Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Economics and Management
Department of Civil and Environmental Engineering

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INVESTIGATION OF LAST PLANNER® SYSTEM PRACTICE ON THE MINNEVIKA BRIDGE PROJECT

Master's thesis in Project management
Supervisor: Ola Lædre
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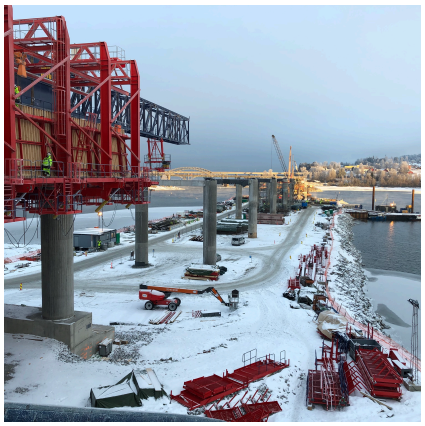

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ABSTRACT

It is clear that construction projects experience complexity, uncertainty, and interfaces. By introducing the Last Planner® System (LPS), one of the most effective lean construction tools in reducing variability and improving reliability, many construction companies around the world have adopted this method of management. PNC, the company under-study, is one of these organizations that has implemented LPS for the first time on their Minnevika bridge project in Norway. While significant numbers of case studies of implementation of LPS in projects exist, few have investigated the LPS process in an infrastructure project as well as how project participants' attitudes to LPS implementation can change during the project execution phase. This study explains the implementation of LPS in an infrastructure (railway bridge construction) project. Different involved parties' perspectives are examined as well as the strengths and weaknesses of the implementation process. Finally, attitude changes towards the LPS during the project were measured and possible measures to overcome the detected challenges of the project are discussed.

The required data was collected through literature study, case-specific observations, semi-structured interviews with open-ended questions, and two surveys. The findings revealed that the project benefitted from implementing LPS, but benefits could have been reinforced if critical team members had participated continuously in the necessary meetings, followed the system without resistance and maintained their commitments. Therefore, the main effective solutions to overcome the challenges can be to concentrate more on showing the benefits of the system to the project team. However, LPS on the Minnevika bridge project was the novel start and detected challenges are often experienced by every organization at the beginning of implementing a new system. Indeed, the Minnevika can be considered as the point of departure and being persistent will help the parties to benefit even more in the next project.

PREFACE

This study has been written as a master thesis (TBA4910, project management) under supervision of Ola Lædre, Professor at the Department of Civil and environmental engineering at NTNU, and in cooperation with an external organization, PNC Norge AS.

The following paper consists of three parts; part one – Master thesis section, part two – The resubmitted paper after first review in the 29th IGLC conference, and part three – appendices that includes the specialization project from last semester, survey, and interview questions. It should be noted that the author was strongly recommended by the supervisor to proceed with the issues in the specialization project in the master's thesis. Therefore, this research ahead is a develop version of the authors specialization project that has been completed by the deeper knowledge and information. The first part includes of seven sections; The first section, titled "INTRODUCTION," consists of a brief background of lean and LPS, the knowledge gap that led to the three research questions of the paper, and the limitations that the author encountered during the research. Section 2, “RESEARCH METHODS ” describes the different ways of achieving required information and the strengths and weaknesses of these methods. Section 3, “LITERATURE REVIEW ”, elucidates the undertaken literature study. Section 4 represent case study “FINDINGS ” from mentioned different research methods based on the Miinevika bridge project. In the following, section 5 as “DISCUSSION ” examines the findings in accordance with the literature and the research questions are answered. Finally, section 6 and section 7 show the “CONCLUSION ” and “REFERENCES ”, respectively.

Part two introduces the paper *(LPS ON THE MINNEVIKA BRIDGE PROJECT)* by the author, Ola Lædre and Brendan Young (Site manager of the Minnevika bridge) at the Proc. 29th Annual Conference of the International Group for Lean Construction (IGLC29) in Lima, Peru that will be online due to the Covid-19. Finally, the last part, includes all the appendices that the author has made use of them.

The author was employed as a trainee at PNC in order to write the master’s thesis. The internship, thanks to Brendan Young, was a great opportunity for the author to get acquainted with the Minnevika project, project team, LPS, and the process on the Minnevika bridge project. During the six months contract, the author with cooperation of the facilitator (Eveline Schnell) was the responsible of LPS process on the Minnevika project.

The author's main duties were defined as; a) Preparation of weekly production evaluation and production planning meeting such as KPI report about the previous production week, documentation of the six weeks look-ahead, photo documentation of the action plan, risk matrix and variance analysis. b) PEP meeting presentation in the absence of facilitator. c) presenting the latest KPI to the participants at end of the PEP meeting. Therefore, the author became totally familiar with how LPS was implemented on the Minnevika bridge project and it led to the in-depth knowledge that helped him to benefit from it in order to write a more valid and accurate thesis.

ACKNOWLEDGEMENT

I would like to express my great appreciation to Professor Ola Lædre for the constructive guidance, continuous support, and his encouragement. He continually and convincingly conveyed a spirit of success in regard to research and the conference paper. Without his guidance and persistent help, this dissertation would not have been possible. My grateful thanks are also extended to Mr. Brendan Young for his advice, immense knowledge, and technical support that had a significant impact on the process of the paper. He gave me the opportunity to be part of the project team. His dynamism, vision, motivation, and skills have deeply inspired me. In addition, a great thank you to Eveline Schnell, LPS facilitator, for her cooperation, patience, friendship, and empathy. I would also like to thank PNC and the project team for the contribution and support.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLE

LIST OF ABBREVIATIONS

NTNU – Norwegian University of Science and Technology

PORR – The construction company- main organisation for PNC company

PNC – PORR Norge Construction

IGLC – International Group for Lean Construction

LC – Lean Construction

LPS – Last Planner® System

LPDS – Lean Project Delivery System

WWP – Weekly Work Plan

PEP – Production Evaluation and production Planning

RNC – Reasons for Non-Completion

MPP – Milestones and Phase scheduling

CPM – Critical Path Method

TPT – Takt Time Planning

MSS – Movable Scaffolding System

PART ONE – MASTER THESIS

INVESTIGATION OF LAST PLANNER® SYSTEM PRACTICE ON THE MINNEVIKA BRIDGE PROJECT

1 INTRODUCTION

1.1 BACKGROUND

A project is a set of activities performed to achieve a specific purpose or goal or in another definition based on Ansah et al. (2016) *"Projects have been considered as temporary based production systems which need to be designed, produced, and delivered within a specified time"*. It is generally accepted that the management of projects must attempt to achieve the goals of projects that were defined before the start of the project. In order to be able to complete projects on time, it is necessary to deploy the tools, skills, techniques and available resources. Productive and efficient project management is a great tool in meeting and exceeding the expectations of the customer. The optimal use of available resources; time, money, human, space, and endeavour for a successful completion of a project within budget and on time are some of the features of an effective project management.

However, according to Ansah et al. (2016), there have been observations and evidence that have indicated the models behind construction management and project management tools like; critical path method; work break down; and earned value management; have failed to complete project within budget on time and the quality desired for the project. These existing failures in the current management method become reasons and requirements for defining the new approach. This approach has been introduced to the construction industry by Koskela (1992), being called lean construction.

The construction industry has a direct impact on the economy, society, and the environment, so appropriate policies and decisions will be an effective step towards achieving sustainable development standards. Since this industry plays an important role in the growth and development of a nation; reducing waste along with more efficiency in less time would lead to significant cost savings for the industry as well as the society. A key part of lean construction is defined using tools. Several tools have been developed over the past decade to manage construction projects and among them, the Last Planner® system (LPS), which is known as the most famous tool that has been used for the management of the construction process and the continuous monitoring of planning efficiency(O. AlSehaimi et al. 2014).

According to Kalsaas et al. (2014), several of the largest construction companies in Norway show their interest in apply lean construction methods in their operations. PNC is one of these construction companies that has adopted LPS, on their Minnevika bridge project not as a requirement in the contract but in order to improve planning and control, reduce uncertainty, take advantage of efficient collaboration among contractors and subcontractors, and measure the weekly project progress. In this research, an attempt has been made to evaluate the use and practice of LPS on the Minnevika bridge project by PNC, one of the largest bridge construction companies in Norway. The strengths and weaknesses of LPS execution on the Minnevika project and possible solutions for the arising challenges besides the investigation of involved parties' experience are studied. The author has investigated both the technical and behavioural aspects of LPS on the Minnevika bridge, which can be considered as a complex project in Norway.

