combination with ICE in the VDC framework

Sacks et al. (2010) claims that BIM should be used to visualize the product to improve transparency. It is easier to communicate, even with non-technical stakeholder through a visual presentation. The model helps the client, designers and contractor work together from early project life and increase value to costumer by reducing non-value activities. The information provided in a 5D model as description and quantity needed reduces overproduction. (H. Forbes & Syed, 2010; Krygiel & Nies, 2008; Sacks, Koskela, Dave, & Owen, 2010)

4.4 Integrated Concurrent Engineering (ICE)

The integrated concurrent engineering methodology has commonly become a part of project planning and meeting methodology in VDC – where key participants as clients, architects, structural engineers, quantity surveyors, mechanical/electrical service engineers, contractors and material suppliers are being involved in an earlier phase of project life. The ICE methodology is aiming to avoid sources to waste in communication processes and lack of digital practices. The ICE block of the VDC framework is commonly focusing on integrated environment and ICE sessions.

ICE Sessions

Participants in ICE session (named *sessions* throughout this paper and not *meetings*) are including all relevant disciplines to agenda points in the sessions undertaken. The sessions are regularly conducted in an interactive room commonly named *Big Room* or *iRoom* (further in this thesis, they are named Big Rooms to avoid any confusion) (Kunz & Fischer, 2009). How often the sessions are conducted are determined by project participants and will vary depending on size and complexity of the project.

Session schedules are integrated in an overall system that provides calendar schedule planner and management system to important professional tools like personal computers and smartphones. The system should also be able to cross check calendars with others project participants to optimize session schedule. Session agenda should be sent out in reasonable time before the session, which will commonly vary as projects have different pace and complexity. There should be clear objectives for each ICE session and clear definitions of roles and operational roles. ICE session types will often vary with purpose, desired outcomes, and session topics. (Fischer, 2017)

When planning the agenda, there are several pieces of puzzle that is determined by desired outcomes and topics. Process steps/time allocation will determine the length of the ICE session which could range from few hours up to several days. Decision making methods, stakeholders & attendees, required resources, room layout & logistics are other factors determined by desired outcomes. Desired outcomes should be stated in the agenda to inform participants what to be accomplished, helps the team hold focus, build concurrence on a path forward, and form a basis of progress measurements during the session helping in regard of session effectiveness. (Kunz & Fischer, 2009)

ICE Session layout

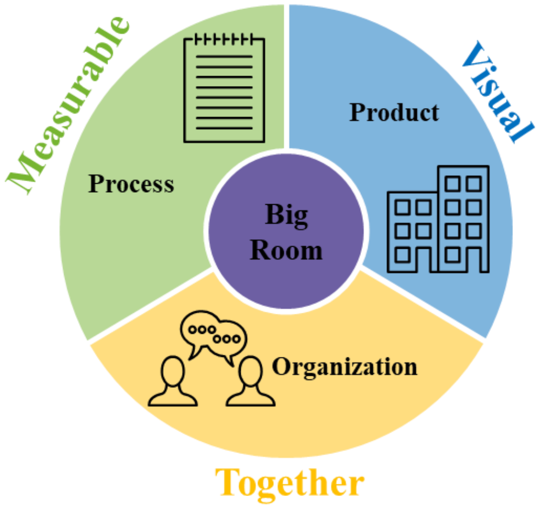


Figure 9: The important Big Room aspects in VDC projects

ICE sessions are normally done in Big Rooms. Big Rooms provides technological solutions enabling physical meeting space for project teams in larger or smaller size. Normally it is only used with larger project teams. The project team space often includes multiple large screens to display different project information. This could be the current budget with future estimations, BIM model, mark-ups, ICE session agenda, or decisions to be made during the ICE session. A Big Room provides several advantages compared to traditional drawings and paper-based meetings. The variety of information as Gantt Chart, estimates, and models can be displayed simultaneously and is more easily accessible to provide better decision-making. In drawings and paper-written meetings, attendees often rely on their own mark-ups and much of the time spent in meetings are spent on explaining and understanding other participants. BIM models and other software tools used in Big Rooms creates easier communication systems. Software presentations illustrates relationships between components and products, which enables on-the-spot decision-making as participants can change factors intuitively to explain and investigate solutions. The included aspects in Big Rooms are shown in Figure 9. The layout is created to enhance aspects from all involved disciplines, some layout examples is illustrated in Figure 10 to show that there is no one-way to create a Big Room, but several layouts can work effectively. However, certain aspects (aspects presented in Figure 9) should be carefully chosen and included in the layout.

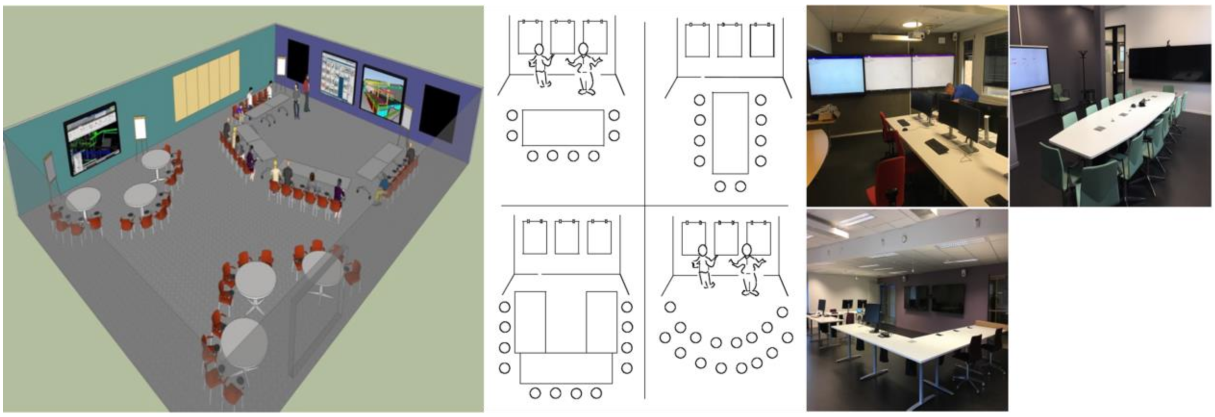


Figure 10: Different Big Room layouts created to show that there is no one-standard Big Room layout

The Big Room methodology is most effective when all participants have devoted time and efforts in preparing. Each ICE session should update project progression by updating work packages to the involved participants. Project manager present information documents as budgets, Gantt Charts and other critical information to display project progress to session participants (American Institute of Architects, 2014).

A facilitator has the role of leading the ICE sessions. The role of the facilitator is further described in Table 4. It is commonly used a facilitator to keep the organization structure of ICE sessions as flat as possible to enhance innovation and encourage participants to contribute to the sessions. ICE sessions working with effective planning and decision-making should have high quality and reduce inefficiency. (Justice & Jamieson, 2012)

Table 4: Facilitator role; how to prepare, lead and finish of ICE sessions adapted from Justice & Jamieson (2012)

	Primary Tasks		Preferred Outcomes
Preparation	1.	Establishing the contract for facilitation	Group organized
	2.	Collecting information on context, work, and participants	Membership determined
	3.	Clarifying the group charter	Purposes and outcomes made clear
	4.	Analysing stakeholders	Roles clarified
	5.	Selecting group members and group leader	Logistics planned
	6.	Building agendas for ICE session	Facilitation work contract clear
	7.	Publishing agenda and spread information	Group, work, participants, and context understood
	8.	Attending to ICE session logistics	Agenda determined and communicated
Group Work	1.	Creating a foundation for working together	ICE session purposes and outcomes achieved
	2.	Managing data generation	Participants worked well together
	3.	Managing analysis and interpretation of the data	Participants satisfied with progress
	4.	Managing decision making	ICE session design effectively implemented
	5.	Managing group dynamics	Facilitation capacity of group enhanced
	6.	Evaluating group process and progress	Next steps clear
	7.	Closing group sessions	Effective group task and maintenance behaviours observed
Implementation	1.	Preparing the ICE session record/outputs	ICE session records/outputs produced and distributed
	2.	Informing and communicating with others	Results of group work communicated to members, sponsors, and stakeholders
	3.	Obtaining approvals of group work, when needed	Approvals of results, when needed, obtained and announced
	4.	Monitoring interim/implementation work	Next steps carried out
	5.	Identifying further needs for group work	Need for further group work determined

Forbes and Ahmed (2010) has broken meeting/session methodology into nine steps to establish effective meeting/session protocol:

1. Have an agenda ready before the meeting.
2. Introduce all stakeholders attending to the rest of the group so everyone knows each other and their background.
3. All project information should be available and easy to visually present.
4. “Post-it” notes should be used to present ideas and work packages and presented easily shown.
5. Use pull planning for each activity.
6. Promote creativity (controlled chaos) to generate ideas.
7. Identify project flow (critical path analysis could also be used) and verify it with all stakeholders.
8. The plan should be written down and agreed on.
9. Go through the plan again and adjust it if needed.

ICE sessions should include all off the above protocols.

4.5 Metrices

Metrices or commonly named measurements is a major factor to continually improve project performance. It is a critical area of VDC and is important to compare project objectives to estimates, for PPM and for future benchmarking. It is one of the few areas projects can be compared directly in terms of project success if the same metrices are used in multiple projects. The theoretical background will be presented below in this chapter, and further analysis of usage of the metrices in projects are presented in the analysis section. Firstly, the POP model is presented as it shows how metrices is used in product, organization and process settings. Later, Table 6, 7, and 8 is presenting possible measurements in projects ranging from daily measurements to evaluation at handover. These tables are further used as reference points when analysing project Bispevika.

VDC divide projects in three functions; product, organization and process which represent the functional intent, designed form or scope, and predicted behaviours of projects. Their aspects are presented in Table 5:

Table 5: POP model for design and construction adopted from Kunz & Fischer (2012)

	Function: Objectives	**Form/Scope: *Design choices***	**Behaviour: *Predictions***
Product	Spaces, elements and systems	Designed spaces, elements and systems	Predicted cost ($)
	Measurable objectives	Values	Predictions: assessed values
Organization	Actors	Selected actors	Predicted cost ($)
	Measurable objectives	Values	Predictions: assessed values
Process	Tasks	Designed tasks	Predicted cost (days or $)
	Measurable objectives	Values	Predictions: assessed values

Column 3 (Form/Scope: Design choices) is specified, designed and built by the project team to address the functional intent shown in column 2 (Function: Objectives). Column 4 (Behaviour: Predictions) is the predicted and measured behaviours of the critical project elements created in column 3. For separation – it is notable that product is usually forming physical construction component or visual models. Involved project participant including stakeholder groups is categorized in the organization model, while the process model is representing project milestones and tasks of the organizational entities to develop the project. The POP model aims to help stakeholder teams to identify requirements, the most suitable designs to meet client requirements, and predict behaviours early in the design process. The objective is to create the

most valuable modelling option, based on analysis of the project during its entire lifecycle. (Kunz & Fischer, 2012)

Further, to determine collaboration, meeting efficiency, valuable stakeholders, project success – it is needed an improved system for metrices/measurements. According to Kunz & Fischer (2012) metrices can be divided into three separate categories based on how often the factor should be measured. The three categories; [1] project controllable factors (daily), [2] project process objectives (weekly or bi-weekly), and [3] project outline (end of project). The categories and factors are represented below in the tables; 6, 7 and 8. The three tables have a set of measurements. They are referred with 1.X, 2.X and 3.X as they are referred to in later chapters. The metrices used are addressing different parts of projects life. Table 6 and 7 is referring to the VDC blocks PPM, BIM and ICE shown in Figure 2. Further are Table 8 addressing the final project objectives agreed on with the client.

VDC strategy and plan includes three steps; visualisation, integration and automation:

Visualization: in what degree are elements of the product, organization and process understood by stakeholders, so they can relate to them. Project will vary in detail of modelling and focus on estimated project time, cost, effort and life cycle energy usage.

Integration: definition and support in relationships between modelled product, organization and process elements. The relationships should be to enable parameters to update automatically when one of the independent parameters has changed.

Automation: elaborating design details, analysing consistency, moving and processing materials as part of prefabrication and assembly at the work face. To what degree of automation should be stated in business objectives.

It is reasonable to select two or three process objectives from Table 6 to measure, track and use for improvement management. These can normally be tracked and managed day to day. If all are chosen, it gets difficult to really focus on achieving them.

Project controllable factors are shown in Table 6.

Table 6: Metrics for project controllable factors in a VDC projects adopted from Kunz & Fischer (2012)

Controllable project factor		Description
1.1	Decisions and rationale recorded	Decision choices should always be rational, and descriptions should be recorded for all activities regarding product, organization and process that are influencing the budget, costs, effort or life cycle energy use more or equal to 10%.
1.2	Coordination requests	Objective should state that more than 90% of all actual activities coordinated among project participants is planned weekly explicit, informed, public and tracked.
1.3	Coordination support	More than 90% of activities in coordination should be reported by intended recipient to be finished within time and scope.
1.4	Prediction basis	Theoretically founded and automated methods should predict more than 80% of project designers' activities.
1.5	Design versions	Objective should state 2 or more design versions in 80% of design cases that are influencing the budget, costs, effort or life cycle energy use more or equal to 10%.
1.6	Risk management strategy	Strategy is well described and followed by 100% of product, organization and process packages that are influencing the budget, costs, effort or life cycle energy use more or equal to 10%.
1.7	Globalization strategy and plan	Objective should be that more or equal to half of all components and services are purchased from global suppliers.
1.8	Lifecycle cost factors considered	Decision choices should always be rational, and descriptions should be recorded for all activities regarding product, organization and process that are influencing the budget, costs, or life cycle energy use more or equal to 10%.

Project process objectives is measured weekly or bi-weekly. These are progress indicators, that individually and collectively have controllable factors and influence the project during its progress. These are shown in Table 7. In Table 7, VDC potential is compared towards 2005 practice (2005 is considered as traditional practice). This should give an indication of potential for improvements.

Table 7: Metrics for project process objectives in a VDC projects adopted from Kunz & Fischer (2012)

Performance factor		Description	VDC potential from 2005 traditional practice
2.1	Detailed schedule conformance	The percentage activities that start and finish within one day of schedule, where design-construction activities can be measured at whatever detailed level the project chooses.	Before: less than 70% or not measured With VDC: above 95% of project activities within objectives. Usually measured in quantities of lookahead plan of two - three weeks.
2.2	Decision latency	The time between information is available to take a decision until the decision is announced.	Practices has shown everything from two days to three weeks. VDC objective is that 98% of all decisions should be made within two minutes from all available information is available.

2.3	Meeting effectiveness	The percentage of participants who self-report they believe meetings are meaningful and timely effective.	This has not usually been measured, but with ICE the objective is that 90% or more of participants should report effective meetings with excellent participation, attendance, and highly relevant meeting content.
2.4	Response latency	The time from sending a request for information to receiving a useful response.	Objective is the same as decision latency. 98% of all decisions should be made within two minutes.
2.5	Stakeholder involvement	Participation, task review and approval from stakeholder.	Not been measured before, but ICE states an objective for 90% or above satisfied stakeholder having significant input in major activities.
2.6	Detailed cost conformance	Percentage of components costs within 2% of estimated costs.	Objective is more than 95% of all components should be within the stated terms. The practice haven't been formally measured in traditional projects.
2.7	Field-generated request for information	On site employees asking for information from design team that has not been provided in model.	The aim is to move from many to zero for questions related to issues that could have been identified before construction.
2.8	Rework volume	All work packages that must unnecessary be done more than once.	In field construction, objective is zero rework waste. In virtual work, 20-40% is acceptable. Design alternatives have value.
2.9	Field material delivery	The percentage of materials delivered to field within 24 hours before schedule.	Past: below 80%, With VDC: objective is that all field material deliveries should be above 95% accurate.
2.10	Meeting efficiency	The amount of meeting activities that are categorized as valuable.	Have not been measured formally before. Objective is more than 70% value-adding activities.
2.11	Meeting agenda appropriateness	The amount of meeting agenda points that is found acceptable for all disciplines at the meeting	Objective is more than 90%, and the topic has not been mentioned before.
2.12	Model coordination consistency	Conflicts, interferences or inconsistencies in models or drawings at multidisciplinary meetings.	Practice claims it is relatively low, with VDC implementation the objective is zero conflicts, interferences or inconsistencies.
2.13	Budget estimate conformance	Percentage of items that are within 5% of budgeted costs in the Guaranteed Maximum Price (GMP) estimate with $0 contingency.	During design phase: 95% of items should be within 5% of budgeted estimates. Construction phase: 95% of items should be within 2% of budgeted estimates.
2.14	Client satisfaction	Satisfaction is self-reported on a scale from 1(low) to 5 (high).	Haven't been formally measured. Objectives with VDC is four or above.
2.15	Safety	Near misses or incidents reported.	Been generally good in practice, should be even better with VDC implementation.
2.16	Visualization	Stakeholders report clarity and accessibility of models and analyses of product, organization and process on a scale from 1(low) to 5 (high).	Not formally been measured, and traditional practices in 2005 uses 2D drawings and Gantt Charts. Aim with VDC is a dramatic improvement with ICE stakeholder engagement.

Project outline objectives is measured at the end of the project. The objectives are compared to estimated budget, schedule, quality and safety objectives. Metrics shown in Table 8.

Table 8: Metrics for project outline objectives in a VDC projects adopted from Kunz & Fischer (2012)

Performance objective		**Description**	**Performance**
3.1	Safety	Near misses or incidents reported.	Been generally good in practice, should be even better with VDC implementation.
3.2	Function	Planned and actual user and owner objectives and support for project facility.	Objective is 100% satisfaction by systematic post occupancy evaluation (POE). A variance on 5% is acceptable.
3.3	Cost	1. Unit costs/costs per square foot or per unit of produced products. 2. Actual final project costs in corporate with approved budget.	1. Reduce 20% for a similar or improved function, quality and schedule compared to traditional practice. 2. AEC projects should have less than 2% unbudgeted change in 98% of the project.
3.4	Schedule	Actual duration of design and construction phases and variance of these.	Has been improved in practice over recent years. Objective is to further determine accuracy.
3.5	Sustainability	Lifetime use of water, energy and materials of project construction. Support in changing facility preferences to suit client should have minimal costs.	Lifetime usage should decrease to less than ¼ of 2005 practice.
3.6	Globalization	Sources of products and services.	More than half of components are obtained from global supply chains.

From the above presented tables (Table 6, 7 and 8), some factors are more challenging to measure and improve than others. It is advised to focus on only a few of the above-mentioned factors in each metrics. Commitments to objectives should be made public, specific, aggressive but realistic (Baiden, 2006). Goals should be reviewed frequently, where the goals may need adjustments due to changes and terms of resources. (Kunz & Fischer, 2009)

Further, Plan Percent Complete (PPC) is describing how much of the planned work were the project team able to finish within a time interval. PPC is commonly measured weekly, where a conformance between 75% and 85% is optimal compared to actual schedule performance.

VDC implementation is divided into three stages of implementation; *Visualisation, Integration* and *Automation*. The stages are presented in Figure 11 and are separated in terms of what degree VDC is implemented in the project (Kunz & Fischer, 2012). Automation- and integration implementations are much more likely to find by contractors that are more familiar with VDC and have multiple ongoing VDC projects (Gilligan & Kunz, 2007).

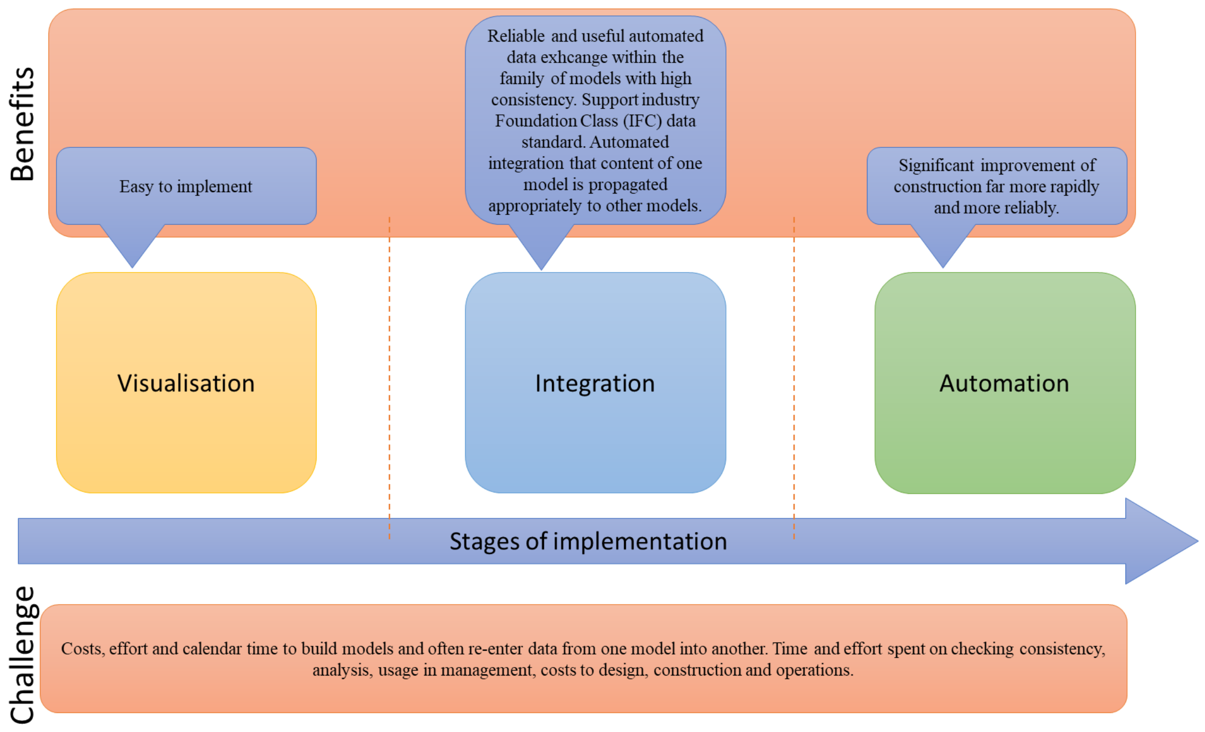


Figure 11: Developed figure from in-text content for stages of VDC implementation with inspiration from Kunz and Fischer (2012)

4.5.1 Latency

Latency is describing delays due to unnecessary inefficiency. Latency has been heavily criticised for unnecessary long response time. With implementation of ICE methodology, latency have decreased from weeks to days and days to hours. Design and management has been the most common reason for latency. (Kunz & Fischer, 2012)

To reduce latency, Fischer (2017) suggests implementing VDC modelling and analysis strategy, process objectives to measure, and a small number (preferably no more than two) additional factors from Table 6. Further, from Table 7 – add process performance parameters as schedule conformance (2.1) and response latency (2.4). Finally, measurable project objectives as safety (3.1), functional quality (3.2), cost (3.3), and schedule (3.4) from Table 8 should be assessed after handover. (Fischer, 2017)

4.5.2 Root Cause Analysis

According to Kunz & Fischer (2012) is what factors and objectives to measure, and how to measure the factors and objectives with metrices – some of the most difficult implementations in design-construction projects. Baiden (2006) are claiming that project objective should be aggressive, but achievable. However, occasionally there will be time overruns, costs overruns, missing personnel or failures in communication in the design-construction process. When using metrices in VDC projects, reporting through measurements is one of the main bricks in the PPM section. ICE session participation, ICE session efficiency, latency and precision in estimates are some of the factors that are being documented when implementing VDC. Lean Construction Institute (2016) claims that metrices can be used as a systematic way to improve budget, schedule and overall quality in delivery, by going through root causes and eliminate waste continuously. Further, it is claimed that before improvements are made, the current situation should be benchmarked. This should help documenting root causes before implementing a strategy for improvements. (Lean Construction Institute, 2016)

The process to determine the root causes can be done by several strategies. However, the most commonly used investigation is the "5 why's" or a fish bone diagram (further described below). The "5 why's" is most useful when problems involve human factors or interactions. It is a flexible tool and can be used in day-to-day activities, which makes it easy to implement in different projects. Firstly, the issue should be written, as mentioned above – VDC is highly focused on documentation. Afterwards, ask the question *why* this issue occurred. The answer should be written to help the team focus on finding the real problem. If the root cause is not identified by the written answer, then ask *why* again. This process is repeated until the root cause is identified. This may or may not take more than five times. Figure 12 below is created to illustrate how a five step Why analysis can change the result if actions is taken at the different steps. In theory, a long-term solution is commonly wanted (described in Table 2, section 4.1), but costs related to the current project and current contract often benefit more from the short-term solution. Figure 12 is illustrating that the first cause may not be the root cause, and the easiest way out of a situation might not be the best way long term.

	Level of problem	**Corresponding level of countermeasure**	**Result if action is taken at this point**
	Productivity on site is low		
1 WHY?	Site is too crowded with material inventory	Rearrange materials on site	Short-term solution
2 WHY?	No one is aware of material management being a problem	Tell them this is a problem	
3 WHY?	Laborers are used to solving problem as a «work around»	Ask laborers to perform properly	Mid-term solution
4 WHY?	Management does not ask laborers for their opinion	Encourage management to ask laborers their opinion	
5 WHY?	Management is not aware that collaboration benefit everyone	Give them appropriate training so they perceive the benefit of collaboration	Long-term solution

Figure 12: An example of "The 5 Why's" analysis

According to Lean Construction Institute (2015) “5 Why” only identify one root cause – even when there often are several root causes to an issue. For this, it is common to use a more robust system for the root cause analysis. The primary aim is to identify factors that resulted in the nature, magnitude, location and timing of the outcome and consequence of an event. Thereby, it is also necessary to identify behaviours, actions, inactions, or condition that should be changed to avoid repeated unwanted events (Dolores & Qyer, 2000). A fishbone diagram can highlight several causes developing one effect. The fishbone diagram can be illustrated as in Figure 13 where multiple fishbone diagrams revealing more causes to a bigger problem is illustrated as well.

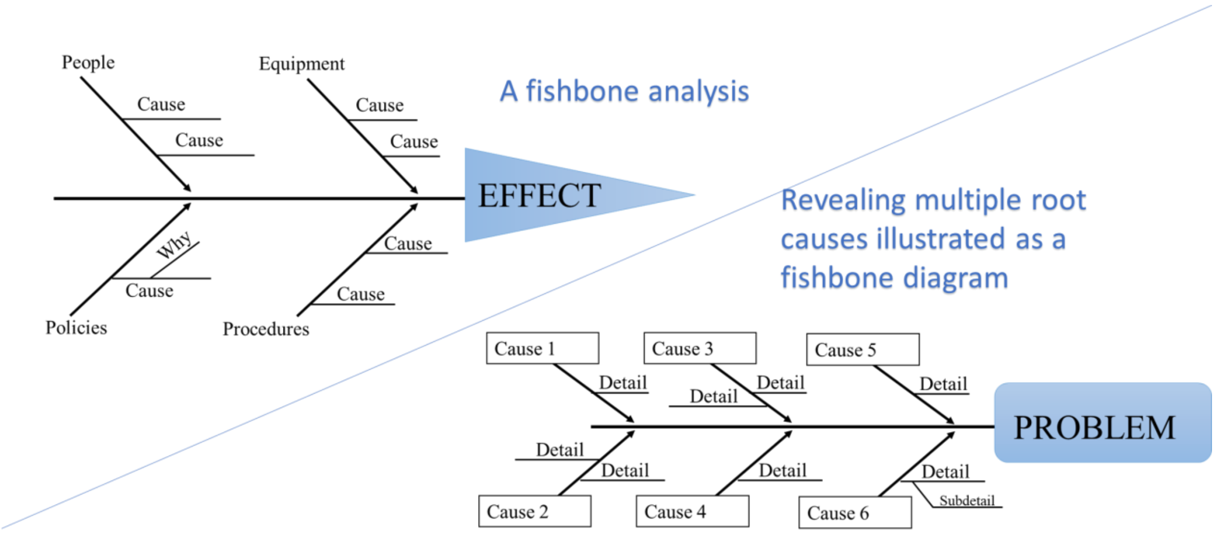


Figure 13: Fishbone- and multiple root cause analysis

When identifying errors, there are several ways to address their aspects. The most commonly used method according to The American Institute of Architects (2015) is the Plan-Do-Check-Act methodology. The circle is illustrated in Figure 14 and begins with identifying the corrective action(s) that will with certainty prevent recurrence of each harmful effect including outcomes and factors (as the why example shows, this refers to the long-term solution rather than the short-term) (Fauchier, 2015). Next step is to check if each corrective action would – if it was pre-implemented, before the event, reduce or prevent specific harmful effects. Then, implement the proposed solution and observe during implementation and after implementation to compare results to before any actions was taken. Lastly, evaluate and adjust the implemented solution to fit perfectly and make it a standardized solution if possible. The four steps methodology is illustrated as a circle in Figure 14 to illustrate that there are commonly ways to improve products, organizations and processes described in Table 5: POP.

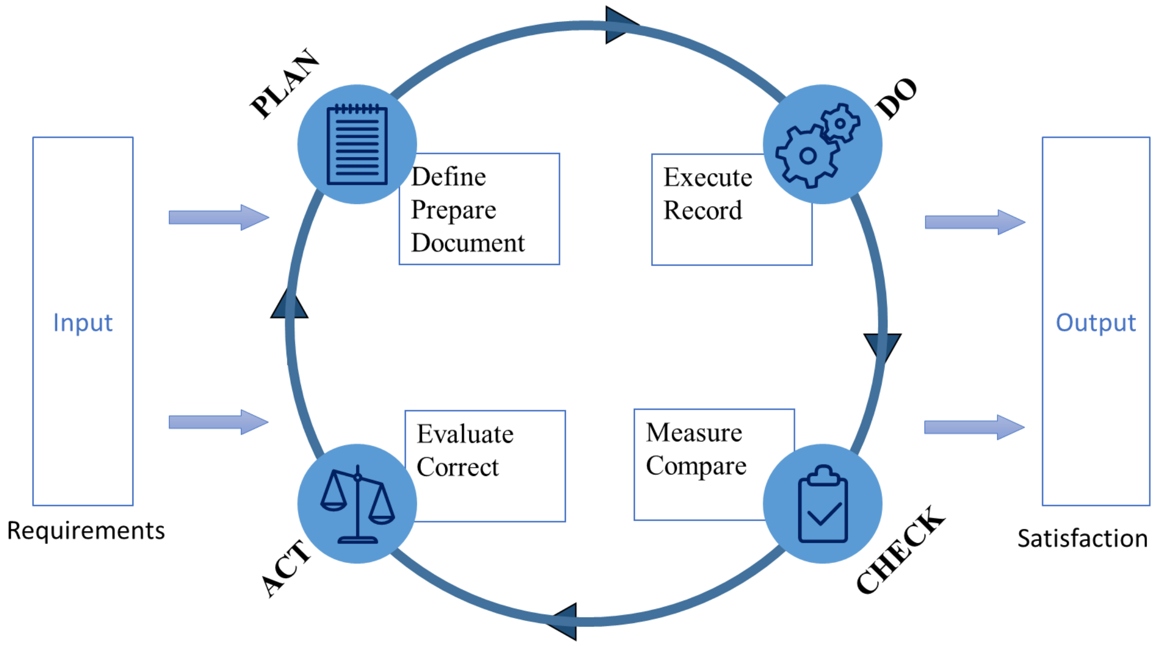


Figure 14: PLAN-DO-CHECK-ACT system

A3-reporting

According to Sobek and Jimmerson (2004) – A3-reporting is a system arriving from the Toyota production system. The system, given its name due to its visualisation by an A3 sheet is a powerful and effective tool. The A3 report is commonly used for presenting ideas for improvement by proactive work towards optimized processes or solve a root cause. This will usually be the document following the PLAN-DO-CHECK-ACT process described above. It systematically guides the solution through a process, document the key outcomes of that process, and propose improvements. (Sobek & Jimmerson, 2004)

The seven commonly used topics are described below and is usually presented on one A3-sheet:

1. **Theme & Background** – first statement of the A3 report should be the *theme* or *title* of the report, clearly highlighting or explaining the problem to be addressed. Background information is describing why the problem is important and the need for improvements.
2. **Current condition** – the author draws a diagram that depicts how the system that are producing the issue currently works. The diagram should highlight the issues and the author should have quantified the extent of the problem in terms of percent defect, downtime hours et cetera. The data presented is established on direct observations.
3. **Root cause analysis** – for the author of the A3 report to understand the current situation in a deep and meaningful way, it becomes imperative that the author understand the root cause of the problem symptoms. The "5 Why's" method is commonly used.

4. **Target condition** – is describing how the system can be improved. This is commonly also known as countermeasures as the implementations counter a specific problem. The section should include a new diagram with the aimed conditions of the system.
5. **Implementation plan** – outlines the steps that must be accomplished to reach the target condition. The list should include who is responsible and when is the deadline.
6. **Follow-up plan** – is referring to the way implementations can be measured to see improvements. It should be possible to compare these statistics to before implementation to prove a better outcome.
7. **Results report** – Toyota problem-solvers draft a special A3 report to report on follow-up results. The follow-up report is critical for maximising learning within the organization.

Chapter 5: Methodology

Chapter five is describing how research and methods have been conducted in context with this thesis. The chapter will present step-by-step from literature research to conclusions. The method is shown as four parts illustrated in Figure 15. The four parts will be presented below, followed by a diagram summarizing the chapter.

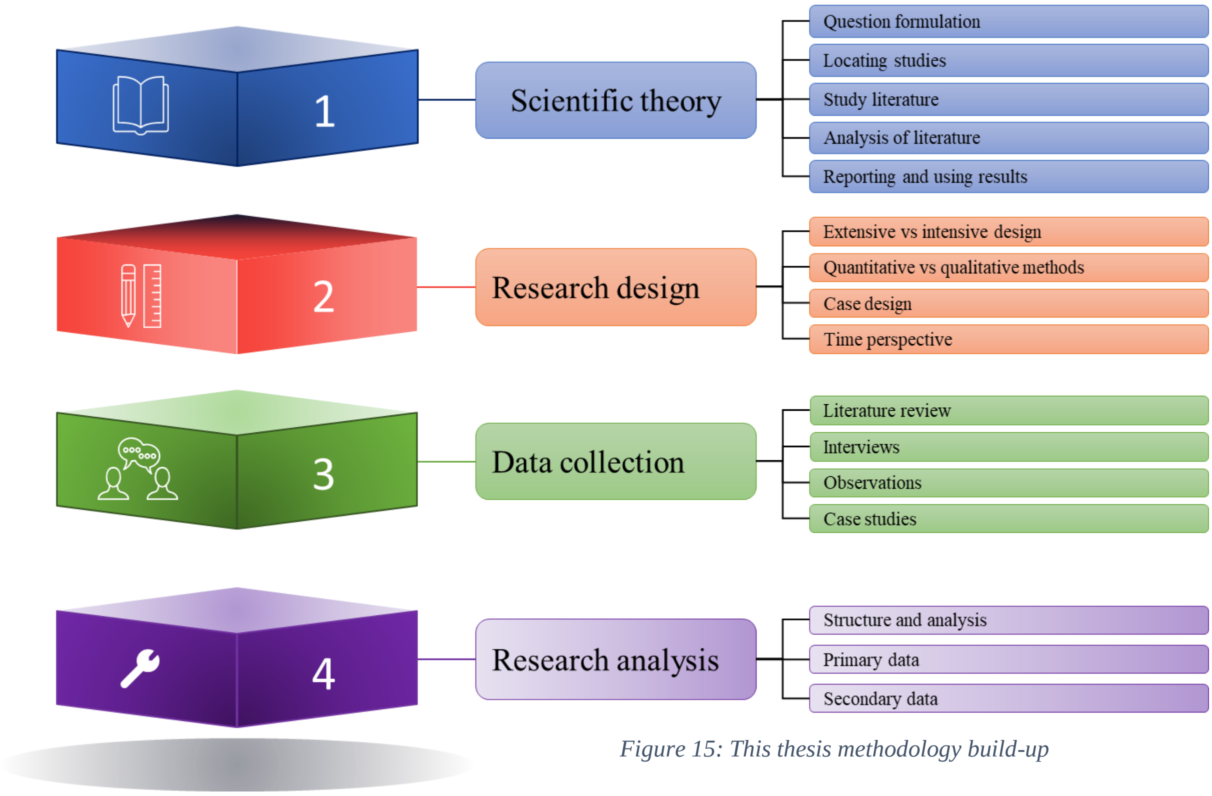


Figure 15: This thesis methodology build-up

5.1 Scientific theory

The scientific theory was found in literature research. To create the theoretical foundation certain research criteria was established. Since Virtual Design and Construction (VDC) is a less researched topic – the scientific theory was challenging. Locating research followed four steps: Question formulation, locating studies, study the located studies and evaluating the studies in terms of relevance and quality. For organizing the relevant and non-relevant articles and cases, Microsoft Excel have been used due to the simplicity of the program. After the above-mentioned four stages has been accepted, the article is regarded as appropriate and relevant for the thesis.

Inductive and deductive research

According to William (2006) inductive reasoning (bottom-up approach) begins with specific observations and measures, detecting patterns and regularities, then formulation of hypothesis and finally the researcher end up with some sort of conclusion or theory. In deduction reasoning, the researcher works from a more general approach to a more specific result (top-down approach). In this case, there might be a theory of the topic in interest, which is narrowed down to a hypothesis that is measurable or able to be tested. Then observations are made according to the hypothesis, which could result in a confirmation of the original theory. The two approaches are differently as they have top-down or bottom-up approaches. This study uses both deductive and inductive study and is then categoriesed as an abductive study. This is illustrated as a wheel in Figure 16. (William, 2006)

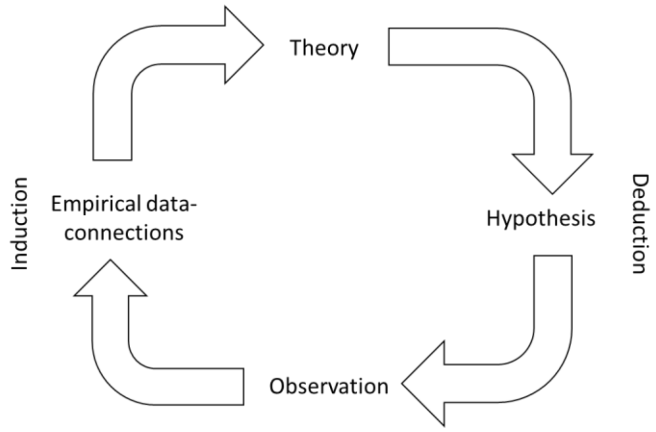


Figure 16: Abductive research model representing thesis theory approach

Further the scientific theory has arrived from multiple sources as Elsevier, Scopus, Martin Fischer (documents received from Stanford's VDC course), and documents retrieved from AF Gruppen and Norconsult. Thereafter, since the theory are compared to traditional practice, only sources later than 2005 have been reviewed in context of traditional practice in the construction industry. The literature review stages with objectives, methods, tools and analysis are shown in Figure 17, with the above-mentioned criteria described in the column *Tools*. Figure 17 is created to illustrate the literature review process in a flow diagram.

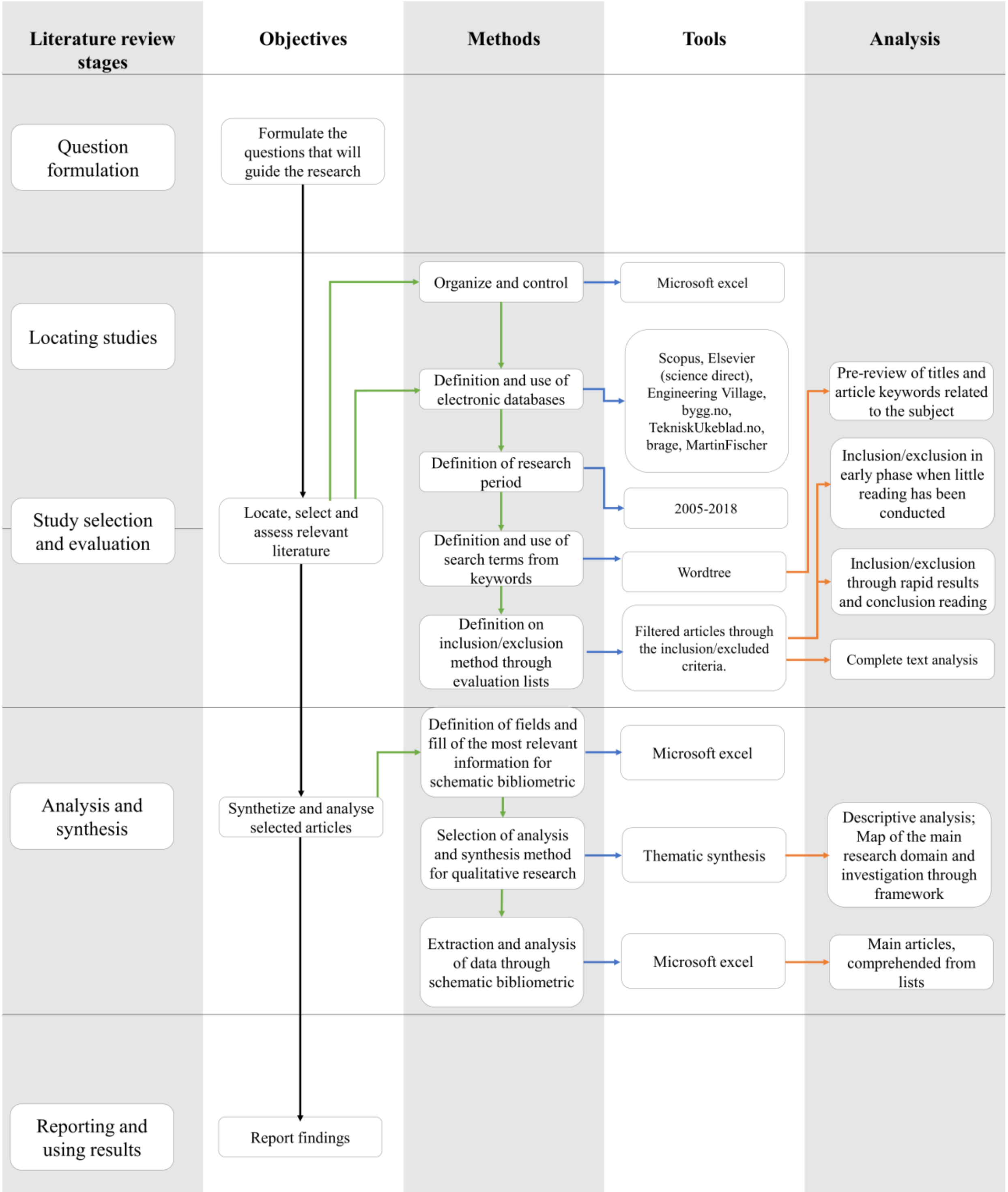


Figure 17: Developed illustration of literature review progress used in this thesis

5.2 Research design

According to Busch (2013) research design follows four principle questions:

- Choose between extensive and intensive design
- Choose between quantitative and qualitative methods
- Choose of thesis overall design
- Choose time perspective

Extensive and intensive design

In an extensive design, the results are evaluated from a high number of sources where questionnaires are the most common approach. An intensive design is based on less sources and is commonly using case studies and interviews (Busch, 2013). This thesis has chosen to use an intensive design as the study is evaluating a complex framework and needs to have longer interviews and evaluation of the projects, actors, and organizations involved. This is a result of the chosen research questions highlighted in Chapter 3: Topic of Master thesis.

Qualitative and quantitative method

According to Busch (2013) are the methods; qualitative and quantitative, highly related to the designs; extensive and intensive. Qualitative method is in relation to intensive design where it is fewer and more carefully selected participants. Dalland (2012) explains that a quantitative method presents measurable data, while qualitative method catches experiences, expressions and aspects not measurable. (Dalland, 2012).

In this thesis, quantitative data is used when mapping the interest for Virtual Design and Construction (VDC) to create a representation of the framework growth. Metrices has also been developed through questionnaires answered after each ICE session. Otherwise, qualitative methods have been conducted to highlight more areas and further evaluation of aspects relevant to the research questions. Qualitative representation is more suitable when the thesis research questions have not been probably researched before. The area of interest needed flexibility, which is most suitable with qualitative research method.

Thesis overall design

Overall design is representing the relation between the scientific theory and challenges faced through the thesis research questions. According to Busch (2013) it’s how the thesis are evaluating challenges from the scientific theory. In this thesis, this is done through one case study and several interviews. The thesis is evaluating one case study where scientific theory are underlining how the case study is analysed. The case study Project Bispevika is chosen due to its complexity and focus on VDC. Further, seven interviews (presented later in this chapter) have underlined potential and challenges with VDC in different kind of projects. The funds for interviews are then compared to practices observed at Bispevika.

Time perspective

To analyse complex developments within projects or organizations using tools or techniques, a time perspective is necessary. Alternative, a possibility is to collect all data at one time to make a cut representation of where an organization or project is.

The project observed in this thesis have limited time perspectives and performances are based on opinions to participants. It should therefore be presented as a semi-limited cut in Project Bispevika. Where interviews from the different projects have been conducted close to each other within the case study. Collaboration with project and engineering managers at Project Bispevika has given results with a wider time perspective than the duration of this thesis. The thesis is still representing a limited time perspective of the project as Project Bispevika has a time perspective of three years (AFgruppenTender, 2016).

5.3 Data collection

Data collection is describing which strategies that is chosen to collect empirical data. The collection is directed by thesis topic, research questions, case studies, and research design (Busch, 2013).

The thesis has used literature research as described in the *scientific theory* section. Thereafter, the techniques: interviews with key participants, use of existing data, participated observations, direct observations or measurements, and case-study has been used to answer the research questions.

According to Dalland (2012), methods for data collection will vary – depending on outcome, starting point, research questions and topics. A data collection is also limited to certain constraints. Constraints as time limitations, resources, access to personnel to interview or limited access to case studies. Table 9 below gives a brief descriptions of data collection methods used in this thesis with descriptions of methods and angles taken.

Table 9: Methods used in thesis for data collection

Method used		Description of method	Angle
1	Literature research	Reading, study and evaluating literature within the topic VDC or related topics.	Done in preparation to other methods, building knowledge to topics, current practice and background.
2	Use of existing data	Research and evaluation of information collected from systems, reports and similar information bases.	If existing data are forwarded it is important to map how the existing data is collected, how it has been used, and if the source(s) are reliable and relevant.
3	Interviews with key participants	Interviews with participants that has desired knowledge to VDC or Project Bispevika. Interviews are attached in Appendix 2.	Interviews in a qualitative project should be semi structure so candidates are able to share their experience.
4	Participated observations	Conducting activities in the environment of research. Observations chosen to use in this thesis is attached in Appendix 3.	Should be done passively so the researcher can focus on researching and not leading an activity.
5	Direct observations or measurements	Specific actions to collect data from participants.	Should be well prepared and a plan should be created on how to collect and when to collect information.
6	Questionnaire	Questions that is written and sent to participants. Questionnaire used to gather data is attached in Appendix 1.	Important to send clear and concise questions to avoid participants that are unsure on what they are answering.
7	Case-studies	Deeper studies about certain projects, situations or activities.	Case-studies is commonly not possible to generalize. They may however give certain insight that numerous methods are not able to present.

Interviews with key participants

Interviews has been conducted with several persons varied between persons related to the cases examined and persons not related. The chosen participants have been selected to understand how VDC is used in the case examined, and to answer the selected research questions – it was important to include and examine practices by multiple companies with people working in different projects and in different positions. This was evaluated to be important because of the VDC framework are integrated in different degrees in different project and organizations. Some of the participants are still undertaking their VDC education at the time interval of this thesis and are using the VDC framework in their first project.

According to Ryan (2002) – interviews are the most common approach to research a qualitative topic. An interview guide should have been prepared ahead of interview (see Appendix 1.a). However, changes may appear, and topics that are planned covered doesn't need to follow the prepared schedule. This is named semi-structured interview where the interviewer can follow the story of the interviewee. Both actors in the interview can bring up topics that are not prepared in the interview. (Kvale, Andersen, & Rygge, 2015)

According to Rubin & Rubin (2011) an interview is constructed by three stages; [1] main questions, [2] follow-up questions related to topic and [3] probes. Main questions are the intended questions related to the topics planned to go through before the start of the interview. Follow-up questions are questions that are asked to get a broader understanding around the main questions. These are usually not prepared but arrive as the interviews are conducted. Probes are questions to get the conversation going and remain a certain kind of flow in the interview progress. (Rubin & Rubin, 2011)

The interviews conducted related to this thesis has followed the semi-structured interview guide. Interview participants has been in different positions, different companies, and has different experience with VDC. Therefore, it has been beneficial to conduct semi-structured interviews where the interviewee has shared their experiences using VDC. All interviews were conducted in Norwegian, transcribed, then a small summary is created for each interview and are presented as a series in Appendix 2 together with an interview guide. Interviews are presented in Table 10. If quotes are used in this thesis, they are translated. This is mentioned in-text and the original and translated version are found in the Appendix 2 series (b to h) after the summary of each interview.

Table 10: Interview objects used in this thesis

	Date	**Position**	**Company**	**Project**	**Attached appendix**
1	21.02.2018	Process manager and head of innovation	Norconsult	General background	Appendix 2.b
2	01.03.2018	Engineering Manager	AF Gruppen	Bispevika	Appendix 2.c
3	14.03.2018	Chief Advisor, operational excellence	Skanska AS	General Background	Appendix 2.d
4	15.03.2018	VDC coordinator	Kruse Smith	General Background	Appendix 2.e
5	20.03.2018	Engineering manager, operations	AF Gruppen	Bispevika	Appendix 2.f
6	22.03.2018	Project manager in design	Norconsult	Bispevika	Appendix 2.g
7	12.04.2018	Vice president of engineering management	Multiconsult	General Background	Appendix 2.h

Use of existing data

Numbers retrieved from engineering- and project managers at Project Bispevika have been further analysed and presented in this thesis. This gives a wider time interval than what would be possible compared to if all materials should be retrieved by thesis author. Parts of this thesis has therefore been created with contribution from Team Bispevika.

Case study

The case study analysed in this thesis has been chosen by AF Gruppen and Norconsult. The project is one of the first projects in Norway implementing VDC to such a high degree. The Team Bispevika rig, placed right next to the project construction site have been the working office for parts of this thesis to retrieve observation of working practices and teamwork on the rig additional to documents. Multiple project- and engineering managers in design and in operations are undergoing their VDC courses during the time interval of this thesis and have been interview objects. In the case study, the author has been given access as observer to follow ICE sessions, day-to-day activities, planning sessions, room layouts, BIM model developments, and rig on-site layout.

5.4 Research analysis

The last step in Busch (2013) four method principles is research analysis. Research analysis is divided into two parts; Secondary and Primary data. Secondary data is found from literature review search and is creating the foundation for the theory chapter. Primary data is the data collected from primary sources as interviews and case analysis. The data is presented in the analysis, results, and discussion chapter.

When the researcher has created a suitable structure of the primary and secondary collected data, it is created a foundation for further analysis. At this stage it is preferable to navigate towards earlier stated research questions. Due to the complexity of the topic and industry it has been evaluated to differentiate research by topics as BIM, ICE and PPM. Topics has also been differentiated to which phase theories and opinions are most suitable to as pre-project, design or construction phase.

The theory chapter is mainly presented by secondary data. Analysis chapter is mainly presented by primary data in terms of observations, measurements, interviews and case study. The primary data combined with secondary data presented earlier creates the foundation for the discussion and conclusion chapters where it systematically develops to answer the research questions earlier presented.

5.5 Research quality & reliability

All four steps in the methodology presented in Figure 15 is a part of creating reliability and quality to the research method. In this section, the reliability to the theory and analysis in this thesis is presented.

Reliability to the theory chapter

The scientific theory is evaluated to have high credibility. The theory chapter has followed the official NTNU (Norges teknisk-naturvitenskapelige universitet) guidelines presented by Norås (2015). Accordingly, sources have been evaluated as presented in the section about scientific theory (Norås, 2015). The theory section is based on a wide variety of sources and cross checked, which is increasing their reliability. All articles within the topic VDC is cross checked against Martin Fischer's theory about the topic and related documents to the VDC education at Stanford. Fischer is the founder of VDC and therefore evaluated as a reliable source. However, some sources are taken from international articles following international standards. These sources have been evaluated to fit Norwegian practices or mentioned otherwise in text.

Reliability to the analysis chapter

According to Yin (2014), when analysis is backed by multiple sources, it increases the reliability. The analysis is backed from sources as observations, interviews, case study, literature review and existing measurements. The analysis is therefore seen as reliable. Additional are information gathered and cross checked with informants with several years in the industry to clarify any uncertainties. Most of scientific theory is public documents and is cited. However, some documents – especially related to the case study and the VDC education are not public and is therefore not trackable.

It has been conducted interviews with participants from several different companies, participants in different positions and with different level of VDC experience. Interviews has been conducted to get more knowledge to the interviewees field of work and opinions to the VDC scheme. VDC is relatively new to the construction industry in Norway and some participants in interviews are undertaking their VDC education during the time interval of the written thesis. It is therefore important to underline that the participants don't have a lot of experience using VDC, but are highly motivated to use it. It should also be considered that the interviewees have worked in several other projects and can compare traditional practices to VDC usage. Information gathered in interviews is therefore seen as highly valuable. Interviews conducted was done in Norwegian and taped, transcribed and topics and parts that is quoted has been translated to English and mentioned in text. To increase reliability, literature researched was conducted before semi-structured interviews. During the interviews, it has been focused on not guiding the interviewee towards any answers.

Observations on-site, in ICE sessions, at the rig working and planning sessions has increased quality to interviews and case analysis. Observations has helped giving a broader picture of how ICE works day-to-day and in sessions, and how that is separated. A possible error in terms of observations is that participants in ICE sessions knows that they are observed, and therefore acts differently. When using a discussion where scientific theory is compared to analysis and interviews, the reliability is strengthened before any conclusions is made. Selective quotes from interviews and personal notes from observation is still affecting the chapter and could affect results, even though it has been focused to remain objective.

5.6 Methodology visualisation/overview

Figure 18 below shows an overview of the methodology and thesis build up. It is created to summarize the chapter and give and extensive overview before the thesis analysis chapter.

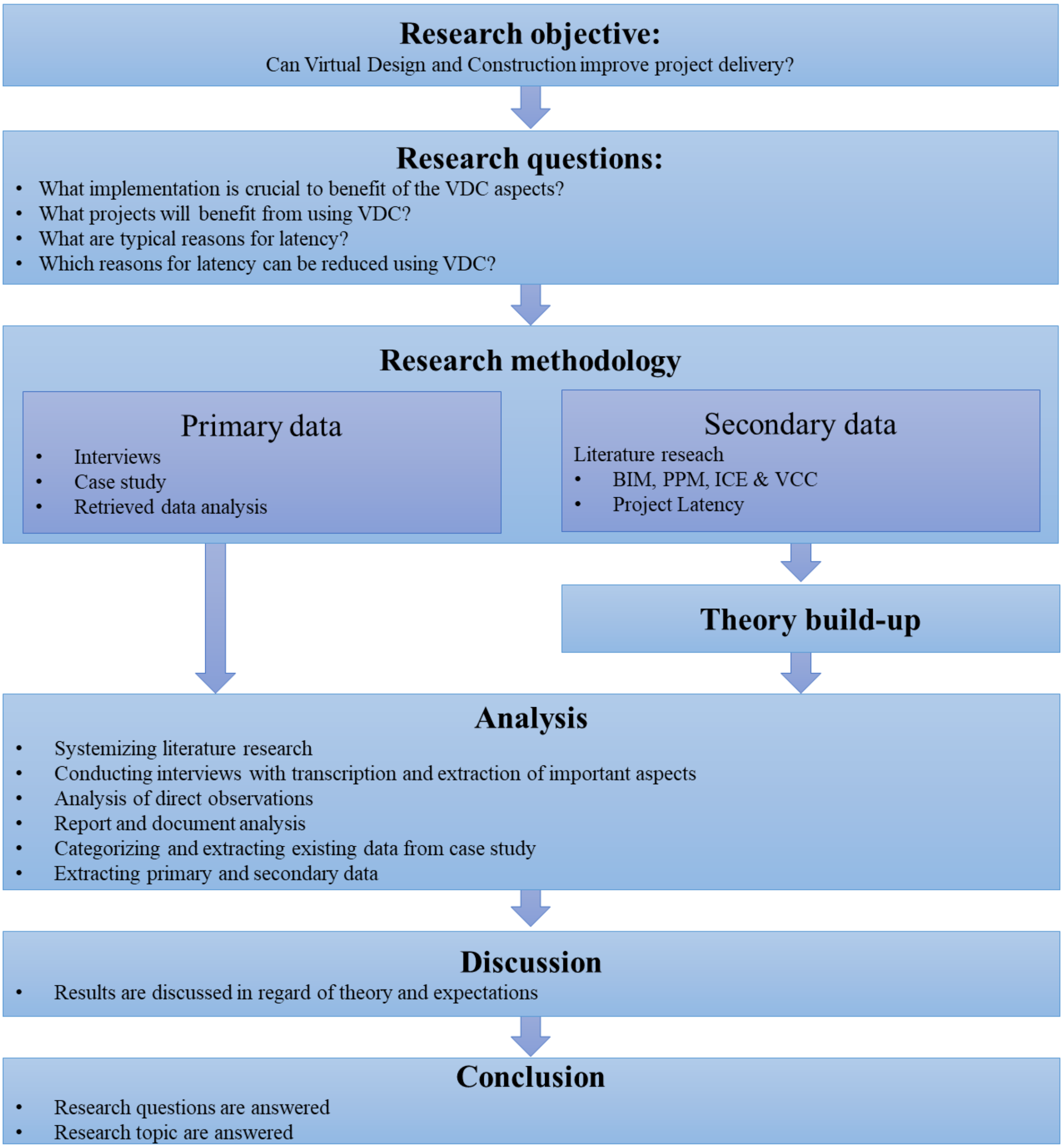


Figure 18: Summarized visualisation of thesis methodology – more detailed than Figure 15

Chapter 6: Analysis

The analysis chapter shall investigate if and how Virtual Design and Construction can be implemented in design-construction projects for more accurate and better project performance. According to the theory chapter of this thesis, VDC should increase building-, project- and process performance (see Figure 2: VDC topics with corresponding performance). The analysis chapter will further analyse VDC as an implemented framework and potential improvements in project performance using VDC. Further, the chapter will analyse what benefits and challenges VDC brings when conducting root cause analysis and to reduce latency.

The three VDC blocks; ICE, BIM, and PPM are further analysed in this chapter. The systems are followed in Project Bispevika as a highly integrated VDC project. Interviews from several companies are used to underline observations in the case. Lastly, in this chapter the VDC framework are evaluated against theory and interviews to shed light on areas with potential for improvements and positive implementations at Project Bispevika. The last subchapter is connecting the three blocks introduced one by one in the case study.

6.1 VDC as an emerging framework

It is notable that VDC consists of several ideas, and arguably combining them creates a form for innovation or a new adapted mindset. BIM has been evolved to include more aspects than before, ICE has helped as a system for communication and integrated delivery, while PPM includes metrices as a system for quality. The tools are old, but they have not been used in this way in this industry before. Important aspects of the VDC framework as Last Planner System has been used for many years, but the combination is arguably relatively new for the industry (KruseSmithVDCcoordinator, 2018).

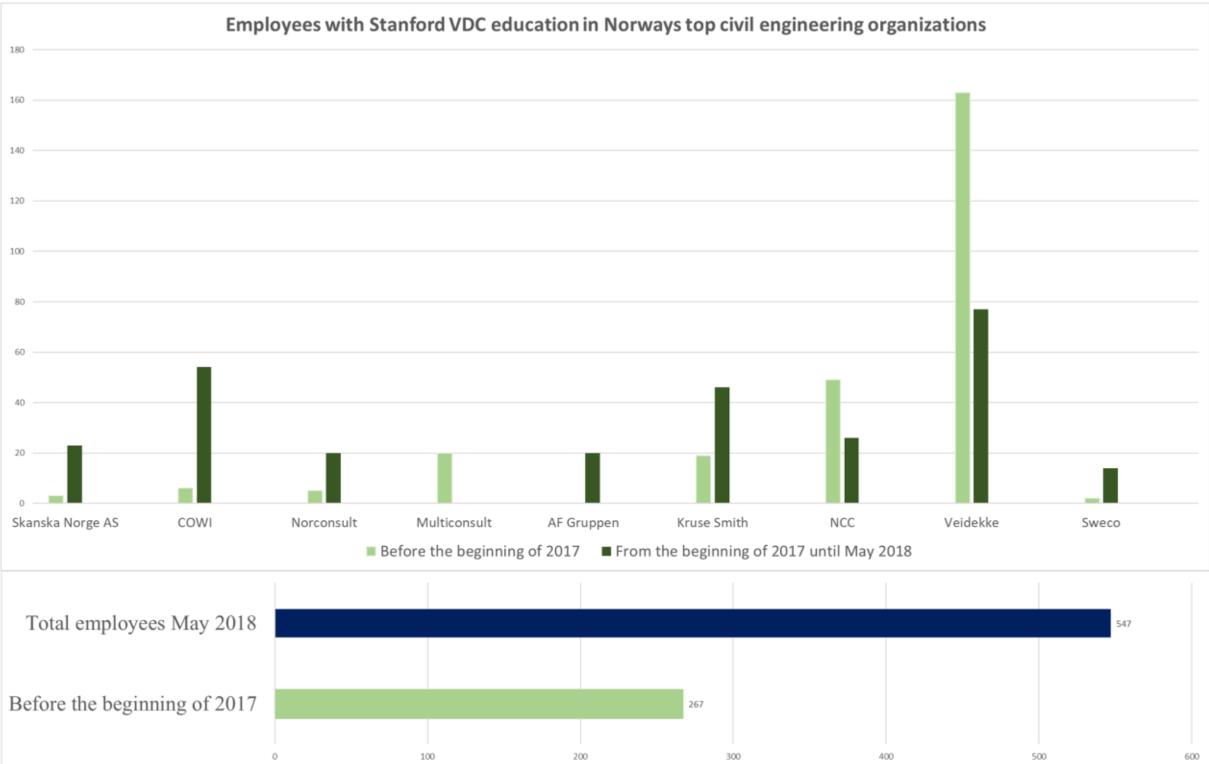
Chief Advisor in Skanska AS (2018) states that there is no definition if you are using VDC or not. It should be categorized to what degree VDC are used in the projects (AdvisorOperations, 2018). Further, Engineering Manager in Multiconsult is explaining that everyone in the industry has different opinions about what a VDC project is. Some organizations have that a 3D model is a VDC project. Some call an ICE session just having a meeting together. There is a lot of stretch in that definition (EngineeringManagerMulticonsult, 2018). However, interviews show that using Virtual Design and Construction has begun to form a template. A level 2 BIM model, ICE sessions in well-equipped Big Rooms, metrices to measure PPC as well as certain aspects in session effectiveness and using the Last Planner System in planning are the most common mentioned techniques. Additionally, some VDC tools and techniques are more suitable for certain kind of projects and unnecessary for other project that does not have the same size or complexity (EngineeringManagerMulticonsult, 2018).

An education at Stanford has helped achieve a template, where interest from organizations in Norway has increased. This is shown in Figure 19 on the next page. Numbers has been gathered from all the presented companies by being in contact with VDC coordinators, BIM coordinators and HR departments to the respective companies. Figure 19 is a visual representation of the interest around the framework by analysing how many employees have gotten the Stanford education. In the representation there is three bullet points that should be evaluated when reading the numbers and is proving that this is not an absolute picture that describes the interest.

- Companies has created their own schemes that are providing aspects close or equal to the Stanford education, but are not counted and presented in Figure 19. Engineering Manager at Multiconsult states that they have 20 employees with the VDC course from Stanford, but further 99 with an extensive course fitted Multiconsult way of working (EngineeringManagerMulticonsult, 2018). The 99 is not illustrated in the graph shown in Figure 19. This could be equal for other companies but haven’t been stated in interviews or it has not been written when HR departments has delivered their numbers and have therefore not been considered at all.
- Organizations have not at all occasions known exactly the number of employees given the Stanford education and have given an approximate number.
- The candidates providing results are categorized as some of the largest organizations in Norway within the construction sector and are often more able to send employees on educational experiences as VDC at Stanford.

Additionally, smaller organizations as Nye Veger AS and NIRAS has stated that they aim to have a small number employees as specialists using other hired employees when projects descriptions claim VDC project deliveries.

When collecting number, it has been divided between number of employees with VDC education from Stanford before the beginning of 2017 and from 2017 until May 2018. The numbers show an increase of employees attending a VDC education in the time interval between the beginning of 2017 and May 2018 compared to before entering 2017. This is indicating that companies see the value in VDC, combining tools and techniques already known to an integrated framework. Further, some companies are slightly rearranging the Stanford course to fit their organization model better.



	Skanska	COWI	Norconsult	Multiconsult	AF Gruppen	Kruse Smith	NCC	Veidekke	Sweco	
Before the beginning of 2017	3	6	5	20	0	19	49	163	2	
From the beginning of 2017 until May 2018	23	54	20	0	20	46	26	77	14	
Total employees May 2018	26	60	25	20	20	65	75	240	16	

Figure 19: Number of employees with VDC education in Norway's top civil engineering companies developed by contacting each company represented

Figure 19 is underlining Chapter 2: Background in this thesis. The increased interest for VDC across the industry has created a demand for VDC in the design-construction process where both consultant and contractor need to adapt the VDC framework from Stanford or similar frameworks to their project delivery process. According to KruseSmithVDCcoordinator (2018), each discipline alone does not get any money for innovation and smarter deliveries, as its not in the contract. Contracts might be one of the next steps to shift the industry to integrated deliveries and it will be even more important for consultants and contractors to deliver VDC projects. This will rapidly increase the need for VDC courses, where consultants and contractors that have moved early will achieve benefits in bidding processes for future projects.

Figure 19 show that more than double as many engineers has retrieved a VDC education May 2018 than numbers of engineers holding the VDC certificate in January 2017. Additionally, an initiative between NTNU, Skanska AS, Veidekke, NCC and Backegruppen has begun in developing educational courses for students to learn VDC where students will achieve educational credits for the course. The course could be ready to be available autumn 2018 or spring 2019 depending on the implementation speed. (NCC, 2018)

6.2 VDC implementation in Project Bispevika

Case-study Bispevika

Project Bispevika is one of the first projects in Norway that is close to fully implementing VDC. Multiple of the participants working as engineering managers and project managers are undertaking their VDC education at Stanford University and are relating it to Project Bispevika. Team Bispevika (the project team working on Project Bispevika) is therefore considered as highly relevant and valuable interviewees. Project Bispevika has been evaluated on three areas. Their coordination, their ICE sessions, and their metrices. Observations and interviews are main distribution channels for information.

Bispevika is considered as an Integrated Project Delivery(IPD) team. Which means that the project team working together are mainly positioned at the rig, distributed by AF Gruppen, placed on-construction-site at Bispevika, Oslo. This makes an integrated environment with faster communication channels. However, with this many different disciplines on the same site, coordination is a key element to benefit from the integrated environment.

The case study is presented in this thesis as illustrated in Figure 20. Coordination is laying the foundation for further work practices. Mentioned in section 4.4 Integrated Concurrent Engineering (ICE) – ICE exists of integrated environment and ICE sessions. Coordination is evaluated as work conducted to create a better integrated environment. Metrices is evaluated as a method for continuously improving project processes.

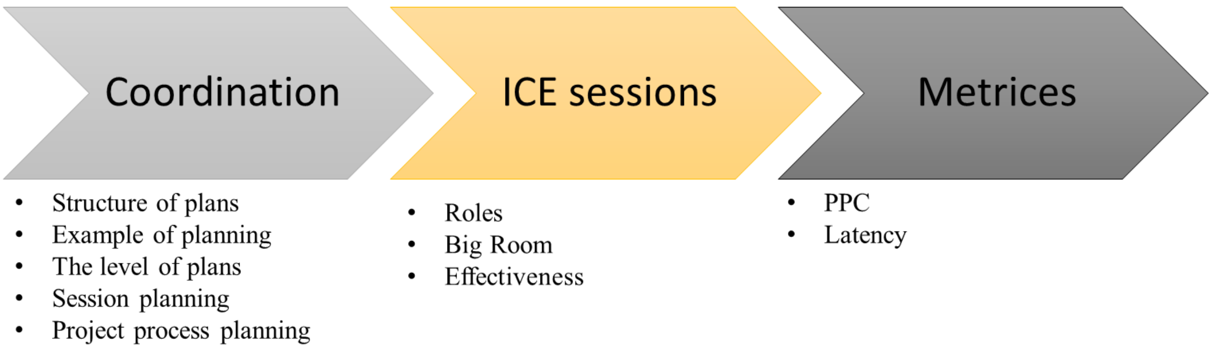


Figure 20: Case-study layout used in this thesis for Project Bispevika

6.2.1 Coordination

Team Bispevika is working with the Last Planner methodology described in section 4.2.3 Last Planner System (LPS). Their traditional structure includes a masterplan, phase plan, looking ahead plan and weekly plan. Team Bispevika has two sets of plans – one for operations and one for engineering. Additional to the traditional Last Planner System (see Figure 5), Team Bispevika has an additional decision-making plan as a separate plan to the above-mentioned system (in the engineering plan set). The decision-making plan is established for easily communicating to the client that certain decisions should be made during this session, which interviews has underlined improved session attendance from the client (ProjectManagerDesign, 2018).

Firstly, before any other activities, the masterplan is developed. The masterplan is thereafter separated into two separate plan systems. One for operations (activities related to on-construction-site), and one for engineering (tasks as work package descriptions, creating BIM model, calculations and authority control, choosing functional necessities, and evaluate materials to reach necessary functional requirements). Differences in the plan structure is that engineering has the additional plan of decision-making, while operations has morning meetings as highlighted in Figure 21 on the next page.

In Project Bispevika, it was firstly created one overall masterplan, this was later separated into two masterplans representing each of the disciplines; operations and engineering. The disciplines have decided to use different representations of their plans. Operations have used a digital solution (Touchplan), while engineering has used a planning-wall presented in the Big Room (further described and illustrated later in this chapter). Milestones in the masterplan for engineering could be *2-5 floor design finished* for B2. Thereafter, each milestone is broken down to phases (named phase-plan), example: *2-5 floor reach maturity level S2* (maturity levels are presented in Table 11). Next level of details is found in a look-ahead plan, which is covering a perspective from 3 to 9 weeks in engineering, while 5-9 weeks in operations. The focus is always on the output of a delivery and what is needed to deliver this output, at this stage, re-planning is not uncommon as project might have changed since the phase plan was developed (this is showed in an example from Project Bispevika below). When further broken down to weekly activities, work-packages should no longer be re-planned as shown in Figure 5.

Table 11: Maturity levels at Team Bispevika in engineering

Maturity levels	
00	Object placed in model.
01	Object ready for multidisciplinary control.
02	Object controlled in own discipline detailed design.
03	Detailed design approved.
04	As built

Daily meetings are small sessions from 10 to 15 minutes each morning. The sessions are focusing on activities that was completed and not completed yesterday, what are on the agenda for this day, who is responsible, and what are planned for the next day. In Team Bispevika, there is also presented an A3 drawing with the construction area where information about unsafe places (example; places with several heavy lifts during that day) where employees are suggested to use other routes. Safety is a VDC objective both in project process objectives (measured weekly) presented in Table 7 and as a performance objective presented in Table 8. A VDC goal should be no incidents on-site and all close to incidents reported so this can be discussed in morning meetings to avoid incidents late. An illustration of the plan build-up is presented in Figure 21 below. (EngineeringManagerOperation, 2018)

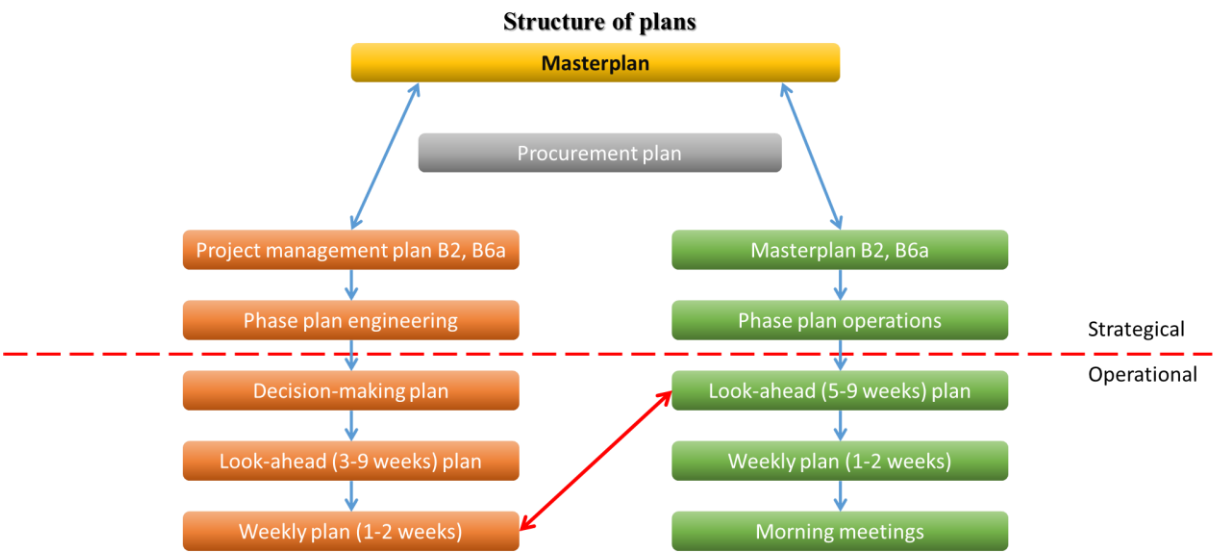


Figure 21: Structure of plans at Project Bispevika

Example phase planning structural workshop process:

The section will present one of the planning processes followed at Team Bispevika. The following example is presented to show how The Last Planner System is used in Team Bispevika within Operations. The example is a representation for planning one phase (structural work) and is based on passive observations from workshops and interviews and are following the process through three sessions. The example is using the phase structural work, which has the start date four weeks after phase session number three. The example is illustrating one way of using pull planning but is not the only way to use it. A summary is presented in Appendix 3.c. The example below will present:

- Work in phase session one and output
- Work up till and during phase session two and output
- Work up till and during phase session three and output
- What aspects of the process has been good and what aspects can be improved. The process is compared to the seven wastes presented in Table 2: Waste in the construction industry .