1.2 KNOWLEDGE GAP

Since the Last Planner® System has been introduced for several years, most of its technical parts have been discussed in different papers during these years. Based on comprehensive literature review, few studies have been conducted about the practice of Last Planner® System and its evaluation in an infrastructure project, while the most papers have been studied about practical issues of LPS. Infrastructure projects can address as complex projects that are executed in widely spread areas and have a direct interface with the environment and public. These projects have higher exposure to general public and involve the state as the client or one of the stakeholders. Therefore, infrastructure management plays a vital role over entire lifecycle of these well-known projects, from design to construction, legal, finance, and operations. In addition, the different involved parties 'experience were examined by defining the strengths and weaknesses of the process, while the few papers have been studied the key participants' value (last planners) towards the process. Finally, the main focus of the reviewed papers is to identify challenges in the implementation of LPS and LPS improvements. However, in this research, the attitudes changes towards the challenges have been measured and possible solutions to overcome the challenges have been addressed. To address the identified research gap, the following research questions were formulated.

1. How is the Last Planner® System practiced on the Minnevika bridge project?

2. How do the different involved parties' value/experience the process? What are the strengths and weaknesses of the LPS process on the Minnevika bridge project from participants' perspectives?
3. How have the involved parties' attitudes towards challenges changed during the implementation of LPS? What are the measures to overcome these challenges?

1.3 LIMITATIONS

Some cases were identified as limitations during the course of the research. First of all, the research is based on a single case study named the Minnevika bridge project. Therefore, conclusive aspects such as positive and negative points of the process, the detected challenges, measures to overcome the challenges, are related to this project and generalizing them to other projects need more study. Secondly, this study is limited to the execution phase of the project. Since LPS was not a requirement in the contract, then the client (Bane Nor) did not adopt it in designing phase. Therefore, the client did not have any plans to participate in the LPS process. Similarly, due to some issues, one of the contractors and subcontractors could not attend regularly in the PEP meeting. Furthermore, collecting data through those mentioned stakeholders, client and one of the contractors, was not feasible. In addition, the number of respondents of the survey was less than the author expected, due to some issues; i.e., Covid-19, the busy work program of the project team, and their rotational work schedule. Finally, increasing the Covid-19 prevalence and setting the laws and strict restriction from the government regarding the Corona, have a significant impact on the PEP meeting. The facilitator in some cases needed to divide the meeting into two different times to reduce the number of participants in the big room (PEP meeting place) which made the coordination between the parties more demanding.

2 RESEARCH METHOD

The research questions were addressed by performing a thorough literature review, document study, case study (Minnevika Bridge project), observations, interviews, and surveys. At the end, the results of these methods are used to answer the research questions.

Using a combination of a literature study and document study gave a theoretical insight into Last Planner® System. With the theoretical background in place, interviews were

performed to gain practical insight. The combination of theoretical and practical insight helped to analyse how Last Planner® System improved the planning on the Minnevika project. In addition, the presence of the author in the project for six months as an employee and in some cases as s LPS facilitator built a deep understanding to assess all the LPS process on the Minnevika bridge project.

2.1 LITERATURE REVIEW

A literature study was conducted mainly during the previous semester and constitutes an important part of this research. It is a great method for obtaining necessary qualitative information. The findings from literature review and comparing them with a case study not only formed the knowledge gap section but also could be a great function in defining the meaning and the concept of lean construction and the Last Planner® System. The purpose of the literature review is to obtain the required information about Lean construction and Last Planner® System, which will be categorized and mentioned later in this section. Lots of the papers have been reviewed and studied in order to reach an understanding of the Lean and the theory behind it, Lean thinking & production, the origin and the emergence of Lean construction, reasons for choosing Lean construction over traditional management, introducing Last Planner® System as one of the Lean construction tools, underlying Last Planner® System principles, and Last Planner® System benefits & challenges.

PNC, the company under study, decided to adopt Takt Time Planning for the superstructure process on the Minnevika bridge project. Therefore, the author has determined to mention TTP in the study not only as a complement to LPS but also as further work in future. So, the literature review regarding TTP definition, TTP stages, TTP and LPS, and the benefits and difficulties are studied in the research.

A combination of both journal articles and conference papers were used to get a broad perspective of the current views of the topics. The reliable resources in order to access relevant literature include Google scholar, Science direct, Oria, ASCE, ResearchGate, and International Group for Lean construction (IGLC) papers. Since LPS has been introduced from 1900s, lots of papers have been published until now. Therefore, finding the most appropriate and relevant literatures was quite challenging and time-consuming.

The literature review is divided into three main categories. The focus and purpose of the first part is to understand the concept of Lean and the theory behind it, Lean thinking & production, Lean construction, and Lean construction tools.

The papers of this section can be used as a starting point for answering part of the first research question and introductory part of the report. The important keywords used in this section were "Lean construction " with more than 1 million hits on Google scholar. "Lean construction foundations " was more specific with 290.000 related papers on Google scholar that helped the author to find the papers related to Lean definitions and its theory, "Howell & Ballard & Lean " was another search with about 6,430 results that were more accurate due to the names of the inventors and developers of Lean construction. "Kosekela & Lean construction " another prominent researcher in the Lean presented about 9000 hits on Google scholar. By considering the systematic literature review, research questions, and evaluation of the related papers, the author has attempted to narrow down the scope of the research as much as possible.

After the final review, twenty papers were selected for this section at the first stage, which was later reduced to the eleven papers according to the evaluation factors that presented in the project management advance course (TBA 4128). The following are two examples of the papers.

1. Koskela, Lauri & Ballard, Glenn & Howell, Gregory & Tommelein, Iris. (2002). The foundations of lean construction. Design and Construction: Building in Value.
2. Howell, Gregory & Ballard, Glenn. (1998). Implementing Lean Construction: Understanding and Action.

The second part is concentrating on the definition of Last Planner® System, Implementation, and principles of Last Planner® System, LPS stages, and the benefits and barriers of LPS. The papers related to this section could be efficient in responding to question No. 1 & 3 by introducing LPS as the most important Lean construction tools that has been adopted on the Minnevika bridge project. The most important search terms used were "Lean construction tools & Last Planner System" with about 33.500 results could give the general information about LPS definitions and principles. "Practice & LPS & Construction" was second keyword for finding the papers to follow up the practice of LPS on real project as a case study. "Implementing LPS & Infrastructure " another term that represented lack of LPS research in infrastructure projects. About 130.000 results and the papers with low number of citations are proof of this claim. Eighteen papers were selected for this part at the final stage, which was

diminished to the eleven papers by the method of evaluation that previously explained. The following are two examples of these papers.

1. AlSehaimi, A.O., Fazenda, P.T. and Koskela, L., 2014. Improving construction management practice with the Last Planner System: a case study. Engineering, Construction and Architectural Management.
2. Salem, O., Solomon, J., Genaidy, A. and Luegring, M., 2005. Site implementation and assessment of lean construction techniques. Lean construction journal, 2(2), pp.1-21.

The third part introduces the Takt Time Planning definition, Takt Time and the relation with LPS, objectives and aims of Takt Time Planning, Takt Time stages, and benefits and challenges of TTP. The main keywords include “Takt Time Planning ”, “TTP & LPS ”, and “TTP and infrastructure project ”. The following are two examples of TTP papers.

1. Frandson, A., Berghede, K. and Tommelein, I.D., 2014, June. Takt-time planning and the last planner. In Proc. 22nd Ann. Conf. of the Int’l Group for Lean Construction. Group for Lean Const (pp. 23-27).
2. Frandson, A. and Tommelein, I.D., 2014. Development of a takt-time plan: A case study. In Construction Research Congress 2014: Construction in a Global Network (pp. 1646-1655).

The related papers used in the research are listed in the reference section.

2.2 CASE STUDY

The Minnevika bridge construction project was selected as case since it is one of the first infrastructure projects in Norway to implement LPS. When opening for traffic in August 2023, it will be the longest railway bridge in Norway at 836 meters long. The Minnevika railway bridge is located in Minnesund, an hour’s drive from Oslo. The 836m long concrete bridge will be standing on 288 pcs Ø1016/20 mm steel tube friction piles in installation lengths up to 58 meters, and foundations consisting of 2 abutments and 18 piers, four of which will be installed offshore. The Minnevika project is part of Norwegian railway operator Bane Nor’s Eidsvoll double-track rail development that includes the construction of a 4.5 km double-track section, with a short tunnel, three shorth bridges and the 836-meter Minnevika railway bridge.