Pull planning in phase plans can be developed using workshops. Team Bispevika have in this case used three workshop sessions. In the workshops; technical, AF Gruppen, and Con-Form has been represented. Con-Form is the structural work subcontractor in Project B2 (and B6a, but this example describes B2 only).

At the beginning of the first workshop, the three disciplines involved (AF Gruppen, Con-Form and technical) agreed on separating each floor in three areas. This is due to the armlength of each crane, where it needs at least two cranes to reach over each floor. It got showed that one crane would reach over area 1 and another crane would be able to reach over area 2 and 3. It is the exact same work that will be done in area 1, 2 and 3. Therefore, it was only needed to set up work-packages for one area and copy this up for the remaining two areas. The three disciplines separated from each other and wrote down all work-packages they would undertake in area 1 and the duration of each work-package. It was seen as important that it was no communication between the disciplines at this point, so no-one would be influenced by each other. Thereafter, the disciplines were brought together, and all work-packages was placed on the wall. Then the Last Planner System is used; which activity is the last activity for the structure to be finalized in this phase? That is the first placed activity on the wall, now called Activity 1. Then the project group asks; what is the last activity to be completed to be able to begin with Activity 1. That is Activity 2. The project groups work backwards until the activity that is the first activity in the phase is decided and illustrated as one long timeline (illustrated in Figure 22). Duration was placed on each activity, where the result was 34 days in total per floor. (PhaseSessionStructuralWork, 2018)

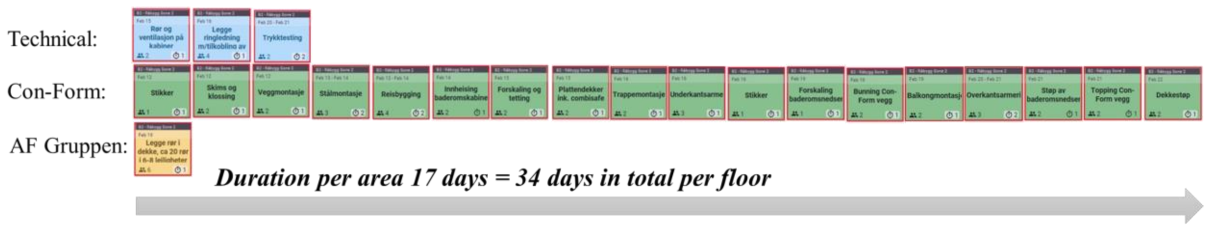


Figure 22: Developed phase plan after first structural phase workshop at Project Bispevika. This plan will be further developed shown in Figure 23 to Figure 26

Before the second workshop – each activity was created as a geometric 3D model. Synchro is used to create a 4D model, and a video is created to visualise and present the construction progress. The second phase workshop is started by showing this video. In the second workshop, the focus is on reducing the number of days to rise the structural work. Questions could be:

- Can we reduce two days to one at this work package? And,
- What work packages can be done parallel to each other?

A critical path is created, which is illustrated in Figure 23. Numbers in the right-hand lower corner are the duration of each activity, where a number faded with a white box are critical and cannot be delayed. Critical path is highlighted with a red box in Figure 23 and Figure 24.

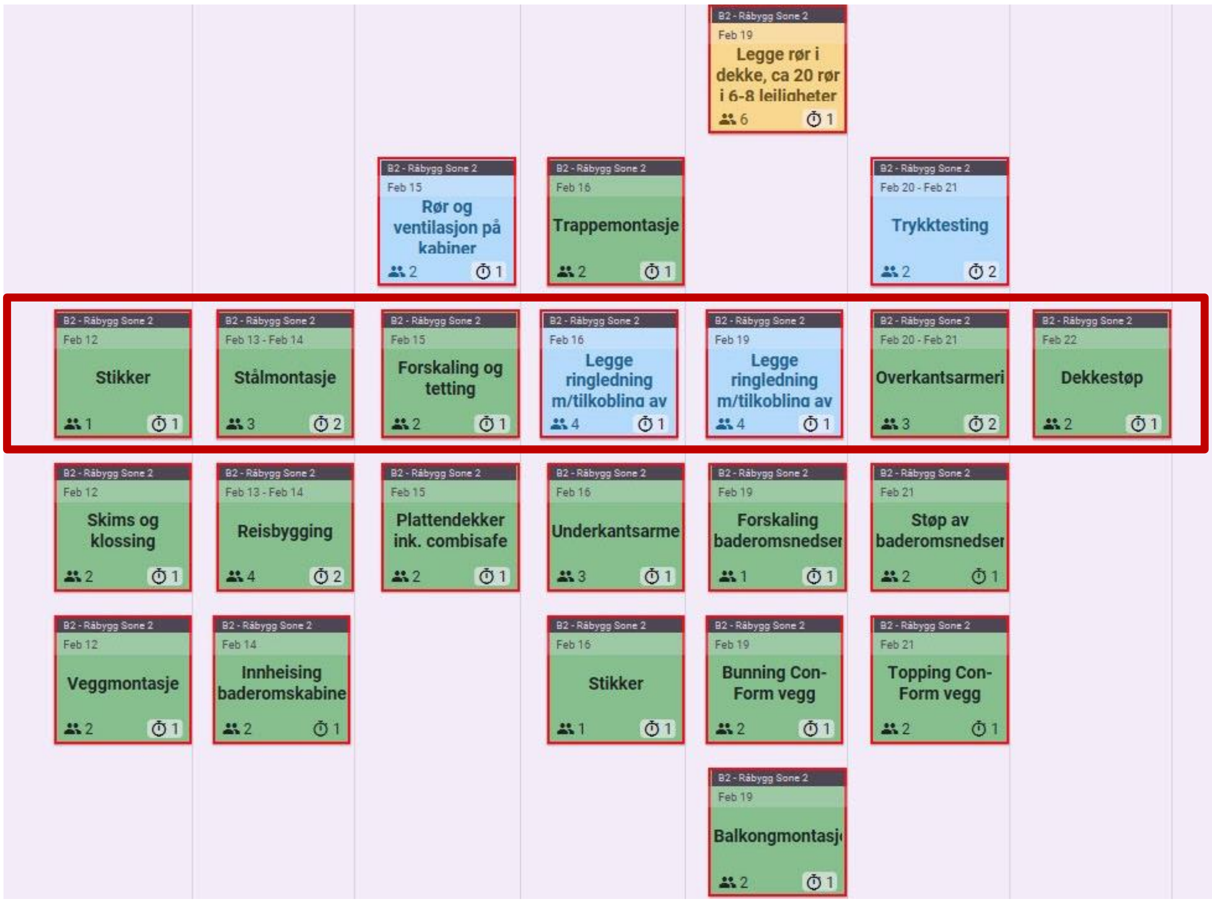


Figure 23: Developed phase plan for one area after second structural phase workshop at Project Bispevika. This plan will be further developed shown in Figure 25 and Figure 26

Since Area 2 and Area 3 are working with the same crane, they will lead the progression where Area 1 has slacks. This created natural overlaps where Area 1 could work simultaneously with Area 2 and 3 combined. Additional, Area 2 and 3 could overlap by one day. This is further illustrated in Figure 24. This session was able to half amount of days used per floor from 34 to 17. The main contributed was a new innovative sprinkle system reducing days in every floor.

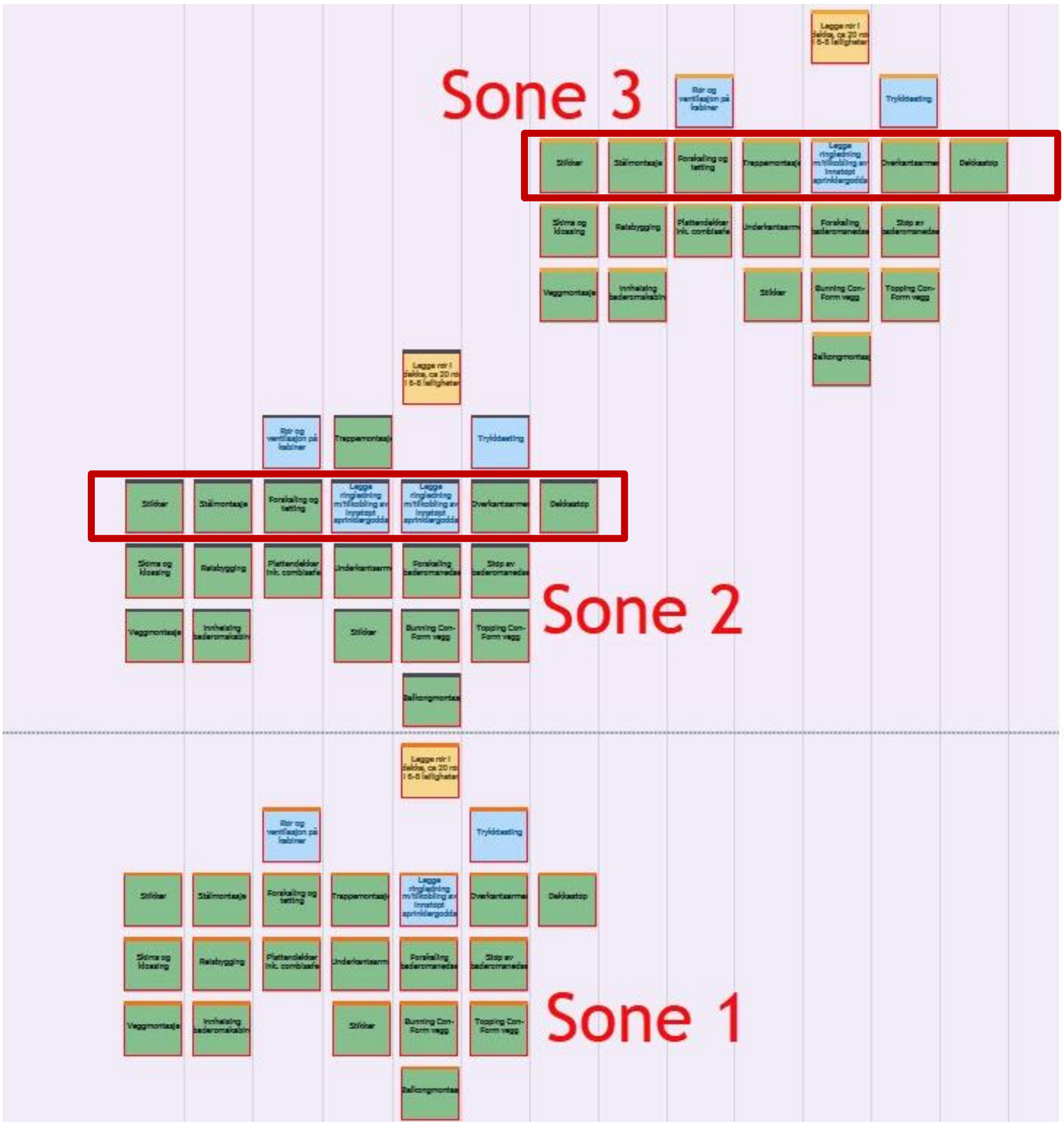


Figure 24: Developed phase plan for all areas after second structural phase workshop at Project Bispevika. This plan will be further developed shown in Figure 25 and Figure 26

Third phase session aim to reduce number of days to rise the structural work even further. Therefore, each participant has the homework to look at their activities, wherever they are on a critical path to analyse if it is possible to reduce number of days per floor. Before the session, each floor was looking at 17 days. Con-Form as the main subcontractor has all green boxes – therefore, they have most work-packages. Technical (blue boxes), AF Gruppen (yellow boxes), car distributor and crane distributor are present at the workshop to make sure capacity is enough for work-packages each day. Con-Form together with AF Gruppen managed to reduce number of days from 17 to 14 because of good preparation and innovative thinking working at separate floors each day. The result after the third workshop is presented in Figure 25 and Figure 26.

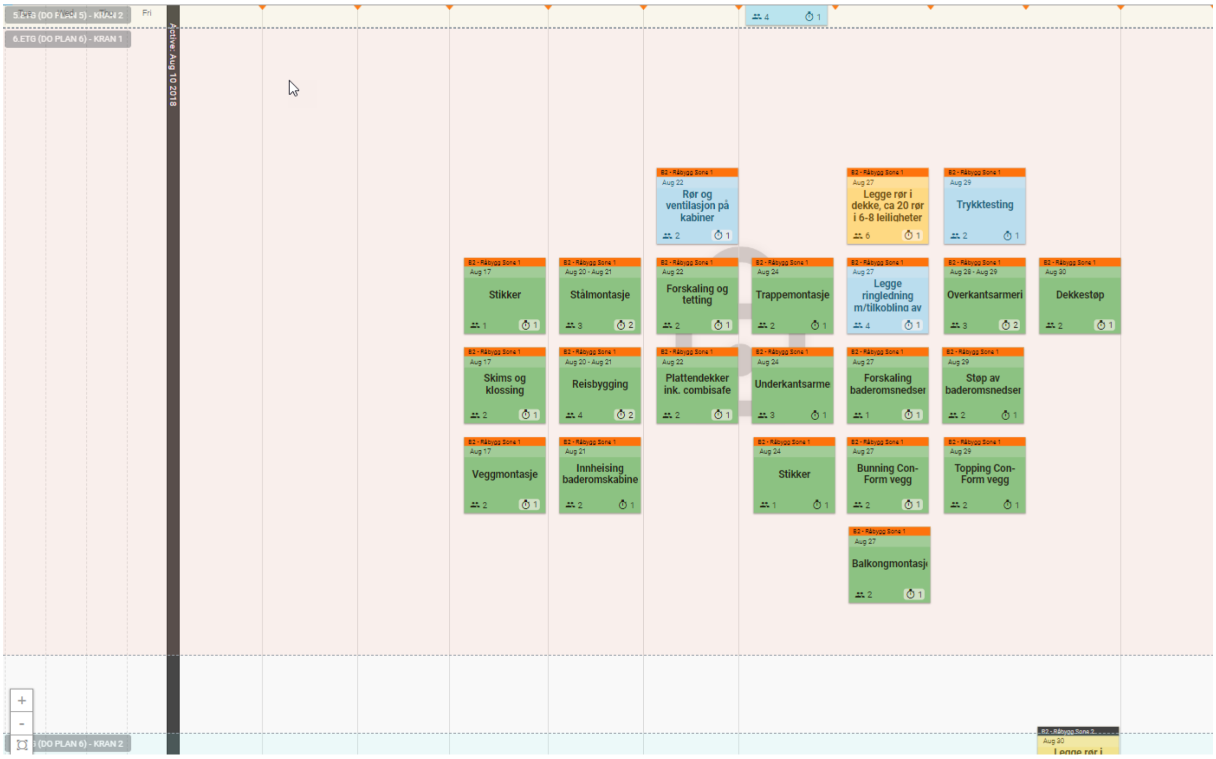


Figure 25: Developed phase plan for area 1 after third structural phase workshop at Project Bispevika. This plan is the finalized plan for area 1 and developed from Figure 22

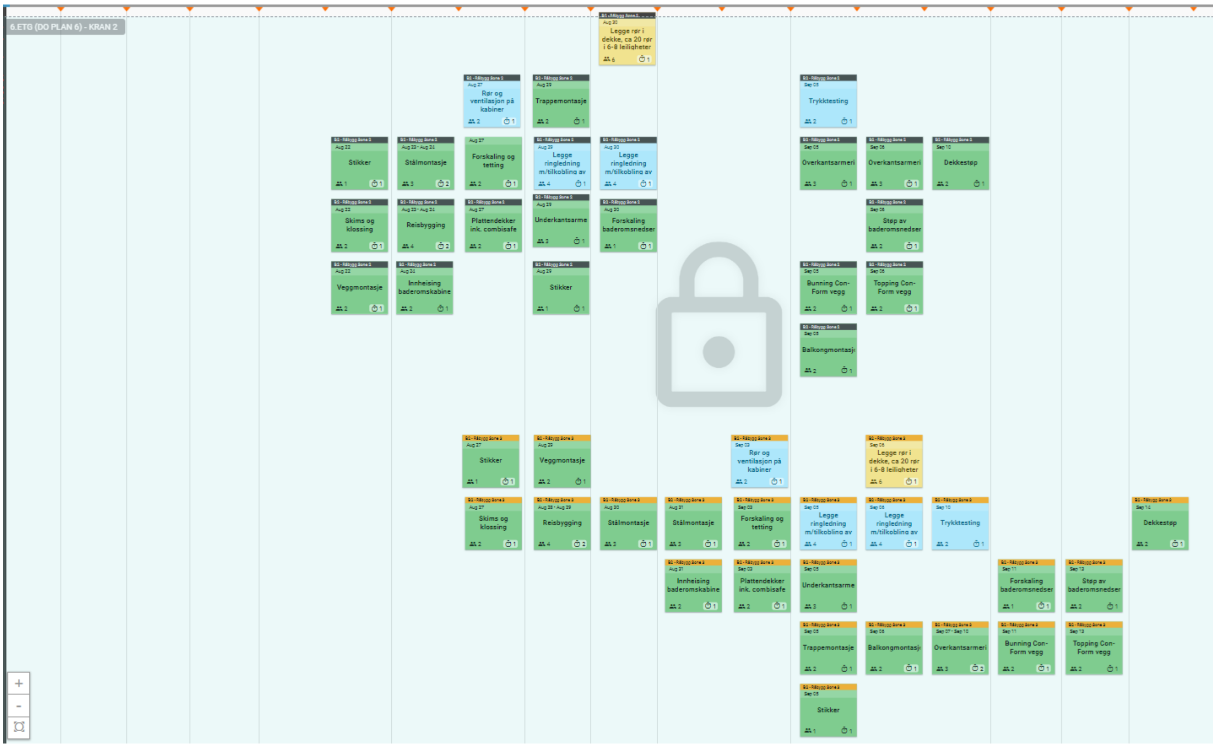


Figure 26: Developed phase plan for area 2 and 3 after third structural phase workshop at Project Bispevika. This plane is the finalized plan for area 2 and 3, and is developed from Figure 22

As seen, Area 1 will stay close to equal as workshop number 2 underlined that this crane is not critical. Area 2 and 3 has required overlaps, work-packages to begin and finish at the same time. The example is illustrated to present how Team Bispevika is working, which parts are good and what areas have potential for improvements. Wastes in the construction industry are presented in Table 2. In the phase workshops they are addressed through:

Waste 1: Correction – Design has been presented as a 4D model in workshop 2 and presented for all disciplines involved in a film with no overlapping work packages.

Waste 2: Overproduction – All work packages was displayed at the wall during the first workshop to make sure no disciplines planned for other activities than their own.

Waste 3: Motion – model is displayed on site in a BIM bank and iPads has been given to employees on site. Information about materials needed is displayed in model the employees can see on site and in office. This shall reduce the amount of movements back and forth to the rig for information not available.

Waste 4: Material movement – in workshop one the floors was divided into three sections where the cranes would be able to work to reduce material movement. Crane and car supply distributors has been present at all workshops. Their attendance makes sure that all disciplines involved knows the plans and therefore can provide the best supply pathway.

Waste 5: Waiting – The three workshops has aimed to reduce amount of days per floor by overlapping processes and floors to create the most efficient construction with minimal waiting.

Waste 6: Inventory – cranes and materials supply chains has been optimized through the three workshops.

Waste 7: Processing – all information about material orders are displayed in the BIM model. The distributors have been present through the workshops and should not be involved in any unnecessary reporting, expediting material orders or excessive coordination. There is one plan, which all participants shall follow.

Above has shown that the workshops have prepared for all seven wastes in the construction industry presented in the theory chapter in Table 2. However, in the workshops – Touchplan are used as planning tool. Touchplan did create a mindset for fully days instead of specific hours per day. However, all participants need to agree to using the same toolset. In this case, one of the subcontractors wanted to use Microsoft Excel as they were used to. Therefore, when displaying this for the workshop session 3 participants – all the preparations that had been done in Microsoft Excel needed to be translated to Touchplan. When already established the plan in Excel, the discipline had sat specific hours to each work package per day, which was not a part of the assignment. So firstly, everything needed to be translated to Touchplan which does not have the same display as Excel, so it was a lot of re-work (Waste no. 1) while the other disciplines in the room had to wait (Waste no. 5). After this was done, some of the aspects of using Touchplan for enhancing innovation was lost due to the mindset to the subcontractor, who had already created a workflow. The plan did become lean and it might not be possible to get a better result than what was achieved- However, this didn’t need to be the case – and is categorized as a lesson learned for later projects (as Bispevika B6a).

Coordination planning system

At Team Bispevika, each plan in Figure 21 are categorized into six different levels. Each level is further described with [1] responsible person for that plan, [2] description on meeting structure, [3] disciplines involved, [4] what topics that are focus areas for progression, [5] if there is any external coordination, [6] what BIM topics that will be regarded as important in their meetings, [7] health, safety and environment, [8] BREEAM and [9] Risk status. The structure of plans and throughput are summarized in Table 12 below. As well as it is illustrated that higher-level plans (ranked no. 1 is highest / ranked no. 6 is lowest) have a strategical decision-making approach. It is also illustrated that high-level plans have a top-down information flow, compared to lower level plans that has a bottom-up information flow. This mean that higher level plans is beginning with “the big picture” – focusing on strategical and concepts views as height and width of the construction. While the bottom-up approach is piecing together small detailed systems to create a large and more complex system.

Table 12: Structure of plans descriptions at Project Bispevika

Level | **Structure of plans** | **Information flow**

Strategical → Operational | Top down / Bottom up

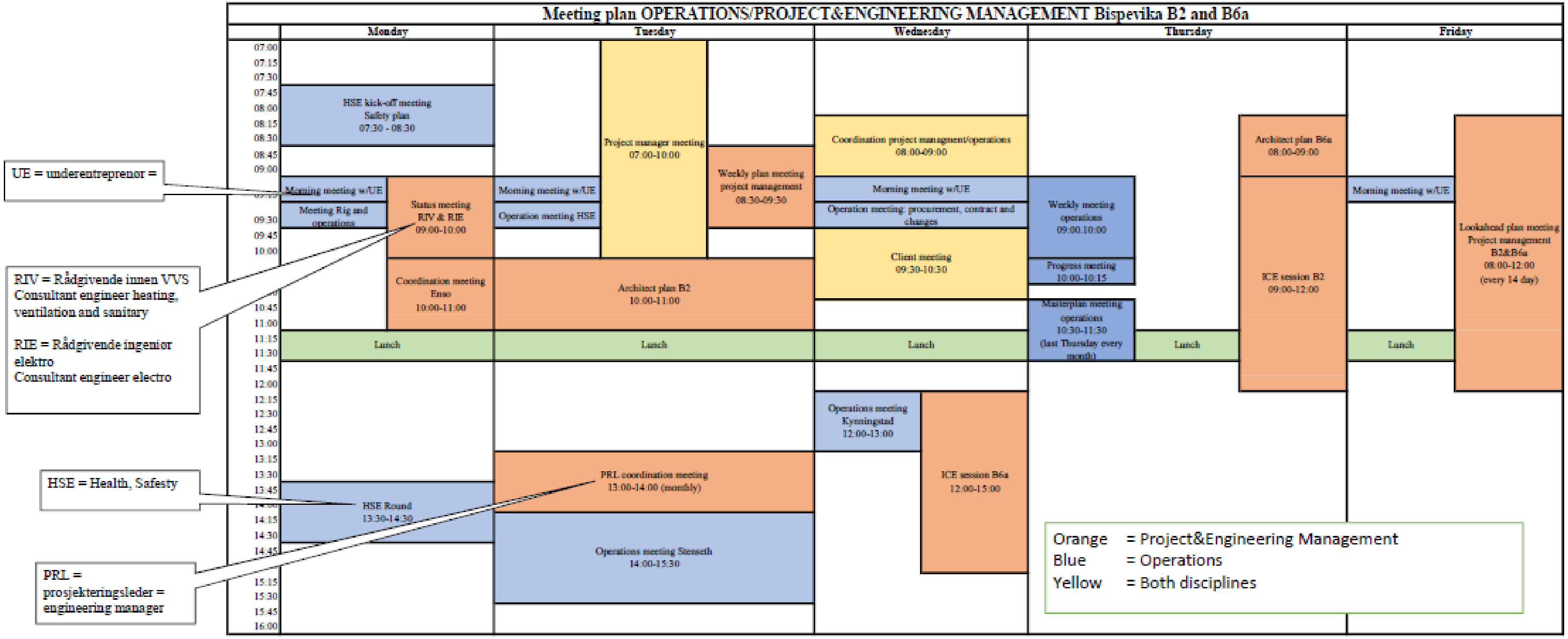
Level of plan (time horizon)		Responsible for plan	Structure of meeting	Involved participants	Progress	External coordination	BIM	Health, safety and environment, BREEAM quality	Risk analysis
1	Project plan B2 and B6a	PGL	Before the beginning of project	BH PL PGL PRL	Main activities, phases, milestones	Sales and optional	BIM manual	Plan for HSE delivery Plan for BREEAM delivery	At beginning Top 10-lists Roughly going through quarterly
2	Phase plan (10-22 weeks)	PGL	In a decent amount of time before the beginning of the phase	PRL (all) PL (all) Consultants ARK	Coordination of activities from the project plan and set times to a weekly level. Focus on innovation.	Sales, optional, BIM and authority	Collision-control Time coordination Level of detail is decided.	HSE risk analysis plan for phase. If external BREEAM deliveries are needed, they are decided.	5 lists of risk
3	Decisionmaking plan	PGL	Decision-making meeting	PRL PL BH	Establish decison points for current phase and decide content criteria for decision-making.				
4	Lookahead plan (3-9 weeks)	PGL	Every second week	PRL (all) PL Consultants ARK	Detailed cordination and secure all assumptions underlining healthy activites. Focus – Decisionmaking plan Topic for ICE meeting is decided.	Client decisionmaking plan and authority cordination. Ecternal disciplines invited – UE/operations optimalization	Level of detail for drawing-free construction site is decided	Sharing from experience, incidents and happenings related to project content. BREEAM delivery per topic.	Top 3 lists
5	Weekly plan (1-2 weeks)	PRL	Weekly	PRL Consultants/ARK	Activities on daily levels, PPU (%), ICE agenda decided	ICE participation is decided	BIM coordinators activities are included in plan	BREEAM	Top 3 lists
6	Morning meeting (yesterday review and plan for today)	PRL	Tuesday, Wednesday and Thursday	PRL Consultants/ARK	Status on yesterday, cause-effect analysis, eventually certain challenges for the day.		Status		All participants identify risks

Meetings are then structured to fit the schedule to all disciplines involved. Therefore, it is created a weekly plan for when meetings and ICE sessions are coordinated. The meeting schedule has three categories: [1] operational, [2] engineering, [3] both disciplines – which are corresponding to the plan levels in Figure 21 for easy coordination. Table 13: Weekly meeting coordination at Project Bispevika is developed to illustrate when each session is in terms of each other. ICE sessions are located on Wednesdays and Thursday, while the different plans are placed on separate days. Theory has shown that coordination is an important aspect of VDC where unnecessary waste is reduced if employees are using time on where to go and find unavailable co-workers. Visualisation through colours and categories are one of several possible initiatives to neglect confusion.

Table 13 is created to illustrate how precise meeting coordination is on the Team Bispevika rig. Additional to the information on the illustrated schedule, information about which room each meeting is in are described. A similar plan (in Norwegian) is placed in multiple locations at the Bispevika rig so all employees know when meetings are, which rooms are taken, and which people are busy. Same as before, schedule is separated between operations, engineering and all participants to maintain a system for coordination.

A part of the VDC framework is aiming to reduce wastes earlier categorized in Lean Construction. The coordination system is analysed as one system. It is recognizable that all plans are following the same groups: operations, engineering and all participants and is displayed with different colours to avoid any misunderstandings by project participants (ref principle 3.5 Table 1). Meetings and people involved are standardized as the same meeting rooms are used to a standard time, including the same people every week (ref principle 3.4 in Table 1). Further, Table 12: *Structure of plans further description at Project Bispevika* are presenting a systematic way to present leadership and what are expected from Figure 21: Structure of plans at Project Bispevika. Table 12 is introducing that there are several different leaders that are responsible for the different sessions. This are helping the organization to continuously learning (ref 1.1 Table 1) as participants needs to adapt to different session methodology, and the session leaders are given opportunities to grow and get challenges (ref 2.1 Table 1) as this is one of the first integrated projects for many participants.

Table 13: Weekly meeting coordination at Project Bispevika



Planning wall

PPM is an important part of the VDC framework. As illustrated in Figure 2: VDC topics with corresponding performance, PPM is a part of *how* the project team is accomplishing the project objectives. The Last Planner System is a part of the PPM block in the VDC framework and the system is used as a part of the planning wall described below.

The engineering and project management progress plan is covering both walls in the Big Room and are located in the second floor at the rig (layout is further described in ICE Session below). The progression plan is illustrating all planned work-packages in Project Bispevika, post-it notes are used to describe the work packages. As seen in Figure 21, there are two plan-sets, this section will only describe and illustrate the engineering management plan. Both plans are also linked together, and operations manager and engineering managers are located at the rig and have weekly meetings to keep track of each other (showed in Table 13).

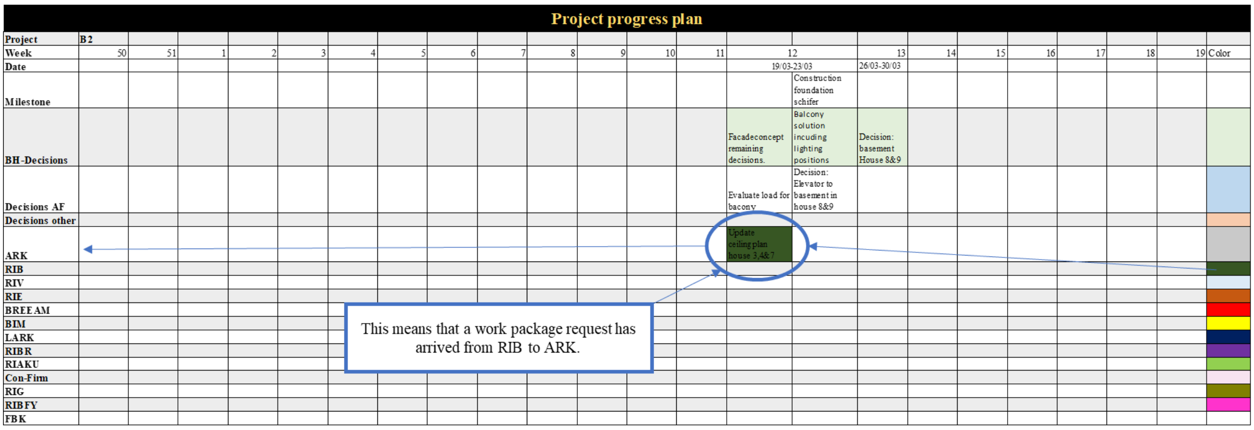


Figure 27: A created example of project progress plan at Project Bispevika in Engineering extracted from progress plan illustrated in Figure 29

As shown in Figure 21, each plan has different lengths of planning. The higher in the hierarchy of plans, the more uncertainty there is for changes. This is described in the chapter 4.2.3 Last Planner System (LPS) and experienced in the phase sessions. The "Should" part of the LPS is

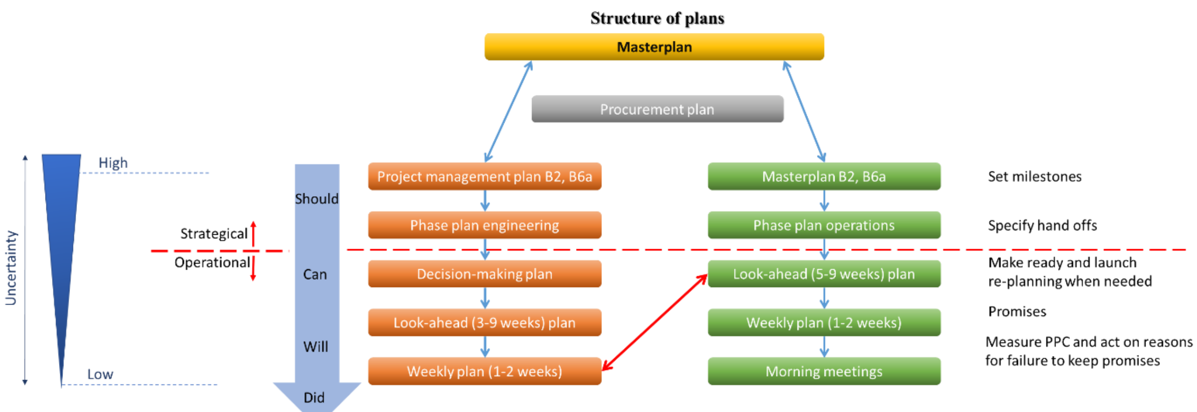


Figure 28: Structure of plans at Project Bispevika compared with the Last Planner System with work-package uncertainty illustrated in Figure 5

what is working on a strategic level (masterplan and phase plan). When developing the look-ahead planning work packages are shifting from “should” till “can” through the last planner process where uncertainty is decreasing rapidly. Further, according to LPS, the “can” work-packages are turned into “promises” when broken down to weekly work packages. Next step would be daily morning activities in operations and done or “did” activities in engineering. This is illustrated in Figure 28 combining Figure 21: Structure of plans at Project Bispevika are connected with the Last Planner System presented in Figure 4.

At Team Bispevika, the Last Planner System has been used effectively with areas of focus:

- **Pull planning** sessions is done by the design team and other relevant stakeholders, to create an overall plan of the project to get the team aligned. In engineering, this is done with visual post-it plans, where people post outputs (a delivery as a drawing, list, decision et cetera) to symbolize a moment of completion (time of handoff). In operations Touchplan is used with the same ambitions. The high focus on pull planning is providing specific goals for each output. The project schedule created in form of pull planning is more precise than traditional planning.
- **Lookahead** is describing a proactive problem-solving attitude. One of the strengths of the LPS is making tasks ready for delivery (explained as healthy activities by seven key points in section 4.2.3 Last Planner System (LPS)). The focus has been on what challenges might arise, unlikely to the traditional planning – where problems are solved as they arise (ref 3.1, 3.2 & 3.3 in Table 1: Toyota Foundation to Lean Thinking).
- **Checking**. When using the LPS, it also integrates a tracking commitment where it uses Plan Percent Complete (PPC) to keep updated on how work actually is performing compared to what was planned (see 3.5 in Table 1). The on-going learning by using PPC system and systematic root-cause analysis is identifying activities that are less reliable than others.
- **Learning** by using PPC and root cause analysis provides useful insight to what went wrong (if errors or delays), and over time enable possibilities to understand trends. This makes it possible to insert counter-measures, and reduce number of errors and delays, as well as getting a more reliable time axis for future projects (ref 1.1 & 1.2 in Table 1). Plan-do-check-act mindset through work packages of weekly work planning has created a work culture enhancing continuous learning.

AF Gruppen are using two types of layouts when presenting their project process plans (one in operations and one in engineering management). According to ProjectManagerDesign (2018) working at Project Bispevika, a planning wall is beneficial in ICE sessions or other meetings conducted in the Big Room at the Team Bispevika rig. It is preferable to see the wall while planning and use different coloured stickers to show who the work-packages are referring to. However, it is added that it is clear that if it was possible to begin over again, all participants should agree on how to make the post-it notes clear and concise, because at Project Bispevika different disciplines has different ways to do this. According to Project Manager, certain disciplines are writing a lot of text on a small post-it note, while others write too little text to provide a clear message. It is also mentioned that disciplines that are not around on the rig all the time will not have access to the planning wall. In Project Bispevika, this includes disciplines as architecture that are only present at the rig three days a week. This can create difficulties if they are not updated on changes at all times. The client is not present on the rig either and does not have access to the planning wall at all times, this creates extra work if there have been any changes affecting circumstances the client should be aware of or included. (ProjectManagerDesign, 2018)

The planning wall in engineering is illustrated in Figure 29 on the next page.

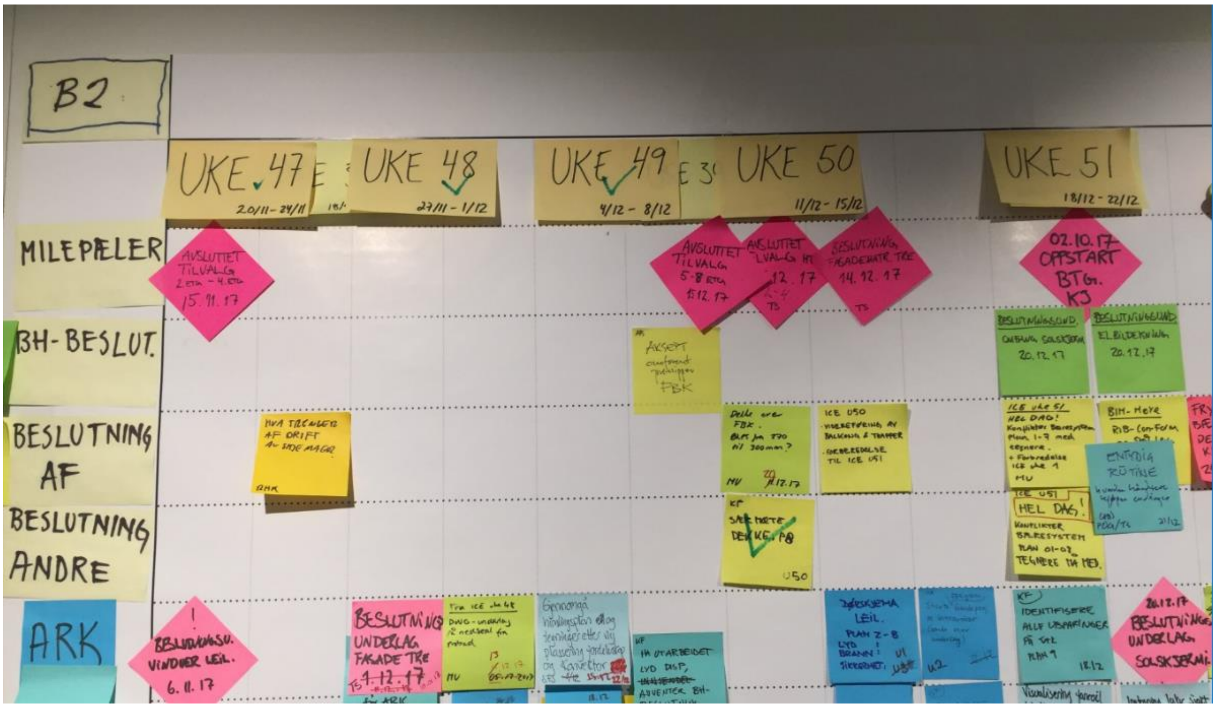


Figure 29: Planning wall with stickers at Project Bispevika how they are used in Design & Engineering

Further, it can be argued that there should be a digital backup of the planning wall. Both for lookback if work packages and for communication outside the rig. If a task has gone wrong – a root cause analysis should be completed, and the error might be before the present day. At Bispevika each note is hanging on the wall two weeks after it has been ticked off and gets pinned (see Figure 30). This is a bit messy and it can be difficult to go back in the "archive" to track root causes and work-packages. All work-packages (finished with or without delays) are pinned at the same stack. It would also be beneficial for performance measurements as PPC to have a digital solution or backup.

Figure 30: Pinned notes from the planning wall displayed in Figure 29

In operations, the planning system has moved from a planning wall as in engineering management to a digitalized solution using Touchplan as digital tool. Observations of phase sessions (see Appendix 3.c) show that Touchplan is used in sessions and is covering one or two of three big screens in the Big Room shown in Figure 35 (6.2.2 ICE Sessions). EngineeringManagerOperations (2018) underlines that most of the participants are contributing more when Touchplan is used. The transition towards a digital solution has been measured weekly. In Figure 31, the results are presented, and a black trendline is illustrating an increase in satisfaction with Touchplan.

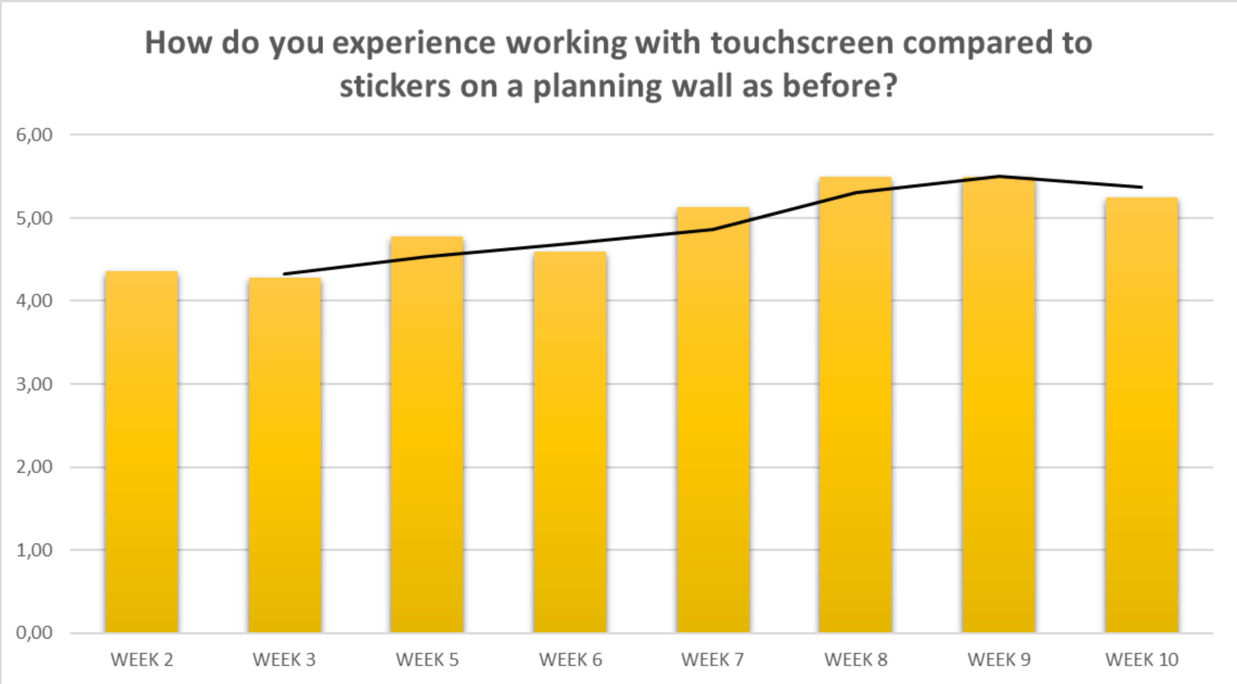


Figure 31: Question 6 results: Touchplan satisfaction in operations at Team Bispevika

The trend-line shows an increase in satisfaction, which can indicate that the Touchplan solutions is preferred rather than planning wall as used in engineering. In operations, however, several subcontractors are used, which makes it more critical for having an available plan online at all times so information is available from all work places and participants are more prepared to sessions. This is illustrated in Figure 32 (shown below) where *Question 2: meeting preparations* and *Question 6: use of Touchplan* are extracted from Figure 46 presented later in the metrices section. The increased satisfaction shows that the participants are getting more satisfied when using Touchplan in the long run, which is underlining that the implementation of a digital solution has been successful.

The Touchplan solution is seen as an initiative to reduce latency. The process is seen as more efficient and the result is more accurate and displays a more straightforward visualization of work-packages. A better and standardized visual presentation of work-packages should create increased meeting effectiveness, addressing performance factor 2.3 presented in Table 7. Project process objective 2.14 Client Satisfaction as well as 2.16 visualization requires the score four or above on a scale to five. The Touchplan initiative should increase client satisfaction as shown in the graph illustrated in Figure 31.

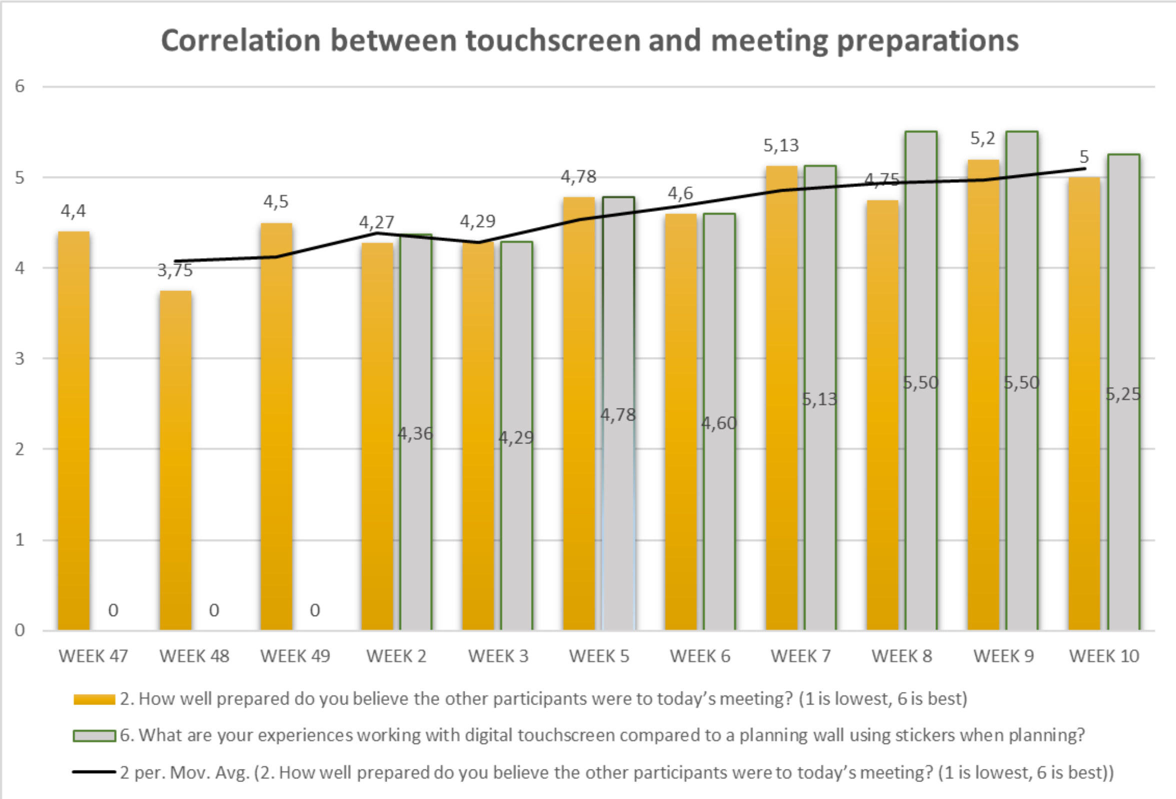


Figure 32: Question 2 results presented with a trendline and Question 6 results presented to illustrate the correlation between ICE session preparations and Touchplan used

The trendline (black line) in Figure 32 shows the increase in session preparations where session participants get more and more used to the Touchplan solution. The results arrive from the participants themselves after each session. Preparations is perhaps the most important factor for an effective meeting, and high-quality decision making (EngineeringManagerOperation, 2018). Therefore, the question "*How well prepared do you believe the other participants were to today's meeting?"* gives an indication of the output for each session. The above-mentioned question has been asked each week where participants are grading their experiences from 0 to 6 (6 is highest score). From week 47 to 49 is measured using a planning wall where Question 2 scored the average 4,2. Compared to week 8 to 10 where the participants have gotten used to working with Touchplan, where the score on the same question averages 5,0. The results shows an increase in preparations from the participants.

Better preparations can come from several reasons. However, Touchplan is considered as a factor for improving performance in the weekly ICE sessions in Operations. Improved session agenda appropriateness (Performance factor 2.11, Table 7) and better model coordination consistency (Performance factor 2.12, Table 7) are other possible VDC factors that increases ICE sessions throughput.

6.2.2 ICE Sessions

The aim of using VDC should be clearly communicated to all project participants. AF Gruppen states in their tender that it is important to notice the small factors as in which order events and communication are happening. During the kick-off meeting, metrices should be clearly stated to work towards success and continuously navigate project process. Ground rules should be established by the project group – this is including aspects as meeting coordination, decision-making methodology, training necessities and roles (See Figure 33). (AFgruppenTender, 2016)

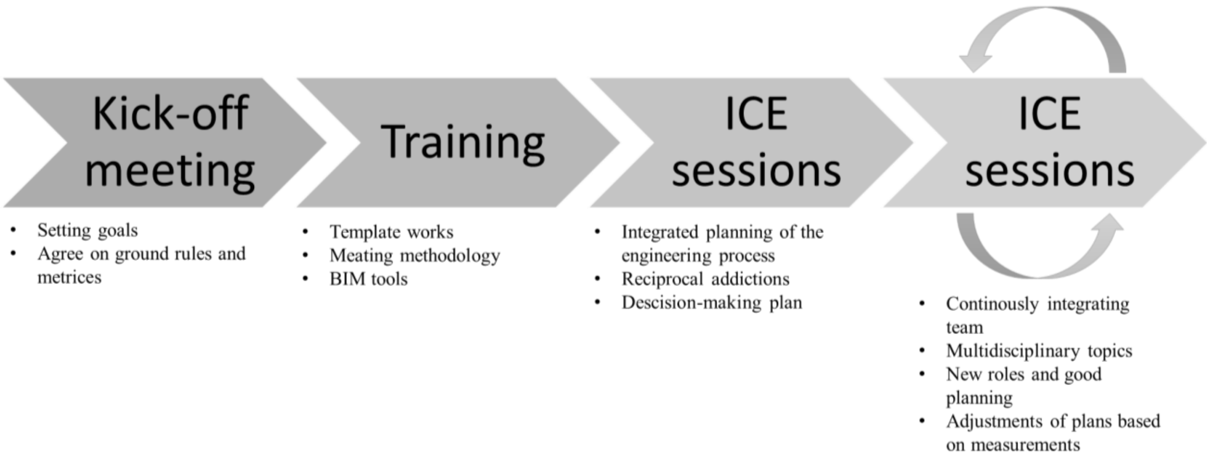


Figure 33: Ground rules for kick-off meeting, training and ICE sessions in Team Bispevika

The ICE aspect of VDC is focusing on process performance and how the project team can accomplish the project objectives. It connects the project objectives to BIM and PPM through integrated environment and efficient meeting methodology.

ICE sessions are held every Wednesday and Thursday in Team Bispevika. As showed in Table 13: Weekly meeting coordination at Project Bispevika – ICE sessions on Wednesdays are focusing on Bispevika B6a and ICE sessions on Thursdays focus on B2 respectively. ICE sessions are scheduled to three hours, but sometimes lasts longer. This has been developed by a “try and fail” strategy where Team Bispevika earlier have used full days. The ICE sessions have been strategically distributed till two different days as sessions has a tendency of becoming less efficient after a certain amount of time (ref 3.2 Table 1). (EngineeringManagerAF, 2018)

Each ICE session in Team Bispevika begins with a 30 minutes session going through todays agenda and the decision-points that should be reached during todays’ session. During the 30 minute start-up, the decision-points are broken down to sub-decisions-point (named Actions). Any opinions to the agenda or actions are addressed at this point. Afterwards, the decision points are worked through one-by-one. After each decision-point is met, a small summary of the sub-decision-points and the agreed decision are presented by the facilitator in the session – which brings everyone to an agreement and the session moves on to the next decision-point for the same process (ICESessionObserved, 2018). The facilitator’s role is earlier described in Table 4, 4.4 Integrated Concurrent Engineering (ICE). At Project Bispevika there is different facilitators in the different team compositions as there are several plans with different persons responsible per plan. During observations at the Bispevika rig, it has shown that the participants involved in ICE sessions are aware of the facilitators role and *Preferred Outcomes* stated in Table 4 was clear and concise. Group worked efficient through agenda decisions-points and discussions was taken effectively to move to next agenda point. (ICESessionObserved, 2018)

The integrated environment is making participation easier for the selected disciplines in the ICE sessions. The ICE sessions are always conducted in Big Rooms. Team Bispevika Engineering management has created their Big Room in the second floor at their rig just by the construction site. In the room, they have a Smart TV with touchscreen. The screen can be separated so multiple models can be presented at the same time. Normally the BIM model and notes for decision making is displayed side by side at this screen. The progress plan is covering both the sidewalls of the room layout where project B2 is covering left hand side presented in Figure 34 and B6a is covering right hand side in the same figure. The table is placed in the middle of the room with plenty of space, so all participants can see the plans, the screen, and all other participants. The room layout has been drawn and presented in Figure 34. (ICESessionObserved, 2018)

Engineering manager at Team Bispevika explains that it has been devoted a lot of time to create a workspace this suitable for all project participants. Multiple disciplines are used to sit at their offices and this might be their first time devoting all work hours at a rig. Therefore, the workspace is important for them to work as efficient as possible. (EngineeringManagerAF, 2018)

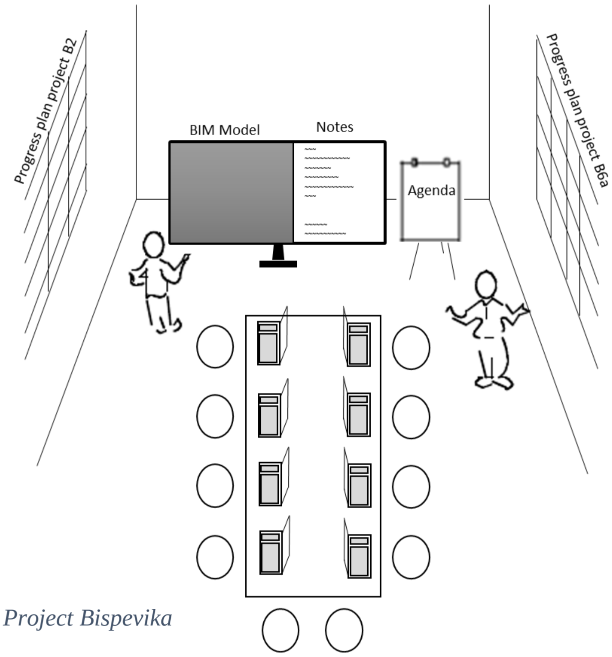


Figure 34: ICE room layout in Engineering & Design at Project Bispevika

In Operations, AF Gruppen has a different layout on their Big Room. According to engineering manager in AF Gruppen (2018) are the space an important part to make sure to visualize the necessary factors at the same time. Second floor at the AF Gruppen rig is driven by engineering. The room layout presented above in Figure 34 works with process planning charts covering both walls (as shown in illustration). Operations (downstairs at the AF rig) has moved to use Touchplan and has therefore implemented an additional screen. The layout of that room has been drawn and are presented in Figure 35 below.

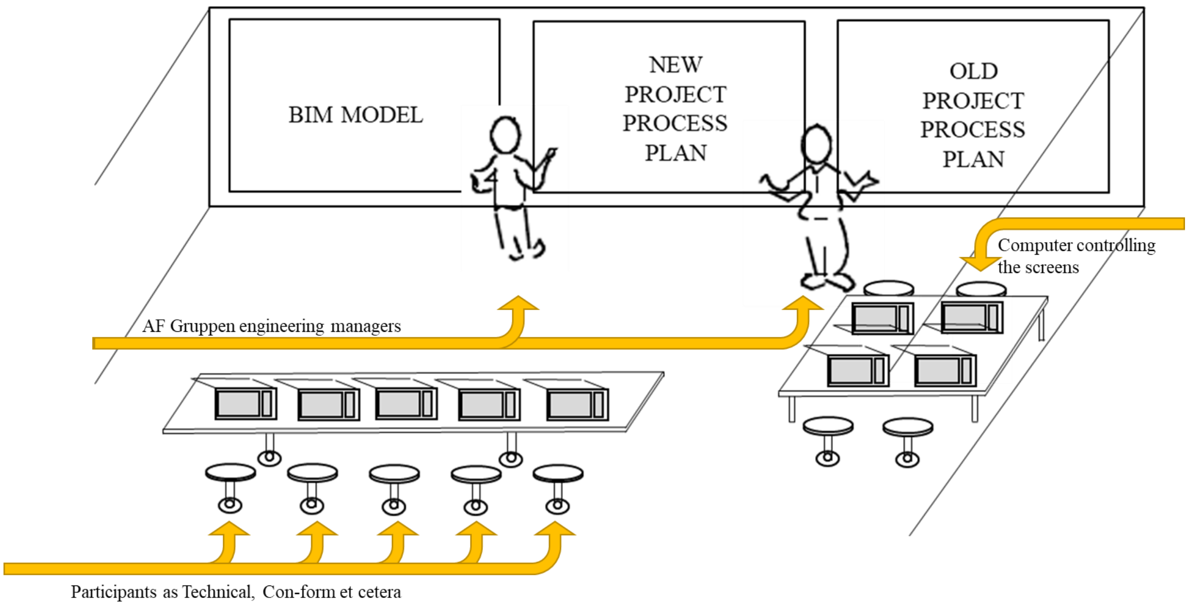


Figure 35: ICE room layout in Operation at Project Bispevika

Figure 34 and Figure 35 has been drawn to show that it may be several different layouts to a Big Room. The important aspects are that participants have enough space to communicate together, see the BIM model live as well as a logical presentation of work packages in form of a process chart or similar are shown. Invitation and agenda to the ICE sessions should be sent in enough time in advance of the session, and the duration of the sessions should vary according to this. Notes should be taken during the session and sent out straight after the session in case of any misunderstandings. The facilitator has an important role to control the ICE session and steer it through the agenda points. According to ProjectManagerDesign (2018), is a large touchscreen essential for efficient sessions. Experience from ICE sessions without this screen has shown that the sessions become less efficient. The form of the sessions should vary according to the agenda and participants (ProjectManagerDesign, 2018). Additional, it gets highlighted that a big high technological screen isn't going to run the ICE sessions. ICE sessions require a mindset from its participants (EngineeringManagerAF, 2018). This is backed by NorconsultProcessManager (2018) that is stating the BIM model isn't there for the group to work on the model in the ICE session. It gets underlined that BIM is used to encourage effective decision-making. This is corresponding with theory described in 4.4 Integrated Concurrent Engineering (ICE).

The ICE session layout has been strategically constructed the way they have. In engineering the Big Room with plenty of space is necessary to be able to include all disciplines involved. In operations, it has been more important with availability for subcontractors as the process is quite different in operations compared to design phase. However, common for the two processes is preparing and how ICE sessions are conducted with what is available. Mentioned in 4.4 Integrated Concurrent Engineering (ICE) – Ahmed & Forbes (2012) has developed nine steps for effective meeting protocols. At Project Bispevika they are answered as:

1. The agenda is ready to each ICE session. This has been the case in both operations and engineering management.
2. All attendees should know which other participants arriving to the session, this is stated in the agenda sent out prior to each session.
3. All project information is available as all sessions in the Big Room have the opportunity to visually present the BIM model and a form for presentation of the progress plan.
4. Post-it notes/stickers are used in engineering while Touchplan is used in operations to present ideas and work packages.
5. Pull planning are used.
6. Creativity is promoted with the use of Touchplan.
7. Critical path analysis is identified with Touchplan. Otherwise are project flow identified at the planning wall by the masterplan.
8. The plan is always written at both disciplines.
9. Adjustments are made together.

With the observations made, Touchplan is arguably a better solution in terms of encouraging innovation (controlled chaos) and a better visualisation of a critical timeline. A digital solution makes it easier to move things around, try different scenarios and skip steps backwards if a change didn’t bring more value. A planning wall does not have a backup at the same way as a digital solution which creates boundaries in terms of possibilities. It requires huge discipline to move notes back and forth – and be precise when moving through a timeline. There is a risk for unacceptable errors and latency could arrive parallel to the increased confusion.

6.2.3 BIM

At Project Bispevika the BIM level 2 model is connected to Synchro and information is displayed in Solibri. When using BIM level 2 – each item is providing information about length, height, material requirements et cetera. Synchro is connected to the model to provide a timeline for the construction. Coordination between AF Gruppen and subcontractor through the BIM model is providing a more precise collision control, as well as early detection of errors. This enables possibilities for earlier corrections, which is claimed to provide huge budget benefits. The 4D model provide workflow sequences where it is easier to coordinate work-packages. The model itself doesn't necessarily need to be extremely precise. It is more important that the model includes information of each sequence and provides information needed for work-packages to be coordinated.

The BIM model provides a platform for communication and information related to the design of the product and delivery process. When using a 3D model early in project life, all relevant stakeholders can see the development of the model and can provide input in the development of the constructions. At Team Bispevika, the model is displayed in ICE sessions and available on the online drive. The model makes sure all stakeholders have the same vision for objectives and functions of the final product. The model can be reviewed together but is preferably worked on at their work stations. Observations has showed that it is possible to work at the model during the session in an effective manner, but also present it visually and coordinate work-packages to be done outside the session (ICESessionObserved, 2018). BIM is used as a communication channel and information is displayed in the model. This is addressing Figure 8 presented in 4.3 Building Information Modelling (BIM).

A complete model gives the client, together with all project participants an understanding of the facility preferences and design details. It is easier to communicate, even with non-technical stakeholders through a visual presentation. Transparency is reduced when all information needed should be displayed in the BIM model. The model helps the client, designers and contractor work together from early project life and increase value to costumer by reducing non-value activities introduced in Table 2. When subcontractors and specialists are using an integrated BIM model, specialists can provide examples on how to optimize the design. The model is available for continuously improvements and it makes it easier for project- and engineering managers to make faster and better decisions.

In the virtual model created by Team Bispevika, information as which materials to be used, costs of materials, and construction manuals is provided. The information provided as descriptions and quantity needed reduces overproduction. This makes it easier to order the exact number of components, which should reduce inventory parallel to reducing over-ordering. The information provided in the model should reduce waste and inefficiency when reducing errors in conducting work-packages.

The above-mentioned improvements can be summarized in Figure 36. It provides better teamwork, information flow and communication by having a visual model that provides all necessary information with inputs from specialists. By having a visual model and information available, project- and engineering managers can make faster decisions and analysis of the model. Coordination is done with sequences of work packages in a chosen system. Quality control is done easier as the model is visual and it's easier to navigate through information.

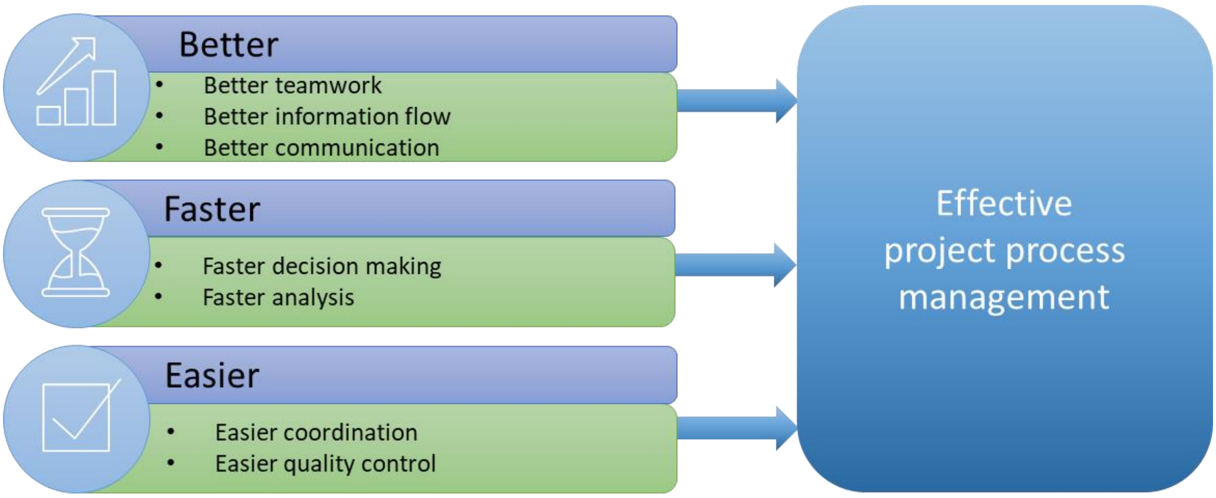


Figure 36: Improved project process using BIM level 2 in VDC projects created based on observations

6.2.4 Metrices

Metrices is a part of the PPM section of VDC and Project Bispevika is a first time – hands on project using the framework. Therefore, when analysing how metrices is being used in this project, this is considered. Metrices may be restructured and measurements may change during the project as participants want to try different aspects of the metrices. Team Bispevika is conducting a set of metrices; ICE sessions in both operations and engineering management is presented below. In engineering- and project management, two sets of metrices is evaluated, where in operation – there is one metrics evaluated. However, it is notable that metrices will be different between operations and engineering as the professions are different in nature. Interviews, researched documents and observations has introduced ideas and lessons learned. The three metrices analysed at Team Bispevika and presented in this thesis are; ICE sessions in engineering, ICE sessions in operations (including PPC), and client decisions in engineering.

Team Bispevika has implemented metrices to retrieve quantified data to be able to improve processes in this project, but also to learn from mistakes and avoid the same mistakes in later projects. Metrices has proven to be challenging industry-wide, but in Project Bispevika it has contributed to better results. The metrices section will analyse how measurements has been used in Project Bispevika and if improvements can be made and what outcomes have and can be gained from the metrices used. This section will analyse ICE sessions in engineering and project management, ICE sessions in Operations, and Latency and root cause analysis in engineering and project management in that order.

ICE sessions in engineering and project management

Metrics used in ICE sessions in engineering consists of a set of questions that is answered after each session. The theory chapter is describing possible metrices and measurements in three tables (Table 6, 7 and 8). Some of these measurements are suitable for ICE session efficiency. Team Bispevika is conducting nine measurements on their ICE sessions in engineering (for full visualisation of their measurements see Appendix 1.a, created in Norwegian). Results are gathered through the questionnaire filled out by participants after each ICE session. Each question in the questionnaire has a score from one to ten where ten is the best. Each question does also have space to write additional comments. The nine questions are as follows:

1. In what degree do you feel you had the possibility to adjust/propose decisions points to the agenda during today's ICE session?
2. In what degree do you feel you contributed to today's ICE session? (came prepared, participation)
3. In what degree do you feel that the rest of the group contributed to today's ICE session? (preparations, activity)
4. In what degree do you think we got to close decision-point on the agenda in today's ICE session?
5. In what degree did you experience that the correct participants were attending todays ICE session?
6. In what degree do you feel that the project progress chart distributed on the wall are helping predict your work packages?
7. In what degree do you think you have benefits in working at the AF-rig outside Thursdays?
   7.1. If a low score (5 or less); in what degree do you believe this is something you can control by yourself?
8. In what degree do you believe you have all the necessary tools at the AF-rig? (internet, extra screens, available meeting rooms et cetera)
9. All in all, in what degree are you happy with the interaction in Project Bispevika?

The nine above-mentioned questions are documented and visually presented in form of graphs. Figure 37 is illustrating all the above-mentioned questions in project B2 and Figure 38 B6a respectively. Figure 37 and Figure 38 is included to show how results can be presented in total and to show the amount of data collected and analysed in this thesis with participation from engineering managers in Team Bispevika. Further analysis of the data is shown further below in Figure 39 to Figure 45 where key information are extracted and visually presented.

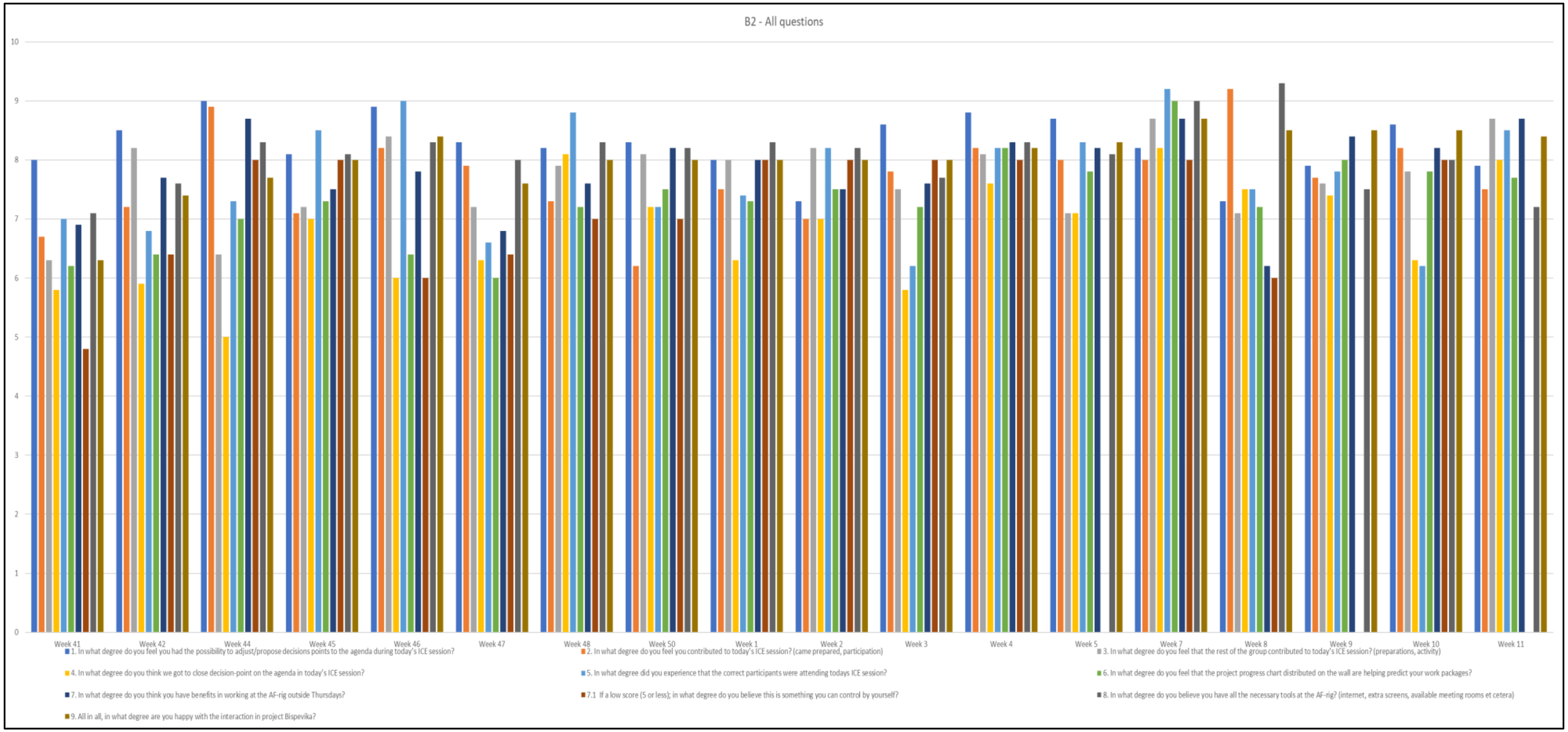


Figure 37: Full questionnaire results at Project Bispevika B2

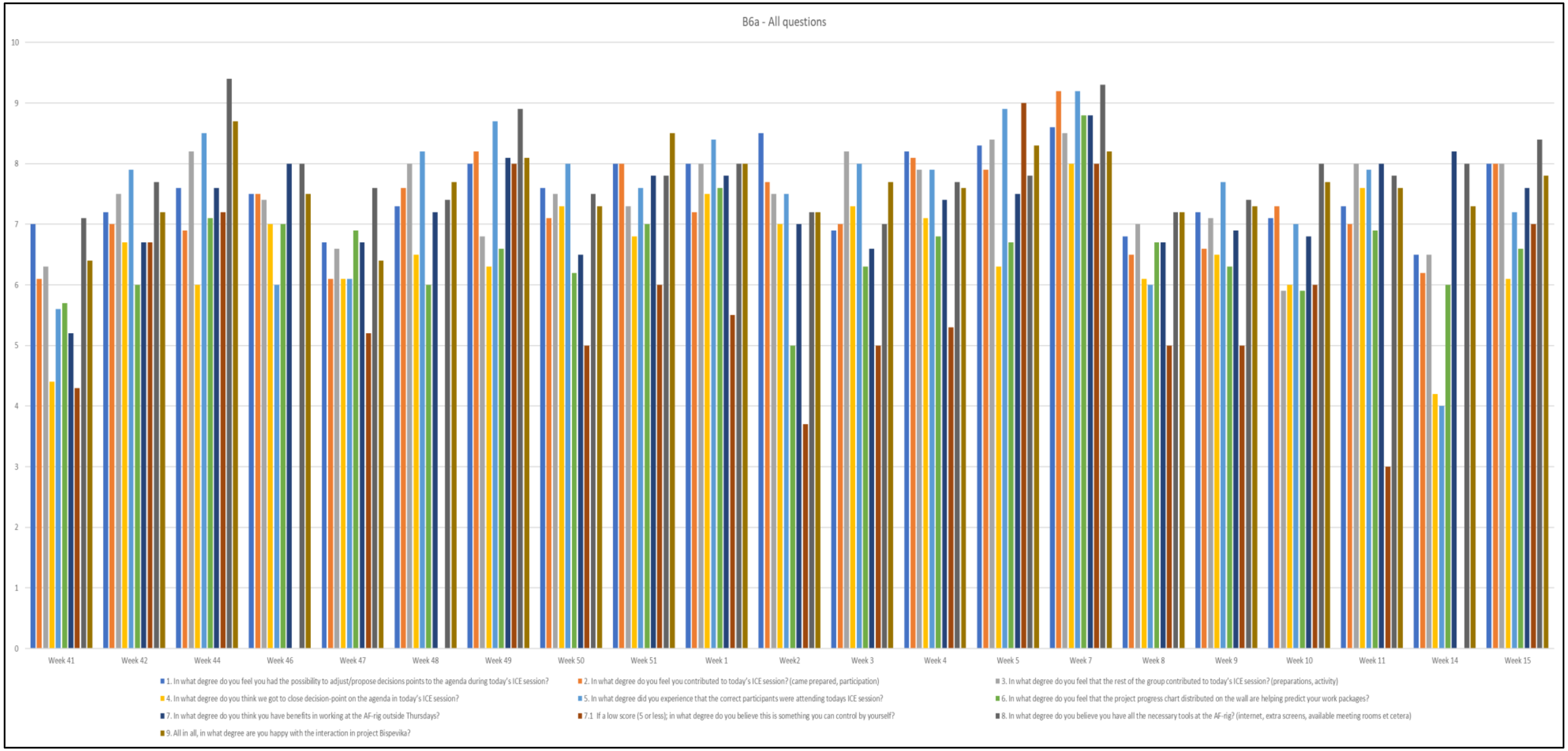


Figure 38: Full questionnaire results at Project Bispevika B6a

From the above showed graphs, topics and questions can be extracted and visually presented. This thesis has extracted certain questions, often presented with trendlines most relative to the theory chapter and thesis scope to gain insight in opinions and possibilities for optimizing processes.