The Norwegian railway infrastructure manager, Bane Nor, has awarded the Hæhre – PNC AS joint venture a NOK 2.2 billion contract for the construction of a double-track section between

Eidsvoll North to Langset, on the InterCity main line, in eastern Norway. PNC, a tunnelling, and bridge construction company with the motto “innovative constructions connect people” is the main contractor responsible for the construction of the Minnevika bridge. PNC Norge consists of headquarters in Oslo and several projects in Norway. In addition, PNC (PORR Nordic Construction) is part of the main organization named PORR, which is a well-known Austrian construction company headquartered in Vienna. The Minnevika bridge project is the first project of PNC where the Last Planner® System has been adopted as a managing system in order to control the overall work process and workflow of the project. This pilot project in regards with the results from implementation of LPS, could be a departure point for PNC to adopt LPS as planning system in future projects.

2.3 OBSERVATION

The author carried out the non-participant and participant observations in autumn semester 2020 and spring semester 2021 respectively. In the previous semester, after consulting with Mr. Ola Lædre and getting acquainted with Last Planner® System and the Minnevika bridge project, Mr. Brendan Young, the site manager of the project, offered non-participant observations in the weekly Production Evaluation and Planning (PEP)-meetings over the Skype. The PEP meetings were held every Thursday from 8.00 am to 10.00 am in the big room and the project team gathered to discuss the work process, collaborate, look ahead planning, and other aspects of LPS on the Minnevika bridge project that are explained in the following.

It was a great opportunity for the author to learn about the implementation of the Last Planner® System on the Minnevika bridge project. The key points and important aspects that were considered during the non-participant observations include,1. Familiarity with the implementation process of LPS on the Minnevika project. 2. It was a great chance to look at the meetings from outside and concentrate more on behaviours and reactions of the participants.3. Familiarity with project team members and observing their interactions, attitudes, and level of cooperation during the meetings.4. Tracking the process of the project. However, the drawbacks can be listed as; 1. Low quality of sound and video in some cases due to internet connections problem 2. Impossibility of follow- up in some cases (look ahead planning & some boards on the wall) due to movements of the project members in the room and fixed host laptop camera. Therefore, not every step of the process and the project members could be observed.

During the spring semester of 2021, the author had the opportunity to be in the project as an employee. It was a great chance for him to have participant-observations through whole the LPS process on the Minnevika project. The author was an participant-observer who followed the guidelines of Saunders et al. (2009)in order to make a proper structure for observations , and took notes from the observations in 12 Weekly work meetings. As a participant- observer, the author took part the meeting and revealed his purpose as a researcher. The positive points of the participant-observation can be named as going through whole LPS process on the Minnevika project, preparing PEP documentation which helped to obtain deep knowledge, observing the behaviours and attitudes in more detail, facing the challenges, and finding the more proper solutions to improve the process as a responsible employee. However, it may also has led to a biased analysis despite attempts to avoid it.

2.4 DOCUMENT STUDY

The document study is written materials that contain information about the phenomena the researcher is interested in studying. The results of examining the document studies are used later in the Findings chapter. The related document studies of the Minnevika bridge project, PEP documents, consist of milestone & phase planning (MPP), look-ahead planning, action plan, risk matrix and KPI measurement such as PPC, variance analyses, order and safety. These documents were sent every Friday (the day after the PEP meeting) by Eveline Schnell, the LPS facilitator of the project, to the project team members' emails.

The main purpose of the document study is to track and get familiar with the process of LPS on the Minnevika bridge project. The other information that can be obtained from these documents, including defining the upcoming tasks, identifying the different risks on the project, analysing the reasons for unfinished tasks, improving the learning process, and estimating the percentage of project progress. One of the basic advantages of the document study in the previous semester was that it allowed familiarity and reviewed the process of LPS on the Minnevika bridge project to the author that did not have easy physical access due to outbreak of Covid-19, time and distance limitations. However, at the beginning, reviewing, and examining the document studies was very confusing and ambiguous, but this issue was gradually solved by attending the weekly PEP meetings over the Skype and obtaining more information about the LPS process on the Minnevika bridge project.

During the spring semester, the author had access to all documentation and in some cases, he was the responsible person for preparing the LPS documents which made the tracking of the LPS process more achievable and straightforward.

2.5 INTERVIEWS

An interview is typically a qualitative research method that involves asking open-ended questions to collect data about the subject and converse with respondents. It is a great technique for obtaining in-depth information about the behaviour, attributes, opinions, attitudes, and experiences of interviewees who are experts in their operation fields. Thanks to Professor Ola Lædre and Mr. Brendan Young who facilitated the process and provided the condition for face-to-face interviews especially in fall semester. Undoubtedly, attending the project and conducting face-to-face interviews had a great impact on obtaining the better results and more accurate answers. In total, the three interviews were conducted which were adopted in answering the RQ 2. The names and the positions of interviewees are listed in the table below.

Table 2.1 The interviews 1

Interview no.	Name of Interviewee	Position on the project
1	Jaroslaw Pomorski	Planner/ Planlegger / Technical Support
2	Brendan Young	Site Manager/ Anleggsleder
3	Maciej Kupper	Site Manager/ Anleggsleder

The interview questions were arranged as semi-structured and open-ended interviews that were a great help for the author to obtain the most accurate and detailed qualitative information. This semi-structured interview offers a considerable amount of flexibility to the author to probe the respondents along with maintaining basic interview structure. In addition, this structure could make a great opportunity for the author to express the interview questions in the format he preferred to get extra information. However, finding a proper time for the interview due to the outbreak of Covid-19, distance limitation, and tightly schedule of the interviewees, who are the key members of the project team, was quite challenging in the previous semester.

The interview questions were structured after the three research questions and consist of three sub-questions for each part of LPS implementation on the Minnevika bridge project in order to obtain information regarding the process of LPS and discover the positive and negative points

of this process. The lists of the questions and the results of the interviews are included in the appendices and findings chapters, respectively.

2.6 SURVEY

A survey is one of the research methods used in this study for collecting data from predefined group of respondents to gain information and insights into various aspects of research questions no. 2 & 3. Two more or less similar surveys were distributed during the semesters. The first survey was answered by 8 participants in February 2020 and the findings are reported by Kassab et al. (2020).The second survey was responded by 9 participants, in the forms of hard copy during the PEP meeting, in November 2020. The second survey included 45 questions, both close-ended and open-ended, in order to obtain accurate qualitative and quantitative information. It consisted of three parts (general, implementation and challenges) and the first and third sections (challenges part) have been built upon Kassab et al. (2020) questionnaire, as a way to measure the developments and attitudes changes towards the LPS during the project.

Collecting data by two surveys with one year interval allowed a longitudinal study. The Likert scale method, that can be utilised to measure attitudes and behaviours (Albaum 1997), was chosen for close-ended questions in order to achieve more precise quantitative data, present the results as graphs, analyse the answers, and compare the results of the two surveys to measure development. The scale range used was 1= very low, 2 = low, 3 = undecided, 4 = high and 5 = very high. The total score was calculated for each question that depended on Likert scale method and was divided by the number of respondents from the survey. The final result was the average scale.

The advantages of the survey included improved accuracy, because of the higher number of respondents compare to interviews, it is quick and easy to analyse, makes for an easier comparison to attain more accurate conclusion, and potentially more reliable answers due the survey's anonymity. However, achieving more precise results require more participants and convincing the last planners, the people with tight schedule, to take their time which is not very simple. All the details, questions and responds related to the survey were described in the appendices and finding chapters.

3 LITERATURE REVIEW

3.1 LEAN CONSTRUCTION

In this section, the information obtained from the literatures in regard to Lean, lean thinking & production, lean construction and its background is studied.

3.1.1 LEAN & LEAN PRODUCTION

"Lean is a way to design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value" (Koskela et al. 2002). In another definition Hamzeh (2011) said "*Lean is a business philosophy and a system for organizing and managing corporate processes including product development, design, production, operations, supply chain, and customer relationships to increase value and minimize waste. Lean is a perpetual quest for perfection pertinent to organizational purpose, business processes, and developing people*". Therefore, it is clear that increasing value and minimizing waste were the main focuses of Lean since its inception. These outstanding features of Lean led to its introduction to the industry by Mr Taiichi Ohno for the first time in the Toyota. Mr Taiichi Ohno was a Japanese industrial engineer who inspired the Lean Manufacturing in the U.S. Engineer Ohno shifted attention to the entire production system from the narrow focus of craft production on worker productivity and mass production on machine (Howell 1999).Toyota in order to cope with capital constraints and low production volumes after world war II introduced Toyota production system (TPS) that can be seen as synonym to Lean production . TPS is described as a production which "**uses less of everything compared with mass production, half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a product in half the time**" (Holweg 2007). As Howell (1999) explained, the main concentrate of the lean production is to optimize performance of the production system against a standard of perfection to meet unique customer needs. It is a way to design and make things differentiated from mass and craft forms of production by objectives and techniques applied in design and along supply chains. According to (Koskela 2001), TPS as a better management theory, involves the following four functions; (1) Management as-organizing, (2) Management as-planning, (3) Management as-adhering and (4) Management as-learning. In addition, Schöttle and Nesensohn (2019) stated that "*TPS is based on systems thinking that handles both the design and management of the work to have*

products with no defects and the best possible flow. This recognition is closely related to the application of collaborative production planning systems within the construction industry like the major lean construction (LC) method LPS".

3.1.2 LEAN THINKING

The origin of lean thinking takes its roots from the Japanese auto industry as lean manufacturing (TPS) that was described in the section 3.1.1 and is still used widely today to guide modern Lean manufacturing practices. Lean thinking forces attention on how value is generated rather than how anyone activity is managed (Howell and Ballard 1998). In another definition, lean thinking is a concept to describe the process of making value or business in a lean way. Howell and Ballard (1998) stated that "*lean thinking considers the project as a production system. Where current project management views a project as the combination of activities, lean thinking views the entire project in production system terms, that is, as if the project were one large operation*". James P. Womack and Daniel T. Jones , founders of the Lean Enterprise Institute (LEI), laid out the five key principles of lean thinking as follows (Womack and Jones 1997).

1. Define value: It is important to define customers' needs and understand what value means for them. Value is defined by Womack and Jones (1997) as "*capability provided to customer at the right time at an appropriate price, as defined in each case by the customer*".

2. Value stream: Identifying all the process and steps that transforms raw materials to working products. Womack and Jones (1997) described value stream as set of all "*specific activities required to design, order, and provide a specific product, from concept to launch, order to delivery, and raw materials into the hands of the customer*".

3. Flow: According to Womack and Jones (1997) It defines as "*progressive achievement of tasks along the value stream so that a product proceeds from design to launch, order to delivery and raw materials into the hands of the customer with no stoppages, scrap or backflows*" or establishing a smooth flow that work is not impeded.

4. Pull: It creates desirable setting for customers to pull products when they need to. Womack and Jones (1997) said "*the system of cascading production and delivery instructions from downstream to upstream in which nothing is produced by the upstream supplier until the downstream customer signals a need"*.

5.Perfection: The pursuit for the perfect product is never-ending process. Therefore, it is needed a to have a system to encourage everyone to improve the process. This means that Lean Thinking must be embedded in the company's culture. The goals of lean thinking according to Howell and Ballard (1998) is to redefine performance against three dimensions of perfection: (1) a uniquely custom product, (2) delivered instantly, with (3) nothing in stores. This leads to increase value and decrease waste.

3.1.3 LEAN PROJECT DELIVERY SYSTEM (LPDS)

The complete understanding of different phases of the project namely, predesign, design, procurement and installation are needed to perceive the entire project (Ballard and Howell 2003).The figure below illustrates a series of project phases in overlapping triangles.

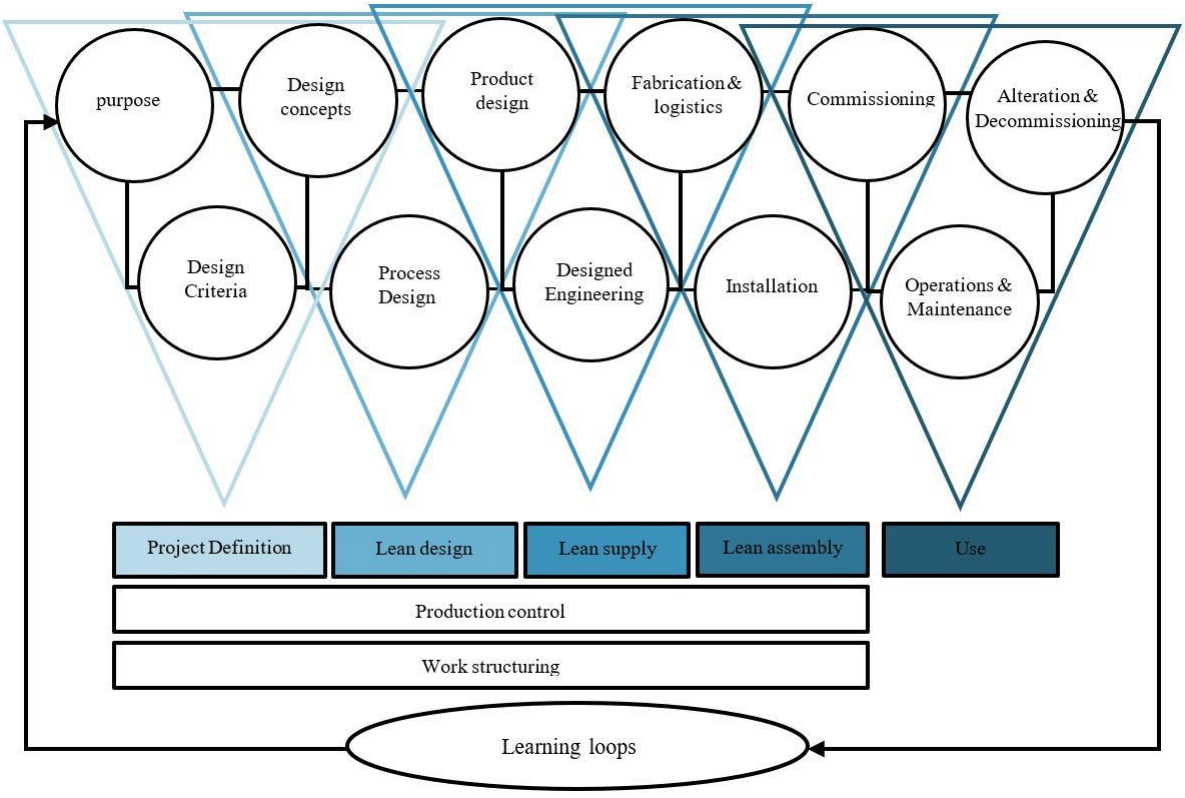


Figure 3.1. Triads of the Lean Project Deliver System (LPDS)(Ballard and Howell 2003)

Project definition: Project definition includes customer and stakeholder purposes and values, design concepts, and design criteria. Since these elements can have effects on the other, having a good conversation between different stakeholder is necessary. This initial phase consists of the representatives of every stage in the life cycle of the facility (Ballard and Howell 2003).

Lean design: Alignment of principles, concepts and requirements are the links between Project Definition and Lean Design. Lean design is carried out through conversations, this time through the development and adjustment of product and process design at the functional system level. Methods to release values compatible with the constraints of customers and stakeholders, such as: When you have time and money. The difference between lean design and traditional practice is that the system will systematically postpone decision-making to the last critical moment, so as to have more time to develop and research alternatives. When the design decision of one expert conflicts with the decision of another expert, the traditional practice of selecting options and completing the design task as soon as possible can lead to rework and interruption. Within the alternatives under consideration. A decision needs to be made during the implementation of the alternative. Therefore, it is important to redesign the supply network to reduce delivery time in economic development (Ballard and Howell 2003).

Lean supply: As Ballard and Howell (2003) stated "*Lean Supply consists of detailed engineering, fabrication, and delivery, which require as prerequisite product and process design so that the system knows what to detail and fabricate, and when to deliver those components*". In addition, lean supply includes the features such as reducing lead time which determine the pace and timing of project delivery.

Lean assembly: Assembly begins with materials delivery and required information for the installation. It should be noted that assembly process fulfilled when the client has beneficial use of the facility (Ballard and Howell 2003).