Part of the aim of ICE sessions is to close decision points and therefore create a way to track progress (how many decision-points has been closed after each session). Figure 39 is showing *Question 4: In what degree do you think we got to close decision-points on the agenda in today's ICE session?* For project B2 (in yellow above) and B6a (in blue below). The two projects have the same composition of actors (except for the architect). However, it is notable that the two projects are quite different in terms of duration, size and complexity – where project B2 is consisting of one building, while project B6a is including nine buildings and are at a relatively earlier stage in the design-construction process. As aspects are more uncertain, it is more difficult to rate Project B6a. It is therefore anticipated that scores for Project B6a will stay below Project B2 and be relatively consistent.

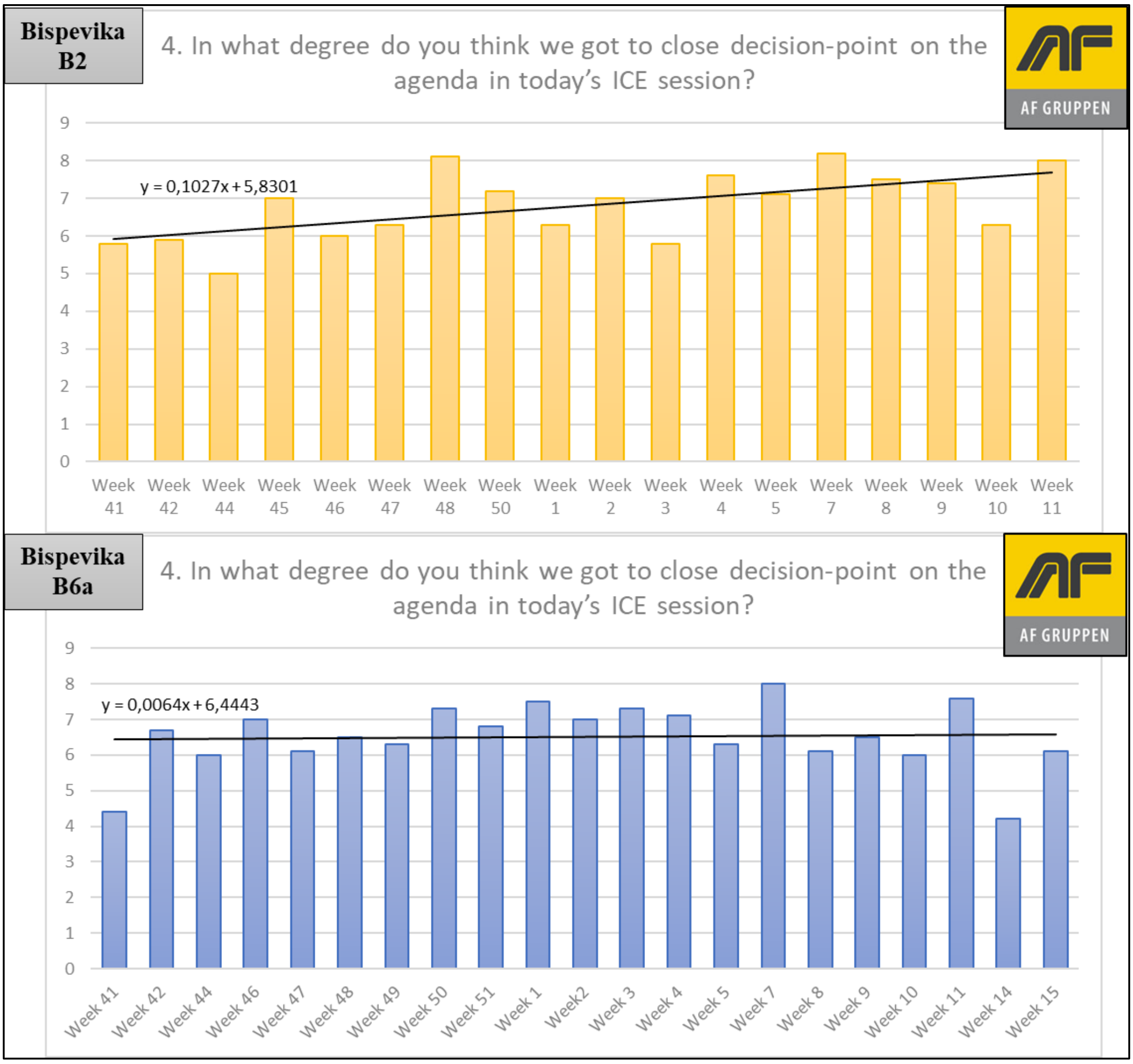


Figure 39: Question 4 results: In what degree do you think we got to close decision-points on the agenda in today's ICE session?

Further, it can be seen that both projects are experiencing an increase in decision-points made when the disciplines have adapted to the ICE session methodology. However, B6a only increases by 0,0064 per week by average – while it is notable that project B2 has an increase with 0,1027 per week using the ICE methodology. The B2 results is equal to 1,762% of starting score at 5,83 per week, which over a 17-week period has resulted in 29,95% increased performance. This can be a result of the participants not used to the ICE session methodology are becoming more familiar with it, and in later sessions participants know how to prepare best for ICE sessions (see Question 2, Figure 40) and are familiar with how using the available tools in ICE sessions (see Question 6, Figure 42) and at the rig (see Question 7, Figure 43). As Figure 39 is showing an increase, it is expected that the following questions correlate to this improvement.

Figure 40 below is displaying question 2: *In what degree do you feel you contributed to today's ICE session? (came prepared, participation).*

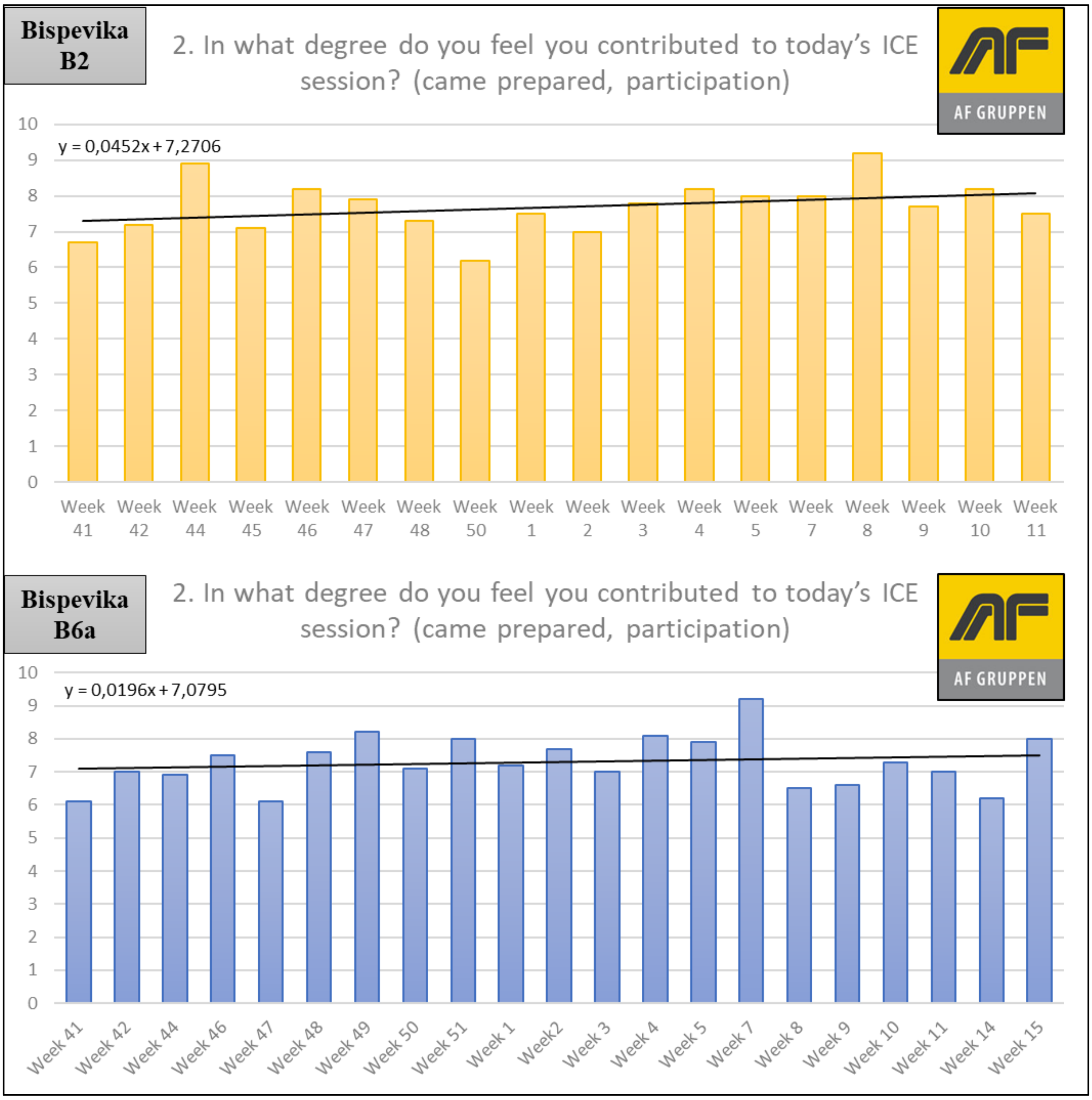


Figure 40: Question 2 results: In what degree do you feel you contributed to today's ICE session?

The results from question 2 shows a slow, but steady increase in participation and preparations for ICE sessions. The results are slightly biased as new representatives will occasionally attend to sessions and the score will drop as all representatives are asked to fill out the questionnaire. B2 (yellow graph) show a 0,0452 increased feedback score per week which is corresponding to increased performance indicated in Figure 39. Preparation also influences the amount that each discipline can affect ICE session topics, decisions et cetera. This is presented in Figure 41 below displaying the correlation between Question 1: *In what degree do you feel you had the possibility to adjust/propose decision point to the agenda during today's ICE session* and Question 3: *In what degree do you feel you contributed to today's ICE session? (came prepared, participation)* in the questionnaire.

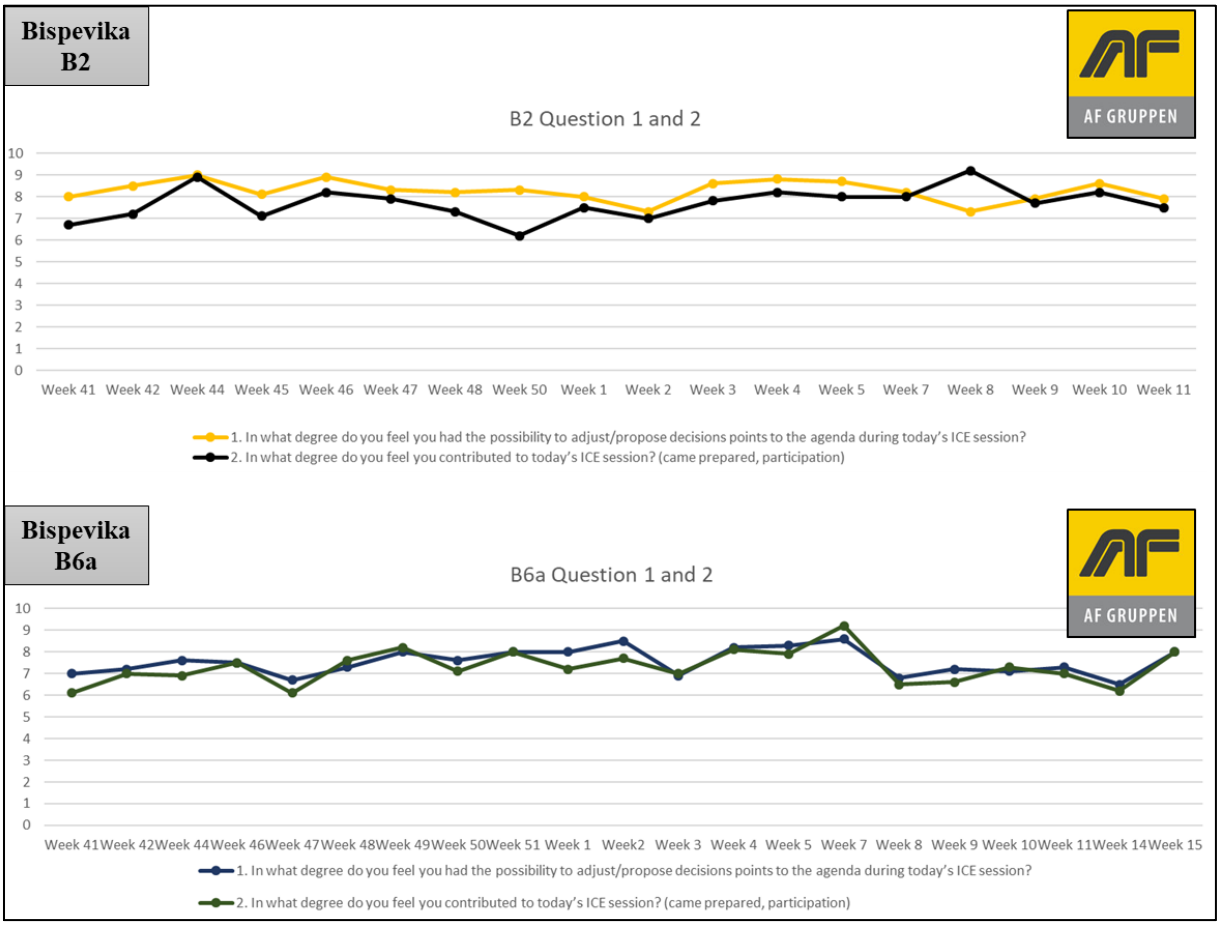


Figure 41: Correlation between Question 1 and Question 2 from questionnaire in Engineering at Project Bispevika

It is then showed that good preparations are affecting attendance in the beginning of ICE sessions and therefore more contribution to adjustments in the agenda. Further, it should be evaluated how available equipment are affecting decision making. The planning wall displayed in the Big Room is commonly used in ICE sessions. Question 6: *In what degree do you feel that the project progress chart distributed on the wall are helping predict your work-packages?* is created to receive feedback if the planning wall is used correctly and if participants are benefitting from its usage.

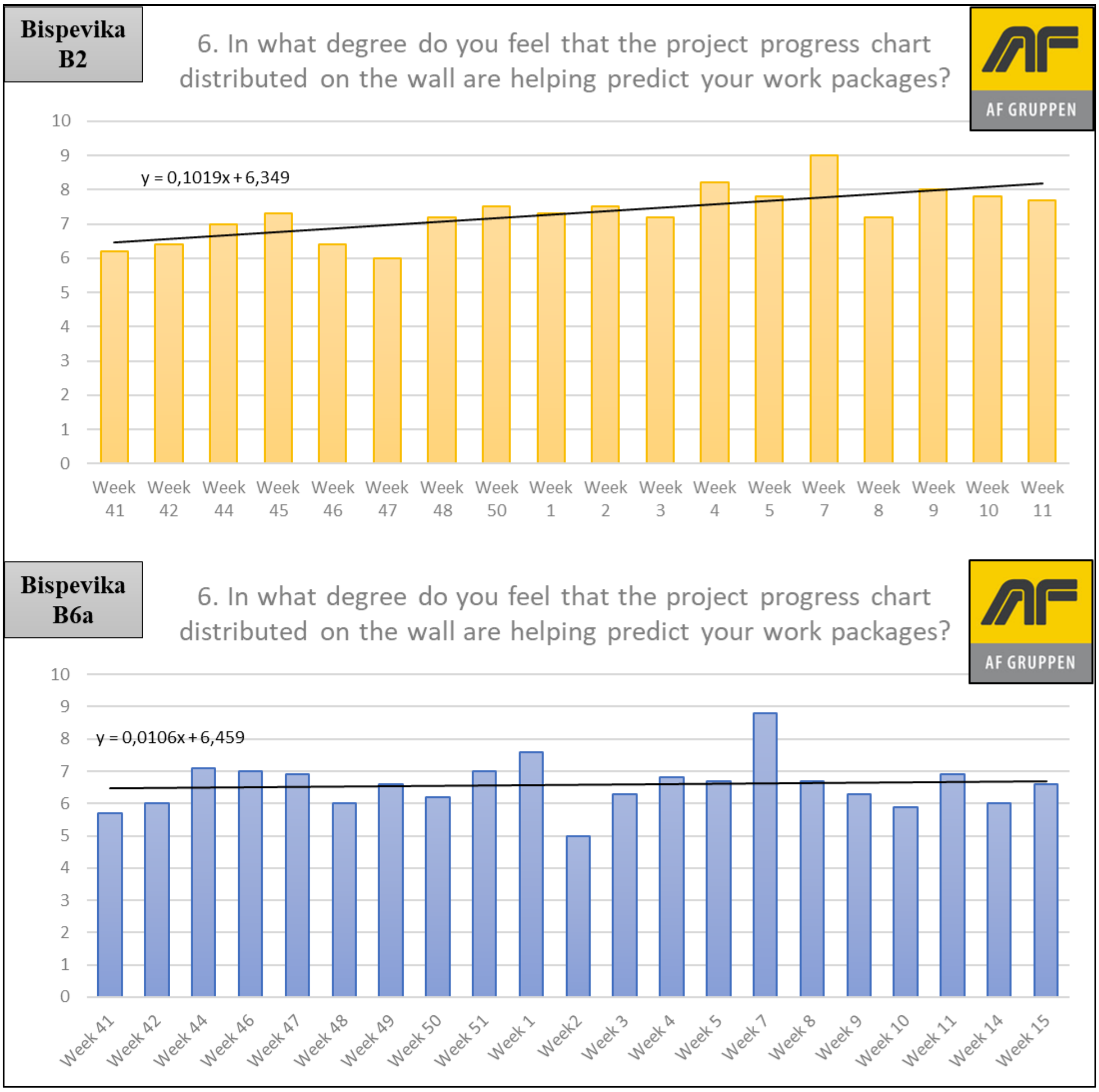


Figure 42: Question 6 results: In what degree do you feel that the project progress chart distributed on the wall are helping predict you work packages?

The results on the feedback received from the project participants show that Project B2 has increased just above 10% per week using the project progress chart, while at Project B6a, the difference is close to zero. This is underlining the theory that work-packages is becoming more clear and easier to predict as more work packages are determined at a weekly level. Further, tools available at the Bispevika rig are important for effective work. According to EngineeringManagerAF (2018) it has been devoted a lot of time to create a good workspace for all disciplines. The above shown graphs is showing that ICE session methodology are becoming more effective. Question 7: *In what degree do you think you have benefits in working at the AF rig outside Thursdays? (Thursdays referring to the weekly ICE sessions)* is illustrating the feedback on working at the rig in general in an integrated environment (Results are presented in Figure 43).

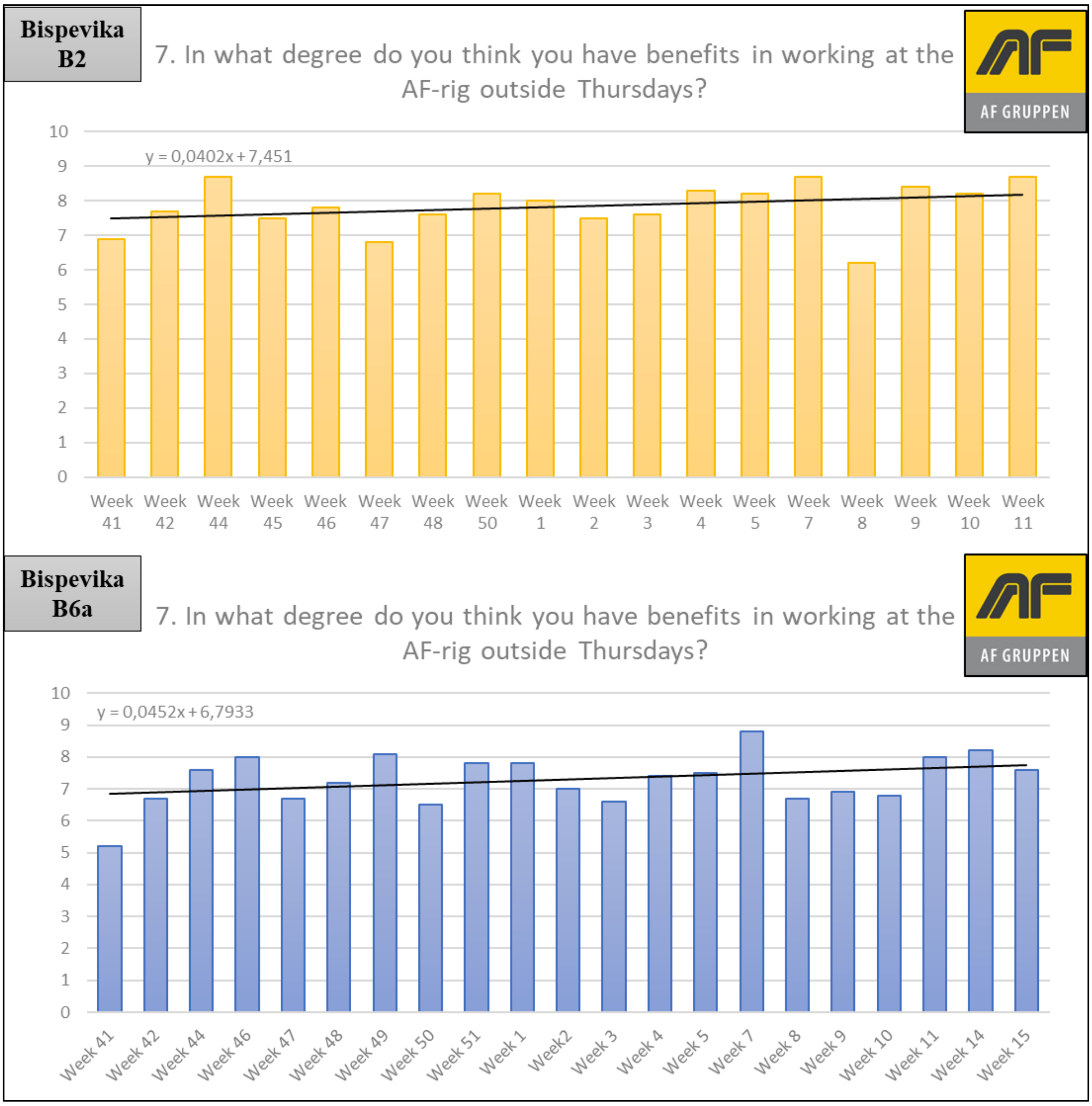


Figure 43: Question 7 results: In what degree do you think you have benefits in working at the AF-rig outside Thursdays?

Project B2 and B6a show a weekly increased score of 0,0402 and 0,0452 respectively. This is underlining that the disciplines are appreciating the integrated work environment more and more as they get used to it. For positive feedback on question 7, the appropriate tools need to be available for employees at the rig. It is therefore expected to have correlation to Question 8: *In what degree do you believe you have all the necessary tools at the AF-rig? (internet, extra screens, available meeting rooms et cetera).*

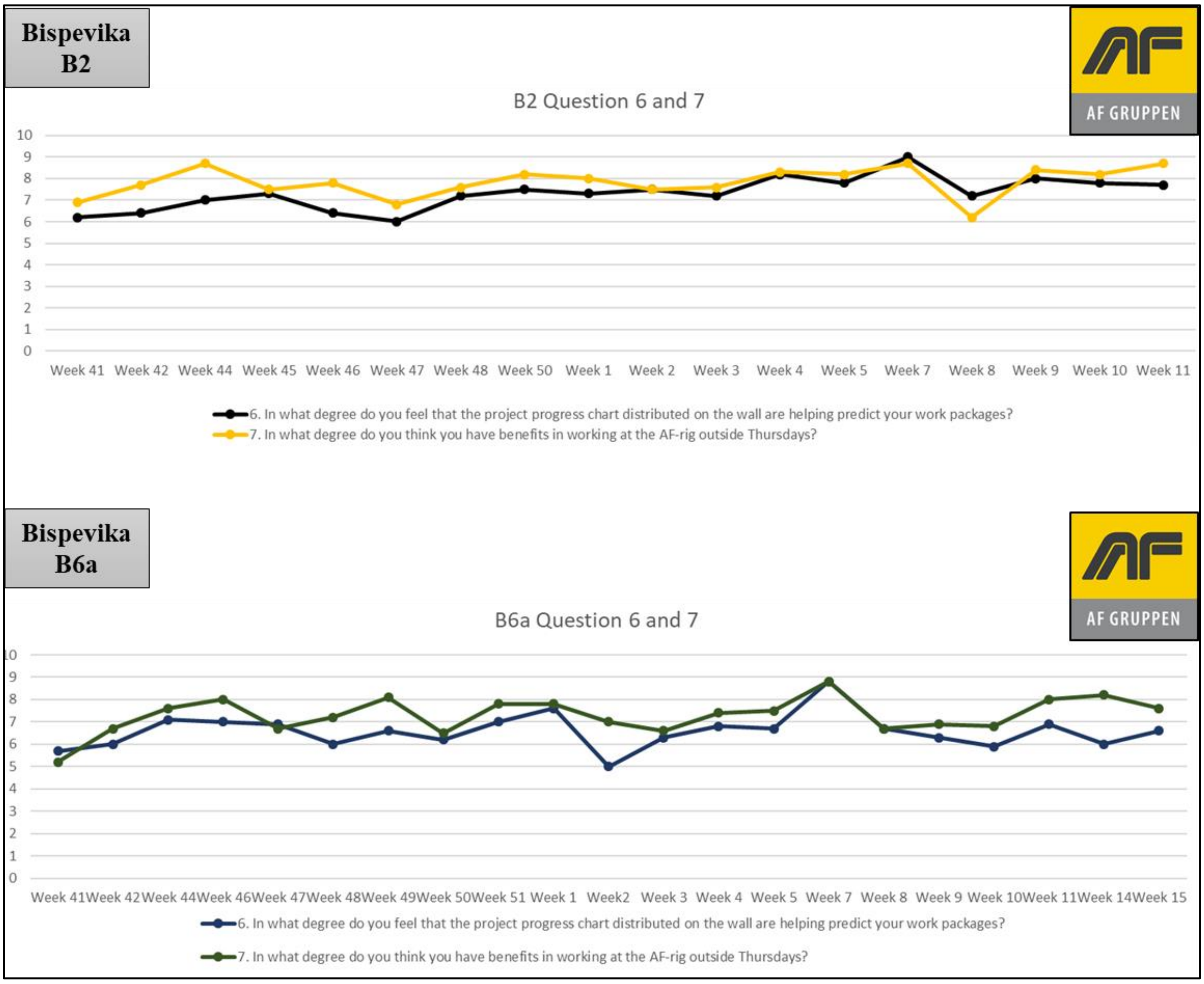


Figure 44: Correlation between Question 6 and Question 7 from questionnaire in Engineering at Project Bispevika

The graphs illustrate a correlation between question 6 and 7. The continually positive feedback underlines that AF Gruppen has used additional time on creating a better work place for all disciplines in the integrated environment at the Bispevika rig.

Finally, the above-mentioned questions have shown a tendency for increased satisfaction, increased workspaces and increased communication pathways. Question 9: *All in all, in what degree are you happy with the interaction in Project Bispevika*? is presented in Figure 45 below.

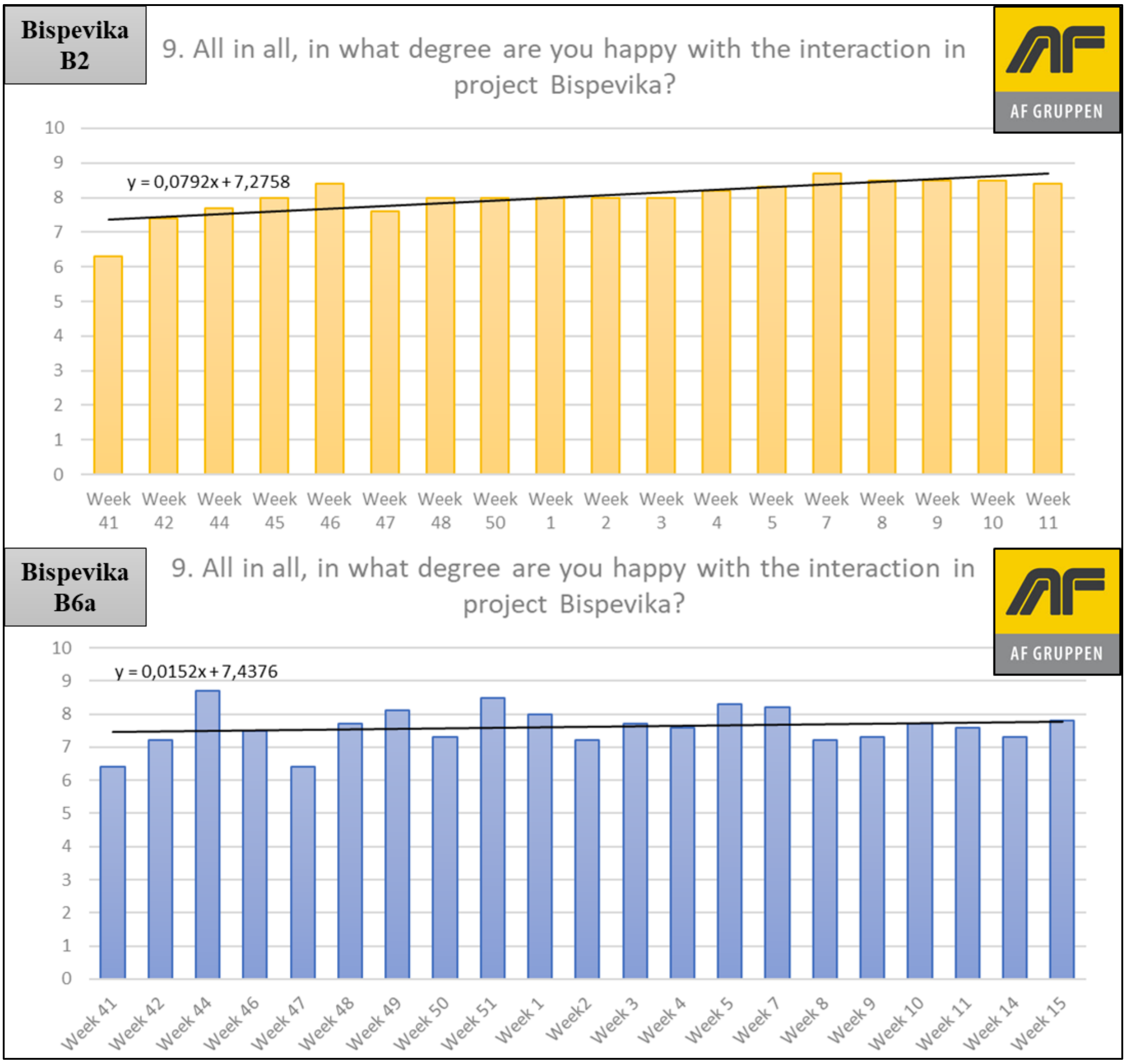


Figure 45: Q9 Results: All in all, in what degree are you happy with the interaction in Project Bispevika?

The trendlines are increasing with 0,0792 (Project B2, yellow) and 0,0152 (Project B6a) per week. The increase is underlining that project participants are settling in at rig Bispevika. Team Bispevika are performing better, especially at Project B2. As mentioned before, Project B6a is less defined and more complex at this stage but is expected to improve as it moves into the phases Project B2 has gone through. It is also expected that Project B6a will benefit from having the same team (Team Bispevika) as Project B2. This should eliminate some of the challenges faced in B2 as finding out which facilitator is most suitable, optimization process of ICE session and work environment layout. The questionnaire has a comment field below each question and participants are encouraged to leave feedback for continuous improvement. For improvements, each question can be visited, and if a score is low one week, a why analysis can be conducted. Documentation are important for not creating wastes in later projects (see Table 2).

ICE sessions in Operations

In Operations management, it is a similar experience. Operations had initially five questions, focusing on the same aspects as engineering, and later adding an additional question when moving from a planning wall (as in engineering) to Touchplan when planning. Additionally, Operations have more different subcontractors where the participants do not have a desk at the rig. Therefore, questions are structured a bit differently. The questions are as follows:

1. How well prepared were you to today’s meeting?
2. How well prepared do you believe the other participants were to today’s meeting?
3. How well did AF Gruppen conduct the meeting?
4. In what degree do you understand what we are going through in the meeting?
5. How well are we able to deliver what we have agreed on during the meeting?
6. What are your experience working with digital Touchplan compared to a planning wall using stickers when planning?

The sixth question was added in week 2 (illustrated with dark blue column in Figure 46) when the project team went from a traditional planning wall to Touchplan. Results from the above presented questionnaire is showed in Figure 46. The full questionnaire is attached as appendix 1.b.

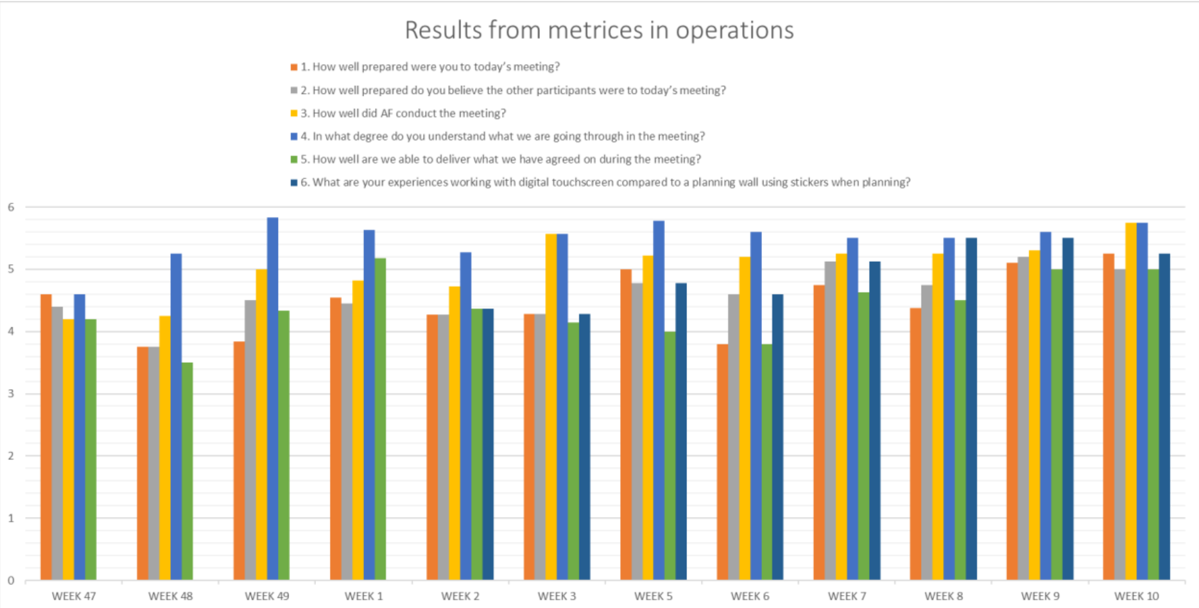


Figure 46: Snip from ICE session in week 10 in operations at Project Bispevika

The results are presented week to week for all participants on a common drive. It is however not mandatory to visit the file to see how the results is progressing. All participants do participate in grading the sessions and is therefore aware of the quality of each session. Week 50 and 51 was not graded as that was Christmas holidays and week 4 was winter vacation. The scale for each question is from 0 (lowest) to 6 (highest).