3.1.4 TRADITIONAL MANAGEMENT

Traditional management by scheduling and controlling activities, endeavours to utilize output measures. From the first moments, construction projects are managed by breaking them into pieces or activities, estimating the time and money to complete each, applying the critical-path method (CPM) to identify a logical order, and then either contracting externally or assigning internally to establish responsibility (Koskela et al. 2002). As Salem et al. (2006) stated the main feature of the traditional construction management is in "*Planning distribute and combine the available resources during a specific time for each of the project tasks, optimizing cost and keeping a right level of quality*". Despite these aspects of construction management, The US Bureau of Labour Statistics reported that the construction industry is facing a severe decrease in labour productivity. But why does this approach, which sounds reasonable, so often fail in

practice? Current research shows that complexity, variability, and uncertainty are the major causes of this decrease in the productivity (Porwal et al. 2010).

Construction projects nowadays are so complex, uncertain, and quick and there is always pressure for shorter duration that adds to the burden (Shenhar and Laufer 1995). Complexity and uncertainty arise from multiple contending and changing demands of clients, the marketplace and technology. It is a dynamic environment that activities are not often linked together in simple sequential chains. Alternatively, work within and between tasks is connected to others assignment by means of shared resources or depends on work underway in others (Koskela et al. 2002). This traditional method of management ignores the workflow and misses the creation and delivery of the value. As Ballard et al. (2002) presented, "*In traditional project management, it is assumed that variability is independent of management action and consequently that the trade-off between time and cost is fixed, the only discretion for decision making is in finding the exact point where the trade-off can best be made*". Therefore, uncertainty and variability are the main struggles that project managers who rely on these kinds of schedules might encounter, but the managers rarely see the problem arising from their reliance on the project level planning and control activities (Koskela et al. 2002).

The failures of traditional project management help to define the requirements for a new approach. There is a mismatch between the conceptual models of traditional management and the reality. Therefore, the need for a new management method is quite clear in order to optimize performance, increase productivity, create value, and flow at projects.

3.1.5 LEAN IN CONSTRUCTION

As explained in the section 3.1.3, the traditional project management in construction industry suffers from some deficiencies and there is lack of a new approach to solve these issues. In addition, by introducing lean to the industry as a successful and effective method in achieving the objectives, minimizing the waste, and creating the value, now is the time to introduce this way of management to other industries, including construction. But how can this method that is tailored to the structure of the manufacturing industry, be adapted to the construction industry?

In the long term, both construction and manufacturing strive to add value to their products via high returns on investment; however, each employ different means to achieve this objective (Salem et al. 2006).

On the one hand, there are significant differences between manufacturing and construction industry. Physical features of end products are one of these differences. While in manufacturing finished goods can be moved as a whole to end customers, deals cannot be transported in construction. In manufacturing, the lifecycle of a product on the market is long enough to develop related research and training capabilities, whereas a product's lifecycle is the relatively short project duration with more difficulty to justify research and training in construction (Salem et al. 2006).

The way of realising work is another differentiation. Work is released, moves down the line, in manufacturing based on the design of the factory. However, in construction work is released by an administrative act, planning (Howell 1999). In this sense, construction is directive driven in contrast to manufacturing which is routing driven. In addition, the construction industry has features that distinguish it from manufacturing: on-site production, one-of-a-kind projects, and complexity that can be hardly managed compared to manufacturing industry(Howell and Ballard 1998).

On the other hand, Lean manufacturing and lean construction techniques share many common elements despite the obvious differences in their assembly environments and processes (Salem et al. 2006). As Howell (1999) explained "*Waste in construction and manufacturing arises from the same activity-cantered thinking*".

After introducing the Japanese techniques that were part of new production system (known as Lean production), the scope of the technique was not limited to the manufacturing. Having the characteristics of both "production" and "service" systems, the construction industry has also taken some steps toward applying the lean production concept (Salem et al. 2006). According to Howell and Ballard (1998) lean thinking views the entire project in production system. Howell & Ballard as pioneers of lean construction after exploring the underlying nature and implications of lean thinking, described it: "*Lean thinking is a new way to manage construction. Many people object on first exposure because lean thinking appears to be the application of a manufacturing technique to construction. One response to the arguments that "construction is different" is to make construction more like manufacturing through greater standardization. It can even be argued that manufacturing is a special case of construction because it alone is characterized by multiple copies of the same product. Both construction and manufacturing require prototyping, that is the design of both product and delivery process*."

In addition, it is noteworthy to mention that lean is as much a philosophy and culture as a set of principles or methodologies that could be addressed in any industry. Therefore, the principles of lean are equally applicable without considering the differentiation between construction and manufacturing industry (Ansah et al. 2016).

Despite these explanations, the extension of manufacturing techniques to construction industry is still an open question. Although, it is important to determine set of tools in order to achieve higher performance outcomes in construction industry.

3.1.6 LEAN CONSTRUCTION TOOLS

As explained above, Lean construction was born out of the success of the lean philosophy that developed in the manufacturing industry (Diekmann et al. 2004). This management approach has been adapted to the construction industry by Koskela in 1990s and since that time, lean construction has emerged as a new concept, both in construction management and practical sphere of construction (Ansah et al. 2016).

According to Koskela et al. (2002) Lean construction can be described as "*an approach to design the system of production to reduce waste of time, materials, and effort with a specific end goal to generate the most conceivable amount of value*". Lean construction is a project management methodology that is based on the principles of lean thinking and lean production in industry. Therefore, Lean Construction shares same objectives as lean production; reduction of cycle time, continuous improvements, pull production control, waste elimination, reduction of variability, continuous flow (Ansah et al. 2016). The application of production control throughout the life of the product from design to delivery, aimed at maximizing performance for the customer at the project level, simultaneous product and process design, and a clear set of objectives for the delivery process are the key features of managing construction under lean (Howell 1999).

There is no doubt that lean construction is the way forward for construction industries around the world. Several lean production techniques and tools have been introduced over the past decade to manage construction projects. These tools can be described as procedural, conceptual, and embedded in programming. The tools include but are not limited to: Last Planner® System, Visual Management, 5S Process, Value Stream Mapping, First Run Studies, Daily Huddle Meetings, Plan-Do-Check-Act, Fail Safe for Quality and Safety, A3 Reports, Target Value Design and Concurrent Engineering. Whereas some of these tools are simple to

adopt, complexities revolve around the others, i.e., Last Planner® System (LPS)(Ansah et al. 2016). Ansah et al. (2016) also indicated that "*Danish contractors had increased productivity by 20%, minimized project duration by 10%, expanded efficiency by 20%, and enhanced profitability 20% - 40% on projects where lean principles are adopted*".

3.2 LAST PLANNER SYSTEM

3.2.1 INTRODUCTION TO LAST PLANNER® SYSTEM

The Last Planner® System was introduced by Ballard to members of first meeting of the International Group for Lean Construction named IGLC-1. Ballard mentioned the Last Planner® System term for the first time in the paper that was published as Improving EPC Performance. The principles of the LPS were developed at IGLC- 2 in 1994, and further elaborated at IGLC-5 in 1997 and made ready to introduce the construction (Rotimi and Zaeri 2016). The Last Planner® system has emerged as one of the most important lean construction tools since its inception. It is one of the first steps taken by the construction organization that embarks their lean journey in order to tackle the challenges of production management on construction sites (Dave et al. 2015).This cascade planning technique has taken its roots from lean thinking with the principles of supporting management through the reduction of performance variabilities, continuous monitoring the production, enhanced reliability, and improvement of project performance in order to allow better control and planning (Rotimi and Zaeri 2016).

According to Hamzeh (2011) and Ballard et al. (2007), LPS has five key principles which are listed below,

1. Planning in greater detail as time gets closer to executing the work,
2. Developing the work plan with those who are going to perform the work,
3. Identifying and removing work constraints ahead of time as a team to make work ready and increase reliability of work plans,
4. Making reliable promises and driving work execution based on coordination and active negotiation with trade partners and project participants,
5. Learning from planning failures by finding the root causes and taking preventive actions.

The LPS has been implemented in a large number of projects in several countries since its inception. Many reports and research papers have confirmed these successes in the construction industry and LPS became gradually a powerful tool for the management and planning of construction. In the following, some benefits of LPS are well documented by (Dave et al. 2015).

- Tackling variability, ensuring task availability, and compressing duration
- Smooth production flow
- Improving flow, making waste visible and continuous improvement
- Building collaboration and trust amongst project participants
- Supply chain integration

One of the primary benefits of LPS is the collaborative planning process that involves last planners for planning in greater detail in order to success of project implementation. But who are the last planner?