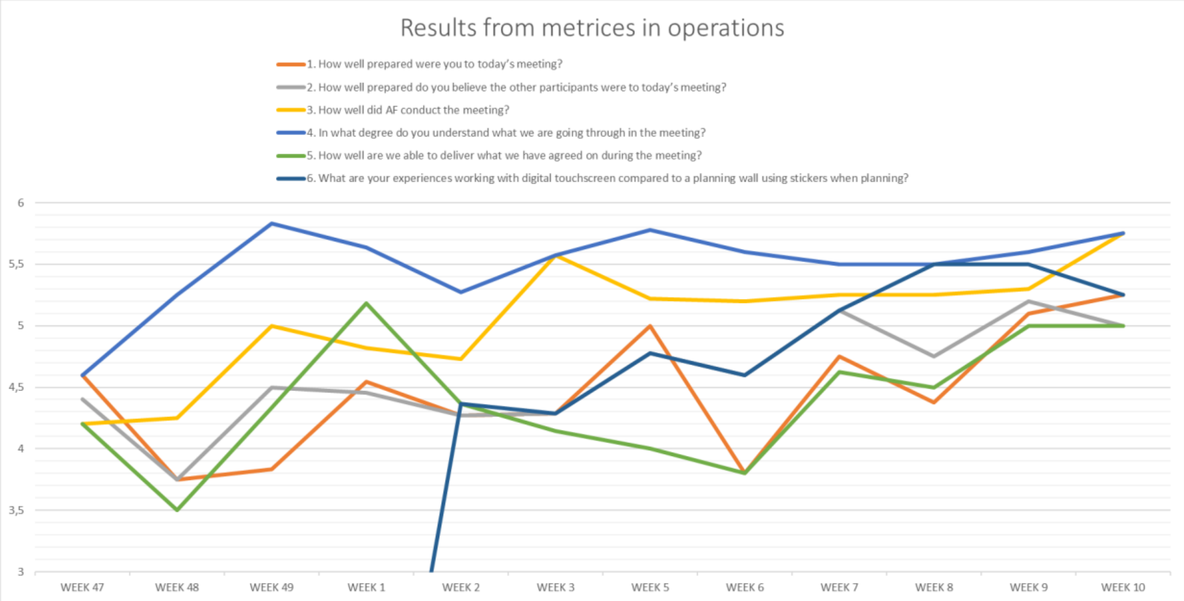


Figure 47: Metrics from ICE session in operation for correlation in operations at Project Bispevika

Figure 47 is created to get a better visualisation of correlation. When evaluating the correlation, it is important to have in mind that this is a fraction of 12 occasions and therefore results may have low accuracy. The figure shows a clear tendency of improvement in all factors as the project progresses. As expected, question 1 and 2 will correlate as every individual is counted in both measurements in terms of their preparations. That correlation is an indication that the team members are answering unbiased. Line 6 (dark blue) shows that Touchplan was easily adopted to the group. AF Gruppen are also conducting the sessions better as shown in line 3 (yellow line).

Plan Percent Complete (PPC) is measured weekly:

Equation 1: PPC

$$PPC = \frac{Number\ of\ work\ packages\ finished}{Number\ of\ work\ packages\ expected\ to\ be\ finished}$$

PPC is measured by engineering manager from AF Gruppen, working in operations. PPC is also weekly updated on a common drive so all sub-contractors and team members can track their performances weekly. PPC are used as an indicator of team performance and is notable not the main focus for a well delivered project. Team Bispevika has a high focus on innovation where several aspects as metrices and Touchplan haven't earlier been used in such a high degree. Figure 48 is showing PPC results from week 47 to week 10.

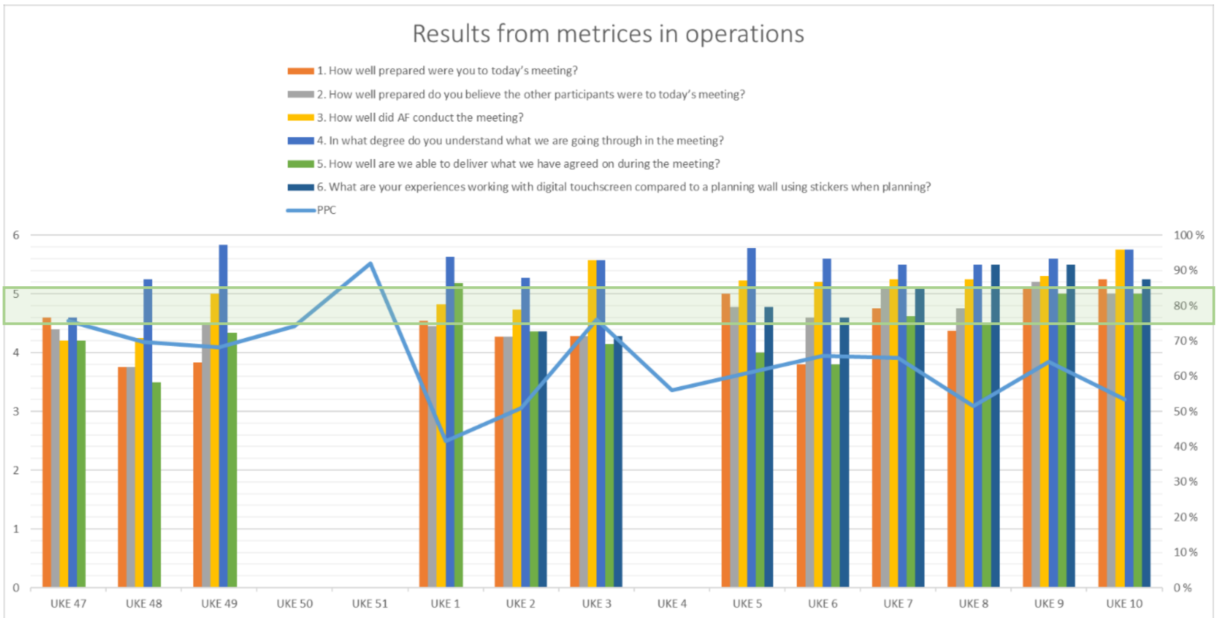


Figure 48: Metrics from ICE in operation including PPC at Project Bispevika

PPC is relatively low as it should be inside the green area displayed in Figure 48. It is explained in the theory chapter that PPC is optimized when every week is between 75% and 85%. Above 85% creates a feeling that most work-packages is completed which makes a slack. Below 75% is an indication of too many work-packages per day and employees could begin to stress – this is known as Muri from Lean Construction (overburden). The PPC line is an indication of unevenness known as Mura from Lean Construction, also known as one of the three waste categories. However, the project on-site has not begun yet at the above shown time interval in Figure 48 and therefore the PPC could be misleading. The graph is illustrated to present how it is shown in Project Bispevika. The adaption of Touchplan is further enlightened earlier in the progress plan section where it shows an increased satisfaction when using Touchplan and is therefore not described in this section.

Latency and root cause analysis in engineering and project management

Engineering management is also conducting metrices on client decisions. It has been noticed that client participation is incredibly important to maintain a high quality of decision-making. Project manager for the design team working in team Bispevika has created metrices for *client participation in meetings* (Figure 50) and *number of meeting per category* (Figure 49). Both figures are showed below. In the theory chapter, Table 7, measurement 2.5 states that VDC stakeholder involvement should be 90% attendance in ICE sessions. Client participation is therefore not satisfying within this time interval.

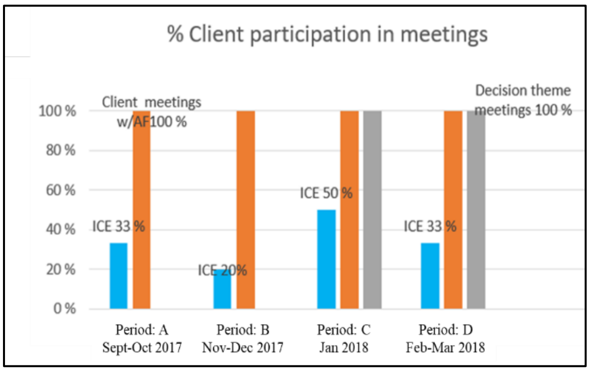


Figure 50: Percentage of client participation in ICE sessions, decision Theme meetings, and client meetings from September 2017 to April 2018 at Project Bispevika

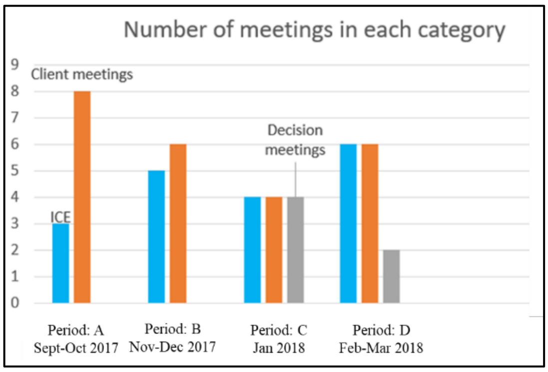


Figure 49: Number of ICE sessions, decision theme meetings and client meeting from September 2017 to April 2018

Figure 50 show that both client meetings, and decision theme meeting have 100% attendance, while client attendance at ICE sessions has only 34% attendance on average. Decision theme meetings was created as a reaction for poor attendance at ICE sessions and the project team needed more participation from the client. According to engineering manager at Team Bispevika, metrices are used to improve project delivery.

"We are using metrices to get data, and use these data to make actions"

- Translated – Appendix 2.c – (EngineeringManagerAF, 2018)

Further, numbers in Team Bispevika shows that client participation in ICE sessions are poor. ProjectManagerDesign (2018) states that:

"I was measuring client participation in ICE sessions. I did see that in OSU and AF meetings, the client participated 100%, while it was poor attendance in ICE sessions. So, I begun inviting to decision theme meetings, where I informed the client that we are going to take these decisions during the meeting, and I would appreciate that they were present. They have arrived in all occasions."

- Translated – Appendix 2.g - (ProjectManagerDesign, 2018)

The above example proves that metrices can be used as improvement management. The decision of having additional decision-theme meetings resolved an issue that had occurred during the project. Further, metrices has evaluated decisions made with the client. Figure 52: *Number of closed decision*, shows that there were no closed decisions in Period D and few closed decisions without delay in Period B (2 decisions without delay illustrated with blue).

This is correlated with client participation in ICE sessions where the client was attending 1 of 5 ICE sessions in Period B and 2 of 6 in period D when it was fewer decision theme meetings than the other periods. Attendance in period D was mainly due to a safety-health-work environment agenda, which the client has a responsible role in. Figure 52 show that a total of 17 out of 41 (41%) decisions was without delay, and the remaining 24 (59%) of decisions was delayed.

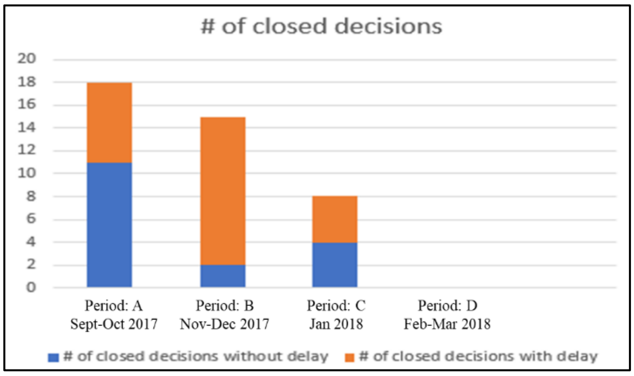


Figure 52: Number of closed decisions between client and AF at Project Bispevika

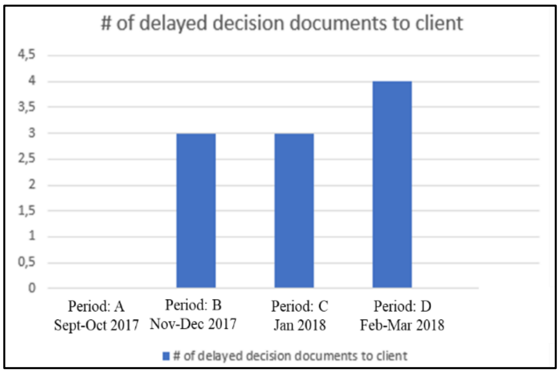


Figure 51: Number of delayed decision documents to client from AF at Project Bispevika

Further, Figure 51 is showing that in period A to D, 10 decisions were delayed between AF and the client – showing the importance for rapid communication channels. The client was stationed at the Bispevika rig in Period A and partly in Period B. And it is underlined that communication goes much faster when the work station is integrated. ProjectManagerDesign (2018) claims that

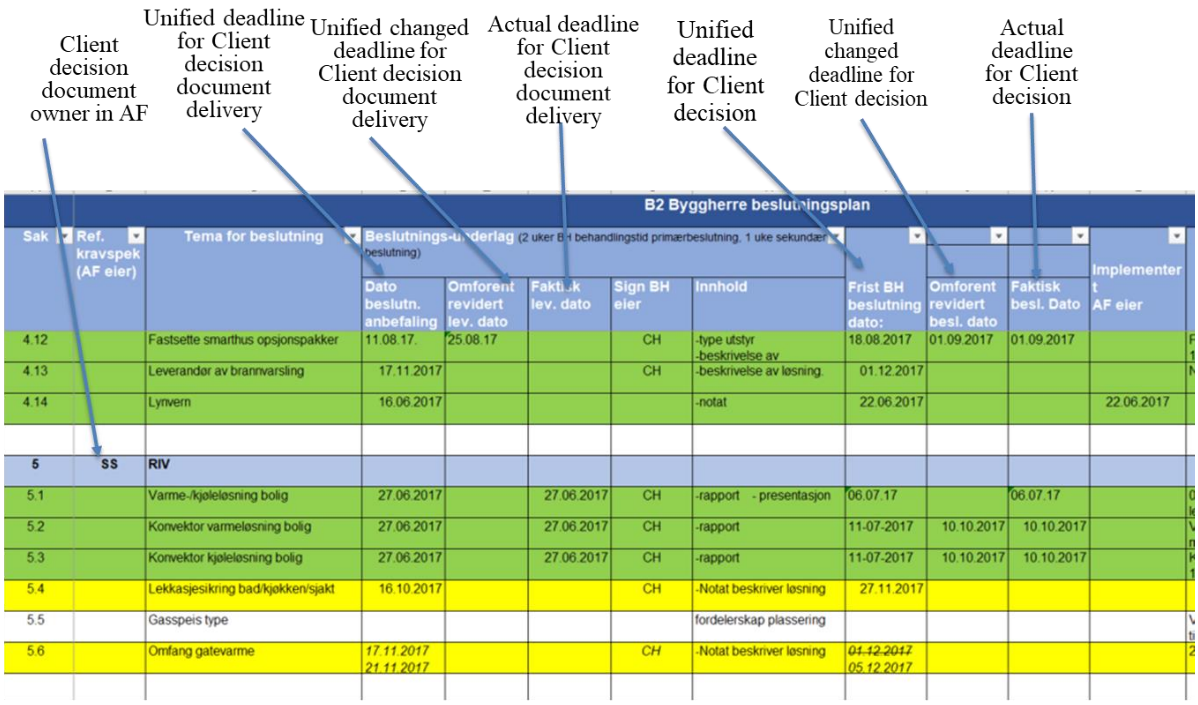
"It is taking more time when we must call them (the client). They might be stuck in meetings. Then we must send a mail, and it takes more time to make decisions. When they were located here (at the rig), it is fewer barriers to joining sessions et cetera as they do not have to book off that extra time to travel to the rig."

- Translated – Appendix 2.g - (ProjectManagerDesign, 2018)

Integrated Concurrent Engineering (ICE) is a big part of the VDC framework and together with PPM and BIM is underlining HOW the project team should accomplish project objectives (shown in Figure 2). Decision and response latency are criticized topics in the construction industry and the above-mentioned situation is underlining reasons for exactly that. The implementations done (inserting decision theme meetings) has created impressing results that arguably are contributing to shorter duration of the overall schedule (Project outline objective

3.4 Table 8) and if so, it will result in lower costs (Project outline objective 3.3 Table 8). The implementation is evaluated to be a success.

A client decision-plan log is shown in Figure 53. Additional to the plan below, it has been added [1] Why, and [2] Root Cause as additional columns. However, the project team is still working with establishing a template that will make the process easier. Theory shows that root causes should be categorized. One example could be a five step process; [1] what was the root cause, [2] root cause should be grouped in disciplines, [3] the delay should be marked within time perspective, [4] does the delay affect activities later in the project, and [5] what was the agreed solution. A result of the above-mentioned example of a documented root cause could be; [1] poor communication, [2] between AF Gruppen and client, [3] made the decision 17 days late, [4] the activity did not affect other activities, [5] and it got solved by a workshop session at the Bispevika rig. After multiple root causes, trends will begin to show certain disciplines involved or a need for new practices as improved communication paths et cetera.



B2 Byggherre beslutningsplan

Sak	Ref. kravspek (AF eier)	Tema for beslutning	Beslutnings-underlag (2 uker BH behandlingstid primærbeslutning, 1 uke sekundær beslutning)								
			Dato beslutn. anbefaling	Omforent revidert lev. dato	Faktisk lev. dato	Sign BH eier	Innhold	Frist BH beslutning dato:	Omforent revidert besl. dato	Faktisk besl. Dato	Implementert AF eier
4.12		Fastsette smarthus opsjonspakker	11.08.17.	25.08.17		CH	-type utstyr -beskrivelse av	18.08.2017	01.09.2017	01.09.2017	
4.13		Leverandør av brannvarsling	17.11.2017			CH	-beskrivelse av løsning.	01.12.2017			
4.14		Lynvern	16.06.2017				-notat	22.06.2017			22.06.2017
5	SS	RIV									
5.1		Varme-/kjøleløsning bolig	27.06.2017		27.06.2017	CH	-rapport - presentasjon	06.07.17		06.07.17	
5.2		Konvektor varmeløsning bolig	27.06.2017		27.06.2017	CH	-rapport	11-07-2017	10.10.2017	10.10.2017	
5.3		Konvektor kjøleløsning bolig	27.06.2017		27.06.2017	CH	-rapport	11-07-2017	10.10.2017	10.10.2017	
5.4		Lekkasjesikring bad/kjøkken/sjakt	16.10.2017			CH	-Notat beskriver løsning	27.11.2017			
5.5		Gasspeis type					fordelerskap plassering				
5.6		Omfang gatevarme	*17.11.2017 21.11.2017*			*CH*	-Notat beskriver løsning	*~~01.12.2017~~ 05.12.2017*			

Client decision plan traffic light colours: green = concluded
yellow = in progress
red = delayed

Figure 53: Decision-plan log between client and AF Gruppen

The initiative for the above shown decision-plan log has a long-term potential if standardized. If logged as described above, after many causes for latency, it could be possible to map typical root causes or root cause categories. It will also be possible to look at typical consequences resulting from the potential root cause categories. Further, it might be possible to detect activities affected at an earlier stage as the engineering manager responsible for the plan are notified through an automated system. Then, when a root cause is detected, an automated system can present what estimated latency are going to be and the consequences based on history of similar root causes. The engineering managers can therefore prepare other activities based on the new information and reduce the total project delay.

Multiple interview objects are underlining metrices as one of the most important aspect of VDC (EngineeringManagerAF, 2018; EngineeringManagerOperation, 2018; ProjectManagerDesign, 2018). Multiple other factors are already being measured, as schedule and budget. This is factors claimed that should be done better, and by establishing metrices commonly measured surrounding this, it could result to better overall project delivery. Experience is not commonly measured, but with Virtual Design and Construction, it is getting measured in some indirect ways as estimates matching real costs and time. Experience and continuous learning, together with benchmarking are mentioned as ways to keep improving projects. With metrices, it is important to use them time and time again. Establish a personal way of using them, maybe they won't work perfectly in the first project (as in Project Bispevika B2), but in time, the metrices will become better. Then in the next project, you take what was good from last project, make it better until perfection – and fix the aspects that went wrong – and add the aspects you wished you did from the beginning of last project. In Team Bispevika will this be in project B6a. VDC is claiming that participants set up a simple metrics system from the beginning of the project. Often, things will change, especially from the first project the VDC framework is used.

When evaluating latency, it is interesting to analyse the large intervals between *unified deadline for client decision document delivery (column 4 in Figure 53)* and *actual deadline for client decision document delivery (column 6 in Figure 53)*. If there is a large gap, on critical activities, the risk for a "domino effect" on other activities are high (a domino effect is that activity 1 affect activity 2 which affect activity 3 and so on). Other aspects that are regarded as important is the quality of the foundation in regard of the decision that shall be made in the client decision plan. It is mentioned that it is not possible to force the client to be more active in the beginning of the project, even though that would be better for the contractor. Therefore, the contractor and consultant have a more important role to be even more precise to ask the right questions, acquiring what is needed from the client and asking what the client need as a result of the project. (NorconsultProcessManager, 2018)

Root Cause Analysis

Currently, latency is measured, with different attempts to create a suitable template. Metrices for root cause analysis is still under development as root causes are complex and different to each other. According to Bispevika Tender (2016), root causes shall be detected through a fish bone structure showed in Figure 54. The current template will be further described below but is taken to account that it is not the finished template. (AFgruppenTender, 2016)

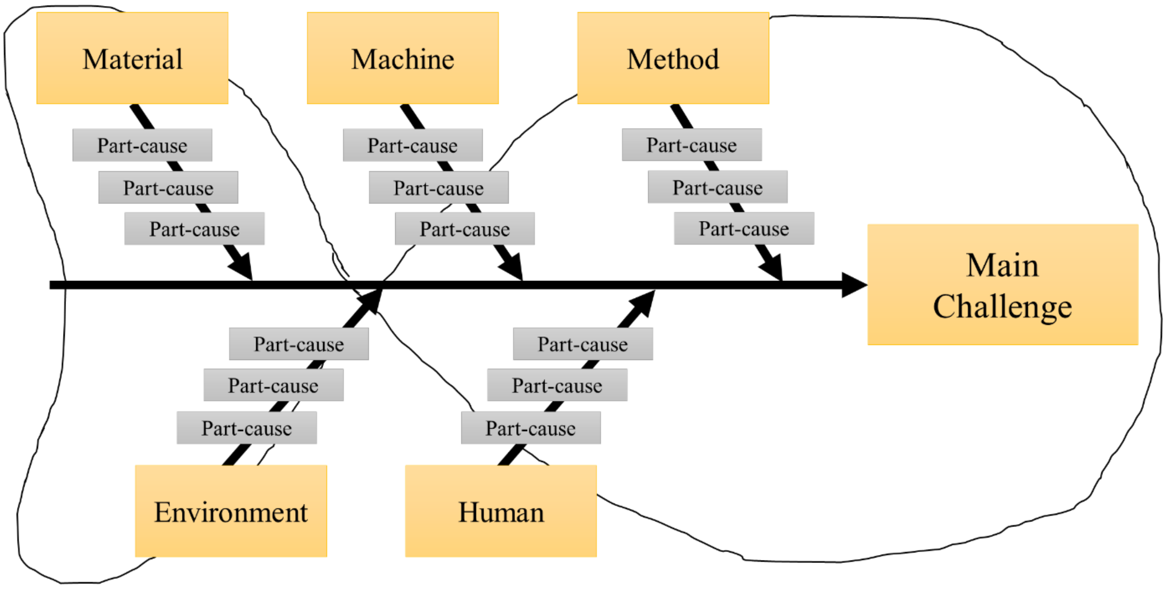


Figure 54: Root cause analysis as a fish-bone structure in Team Bispevika

When a root cause has been detected, AF Gruppen could handle the topic in several ways, but usually it goes through three main steps:

- Identification and analysis
- Solution for improvement
- Implement solution

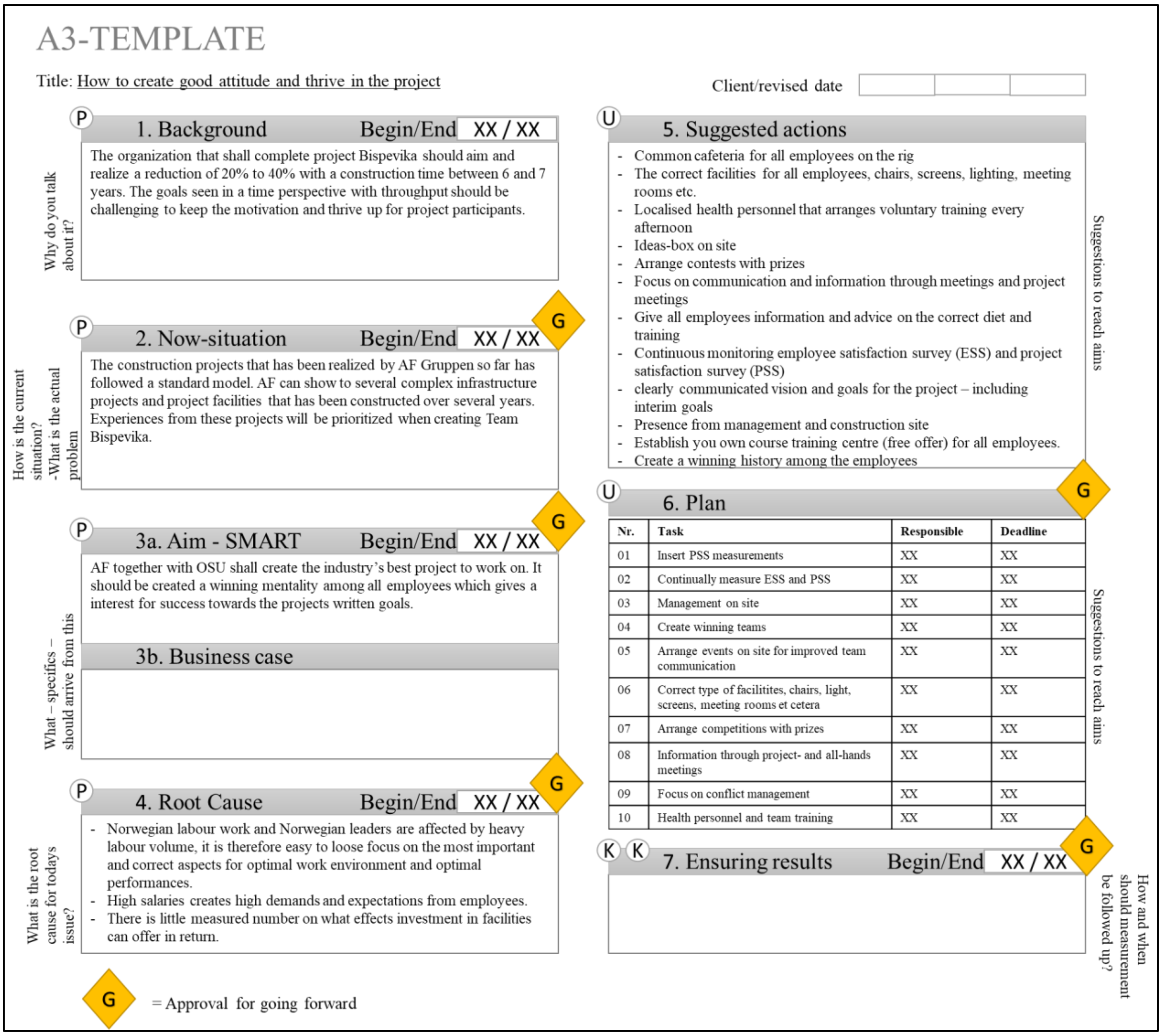
AF Gruppen is focusing on continuous improvements and are claiming that root cause analysis is one important source to learn from earlier experiences. Tools and techniques that has been used several times before are used as a standing point for improvements and may be exemplified by *project evaluations* and *A3 problem solution techniques*.

Project evaluation is done through and after each project where AF Gruppen is laying a foundation for continuous learning, experience sharing to other parts of the organization, and secure that the learning is documented in a logical way. Project evaluation includes a systematic information gathering, analysis and discussion around the challenge and an evaluation of the overall project. Project managers in AF Gruppen are responsible for conducting project evaluation, with participation from several managers throughout the company (AFgruppenTender, 2016). This is considered as an adapted version of the PLAN-DO-CHECK-ACT system focusing on continuous learning explained in 4.5.2 Root Cause Analysis.

A3 Problem Solving tools is a standard format, which is used in problem solving, ideas, plans, and status overview at Team Bispevika. It has arrived from Lean methods in AF Gruppen and have been used through many years. It is further adapted as an important way of problem solving in AF Gruppen’s VDC framework. It is built by eight steps developed to force the user to see all aspects of the ideas, problems and challenges. The method is developed to make sure no decisions are made too fast. The eight steps in A3 problem solving in Project Bispevika is:

1. Background to the problem
2. Description of current situation with specific data and facts
3. Description of goal – SMART (specific, measurable, actionable, reasonable & time)
4. Business case
5. What is the actual root case? Preferably use the 5 Why’s
6. Through brainstorming solutions relate to ideas and are thereafter ranked and prioritized.
7. Prioritized solutions are delegated to a plan with responsible person with deadline.
8. After implementation, differences should be measured that shows that aimed improvements had been reached.

In AF Gruppen, project improvement is conducted in two parts. Firstly, brainstorming of actions to reach a goal, where prioritizing the combination of effort and effect. Next step is to go through the A3 systematically where evaluation of the process is done afterwards. Several A3 processes was undergone before project start at Project Bispevika, where one of them is presented in Figure 55 below. The A3 reporting are corresponding with theory presented in section 4.5.2 Root Cause Analysis and are seen as a logical way to conduct improvement management.



A3-TEMPLATE

Title: How to create good attitude and thrive in the project

Client/revised date

1. Background — Begin/End XX / XX

Why do you talk about it?

The organization that shall complete project Bispevika should aim and realize a reduction of 20% to 40% with a construction time between 6 and 7 years. The goals seen in a time perspective with throughput should be challenging to keep the motivation and thrive up for project participants.

2. Now-situation — Begin/End XX / XX

How is the current situation? -What is the actual problem

The construction projects that has been realized by AF Gruppen so far has followed a standard model. AF can show to several complex infrastructure projects and project facilities that has been constructed over several years. Experiences from these projects will be prioritized when creating Team Bispevika.

3a. Aim - SMART — Begin/End XX / XX

What – specifics – should arrive from this

AF together with OSU shall create the industry's best project to work on. It should be created a winning mentality among all employees which gives a interest for success towards the projects written goals.

3b. Business case

4. Root Cause — Begin/End XX / XX

What is the root cause for todays issue?

- Norwegian labour work and Norwegian leaders are affected by heavy labour volume, it is therefore easy to loose focus on the most important and correct aspects for optimal work environment and optimal performances.
- High salaries creates high demands and expectations from employees.
- There is little measured number on what effects investment in facilities can offer in return.

5. Suggested actions

Suggestions to reach aims

- Common cafeteria for all employees on the rig
- The correct facilities for all employees, chairs, screens, lighting, meeting rooms etc.
- Localised health personnel that arranges voluntary training every afternoon
- Ideas-box on site
- Arrange contests with prizes
- Focus on communication and information through meetings and project meetings
- Give all employees information and advice on the correct diet and training
- Continuous monitoring employee satisfaction survey (ESS) and project satisfaction survey (PSS)
- clearly communicated vision and goals for the project – including interim goals
- Presence from management and construction site
- Establish you own course training centre (free offer) for all employees.
- Create a winning history among the employees

6. Plan

Suggestions to reach aims

Nr.	Task	Responsible	Deadline
01	Insert PSS measurements	XX	XX
02	Continually measure ESS and PSS	XX	XX
03	Management on site	XX	XX
04	Create winning teams	XX	XX
05	Arrange events on site for improved team communication	XX	XX
06	Correct type of facilitites, chairs, light, screens, meeting rooms et cetera	XX	XX
07	Arrange competitions with prizes	XX	XX
08	Information through project- and all-hands meetings	XX	XX
09	Focus on conflict management	XX	XX
10	Health personnel and team training	XX	XX

7. Ensuring results — Begin/End XX / XX

How and when should measurement be followed up?

G = Approval for going forward

Figure 55: A3 reporting in Project Bispevika – How to create good attitude and thrive in the project – adapted from (AFgruppenTender, 2016)

6.2.5 Evaluation of VDC implementations

The literature review study provides an understanding of how Virtual Design and Construction (VDC) have adapted to the design-construction process, the different parts of VDC, and how VDC can improve the AEC industry.

Developed by Kunz and Fischer (2012), VDC seek to increase efficiency of the design-construction process. PPM practices combined with BIM visualization and information flow has created the foundation for ICE implementations. VDC is focusing on three main components; the product, the organization, and the process, which is found in all projects. The components are evaluated in Project Bispevika below. Metrices are used to measure project performance and progress and is evaluated as an independent system.

Product

When evaluating the product of the POP model in this thesis – it is regarded as the digital model. Firstly, the model should be evaluated as appropriate for the size and complexity of the project. It is not necessary to create a 7D model if the client is not taking the model into the operation phase. For projects as large and complex as Project Bispevika the digital model should be created as a BIM level 2 model and be available for all relevant participants. Designers that are contributing to the product should work at the same digital platform which should notify participants when changes are made.

Level of Development (LOD) should be agreed on before designers begin working towards a milestone. A common mistake is that a designer spends unnecessary amount of time to create a model (example a model of the kitchen) at LOD400 when the BIM model only should have a LOD200 or the other way around. The high LOD model will need additional work to be stripped down to fit the BIM model (Waste 1 Table 2). A model delivered with a too low LOD will need additional work, which can result in unnecessary wait if the work-package is on a critical line (Waste 5 Table 2). This has been a challenge at Project Bispevika with potential for improvement (ProjectManagerDesign, 2018).

In Kruse Smith, VDC coordinator (2018) explains that they work explicitly with MMI (Maturity Model Index) when working in sequences in the design phase. Their MMI is shown in Table 14 below. The table is retrieved in interview with Kruse Smith and attached in Appendix 2.e. According to Engineering Manager at Multiconsult (2018), kitchen and such arrives from a special subcontractor. Maturity level is a challenge at every project and must be agreed on every time. Often in the construction industry, there will be new subcontractors and new cooperation between firms per project. And although it will be teams that have worked together before, there are new people involved. Therefore, it is challenging to achieve that everyone is working at the same pace. All such things must be repeated every time.

Table 14: MMI - Kruse Smith, adopted from BIM-Manual Kruse Smith

	Process	**Geometry**	**Information**
100 Idea	The object is presented as a sketch for visualization and analysis.	It is no criteria other than volume on the object. Even though it is modelled as a sketch, it should have accurate details in volume.	There is no criteria for information about the object.
200 Redefined ideas	The object is further processed from the idea. The object is currently chosen as a solution.	The object is presented in the BIM model. Should have approximate amounts, size, shape, location and briefing.	The object includes alternatives for material. Names on components relevant for the object.
300 Ready for multi-disciplinary control	The object is checked for conflicts up against other elements at their own discipline. It should be prepared for a multidisciplinary team.	Graphical presented in the BIM model with the correct size, shape, location, and briefing.	The object includes the correct material and information about specific criteria for object.
350 Approved multi-disciplinary control	Object is multidisciplinary coordinated against all disciplines in the project/area. Should at this point be no conflicts.	Graphical presented in the BIM model with the correct size, shape, location, and briefing.	The object includes the correct material and information about specific criteria for object.
400 Ready for production	The object is approved by the project team and ready for production/ construction.	Graphical presented in the BIM model with the correct size, shape, location, and briefing.	The object includes the correct material and information about specific criteria for object. Additionally, the object includes production related information specs.
500 As built	Object is confirmed built.	Graphical presented in the BIM model with the correct size, shape, location, briefing and are corresponding with the built component.	Fabrication, connections, and information should be modelled and placed as appendix to the object.

Organization

Organization in this chapter is including how Team Bispevika is working together, how the workspace is created and how ICE sessions are conducted. An improved organization performance is achieved through improved communication, teamwork and meeting structure. Integrated Concurrent Engineering (ICE) using Big Rooms and integrated environment are addressing some of these aspects. It is necessary that all participants involved contribute proactively to reduce unnecessary waste. As seen in Project Bispevika – using Big Rooms and integrated environment can improve meetings/sessions over time. It has been shown that metrices can be effectively at the end of each ICE session to collect data to shed light on issues at the workplace. According to Advisor Operations (2018) at Skanska AS, five out of ten parameters measured should focus on employee satisfaction.