3.2.2 LAST PLANNER

Construction consists of different tasks that require planning by different people, in different work posts of the organization. Eventually, as Pellicer et al. (2015) stated "*somebody decides what specific job will be done (assignment) and by whom the following day, these persons or organizations are: site supervisors, foremen, subcontractor, supplier, etc*". In the same definition, O. AlSehaimi et al. (2014) described last planner as "*the person or group accountable for production unit control, that is, the completion of individual assignments at the operational level*".

3.2.3 LPS VS TRADITIONAL PROJECT MANAGEMENT

Traditional project management was described in the section 3.1.4. The main difference is that planning, and control are separated in traditional construction project management, while these can be seen as an integrated process in the LPS of construction management. This feature makes the plan more predictable and reliable that leads to reduction in lead time in the construction phase (Daniel et al. 2017) . The following table shows the principles differences between LPS and traditional project management.

Identifying the more fundamental differences between lean production and traditional management is beyond the scope of this research.

Table 3.1.Comparison of Principles of LPS and Traditional Project Management (Kalsaas et al. 2014).

LPS	Traditional
Non-deductive: Decentralised decisions to remove constraints and realize the plan. Continuous control.	Deductive: Centralised master plan without systematic focus on removing constraints. Control afterwards
Horizontal involvement	Limited involvement. Expert planning
Vertical involvement	Limited involvement. Expert planning
Continuous improvement through continuous learning, measuring of PPC, casual analysis and sharing of experience	Monthly reports, e.g., on earned value. Lesson learned after completion of projects
Pull based project control through reversed scheduling and removal of constraints towards construction	Centralized critical path method in planning and pushing the work towards downstream activities
Simple and manual planning technique	Computer based expert planning

3.2.4 LPS STAGES

The Last Planner® System is a holistic system that means each of its parts is necessary to support lean planning and execution. According to Daniel et al. (2017), the LPS integrated components include, master planning, phase planning, make-ready process, weekly work planning, and learning.

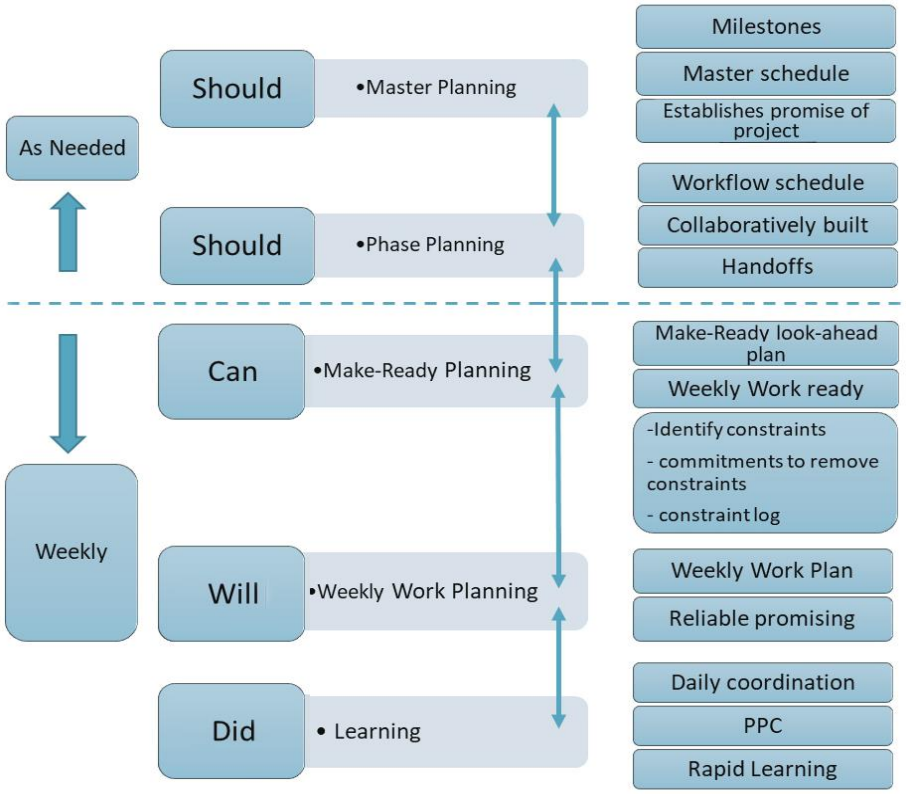


Figure 3.2. Summary of Last Planner® System of production control (Ballard and Tommelein 2016).

3.2.4.1 MASTER PLAN

As an output of the "*pull session*" meeting that last planners participate; a master plan is provided with the commitment of all parties. The master plan or milestone planning captures the entire task to be implemented throughout the project and at the same time shows the required time for each task to be completed. It identifies the project milestones and initiates the means for achieving them (Daniel et al. 2017).

Pull session is the key stage of this phase because a committed group of decision-makers and those who work behind the plan, define milestones and perform planning as a team. They have face to face discussions of every important task to make a backward plan and creating a schedule buffer that is allocated to critical and risky tasks in the plan which forcing the participants to think out of the box (Pellicer et al. 2015). The initial output is a logic network showing the temporal dependence of tasks to be performed in the phase, process, or operation being planned. A schedule can be produced by estimating task durations (Ballard and Tommelein 2016).

The pull session must be driven by an external facilitator, beside the involving the site manager and the site superintendents in the session, but they do not lead it. The participants must have to be invited formally. The expectations of meeting are: (1) identify tasks, including time and resources needed; and (2) identify constraints to perform those tasks .There are some physical provisions requirements in order to have a successful pull session, 1) A wide room with a proper arrangement of the tables to accommodate the participants; (2) A big blackboard to display the different tasks; (3) Sheets of colour paper (post-it or similar) to stick it to the blackboard; (4) Colour markers; and (5) A camera (Pellicer et al. 2015).

In addition, the pull session generally follows these steps (Pellicer et al. 2015):

1. The facilitator writes down the end date of the project (as a milestone) in the right side of the Board.
2. The facilitator asks what is the last task that it should be carried out in order to reach that milestone (end date).
3. The last planner responsible for this task writes down the needed information in the different colour post-it which contains the information about organization, task, time scheduled, human resources needed, and constraints. Then, facilitator sticks it on the

board on the left side of the milestone. Different colour can be used to modify every contribution.

4. This process should be done for each task; Overlapping has to be considered too.
5. The construction site manager and the superintendent must monitor the logic of the construction and ask questions to the other participants, if needed, to check time and resources.
6. When there are no more tasks that precede the last one stick on the board, the schedule is over.
7. The facilitator, with the help of the site manager and the site supervisor, reviews all the tasks to ensure that everyone agrees and are committed to this schedule.
8. The site manager introduces the schedule and distributes it to every stakeholder involved.

3.2.4.2 PHASE PLANNING

It is a process used in developing a reliable construction programme from the master plan by direct involvement of the subcontractors, contractors, suppliers, designers, and other stakeholders on the project including the client. The project's workflow is determined and the participants together to form a more concrete schedule for the project. That is the reason, why this process is also called Collaborative programming (Daniel et al. 2017).

Collaborative planning, as Howell and Ballard (1998) explained "*Collaborative planning refers to the act of bringing all subcontractors to the same meeting and planning in a true collaborative fashion at each stage, i.e., phase, lookahead and weekly aspects*". This is one of the main focus of LPS that involves the last planners and who are responsible for planning in greater details in order to have effective program for implementation. Another aspect is that collaborative planning is another name of LPS that use in Norway. LPS has been implemented under different names and in Norway, several of the largest construction companies in Norway show their interest in LPS or what they call "Collaborative Planning (Veidekke and Kruse Smith), Trimmed Construction (Skanska) and Collaborative Project Execution (Nymo)" in their operations(Kalsaas et al. 2014).

3.2.4.3 LOOK-AHEAD PLANNING

The look-ahead planning is a medium-term planning for project activities. This plan identifies the constraints and introduces a path to avoid or eliminate bottlenecks. Look-ahead plan

forecasts six weeks in advance approximately and looks forward to increasing the construction flow. Within the master plan, the look-ahead plan is produced by the construction site manager assisted by the last planners if needed (Pellicer et al. 2015). One of the differences between LPS and traditional management is look- ahead planning where Daniel et al. (2017) mentioned that "*in the traditional way of managing projects, the look-ahead plan (master programme) only provides advance notice of the start date of an activity and does not consider the complex network of flows, their sequence, matching workflow with capacity, or maintaining a backlog of workable activities*".

According to Ballard et al.(2002), the functions of lookahead planning including;

- Shape workflow sequence and rate
- Match workflow and capacity
- Maintain a backlog of ready work (workable backlog is explained in following)
- Develop detailed plans for how work is to be done.

The lookahead windows may be shorter or longer than six weeks, depending on the rapidity of the project and the lead times for information, materials and services (Ballard et al. 2002). On the one hand, the extending lookahead window can offer the possibility of better control over workflow. On the other hand, the ability of controlling workflow on site can be affected by pulling too far in advance. In consequence, period of the lookahead window is a matter of local conditions and judgment (Ballard et al. 2002).

3.2.4.4 MAKE READY PROCESS.

The works that break down into detailed tasks need to be considered as make-ready process in order to match the available resources for execution based on realities on construction site. Therefore, the make-ready process is used to eradicate the constraints or blockers to planned activities identified in the look-ahead planning before they are passed into production on site (Daniel et al. 2017).

Screening for constraints can be performed in eight flows which include resources, information, equipment, material, prerequisites, safe workplace, external conditions (Koskela 2000) and common understanding (Pasquire and Court 2013).

3.2.4.5 WEEKLY WORK PLAN

The weekly work plan is scheduled every seven days named as the weekly meeting with the involvement of participants such as last planners. The plan which, is produced during the meeting, established the detailed assignments that should be performed during the following week through promises of the last planners. WWP is done to review the task planned in the previous week in order to plan for the week ahead collaboratively with the team. At this point, only tasks that meet the four criteria of production are entered onto the WWP (Daniel et al. 2017). These criteria including (Ballard and Tommelein 2016);

Well-defined: One of these requirements is tasks should be defined so that performer can understand what should be done, where, when and by whom. In addition, it can determine the necessary resources, what is needed by way of materials, information, tools, and equipment to perform the task.

Sequence: This feature can be described as the order in time of a set of tasks. Performing the tasks at the current moment without incurring a penalty later, is a necessary factor for inclusion on weekly work plan.

Soundness: For involving a task into weekly work plan, it should be removed from all possible constraints before starting the execution. The purpose is to perform the task according to schedule.

Size: According to this feature, the task should be sized to the capability of those who are responsible for performing that. This improves workflow reliability. More works is assigned to performers who increase their capabilities and capacities.

The tasks which do not included these criteria must be made ready in the first point before advancing them to the lookahead plan. In addition, tasks meeting the four criteria but not entered onto the WWP are held in a "*workable backlog*" or *Plan B*. Daniel et al. (2017) stated that "*The workable backlog enables the workforce to drop onto these tasks if for any reason they are unable to complete work on the WWP*". As Ballard and Tommelein (2016) recommend, "*workable backlog refers to tasks that have been released for commitment, and "Plan B" for tasks included on commitment plans to serve as fallback or follow-on work*".

The first objective in Last Planner® System is to identify what **should** be done. The master plan identifies the important milestones of the project and phase planning by utilizing the Reverse Phase Scheduling (RPS), pulls plan to the milestones in order to validate the schedule. This reverse planning can help to identify the allocation of float in schedule and define the work that releases work to others. The second objective is to turn the work that should be done into work that **can** be done. This making ready process will be done through look-ahead planning of six weeks in advance. If an upcoming task has any of the constraints (eight constraints mentioned in 3.2.4.4) then the constraints need to be solved in order to have efficient schedule. The final objective is to fulfil the task that **will** be done via the weekly meeting planning. During the WWP the last planners, contractors and subcontractors who will be in the field directly managing or performing the work, commit to finish the assignments (Frandson et al. 2014).

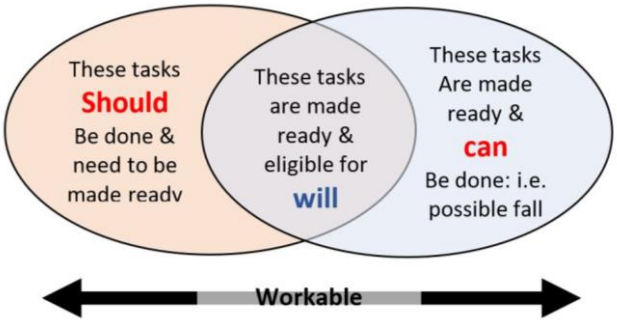


Figure 3.3 Commitments plans (Ballard and Tommelein 2016)

Tasks that are not critical and not included in SHOULD side (Fig 3.2 above), may be placed into workable backlog under two conditions.1) If they can be implemented now without incurring a penalty later.2) If there is more capacity. There are two plans in regards of commitments, plan A and plan B. The tasks of plan A are those which are truly speaking commitments, which should be done; other tasks are depending on them to be completed. Plan B consists of fallback/follow-on tasks in case Plan A tasks cannot be completed, or as follow-on work in case Plan A tasks are completed earlier than expected (Ballard and Tommelein 2016) .

Daily huddle is another aspect that should be considered when it comes to weekly work plan. Daily huddle meeting is used to monitor how activities planned for the week are performing each day. The main focus of this meeting that held by participation of groups of interdependent players, is to guide the planned production from deviation and to re-plan when is predicted. In

other words, they share what commitments they have completed or need help with them (Daniel et al. 2017).

3.2.4.6 MEASUREMENT AND LEARNING

The key metrics measured of learning are, percentage plan complete (PPC), the reason for non-completion (RNC) and a developing reliability index using metrics from tasks made ready (TMR) and tasks anticipated (TA) In practice, PPC measurement, and recording of RNC not only encourage learning but also could be a positive tool in increasing productivity (Daniel et al. 2017). These three metrics (PPC, TMR, TA) involve comparison of task sets in different weeks of the lookahead window. A six week lookahead window is assumed in the figure below (Ballard and Tommelein 2016),

Figure 3.4. Six weeks ahead (Ballard and Tommelein 2016).

3.2.4.6.1 PERCENT PLAN COMPLETE (PPC)

As O. AlSehaimi et al. (2014) described PPC is "*a measure of the proportion of promises made that are delivered on time. It is calculated as the number of activities that are completed as planned divided by the total number of planned activities, presented as a percentage*". PPC measures workflow reliability, i.e., PPC compares the tasks that were completed (Week-1 in figure above) to the tasks in the weekly work plan for that week (Week0)11. Increasing PPC means increasing performance, both in the production unit that executes the Weekly Work Plan and the production units downstream for better planning. Moreover, identifying upcoming resource needs let the managers to pull those resources from upstream supply to where they needed to be available (Ballard et al. 2002).

3.2.4.6.2 TASKS MADE READY (TMR)

This metric is the same as PPC but performed earlier in the look ahead process, comparing the weekly work plan (Week0) against an earlier week in the lookahead window (Week n) in the figure 3.3. TMR measures the ability of the project team to determine and remove constraints ahead of the schedule that planned for the specific tasks (Ballard and Tommelein 2016).

3.2.4.6.3 TASKS ANTICIPATED (TA)

TA is another metrics that measures the percentage of tasks for a specific week. Those tasks were anticipated in an earlier plan for that target week. Providing a relative measure of how the project team can cause what is going to happen on the project in the weeks ahead, is the main objective of this indicator. The right work cannot be made ready without this critical planning (Ballard and Tommelein 2016).

3.2.4.6.4 REASON FOR NON-COMPLETION (RNC)

Each week, last week's weekly work plan is reviewed to determine what tasks were completed. Those not completed when planned are assigned to a category which describes the reasons for non-completion. If a task has not been performed, then a reason is provided. These categories are generally established prior to the start of the project and show the possible reasons that might be expected during execution of the project. However, as the project evolves the new reasons might be added to this category based on the different project situations (Ballard and Tommelein 2016). Reasons are examined to find main causes and action taken to avoid repetition. These failures can be, lack of materials, equipment, technical issues etc. Whatever the cause, continued tracking of reasons of failure will measure the efficient of remedial actions. If action could not help to eradicate the root cause of the failures, then different action is required to be taken (Ballard et al. 2002). In the figure below, as an example, RNC are compared in two different projects.