In Team Bispevika it has been a high focus on creating an atmosphere where employees work for each other and work towards an ambitious project delivery in terms of quality, size and schedule. ICE sessions are one of the new implementations at Project Bispevika and it has been experienced that project participants are less experienced with the method. EngineeringManagerAF (2018) has explained that not all participants are equally open for the change. However, the graphs presenting data from Project B2 and Project B6a shows an overall increase in satisfaction. Further, it is important to document and standardize improvements for processes and techniques, so they are not lost when other employees are leading sessions in future projects. As mentioned in the ICE session section – at Project Bispevika an agenda is sent out the Friday before for Project B2 and at Monday before for Project B6a. This is chosen because of the rapidness of the sessions conducted (every week). The agenda includes the session timeline, what disciplines that are present, what discipline is responsible per agenda point, and what is the goals for each session. Next step will be to create a template so leaders in future projects easily can adapt the aspects. In Kruse Smith a template is created and are presented in Figure 56 below. It is retrieved through interviews with Kruse Smith representatives:

KRUSE SMITH

Planning and conducting meeting

Headline

Date:
Meeting place
Meeting type

Focus areas of session		Participants						Agenda						
Focus of session	Aimed result	Invited	Present	Disciplines/ Functions	Preperations	Planning team	Summary	Agenda	Responsible	Time (Start)	Duration (minutes)	Meeting room, tools, models og techniques	Did we reach aimed result?	Comment
								Anchor agenda i regard of plan and present a short summary of status		09:30	00:10			
								Going through actions in BIMSync		09:40	00:15			
										09:55				
										09:55				
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								Verification of new actions in BIMSynnc		09:55	00:05			
								Going through progress plan forward and establish resposnibilities untill next meeting		10:00	00:10			
								Summary		10:10	00:10			
								Finished		10:20				
								Duration of session (in hours)		00:50				

Figure 56: Example on an invitation to an ICE session (KruseSmithVDCcoordinator, 2018)

As mentioned, Project Bispevika is a first hand-on VDC project. The construction of team worksite and the winning team working together are not used to the integrated surroundings. The statistics measured at Project Bispevika is showing that the project team is adapting to the surroundings and coming projects as B6a should have improved delivery. However, in interviews it is highlighted that the processes and methods used is dependent on specific individuals within the organization for them to work optimal (KruseSmithVDCcoordinator, 2018). Therefore, it is more important to document processes and solutions that works well and creates solutions to problems.

Processes

Improved processes are in this thesis considered as improved planning and coordination. In Project Bispevika, several methods have been used and explained earlier in the analysis chapter; The Last Planner System, meeting plan, level of plans, planning wall vs digital solutions are some of the planning systems evaluated earlier in this chapter.

A digital solution (example Touchplan) has proven to be beneficial in many areas compared to a planning wall. It is easier to move work-packages around without losing history which is beneficial in terms of innovation and Lean philosophies for making more efficient routes. Work-packages can be shown in a more template way with general information as time and name, while additional information can be displayed when clicking on it. It is easier to change colours and such as the participants do not need to make whole new post-it notes. Errors are easily corrected, and history is better saved. This makes it easier to identify root causes and to see if latency affects other work packages. Integrated systems in Touchplan connects workflows and creates a system for better delivery. If PPC is measured on a daily level, it is a lot of punching doing this by hand. It requires a lot of discipline on the wall and in the head of the person responsible, and the risk of something losing out is high. Touchplan works better on aspects like this.

Further, it could be argued for potential benefits with a planning wall as it is an easier system with post-it notes, and project participants do not need to learn the Touchplan system. However, when the adoption is made, the graph presented in Figure 31 is showing that participants are more satisfied with the Touchplan system.

If a planning wall is preferable, it is possible to move away from post-it notes and create a template of how each note is presented. The suggested solution is creating company cards. The thesis will present one drawn suggestion for the company Norconsult created based on interview opinions. Each card should be marked with a card number and which card this is delivering a package to in the workflow process. It should also include what is needed from others to deliver the work package and what is the expected output of the card, as well as start date, duration and estimated finish date. All shown in Figure 57 on the next page.

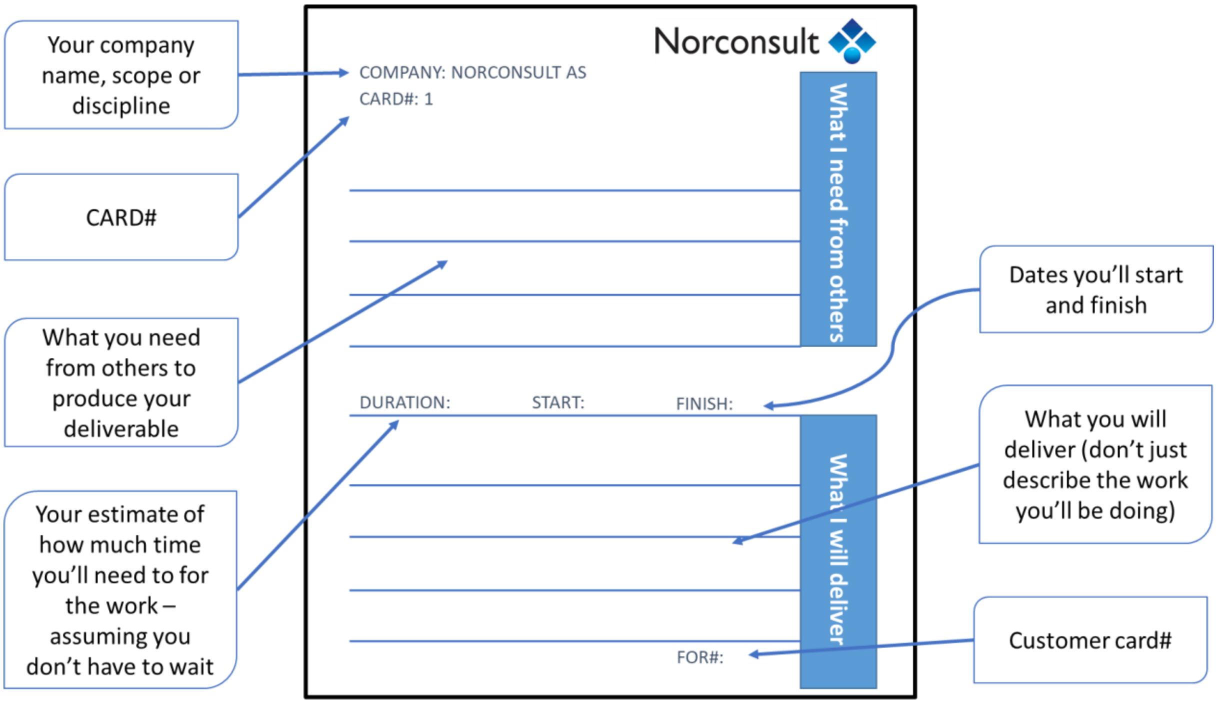

Figure 57: Example on a LPS card

According to EngineeringManagerMulticonsult (2018), the Last Planner System is all about levels. Last Planner is just a definition of a plan using four or five levels. In the top levels (master and phase planning) it is more important to establish sensible phases, and preferably logical steps within the phases that has manageable sizes. At a very early stage, it is more important to gain control over the concept. Concepts as if the construction should be high or wide? Should the technical room be in top floor or first floor? Then later when work packages are beginning to be more specific, the Last Planner System aims to help with pull planning to create the most efficient workflow, lookahead to work with proactive rather than reacting problem solving, checking work packages by having them visually presented and tracking PPC. Additionally, learning is done by detecting root causes and latency and improve processes and overcome challenges. The most important aspects of the Last Planner System are extracted from interviews and created as an illustration in Figure 58.

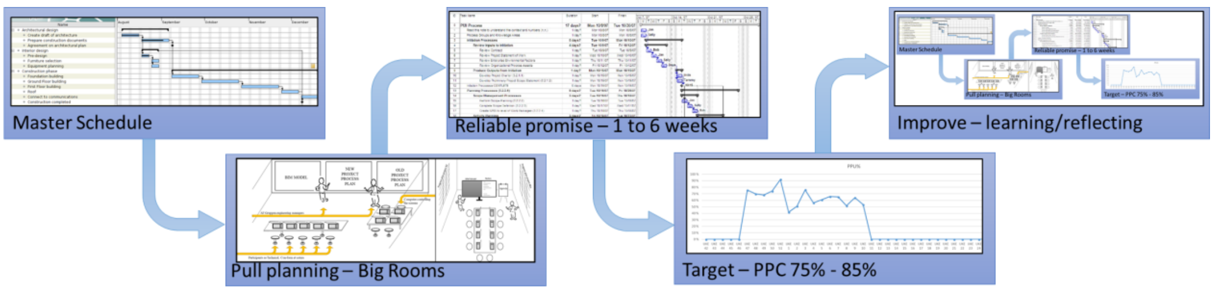

Figure 58: Last Planner System functions

Metrices

Metrices are the least explored part of the VDC framework and one of the toughest implementations to get right (AdvisorOperations, 2018; EngineeringManagerMulticonsult, 2018; KruseSmithVDCcoordinator, 2018). This has been underlined in the theory chapter and has been evaluated in the analysis chapter accordingly. To improve project performance, it is beneficial to have quantitative numbers measured. Therefore, it is seen as important to create a set of metrices to collect data. At Bispevika, time and place for retrieving data has naturally been set to ICE sessions, where engineering managers from AF Gruppen has taken responsibility to collect these data. Additionally, an initiative by Project Manager in Design has measured client decisions. Bispevika is an example of how metrices can be used to improve project delivery.

At Project Bispevika, measurements are conducted to retrieve data, and make changes for improvements based on this data (EngineeringManagerAF, 2018). It has been done in two similar ways with small differences in terms of questions. Both engineering manager in design and engineering manager in operations has used the metrices to improve processes. They have used standardized questions and followed their plan with retrieving data and they are presented naturally. Measuring client decisions has been a more difficult aspect to measure. The first attempt has been on Project B2 where it has been difficult to categories root causes because they are very different in nature. However, also in this metrics it has been shown earlier in the analysis chapter that the metrics underlined an issue and corrections was taken to improve client participation in meetings.

Metrices are in Project Bispevika evaluated to be a successful implementation. Especially when considering that participants using metrices in this project are undertaking the Stanford VDC education during the project life and it’s the first hand-on VDC project that is conducted. However, it is possible to compare the use of metrices at Project Bispevika to other companies. Kruse Smith have used a simple approach in ICE sessions. The questionnaire used at Kruse contains three questions:

1. Do you believe the other participants was prepared till todays session? (Yes/No)
2. How effective and useful was the meeting for you? (1-6)
3. How well did you contribute for the meeting to be of most use and efficient? (1-6)

However, KruseSmithVDCcoordinator (2018) explains that the questions are mature enough for being exchanged as it gets boring with the same questions week in – week out. The questions are sometimes asked anonymously, sometimes in plenum, sometimes at a sheet and sometimes as a conversation.

Further, according to Advisor of operational excellence at Skanska AS (2018) it should be a standard set for questions. The below suggestion is a subjective opinion and not a standard set used at Skanska AS. The suggestion is retrieved through interview;

- Estimated costs compared to real costs
- Safety
- Quality, measure KS-point at phase shifts
- Environmental impact
- Five indicators on employee satisfactions.

Further, it is underlined that measurements should have the following two criteria:

1. Easy to attain and reliable when measured.
2. Parameters should be clear to neglect all confusion around the questions.

The parameters could be displayed as a representation of an overall score ranging from 0 to 100 – where 100 is the best. In interviews, it is underlined that Kruse Smith still have big challenges with measuring PPC. In the construction industry it is typical to measure in percentage on big activities, but there is no real control. It is difficult to place direct comparable material between VDC projects and non-VDC projects as certain aspects are not measured. This could be; how many fires did *not* arise when using VDC (KruseSmithVDCcoordinator, 2018). A big part of the job to engineering managers are putting out fires (Fjellvang, Project Bispevika , 2018). It will therefore be easier to see the difference after several VDC projects. It is also underlined that it is easier to measure PPC in construction phase before all work packages are fairly settled compared to design where design often has changes, where revisions are considered to have value.

In comparison, it has been beneficial for Team Bispevika to use standardized questions where it is possible to collect data and display this. Further, it is evaluated to follow Advisor Operations (2018) at Skanska's two criteria for reliable measurements described above. The aim at this point in Project Bispevika was not to give the project an overall score, but to improve processes and learn from using the VDC tools and techniques. Further, documentation on environmental impact, quality and safety should become a part of project delivery. According to theory it can be concluded that it is not necessary to measure everything, but take a small sample of project controllable factors, project process objectives and project outline. Learned from observations and interviews at Project Bispevika with input from external interview participants, the following have been developed as a logical set of metrics:

- Two measurements from project controllable factors that could be implemented at Project Bispevika.
    - 1.3: Coordination support. The goal should be that the planning wall/Touchplan should contain above 90% of all work packages conducted. This will result in more visualization of the project progress. According to ProjectManagerDesign (2018) have the consistency been a small issue in design and engineering at Project B2. If it was measured, employees would have more discipline with preparing notes and place them on the board.
    - 1.5: Design versions. Due to the project size and complexity, every design case that will influence the budget, schedule, effort or life cycle energy use more than 10% should have two or more design alternatives. If design versions are measured, innovation is important which is an important aspect of VDC.
- Four measurements of project process objectives should be implemented and measured at a weekly basis in ICE sessions. This part – Team Bispevika has proven to perform well. The two most important measurements are:
    - 2.1: Schedule conformance. Should be easier to measure in construction phase. VDC practice should have the goal of all project activities should begin and end within one day of estimated dates. This should be measured in structure phase by engineering manager in operations that already have been conducting a lot of preparations through the workshops explained in 6.2.1 Coordination.
    - 2.4: Response Latency. This is already implemented by project manager in design up against client decisions. It could further be implemented between all disciplines. It should be set a standard of acceptable response latency.
    - 2.5: Stakeholder involvement. It has been criticised that it is not easy to get the correct stakeholders to attend at certain times. Measurements at this topic has been proven to be an issue at Project Bispevika and actions were taken. An integrated environment is beneficial and stakeholder involvement should be measured.
    - 2.10: Meeting efficiency. At this point a digital standard solution could be established and participants could check of all activities in the session that where

beneficial for their discipline. This would be an easier solution and combine several questions in the current questionnaires. VDC objective should be 70% valuable activities or above.

- Four measurements of project outline objectives. Safety, functional quality, costs and schedule should be measured. Costs and schedule should be compared against estimations, safety should be zero incidents and all close incidents should be reported. Functions should have 100% satisfaction post occupancy.

The 10 questions above should create a foundation that makes it possible to create a standard set for an overall score at the end of the project. Further, employee satisfaction should be measured and comments for improvement should be encouraged. Metrices should become better per project the system is used and project performance should increase accordingly. However, there is many sets of measurements that can be used. This is just one example.

Project Bispevika has chosen anonymously questions, a set of ten questions in Design & Engineering, and a set of six questions in Operations. A high number of questions can prove beneficial as AF Gruppen is trying to establish a culture for integrated environment and learn from the disciplines involved in terms of what is working best. Certain aspects as room layouts, tools used, and office landscape will be standardized. Then it is time to shift questions to focus on aspects around processes- and project results. It will be easier to focus on latency and root causes when external factors are standardized. This seems like a logical way to establish metrices and practices in the first VDC project.

Chapter 7: Validation

This chapter are questioning results achieved by evaluating sources, theory and methods used in this thesis.

7.1 Sources

Virtual Design and Construction (VDC) is a less researched topic, which has made it difficult to find reliable sources. As VDC is a developed framework consisting of several ideas from Lean construction, Integrated Concurrent Engineering and BIM – information has been found at these places and cross checked towards the main source of information – the VDC guidebook developed by Kunz & Fischer (2012). Lean and BIM have been the most researched areas, where ICE practices and especially PPM practices is less researched. This has raised questions to the theory adapted, which has further needed explanations through interviews. All sources have been cross checked and it has been focused on using as modern sources as possible when writing about digital tools (as BIM) and techniques using digital solutions. There has been a focus to analyse how VDC is working towards non-VDC projects and not old practices. The theory developed has been used as the foundation when evaluating case Bispevika.

In this thesis – one case (Project Bispevika) has been analysed. When evaluating one case, it is high uncertainty around the results. The analysis is therefore based on a "lessons learned" approach rather than a description of how VDC should work in all projects. At Project Bispevika, several attendees are undertaking their VDC education and writing reports covering different aspects of the VDC framework at Project Bispevika. This has given the case more focus from management and given project participants time to work with VDC concepts. The case study has benefitted from the high VDC focus, and case studies of different projects would most likely not give the same results. It is already stated in AF Gruppen tender that Project Bispevika will be a milestone in AF Gruppen history – where Project Bispevika will be their first VDC project.

7.2 Methods

Methods used to gather primary data has been case analysis, interviews and document treatment. Documents retrieved by Team Bispevika engineering- and project managers in design and operations. In the thesis it has been discussed what criteria is important to attain the correct results. The thesis has also discussed other ways to measure; having fewer questions, changing questions, anonymously answers has been compared to non-anonymously answers, to mention some of the aspects evaluated.

Interviews have been done with seven attendees. Additional, several participants have contributed with numbers with interest and opinions to the thesis. The time interval has created limitations where more interviews could give a deeper and broader understanding of some topics. Interviews have been conducted at different times in the thesis with opportunities to send questions post-interview if more questions have been necessary. Interview participants have answered logical in terms of each other and in terms of theory and analysis conducted. Three interview attendees have been working on Project Bispevika and four interview attendees has been working in different companies. Interviews have been conducted in three sequences. First interviews have focused on understanding current processes. Second round have focused on how VDC is used and the benefits experienced in the industry. Third phase has been to understand criticism for VDC and what projects would not benefit from the integrated framework.

It is experienced that if more participants where involved, it would be possible to create more reliable categories for types of latency and root causes. It would be beneficial for the thesis to have more attendees and participants with broader background. It has been several times criticised the client for poor participation and poor initiative, which has been evaluated as one of the most common reasons for latency (see 7.3 Results below). It would be beneficial to talk to a series of clients and gain their opinion of inclusion from contractor and consultant.

7.3 Results

Results in this thesis shows that there is an increased interest in the VDC framework from Norwegian companies. Consultant and contractors in smaller and larger firms are sending their employees to the Stanford VDC education or attaining the knowledge by having specialists inside the area. It is however not the VDC education that is important, but what is learned by it. Companies have created their own educational frameworks with similar scope that is larger or smaller than the Stanford VDC education. The internal educations include ICE, PPM and BIM aspects and is considered valuable for employees, even without the Stanford diploma. Figure 19 is therefore not considered perfectly correct. Numbers illustrated are the numbers on employees sent to this exact course and does therefore not show a perfect presentation of the knowledge within each firm and will show bias to organizations that hasn’t created an internal education. The Stanford VDC education is more suitable for a contractor than a consultant and should show that contractors are more focused on sending employees at this course as it is more of value.

Further, it is shown that BIM is highly implemented in organizations and multiple contractors and consultants are shifting towards a paperless industry. Objectives for delivering paperless projects are commonly mentioned to be within the 2020's. This is showing a digital shift. ICE practices are fairly implemented in consultant companies where contractors benefit from integrated environments at the rig and Big Rooms. Results from case analysed is logical compared to theory, where ICE sessions are working best in well-equipped Big Rooms. Theory indicated that project delivery should perform better with integrated environment. Question 9 in Appendix 1.a illustrated in Figure 45 underlines the theory and shows and increased overall satisfaction. Results from metrices at Project Bispevika are in general showing that the team is performing better parallel to weekly development.

The results from metrices used at Project Bispevika is seen as fairly reliable. The case Project Bispevika has been given a lot of attention and managers want the project to perform well. The room for innovation given and number of observants given access to the area will not commonly exist. As mentioned many times before, when this is the first time working in an integrated environment with the project team. Few participant desires to be looked at as negative and might answer a bit biased in questions regarding their satisfaction working with Touchplan and satisfaction with the AF Gruppen rig. Especially when a participant is encouraged to state why they are not satisfied if this is the case. It can arguably also be claimed that each participant that is working in the integrated environment does not have any projects of this kind to compare to Project Bispevika. Therefore, metrices will achieve more precision in projects where all attendees have been working in several integrated environments with Big Rooms and metrices before.

It has been claimed that projects will deliver better as VDC is implemented in more projects. However, for improved processes – projects are dependent on certain individuals to drive the project. As well as the project must be of a certain size and complexity to achieve the improved aspects of the VDC framework. Therefore, it is not certain that the same results would be achieved through any other case. More research on different cases with different teams and implementations is necessary for reliability to the results.

PPC is further described in theory and analysis chapter. Plan Percent Complete is created to give an indication of how well the project team are performing and should be measured at a weekly basis. The results should be between 75% and 85%. In theory this is described for the construction industry in general and is the mindset adopted industry wide. However, interviews have shown that in design phase, it could alternatively work with LOD- or MMI deliveries where it should be created a standard industry-wide and not per organization as delivery teams are changed frequently. PPC works best in construction phase, but only if all participants are aware of how it is measured and of the project team is using a digital solution. If this is done by hand, it requires a lot of discipline on paper and in calculations. It is therefore important to consider other possible routes to track progress. At Project Bispevika, no solution is made in Design and Engineering, while PPC is used in Operations. This is evaluated to be a possible improvement for Project Bispevika B6a and other future projects.

Determining *typical root causes to latency* is considered to be unachievable with one case study. The root causes detected in this study is therefore backed up by interviews and are considered as *possible root cause categories to latency*. The three adapted root cause categories to latency is poor communication, wrong people present and little specification in the early phase. Interviews has shown that these are root causes the industry is aware of but are not able to reduce even with several initiatives tried before. However, the case study has shown multiple initiatives where troubles within the three categories mentioned above has been solved. Initiatives proven to address the issues mentioned is proper meeting agenda, decision theme meetings, and integrated environment. These initiatives are not considered to work in all cases but evaluated as a possible solution as they have worked in Project Bispevika.

In the analysis section, it is claimed that Touchplan is proven to work better than a planning wall. This is considered for operations and is not arguably true for engineering phase. As the project team is working in the second floor at the Bispevika rig and have access to the planning wall to all times (except the client and the architect, but this has been their choice), Touchplan might not be a necessity. The Touchplan solution made it easier to copy up work packages and drag them around on a time scale. At the engineering planning wall, this is not necessary. However, it is not claimed that the planning wall used is preferred above Touchplan in engineering but remains uncertain how much benefits it would be using the Touchplan solution.

Chapter 8: Conclusion

The question this master thesis aim to answer is:

Can Virtual Design and Construction improve project delivery?

Yes, this thesis concludes that certain types of projects will improve project delivery when using the Virtual Design and Construction framework. However, it is evaluated in this thesis that not all projects will have the same benefits using VDC. The project should be of significant size and complexity. Smaller and less complex projects will not have the same value of implementing Virtual Design and Construction to the current knowledge-level in the industry and costs of implementations. It is critical to have the correct individuals present and the project needs support for innovation and space for implementations from the management. Early VDC movers will have more costs in their projects, where benefits gained from the VDC framework is evaluated to not be clearly shown. However, benchmarking and lessons learned will drive costs down in later projects using methods proven to work.

For organizations to benefit from using VDC – certain implementations have shown to be critical. ICE sessions should be conducted with well-equipped Big Rooms. Touchplan has in this thesis proven to work better than a planning wall to distribute, visualize and access work-packages. The Big Room needs to have enough space, where the agenda should be sent out early and displayed during the ICE sessions. Notes should be taken during the session and the BIM model should be displayed as a live model on one of the screens. Processes should be optimized and standardized. Metrices are used to measure performance level and collect data. Actions are taken accordingly after results retrieved from the metrices and has shown to create the ability for improving processes and resolve issues in projects. Last Planner System should be used after the early phase. It is preferred to use a digital solution or have a digital backup. A 4D BIM model should be used in combination with the Last Planner System. Synchro has shown to be capable of connecting the two. In the design process, LOD or MMI should be used to track progress, or at least as outputs on work-packages – while in construction process PPC is preferred.

Teamwork is an important aspect at Team Bispevika. Their ambitions to create “winning teams” and satisfied employees at the Bispevika rig has been given high priority. This thesis is highlighting the importance of early involvement from the client. Preferably having the client in the integrated environment and incentives for team performance should be written in the contract with the focus on team rather than individual discipline gains. The client should be challenged in terms of requirements, construction ambitions and usage after handover as early as possible with specific objectives stated.

The three top possible root cause categories for latency detected through this thesis are poor communication, wrong people present and unclear specifications from early project phase. VDC engagement in projects stimulates the early inclusion of stakeholders. The improved collaboration in multidisciplinary teams and ICE methods improves decision-making and creates a foundation for better project throughput. VDC is creating an arena for easier information flow and a shift from working separately and sequentially with focus on individual delivery to a wider project team working towards a common goal. Further, metrices are used to determine success measured in quantity, detect issues and challenges, where root cause analysis, A3 reports and the plan-do-check-act system are tools used for continuous learning.

If project size and complexity is similar to Project Bispevika analysed in this thesis – VDC has the potential to improve project delivery. The combination of tools, motivation and project characteristics is determining project outcome. Therefore, this thesis claims that VDC does not deliver better results alone as a tool. VDC has the potential to improve performance if the project team and external stakeholders is motivated and determined in doing so in a project that has the required characteristics.

Chapter 9: Further research

The results of this thesis have concluded three possible root cause categories for latency in the design-construction process. For reliability, these categories should be evaluated against several other projects. Further, it should be conducted research that the same implementations as used in Project Bispevika are reducing latency in other case studies – and if other implementations have been conducted with results on similar situations as poor attendance from the client.

VDC is a less researched topic and more research is required on how it can fit smaller and less complex projects. Most research and attempts of using VDC have been focusing on large complex projects as Project Bispevika. Further, metrices should be used in the different projects. This thesis has had a limited time interval and have therefore used one case study and have analysed limited amounts of metrics sets. In this case, the metrices are considered a success, but has limited focus. It would be beneficial for organizations to see other attempts on measuring processes and what results are found.

The VDC framework is in this thesis evaluated to be most suitable for the construction phase of the design-construction process. It would be beneficial for consultant firms to conduct more research on what aspects of the VDC framework can work in the early phase of project life.

In this thesis it has been presented that VDC could become a part of the NTNU education from autumn 2018 or spring 2019. The education is supported from the companies Kruse Smith, Backegruppen, Skanska and Veidekke. The initiative is seen as highly beneficial for students. The VDC education will have to be adapted to benefit students not working on construction projects and not writing their reports on their current projects. A different mindset to the education is needed and the initiative will have to be continuously revised to improve the course.

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APPENDIX

APPENDIX

The following documents are included as appendices in this thesis (note that some appendices are in Norwegian as this is how they are used due to Norwegian participants):

Appendix 1: Questionnaires

a. Questionnaire in ICE meetings in Engineering
b. Questionnaire in ICE meetings in Operations

Appendix 2: Interviews

a. Interview guide to VDC participants
b. Interview with Process Manager and Head of Innovation, Norconsult
c. Interview with Engineering Manager, AF Gruppen
d. Interview with Chief Advisor, operational excellence, Skanska AS
e. Interview with VDC Coordinator, Kruse Smith
f. Interview with Engineering Manager Operations, AF Gruppen
g. Interview with Project Manager in Design, Norconsult
h. Interview with Vice President of Engineering, Multiconsult

Appendix 3: Observations

a. ICE session
b. Project Bispevika presentation
c. Phase sessions

Appendix 1: Questionnaires

Appendix 1 is holding information from questionnaires used at Project Bispevika. The questionnaires have been used from project and engineering managers in operations and engineering meetings. It has been conducted further analysis from numbers retrieved from the questionnaires.

In appendix 1 there are two questionnaires.

a) Spørreskjema B2 (Engineering)
b) Spørreskjema B2 (Operations)

Both questionnaires have been answered weekly.

Appendix 1.a

Spørreskjema B2 (Engineering) UKE______

1 - Grusomt
2- Forferdelig
3 - Veldig dårlig
4 - Dårlig
5- OK
6 - Bra
7 - Veldig bra
8 - Supert
9 - Fantastisk
10-Kunne ikke blitt bedre!

1. I hvor stor grad synes du at du fikk mulighet til å komme med forslag/påvirke agendaen til ICE møtet?

1 2 3 4 5 6 7 8 9 10

Eventuelle kommentarer (frivillig)

____
____
____

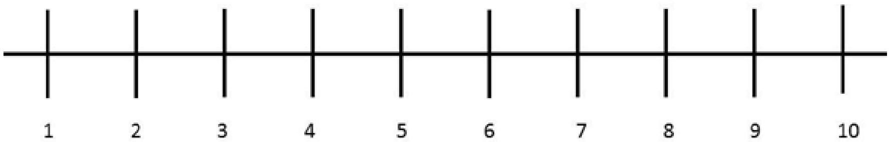
2. I hvor stor grad synes du at du selv bidro? (stilte forberedt, deltar aktivt)

1 2 3 4 5 6 7 8 9 10

Eventuelle kommentarer (frivillig)

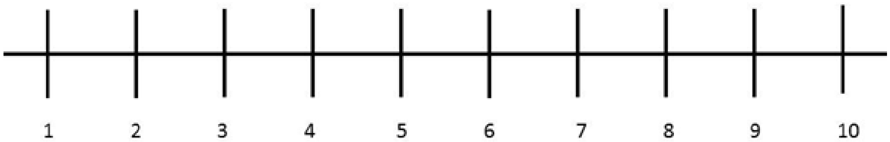
____
____
____

3. I hvor stor grad synes du at du at andre bidro i ICE-møtet (stilte forberedt, aktiv deltagelse)



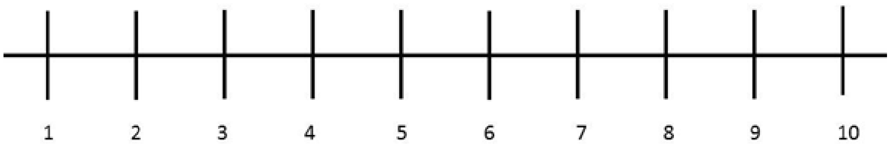
Eventuelle kommentarer (frivillig)

4. I hvor stor grad synes du vi fikk lukket agendapunkter i ICE-møtet?



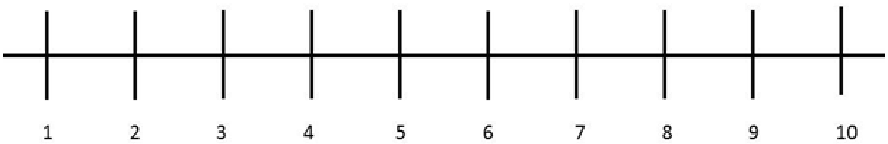
Eventuelle kommentarer (frivillig)

5. I hvor stor grad opplever du at rett personell var tilstede på ICE-møtet?



Eventuelle kommentarer (frivillig)

6. I hvor stor grad opplever du at planveggen bidrar til forutsigbarhet i arbeidet ditt?



Eventuelle kommentarer (frivillig)

7. I hvor stor grad får du utbytte av å jobbe på AF-riggen utenom torsdager?

1 2 3 4 5 6 7 8 9 10

Eventuelle kommentarer (frivillig)

____

____

____

7.1 Dersom du opplever lite utbytte (5 eller mindre), i hvor stor grad opplever du at dette er noe du selv kan styre?

1 2 3 4 5 6 7 8 9 10

Eventuelle kommentarer (frivillig)

____

____

____

8. I hvor stor grad synes du at du får tilrettelagt utstyr på AF riggen (internett, ekstra skjerm, tilgjengelige møterom etc)

1 2 3 4 5 6 7 8 9 10

Eventuelle kommentarer (frivillig)

____

____

____

9. Alt i alt - hvor fornøyd er du med samhandlingen på prosjekt Bispevika?

1 2 3 4 5 6 7 8 9 10

Eventuelle kommentarer (frivillig)

____

____

____

Appendix 1.b

Spørreskjema B2 (Operations) UKE______

1. Hvor godt var du forberedt til møtet? (1-6 hvor 6 er best)

☐	☐	☐	☐	☐	☐
1	**2**	**3**	**4**	**5**	**6**

2. Hvor godt forberedt mener du andre var til møtet? (1-6 hvor 6 er best)

☐	☐	☐	☐	☐	☐
1	**2**	**3**	**4**	**5**	**6**

3. Hvor godt gjennomfører AF møtet? (1-6 hvor 6 er best)

☐	☐	☐	☐	☐	☐
1	**2**	**3**	**4**	**5**	**6**

4. Forstår du hva vi driver med i møtet? (1-6 hvor 6 er best)

☐	☐	☐	☐	☐	☐
1	**2**	**3**	**4**	**5**	**6**

5. Oppnår vi å gjennomføre det som planlegges i møtene? (1-6 hvor 6 er best)

☐	☐	☐	☐	☐	☐
1	**2**	**3**	**4**	**5**	**6**

6. Hvordan opplever du å jobbe med planlegging i Touchplan kontra lappeplanleggging slik som tidligere?

☐	☐	☐	☐	☐	☐
1	**2**	**3**	**4**	**5**	**6**

Kommentar eller forslag til forbedringer:

Appendix 2: Interviews

Appendix 2 consists of a composition of interviews. A summary of each interview is presented below after the initial interview guide. When specific parts of interviews are presented in the thesis, it is referred to the appendix. If quotes are used, they are translated and presented in the corresponding appendix. The following are in Appendix 2:

a) Appendix 2.a – Interview guide to VDC participants
b) Appendix 2.b – Interview with process manager and head of innovation Norconsult
c) Appendix 2.c – Interview with Engineering manager AF Gruppen
d) Appendix 2.d – Interview with chief advisor, operational excellence Skanska AS
e) Appendix 2.e – Interview with VDC Coordinator Kruse Smith
f) Appendix 2.f – Interview with Engineering manager, operations AF Gruppen
g) Appendix 2.g – Interview with Project manager in design Norconsult
h) Appendix 2.h – Interview with Vice President Engineering Management, Multiconsult

Each of the interviews (Appendix 2.b – Appendix 2.h) is beginning with a reference box holding the following information for referencing in-text-context:

- Date of interview
- Position to interviewee
- Company interviewee are working in
- Structure of interview
- Reference used in text

Appendix 2.a Interview guide to VDC participants

All interviews have been semi-structured. The following questions are just a guide to keep the conversation relevant to the thesis. Interviews have taken turns where information achieved is not always related to the below mentioned questions. Some interviews have also suffered from time limits where some questions have been prioritized above others.

VDC med fokus på resultater:

1. Hvilke endringer har du opplevd når du har hatt ett fokus på å bruke VDC i prosjekter sammenlignet med når du ikke har hatt dette tidligere?
2. Opplever du en prestasjonsendring hos dine kollegaer som tar eller har tatt VDC utdannelsen?
3. Har du sett endringer i resultater når dere bruke VDC eller lignende verktøy i prosjekter i tidligere prosjekter?
4. Er det noen aspekter ved VDC som du mener er ekstremt viktig som du mener bidrar til bedre leveranser?

Integrated Concurrent Engineering (ICE):

1. Hvilke ICE implementering har dere tatt i bruk i deres selskap?
2. Når/om dere gjennomfører ICE sesjoner:
    a. Hvordan er deres utforming på rommet?
    b. Hvilke verktøy bruker dere under sesjonene?
    c. Hva er lengden på deres sesjoner?
3. Har dere prøvd ut hel-integrerte prosjekter og eventuelt hvordan har dette gått/ditt inntrykk av dette?

Building information modelling (BIM):

1. Til hvilken grad bruker dere BIM i deres leveranser og mener du at dere bruker BIM nok i deres selskap?
2. Har dere noen videre ambisjoner med BIM?
3. Hva er dine meninger med å kombinere BIM med andre verktøy? Eventuelt hvilke muligheter ser du her?

LEAN/Production and process management (PPM):

1. Hvilke målinger (metrices) bruker dere i deres selskap?
2. Er det noen av målingene dere foretar som du ser at dere kan få bruk for og lære av i senere prosjekter?
3. Er det noen målinger du mener kan bidra på korttid (innad i samme prosjekt)? Eventuelt hvilke?
4. Er det noen målinger som du er blitt positivt overasket over kan bidra til bedre prosjekter/målinger som du har overvurdert og mener ikke kan gi verdi i senere prosjekter?
5. Måler dere latency i deres selskap? Eventuelt hvordan og hva har vært deres resultater her?
6. Hva er typiske rot-årsaker til latency hos dere?

Appendix 2.b – Interview with process manager and head of innovation Norconsult

Reference box	
Date	***21.02.2018***
Position	***Process Manager, Innovation Management***
Company	***Norconsult***
Interview Structure	***Semi-structure***
Reference in text	***ProcessManagerNorconsult, 2018***

The interview was the first interview in regard of the thesis. It focused on how Norconsult is working in projects, what is typical, what challenges occur time and time again, and what are VDC to Norconsult. Process Manager explains about how VDC has been adapted to Norconsult. It gets explained that VDC is an increasing topic of interest. More and more employees are sent on course to Stanford and practices are explored in project relevant to the topic. Process Manager highlights the difficulties in the early phase of construction project, and that design take additional time in term of design loops as the client commonly struggle to explain what he/she wants. The track of progress has usually be done in a form of drawings, where efficiency as been measured in drawings per booked hour. This has to change as the industry is moving towards models instead of drawings. Companies as Bane Nor and Vegvesenet are aiming for drawing-free project deliveries by 2020. Further, it gets explained that ICE meetings should be measured in terms of satisfaction, experience has also shown that Big Rooms are improving quality of the meetings. The biggest challenge is the culture change that is needed. VDC is nothing new, but skills need to be improved.

Quotes extracted from interview and used in thesis:

Det jeg ihvertfall har sett som blir desto viktigere når vi jobber med VDC er hvor mye tid vi setter av til interaksjoner med kunden. Det største forbedringspotensialet jeg har sett gjennom flere oppdrag jeg har prøvd å styre arbeidsprosessene i er at om vi setter av nok tid til i oppstartsprosessen med kunden med å definere tydeligere mål, milepeler, sett på avhengigheter, sett på hvilke beslutninger som skal tas og i hvilken rekkefølge. Å få en kultur for at vi har en felles forståelse om hva som må til, så er fryktelig mye av jobben gjort.

What I have seen through multiple projects when we are working with VDC is the increased amount of time we spend to interact with the client. This is one of the factor with most potential – that we spend enough time in early phase to define project goals, objectives, which *decision that should be made and in which order to take them. If we develop a culture with common aims. Much of the job is done.*

Det er viktig å få til en kultur hvor kunden involverer seg og tar de beslutningene som trengs når det er satt opp at kunden stiller i møter hvor beslutninger skal tas. Hvis ikke så blir jo hele prosjektet forskyves. Det må spesifiseres fra starten at vi skal jobbe som et integrert team. It is important to establish a culture where the client is included from the beginning of projects and are invited to work with the decision-making group in important meeting throughout project life. It should be a discussion about client involvement before project start.

Det er ikke meningene at en skal sitte å dra i BIM modellen i møtene, men at det handler med stor grad i å ta effektive beslutninger og da er BIM et glimrende verktøy. The most important is to make the people work together in the best possible way, where BIM is a tool to accomplish exactly that.

It is not necessarily important to adjust BIM models while in a meeting, but to make effective decision-making and BIM is working as a powerful tool.

Det er kjempebra at vi får flere med den kompetanse, men jeg tenker at oppdragslederen der vi skal prøve å ta dette i bruk så må de ha grunnleggende kompetanse og gi disse et mandat i å styre oppdragene. Der har jeg sett tydelige utfordringer, at ikke mandatene er helt til rette på hvordan få det til.

To really make use of the education the employees are getting by the VDC training, it has to be adopted in all project phases. People higher in the project hierarchy needs to be aware of VDC practice.

Om en skal bruke en dag til dette så kaster en bort tiden til folk. Det vi har gjort er å ha en time i starten av en dag hvor en finner ut av hva en skal endre på og hva skal vi beslutte av disse tingene. Så sitter en liten gjeng og gjør dette over 2 til 5 timer. Da kan vi møtes igjen og huke av disse tingene. Men om vi skal detaljprosjektere med 8 til 15 mennesker i et rom så sitter mange uten noe å gjøre.

One of the principle challenges with ICE meetings is to not be tempted to start designing together. Meeting participants often get dragged to much towards the technical and wants to start design detailed solutions. This results in some people working, but some will sit there without anything to do. Therefore, it is important to stay focused on the decisions to make.

Appendix 2.c – Interview with Engineering manager AF Gruppen

Reference box	
Date	***01.03.2018***
Position	***Engineering Manager***
Company	***AF Gruppen***
Interview Structure	***Semi-structure***
Reference in text	***EngineeringManagerAF, 2018***

Engineering Manager in AF Gruppen is undertaken her VDC education during the time of this thesis. She explains that the VDC course is experienced differently by each participant. For a contractor like AF, it is easy. It has the tools, described as how they can be used in the project as ICE sessions, big rooms, coordination and so on. Just press play and you are there. For a designer on the other hand, it is harder as it has to be adapted. The biggest change was the use of metrices. To actually quantifying processes. She explains she is using the metrices to measure, see a problem, and then react to this problem.

Engineering manager explains that she is measuring how well the project team are working through the ICE sessions. How many agenda decision point are attained, how well the different disciplines are performing, if the disciplines are happy with the tools and techniques used at the AF rig. It is quite a change moving from their own office to sit in an integrated environment at a rig – right next to the construction site. We spend a lot of time to make sure all participants are satisfied with their working place. For many this is the first time in an integrated environment she explains.

She then explains that the ICE sessions have changed a bit. Before it was a whole day covering one of the project B2 and B6a. Further they have seen that a three-hour session is more effective. It has therefore been divided to one session on B2 at one day and one session a 3 hours on B6a another day. The ICE sessions are using a Big Room with planning walls, agenda, notes, and BIM model. It is underlined that participants have different views on the sessions. It is not a "one generation against another" but a culture thing. Some people are used to handle this a different way and do not see the efficiency in the ICE way. At least not yet.

It is later highlighted that the VDC course are very technical. It neglects much of the aspects of the humans. It is the people in a project that drives the project forward and it is a cultural thing to be able to use VDC in the best possible way.

Jeg bruker det vel mest på målinger, jeg bruker ikke så mye tid på å implementere VDC for det er der. Jeg bruker målinger derimot for å få data og bruke disse dataene for å gjøre tiltak.

We are using metrices to get data, and use these data to make actions

Appendix 2.d – Interview with chief advisor, operational excellence Skanska AS

Reference box	
Date	***14.03.2018***
Position	***Chief Advisor, operational excellence***
Company	***Skanska***
Interview Structure	***Semi-structure***
Reference in text	***AdvisorOperations, 2018***

Chief Advisor in Skanska on VDC has multiple publications of the use of VDC, Last Planner system. He also has knowledge to Project Bispevika which takes some conclusions in this interview.

He explains that in Skanska, they are using Solibri as BIM tool, which is different to Bispevika. He explains that Last Planner system is central in their last planner system and they always begins their ICE sessions to go through the last planner to mark where they are at the moment. Thereafter they update the project in term of project process completion (PPC) and disciplines corrects their work packages if needed. Agenda with decision points are then showed on the screen of their ICE sessions showed in Solibri. The exception is if the work should be done using Virtual Reality, then Unity is used as program. It is no written duration at the ICE sessions in Skanska. They vary according to what decision points that re to be met during the session. However, normally, three-four hours has been a logical duration.

Chief Advisor states that there is no definition if you are using VDC or not. It is like asking if you are using HSE (Health, Safety and Environment) or not. It should be categorized to what degree are you using VDC in your projects.

Projects that has had a focus on using VDC implementations has shown better results in term of costs, schedule and quality than other projects. But we are still struggling to find the correct measurable parameters.

It is currently a lot of focus on measuring methods used in the project. To measure the quality are more difficult in a way. However, Skanska has found ten parameters for finished projects:

Noted: the parameters below is a try on how Skanska could operate and not any written correct way of measure:

- Costs: Estimated/real

- Safety: RUH and PSI
- Quality: KS-points at phase shifts
- Team: 5 indicators on employee satisfaction
- Environment: Sources

The above-mentioned parameters should result in an overall VDC score ranging between 0-100.

Additional to this, Chief Advisor has two criteria for the measurements:

- Parameters should be clear
- Measurements should be reliable and easy to collect.

Appendix 2.e – Interview with VDC Coordinator Kruse Smith

Reference box	
Date	***15.03.2018***
Position	***VDC coordinator***
Company	***Kruse Smith***
Interview Structure	***Semi-structure***
Reference in text	***VDCcoordinatorKruseSmith, 2018***

Kruse Smith is one of the organizations in Norway that attained a high focus on VDC and sent several employees on the Stanford education.

It begins by starting with how Kruse conduct ICE sessions. Firstly, they have a template for the invitation to ICE sessions (attached below). In the invitation, it is defined; topics of focus that should be specific that you can answer yes or no, which persons that is invited and what positions they have – together with what preparations they should do before the meeting. The agenda is normally sent three-four days before the meeting, but if time allows it, preferably as early as possible. The rapidness of meetings is varied.

Further, VDC coordinator explains that Last Planner System is something Kruse is working a lot with developing into their principles. He explains that Last Planner system is nothing new arriving with VDC and has been used by Kruse since 2008. Now, he works a lot with combining it with 4D, as they see that the combination of the two can provide significant positive effects to the project. Earlier, Last Planner has been used at phase meetings and looking ahead meeting (6-8 weeks). Kruse does work towards healthy activities. Normally post it notes has been used. Now, Kruse is working hard to create the total package of Kruse smith's way of delivering. With all practices and courses included.

Moving on to PPC, it is underlined that this is something Kruse Smith still has big challenges with. To measure PPC, is typical for the construction industry to measure in percentage on big activities. There is no control, and we don't know where we are at.

VDC coordinator says that he is yet to see a firm implement Last Planner system fully. It only gets partly integrated and aspects are missing. Project using VDC tools are too dependent by certain individuals to make it work. There are several examples of it working well, however there are also several example with it not working on similar projects. I almost see its missing some digital advancements. If you are to measure PPC on a daily level it is a lot of punching.

Doing this by hand, it is necessary with a lot of discipline on the wall and in your head, and the risk for something to lose out etc are high. It is typical that the feedback loop takes too much time and the different levels aren't corresponding anymore. Touch plan etc has worked in some project, but not all. We see a tendency that programs want to do everything for you, while we only need small parts. When they try to do everything, it doesn't work as well.

In term of PPC are we improving in the way we measure it. Still there are aspects that is hard to measure. AS how many fire that didn't arrive due to what we have done differently using VDC and Lean.

Questions used in ICE sessions are focusing on what can be improved and what was satisfying and are graded from 1 to 6. The way Kruse does it is varying, sometimes anonymously, sometimes in plenum, sometimes at a sheet and sometime just as a conversation. We are ready to shift the questions now as they are getting boring when the same questions arrive every time.

Design work is done through MMI (maturity model index) which is close to Lod. This makes it easier to create a decision list. Thereafter, BIMSync is used. MMI index to Kruse is attached below.

According to Kruse, integrated delivery reduces a lot of latency. The project is slowed down not due to the tasks take a massive amount of time, but it's the time between the tasks. People are just waiting. It's frustrating and unnecessary according to the VDC coordinator. At the moment, it is the one shouting the highest that gets his things first, which is bad, as the way the contracts are, there are no teamwork incentives, so the guy that shouted the highest gets the best delivery and most money., Last Planner works for making sure it's a flow in the project and not per discipline, which helps. Integrated project delivery created a field for innovation and ideas. Each discipline alone does not get any money for this, as its not in the contract.

Møteplanlegging og gjennomføring		HVL, nybygg Nordtomta A1						Dato:						
								Møtested						
								Møtetype:		Prosjekteringsverksted				
Fokusområder for møtet		Deltakere						Agenda						
Fokus for møtet	Ønsket resultat	Inviterte	Tilstede	Disiplin/ funksjon	Forberedelser	Planleggings- team	Oppsummerings- team	Agenda	Ansvarlig	Tid (Start)	Varighet (minutter)	Møterom, teknikk, modeller og verktøy	Ble forventet resultat oppnådd?	Kommentar
										09:55				
										09:55				
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								Verifisering av nye punkt i tiltaksliste/Bimsync		09:55	00:05			
								Gjennomgang av fremdriftsplan, fokusområde for neste møte og ansvar for planlegging		10:00	00:10			
								Oppsummering		10:10	00:10			
								Slutt		10:20				
								Varighet på møte (timer)		00:50				

Evaluering				
Pluss	Delta	Forberedelse (J eller N)	Møtekvalitet	Egeninnsats (1-6)
		0,0 %	0,0	0,0

Resultat
0 %

Forbedring av møtet:
Oppsummeringsteamet vurderer systematisk forbedringer av møtet, basert på evaluering av møtet.

Dette gjøres:
(angi frekvens - månedlig, kvartalsvis, halvårlig)

MATURITY MODEL INDEX

	100	200	300	350	400	500
	Idé	Foredlet idé	Klar for tverrfaglig kontroll	Utført tverrfaglig koordinering	Produksjons-underlag	Som bygget
Prosess	Objektet er fremstilt som en skisse for visualisering og analyse.	Objektet er videre bearbeidet fra idé. Objektet er foreløpig valgt som løsning.	Objektet er kontrollert for konflikter mot andre objekter i egen disiplin. Alle objekter av tverrfaglig betydning skal være representert i modellen.	Objektet er tverrfaglig koordinert mot alle andre disipliner i prosjektet/området. Ingen gjenstående tverrfaglige konflikter.	Objektet er godkjent av prosjektgruppen og klar for produksjon/bygging.	Objektet er bekreftet bygget.
Geometri	Det stilles ikke krav til annet enn volumobjekter. Objektet er å betrakte som en skisse selv om det er modellert med tilsynelatende nøyaktig og detaljert geometri.	Objektet er grafisk framstilt i BIM-modellen som et generisk system, objektet har omtrentlige mengder, størrelse, form, plassering og orientering.	Objektet er grafisk fremstilt i BIM-modellen som et bestemt system med riktig størrelse, form, plassering og orientering.	Objektet er grafisk fremstilt i BIM-modellen som et bestemt system med riktig størrelse, form, plassering og orientering.	Objektet er grafisk fremstilt i BIM-modellen som et bestemt system med riktig størrelse, form, plassering og orientering med detaljert utførelse.	Objektet er grafisk fremstilt i BIM-modellen og tilsvarer hver komponent i en konstruksjon/system. Objektet har riktig størrelse, form, plassering og orientering med detaljert utførelse.
Informasjon	Det stilles ingen krav til informasjonen i objektet.	Objektet inneholder forslag til materialvalg. Navngiving av objekttyper iht. modelleringskrav.	Objektet inneholder riktige materialer og informasjon iht. til modelleringskrav.	Objektet inneholder riktige materialer og informasjon iht. til modelleringskrav.	Objektet inneholder i tillegg produksjonsrelatert informasjon i henhold til modelleringskrav.	Fabrikant, sammenføyninger og informasjon om installasjon skal være modellert/vedlagt objektet.

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4 MMI-verdier

Appendix 2.f – Interview with Engineering manager, operations AF Gruppen

Reference box	
Date	***20.03.2018***
Position	***Engineering Manager in operations***
Company	***AF Gruppen***
Interview Structure	***Semi-structure***
Reference in text	***EngineeringManagerOperations, 2018***

Engineering manager for operations is coordinating meetings with subcontractors at Project Bispevika. The conversation mainly focusing on how he is using the last planner system with several subcontractors not stationed on site. The conversation is also focused on metrices in operations where engineering manager are showing files while talking. Metrices are showed below.

Engineering manager explains that last planner is basically integrated planning. That the one that is supposed to deliver the work is actually planning it. Engineering manager explains about a phase meeting series that has been going on to construct the structural work. The third session is Thursday after the interview where the participants will use the last planner methodology. This meeting is further explained in Appendix 3.b phase session.

Further, we talk about the process of reaching where the situation is per moment:

The sessions has been through two earlier sessions. Con-form, technical and AF Gruppen are present, as well as people responsible for cranes and trucks to make sure we have capacity.

In the first session, the group agreed on separating each floor into 3 zones. It can be natural to split in zones after example sprinkles or cranes. In this case it was cranes that only reached over a certain length. Thereafter, the group went through all work packages needed for zone 1. This was then multiplied for zone 2 and 3. It is shown that the same work is going through all three zones. Thereafter each discipline (Con-form, technical and AF) was separated and said that the only thing you are to do is to write up all activities your discipline are doing for zone 1. No communication with each other. All activities were listed on one line. Then we began with: What is the last activity to be done in the project. Then we put this on the wall, then we asked which activity is the last to finish for us to begin the last activity, and so on. The first session ended up that one zone took 17 days. And crane two must do both zone 2 and 3. So critical way was 34 days per floor at the end of first session.

Then, AF Gruppen added all activities in Synchro before the next session. This creates a 4D presentation of the construction being raised. All activities were linked together to show the pace of the construction. This was presented at phase session 2. After the video was shown, the participants begun. What activities can be reduced from two to one day? What activities are only taking a few hours? The most critical factor was a new system for sprinkles. A new subcontractor had an innovative idea that reduced the amount of days per zone from 6 days down to one day per zone. After second session each zone was down at 9 days while zone 2 and 3 could overlap with one day. Therefore, 17 days per floor. The goal is to reach 10 days per floor. Engineering manager explains that he doesn't believe they will reach that goal without drastic activities. Activities as putting in another crane would enable it, but at a high cost. The money is better distributed for an early beginning on other phases and save days at those places. It is still one meeting to reduce further days.

Further, we are discussing engineering manager use of metrices. He explains that he is conducting measurements at weekly sessions through 6 questions:

1. How well prepared where you to today's session?
2. How well prepared did you feel the other participants were for today's session?
3. How well did AF conduct the session?
4. Do you understand what we are doing?
5. Do we achieve what has been planned in the session?

Additional, after moving from a planning wall to a Touchplan, the question:

6. How do you experience to work with the Touchplan compared to stickers used on a planning wall as earlier?

Further, he explains that the attendees are having a comment field where they help improving the sessions.

PPU and results are presented in form of graphs on a common drive where the involved can see progress and correlation. Question number one is the most important for the rest of the session. The results is shown below.

Further, root causes are evaluated and engineering manager is underlining that wrong people present are one of the main causes for latency. It is also shown that as fast as people are switched in the meeting sessions, the results are decreasing rapidly. Further, latency is highly correlated to communication between operations and engineering. They need to have the same focus.

When engineering management is working on foundation above 8th floor, while operations shall begin with 2nd floor next week are a problem. It is underline that even though it is obvious for most, it is not obvious for some when external pressure from other places makes them shift focus. And we have had troubles in software. An error was detected just a couple of days ago where a column that in the model was 12,06m, but when it got clicked on it was only 6m in the information section. This was the case in just a few of the columns and had not been ordered yet, but it could result in a huge latency and outlay.

Engineering manager explains that his morning meetings would consist of safety briefing and 10-15 minutes going through what is on today's agenda, what was done yesterday, and what's for tomorrow.

											Post-its		Touchplan								
	UKE 42	UKE 43	UKE 44	UKE 45	UKE 46	UKE 47	UKE 48	UKE 49	UKE 50	UKE 51	UKE 1	UKE 2	UKE 3	UKE 4	UKE 5	UKE 6	UKE 7	UKE 8	UKE 9	UKE 10	U
Planlagte oppgaver i ukeplansmøte						41	43	44	58	25	24	57	25	25	23	35	46	33	25	30	
Planlagte oppgaver utført						31	30	30	43	23	10	29	19	14	14	23	30	17	16	16	
Fjernede/Tilkomne lapper						0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Oppgaver tilkommet etter ukeplans møte						19	17	15	11	5	14	7	1	1	1	5	0	0	0	1	
Ikke planlagte oppgaver utført						10	16	13	9	4	3	6	1	1	1	5	0	0	0	1	
PPU	#####	#####	#####	#####	#####	76 %	70 %	68 %	74 %	92 %	42 %	51 %	76 %	56 %	61 %	66 %	65 %	52 %	64 %	53 %	#
PPU (Tilkomne oppgaver)	#####	#####	#####	#####	#####	53 %	94 %	87 %	82 %	80 %	21 %	86 %	100 %	100 %	100 %	100 %	#####	#####	#####	100 %	#
Tilkomne oppgaver, dividert med totalt antall	#####	#####	#####	#####	#####	32 %	28 %	25 %	16 %	17 %	37 %	11 %	4 %	4 %	4 %	13 %	0 %	0 %	0 %	3 %	#
1. Hvor godt var du forberedt til møtet? (1-6 hvor 6 er best)	0	0	0	0	0	4,6	3,75	3,83	0	0	4,55	4,27	4,29	0	5,00	3,8	4,75	4,38	5,1	5,25	
2. Hvor godt forberedt mener du andre var til møtet? (1-6 hvo	0	0	0	0	0	4,4	3,75	4,5	0	0	4,45	4,27	4,29	0	4,78	4,6	5,13	4,75	5,2	5	
3. Hvor godt gjennomfører AF møtet? (1-6 hvor 6 er best)	0	0	0	0	0	4,2	4,25	5	0	0	4,82	4,73	5,571	0	5,22	5,2	5,25	5,25	5,3	5,75	
4. Forstår du hva vi driver med i møtet? (1-6 hvor 6 er best)	0	0	0	0	0	4,6	5,25	5,83	0	0	5,64	5,27	5,571	0	5,78	5,6	5,5	5,5	5,6	5,75	
5. Oppnår vi å gjennomføre det som planlegges i møtene? (1	0	0	0	0	0	4,2	3,50	4,33	0	0	5,18	4,36	4,143	0	4,00	3,8	4,63	4,5	5	5	
6. Hvordan opplever du å jobbe med planlegging i touchplan k	0	0	0	0	0	0	0	0	0	0	0	4,36	4,29	0,00	4,78	4,60	5,13	5,50	5,50	5,25	

Appendix 2.g – Interview with Project manager in design Norconsult

Reference box	
Date	***22.03.2018***
Position	***Project manager in design***
Company	***Norconsult, working on Project Bispevika***
Interview Structure	***Semi-structure***
Reference in text	***ProjectManagerDesign, 2018***

Project manager in Design at Project Bispevika is explaining that she is conducting measurements against decision made by the client. The interview is focusing on how a log is set up, what is latency in terms of decisions, how it is measured and root cause analysis.

Further, project manager is explaining that Touchplan in ICE sessions are working really well. She has participated in several Ice sessions without it in other projects, and commonly, they do not have the same flow as in an ICE session. ICE sessions have to change as the agenda changes. Sometimes it might be more practical to sit together and work through troubles in design.

Root causes has been difficult to categories. So far, it has been project B2 that has been used as project to measure. Next try will arrive in project B6a.

Further, project manager is showing their last planner and are going through aspect I am not sure of yet. It is shown how maturity levels are used to set milestones for specific teams. There is also separate milestone that are in terms of what apartments that are sold to what times. It has nothing to do with the construction, but the engineering planning and design of the apartments. Is mentioned that in the first floor (in operations) they use synchro and touch plan. Which might be a better way of using the planning system as things are being forgotten at this planning wall. It is also easier if you need to go back, as there is no backup of the planning wall.

Project Manager underlines that the correct personnel is important to get things done in meetings. When doing measurements, we agree on that it's the big differences between estimated delivery and actual delivery is important. The uncertainty is creating a risk for following activities to be affected.

Da målte jeg faktisk client meetings – der så jeg på hvor mye de var tilstede på ICE møter, hvor mye de var tilstede på OSU og AF møter, der er det jo 100% prosent. I og med at det har vært *litt labert på ICE, så har jeg kjørt litt mer sånn decision theme meetings. Da sier jeg at «det skal taes beslutning på det og det punktet, jeg vil gjerne at dere kommer» – da kommer de. Så de må styres.*

I was measuring client participation in ICE sessions. I did see that in OSU and AF meetings, they client participated 100%, while it was poor attendance in ICE sessions. So, I begun inviting to decision theme meetings, where I informed the client that we are going to take these decisions during the meeting, and I would appreciate that they where present. They have arrived in all occasions.

Og kvalitetet på grunnlaget i forhold til byggherrebeslutningsplan. Byggherre bryr seg jo egentlig ikke før de får det i hånden ikke sant. Vi får ikke tvunget byggherre til å gå inn mer aktivt i starten selv om det hadde vært bedre for oss. Så vi må være enda mer tydelig på at vi etterspør at det er dette dere trenger og er det dette dere trenger som grunnlag. Jeg tror at neste byggetrinn blir bedre. Jeg har sett en forbedring utover prosjektet i den rollen de har. Og at de deltar mer aktivt. Jeg savner jo at de satt her nede, tidligere så satt de jo på riggen. Det hadde vært veldig fint, så det er noe med at du ringer også er de i møter så må du sende mail og det tar tid osv. Og det at de er med i møter, det er lettere å møte opp når du ikke trenger å dra ned til riggen.

The client doesn't really care before the product is delivered. We can not force the client to be more active at an earlier stage of the project, even though that would be better. Therefore, we must be more precise with what the client is requiring and what we are the objectives. I believe the next building will become better. We have seen the client getting engaged more in the role they have. And they are more active.

I do miss the client sitting here at the rig, as they used to before. It is taking more time when we have to call them, and they might be stuck in meetings. Then we have to send a mail, and it takes more time to make decisions. When they where located here, it is also fewer barriers to joining sessions et cetera as they do not have to set off that extra time to travel to the rig.

Jeg tenker at det der med måling er helt essensielt. Vi måler på så mye annet. Vi måler så mye på fremdrift med kroner og øre, men så måler vi på så lite annet som erfaring. Og det er jo helt grunnleggende for å gjøre det bedre videre. Man skjønner det ikke før man begynner med det, men da ser man verdien i hva det er. Bare det å måle noe, det trenger ikke være noe vanskelig. Men bare det å måle noe. Mitt mål er jo å lage en byggherreplan med innebygd parametere. Så du bare kan skrive inn sånn og sånn og så bare spytter den ut. En mal da på det.

I believe that using metrices is critical. We are measuring progress in cost and time, but we are not measuring experience. And experience are the key to delivering better results in the future. You do not understand it before you have begun with it, but then you see the value of what it is. Just to measure something – it doesn't have to big something difficult - but to just to set a goal. My goal is to create a client decision plan with integrated parameters. So you can just plot in that an that, and it will spit out. A template in a way.

Jeg liker veldig å kunne se ting. Men folk henger opp mye som ikke er tydelig. En burde hatt noe sånt som maks 20 bokstaver per lapp. Også ser man at det var lurt å kjøre noen sånne Diamonds for å skille de ut. Vi har jo jobbet som en optimaliseringsprosess. Så den er mye bedre enn hva den var. Men sånn som ark som bare er her tre ganger i løpet av uka og da ikke har tilgang til den til enhver tid har jo ikke samme glede av den. Byggherre også for den saks skyld. Så for dem hadde det funka bedre med en digital løsning.

I like to be able to se things. But people are putting up much that is not readable. We should have had something like maximum 20 letters per sticker. And we see that it can be smart to put up some diamonds for separating stuff. We have working with this like an optimization process. So, it is much better than what it was in the beginning. But like ARK which is not at the rig more than three times a week doesn't have the same positive aspects as us using it. Client as well. So, for them, it would have worked been better with a digital solution.

Appendix 2.h – Interview with Vice President Engineering Management, Multiconsult

Reference box	
Date	***12.04.2018***
Position	***Vice President Engineering Management***
Company	***Multiconsult***
Interview Structure	***Semi-structure***
Reference in text	***EngineeringManagerMulticonsult, 2018***

Interview is with a project management for the largest projects in Multiconsult.

Firstly, the conversation is about Last Planner. Project Manager states that Last Planner is all about of levels. Companies are always planning; Last Planner is just definitions that uses Four to Five Levels. They begin at the top levels; master and phase planning. To go down through the levels of planning with last planner is not seen as appropriate at very early stages in Multiconsult.

That system works when things start to become very specific. In a construction phase for example, things are very specific. You know what to build. But in the early stages, everything is loose, and everything is in play. We are working on major iterations. When it's about building high or wide on a large plot, LPS is not appropriate. Then we have more benefits using an overall plan. But when we are closer to creating the model or drawings, then LPS are better.

From sketch-phase and through to design is considered early stage. We are working on Master and phase planning, establishing sensible phases. We also work with steps within the phases. How to divide a phase into sensible steps. In manageable sizes. So we know where we are going over a period of time. Then we see if we are where we were supposed to be? If not, what are we doing to get there? And that depends on where you are, different approaches of where you are in the project. At a very early, we talk about gaining control of the concept. Then we get control of the geometry. The size and location of the technical room, heights etc. Principles around a facade solution etc. So on with calculations etc.

I believe that all companies have a broad span of how the customer is involved. We are very clear about working with expectations and expectations already at project kick off. Where are we going? What are the construction going to be used for? What is its purpose? What is the ambition level? Then keeping the customer involved continuously. Multiconsult does not have a specific methodology. But it is some parts of costumer involvement in the ground methodology. Multiperm is our project implementation model. It says how we break up projects in phases. Its not a forced way of doing projects, but a starting point for a standard. Think of it as a ground template that can be changed according to who is project manager and client.

Normally in an project, issues are varied. It is rarely an isolated issue that creates delays. What we have is that we have a checklist on how to diagnose a mission. Key questions in relation to putting an overall reason for where the shoe pushes. Put a discipline on how this works. Have we gone up the communication channels?

Everyone in the industry has different opinions about what a VDC project is. Some have that a 3D model is a VDC project. Some call an ICE meeting just having a meeting together. There is a lot of stretch in that definition. In Multiconsult, when talking about VDC, its about process and way of working. Multiconsult have worked very systematically with improvements of processes for about 20 years. Newest for the industry is perhaps the ICE methodology. That has been integrated, but in selected projects. Not all projects work like this, not all projects are appropriate to work like that. Large complex projects are very appropriate. VDC to Stanford is well built around a total contract. So you get a lot more out of it when you're together with a contractor and can look all the way to the construction phase. To bring in all actors that will influence decisions in the same room, it is very appropriate. In smaller projects, there are of course elements in ICE that are interesting, but it isn't necessary to integrate it fully.

It is proven that ICE sessions underline better processes and better quality decisions. We have permanent rooms at Multiconsult. In the Big Rooms it is three big touch screens.

We provide a BIM model appropriately for the customer. Unless he will take the entire model into operation phase, it is not necessary to make a full 7D model.

Progress is often considered against maturity and status. You can have 100,000 objects in your model.

Kitchen and such comes from a special subcontractor. Maturity level must go through every time. Often in the construction industry, there will be new cooperation per project. And although it will be the same as before, there are new people. So that everyone is working at the same pace is a challenge. All such things must be repeated every time.

Multiperm is based on VDC methodology. It is important for us to point out the VDC methodology to suit us than the Stanford course. We believe that we are getting more out of building the VDC methodology internally. Point it right to what we deliver. Just under 20 has the formal Stanford course. Through Multiconsult's course, that is more than twice as big as Stanford and are focusing more on management, there is 99 employees over the past two years.

Appendix 3: Observations

Appendix 3 are containing small summaries from observations done on-site. Additional to the summaries below, the author has spent several days at Project Bispevika observing the project team. Appendix 3 has the following reported observations:

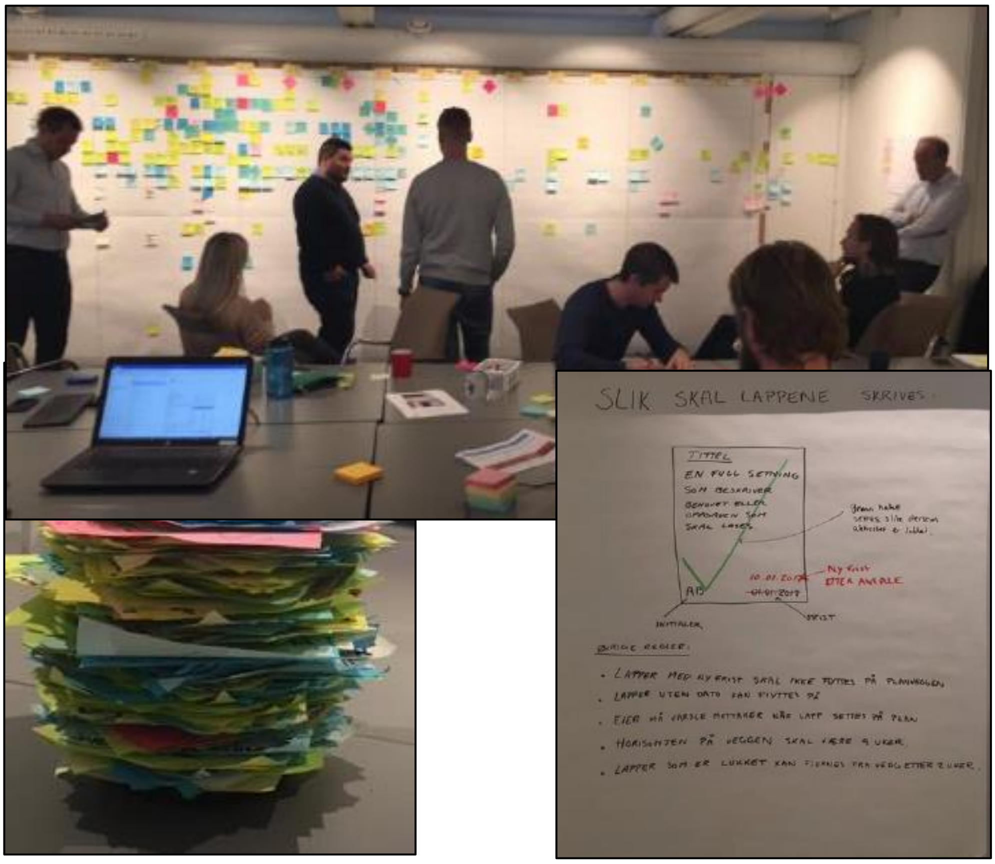
a) ICE session
b) Project Bispevika presentation
c) Phase session

Appendix 3.a – ICE session

Opening box	
Date	***01.03.2018***
Activity	***ICE session***
Duration	***Approximately 4 hours***
Type	***Observing***
Reference in text	***ICESessionObserved, 2018***

The ICE Sessions begun with going through todays agenda. The Agenda was clear and concise with which decision points was to be finished after todays meeting. The disciplines represented (ARK, LARK, AF, RiB and RiV) was able to make comments to the plan.

It was one big touch screen separated into two sections. One section presenting notes from todays meeting which was written by the facilitator. The other part of the screen was the BIM model, making it easy to make snips and paste in notes. The walls was covered with the process plan for both projects. B6a is showed in picture. Notes finished was stabbed as showed in next picture. Each note should be written as the third picture.



Appendix 3.b – Project Bispevika presentation

Opening box	
Date	***02.03.2018***
Activity	***Presentation***
Duration	***1 hour***
Type	***Observation***
Reference in text	***PresentationBispevika, 2018***

Engineering manager had a presentation about Bispevika as a project. Extracts of project are shown in pictures below.

Short facts:

- 10 Buildings should be constructed
- 1150 million NOK is in involved as a total enterprise
- 365 apartments over 48 000m^2
- Business, restaurants, culture over 8 000m^2
- 5 constructions are constructed above water
- 20 000m^2 are constructed over pillars
- Construction time just below 3 years
- 6 tower cranes are used in the projects

Use of VDC in Project Bispevika:

- Extensive use of BIM
- Weekly Ice sessions
- Planning after project phases – put in a system

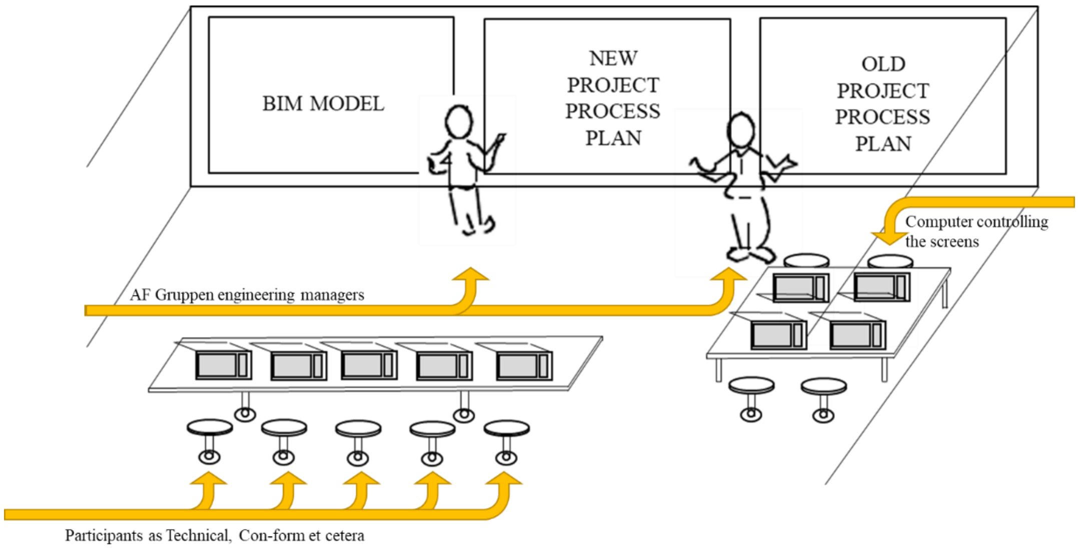
- Facilities: Big Room, open integrated environment at rig, smart screens
- Consultant working at the rig
- Quantify goals

Appendix 3.c – Phase session

Opening box	
Date	***02.03.2018***
Activity	***Phase session***
Duration	***3 hours***
Type	***Observation***
Reference in text	***PhaseSessionOperations, 2018***

The phase sessions had the following room layout: (drawn and shown in Figure below).

- 3 Big screens, the BIM model, the project process plan that was worked in and the old project process plan which was used to make notes.
- Con-form, technical, AF Gruppen Engineering mangers, responsible for trucks and responsible subcontractor for cranes was present in the meeting.



The process up to this point is described in *Appendix 2.f – Interview with Engineering manager, operations AF Gruppen.* At this point, each zone used 17 days. This meeting was supposed to reduce the number of days per floor even further. Con-form that is the main subcontractor for structural work had the homework to see which activities can be overlaid. Con-form representative had used all lean experiments he knew and came with a result. Con-form representative showed his A3 excel sheet with each activity duration and time of beginning. However, the project team are using touch screen and at this point, they project team had agreed on not marking activities in terms of hours, but days. This is to have an open mind for innovation and not be to narrow minded on one plan. A lot of the work was about translating the excel sheet into touch screen activities while the majority of the group was watching from the side-line.

The con-form representative had started overlapping floors, with activities that could begin at floor X+1 before floor X actually had finished. This helped reduce number of days, and after a 3-hour session – the number of days was reduced from 17 till 14.