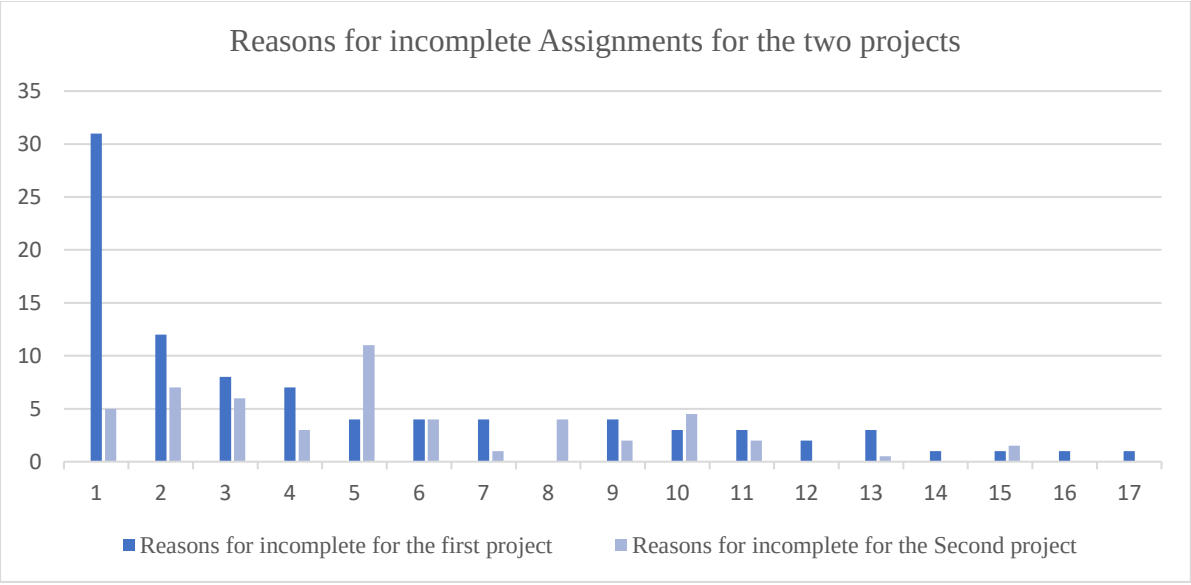


Figure 3.5 Reasons for Incomplete assignments for the Two Projects (O. AlSehaimi et al. 2014).

1)Prerequisite work.2) Material. 3) Approval. 4) Changed priority. 5) Labour. 6) Equipment 7) Design. 8)Late request for inspection. 9) Overestimate achievement. 10) Incomplete information. 11) Defects require rework 12) Scheduling/ coordination. 13) Interface with other packages. 14) Space. 15) Weather. 16) Other (technical specification). 17) Other (rock under floor).

3.2.5 LPS CHALLENGES & BENEFITS

Many construction companies try to use lean tools at level of operations through use of WWP and other tools of LPS to take advantages of this new management method. However, it should be noted that besides the numerous benefits of this tool, many organizations face significant implementation obstacles (Ballard et al. 2007; Viana et al. 2010). As Hamzeh (2011) stated "*researchers in the field of changing management have reported many failures and partially achieving of lean production by organizations that have attempted to implement LPS. However, most companies either failed or only partially achieved lean production in its true form*". The softer aspects of execution, such as organisational processes and people are the majority of these barriers that is explained in the following (Dave et al. 2015). Earlier in this report, the benefits and advantages of adopting LPS compared to traditional project management were repeatedly mentioned.

According to Rotimi and Zaeri (2016), there are various benefits attributable to LPS implementation on construction projects, including,1) Identifying the main reasons for project variances. 2) Achieving continuous improvement through PPC measurement.3) Successful completion of projects through weekly planning by project team and 4) Decreasing problems due to the project structure. Further benefits can be mentioned as: avoidance of repetitive project mistakes, fulfilment of promises made by team members to each other, and identification of the reason of broken promises.

In spite of the benefits outlined above, there are some challenges in implementation of LPS that has adopted on construction projects. These challenges can act as barriers to full implementation of LPS in organizations. In some cases, the result of lack of leadership during the process can be considered as implementation challenge. In other cases, lack of commitment by upper management is the main issue. There are two sets of factors, local and general that impact the execution of new methods such as LPS. Local factors are potential challenges related to project circumstances and the team including, the relatively new experience in lean methods, traditional project management methods, newness of LPS to team members, lack of

leadership and team chemistry. The impacts of general factors can be listed as; human resource, organizational inertia, resistance to change, technological barriers (Hamzeh 2011). In addition, climate of organization can be another factor. Hamzeh (2011) defined Climate as "*an organizational characteristic that employees live through and experience while working for an organization. The climate shapes their behaviour, performance, and the way they perceive the organization*". When it comes to LPS implementation, the specific cultural barriers such as attitude to work could show up (Johansen and Porter 2003).However, by considering cultural analysis tools and measurements, it is possible to find out the factors of success or failure of certain practices in cultural conditions (Ravi et al. 2018).

Based on Porwal et al. (2010) the challenges of construction professionals fall into two categories;1) implementation stage, when LPS introduce to the project team and pilot projects are in progress. Senior and mid-level management face these organizational problems in the initial stages .2) Using stage, LPS is used by a professional team and technical challenges related to human capital that is needed for using LPS are introduced. The listed below are these challenges (Porwal et al. 2010).

IMPLEMENTATION CHALLENGES

- Lack of training
- Lack of leadership/failure of management commitment
- organizational climate
- Organizational inertia & resistance to change
- Stakeholder support
- Contracting and legal issues/contractual structure
- Partial implementation of LPS & late implementation of LPS

USER CHALLENGES

- Human capital & lack of understanding of new system
- Difficulty making quality assignments/human capital–skills and experience
- Lack of commitment to use LPS & attitude toward new system
- Bad team chemistry & lack of collaboration
- Empowerment of field management/lengthy approval procedure from client and top management
- Extra resources/more paperwork/extra staff/more meetings/more participants/ time

- Physical integration

In addition, Dave et al. (2015) described several challenges that emerges from literature and observation from organisations practicing LPS.

- Inability to effectively deploy collaborative aspects
- Partial deployment of LPS
- Reduced importance of robust phase and master plans
- Missing continuous improvement
- Missing the links between detailed and high-level plans

The following table listed the benefits and barriers of LPS implementation in two projects.

Table 3.2.Benefits & barriers of LPS implementation (O. AlSehaimi et al. 2014).

Project	Benefits	Critical success factors	Barriers
1	Enabling site supervisors to plan their workload	Top management support	Lengthy approval procedure by client
	Improving learning process	Commitment to promises	Cultural issues
	Improving planning and control practice	Involvement of all stakeholders	Commitment and attitude to time
	Enabling accurate prediction of resources	Communication between parties to achieve teamwork	Short-term vision
	Reducing uncertainity	Close relationship with suppliers	
	Preparing team members to collaborate	Motivating people to make change	
2	Enabling accurate prediction of resources	Commitment to promises	Involvement of many subcontractors
	Improving planning and control	Communication and coordination between parties	Lengthy approval procedure by client
	Enabling site supervisors to plan their workload	Involvement of all stakeholders	Commitment and attitude to time
	Improving site management	Top management support	Cultural issues
	Improving learning process	Close relations with suppliers	Short-term vision
	Reducing uncertainty	Managing resistance to change	

What are the measures to overcome?

These challenges can be analysed from two perspectives. First from people and process perspective i.e., the need for training and change management, and secondly that LPS itself may need updating to fulfil the essential needs of the industry. In regards with the first problem, there is lack of training material on the LPS implementation. Several consultants with different backgrounds have vary opinions with execution of LPS. Some consultants emphasise the use of weekly planning while neglecting the aspects of lookahead and reverse phase planning. In addition, it should be noted that LPS has not yet found a place in textbooks or standard academic curriculum. Therefore, many graduates have no idea about LPS. The second issue needs a much deeper investigation with theoretical basis. Some broad suggestions are mentioned below (Dave et al. 2015);

- The collaborative part of the planning needs to be considered with a fresh perspective. Much of the time during collaborative meeting is used for collecting information Using an information system can minimise this time and help the team for efficient planning.
- The information flow from high level plans to short term plans, and more importantly from short-term plans to the Master level plans needs to be explicitly determined in the LPS.
- In addition to PPC and RNC, more systematic continuous is needed to achieve better and more accurate analysis and tracking of task conditions.
- The role of information systems and product modelling systems (such as BIM) should be integrated/considered in the new LPS model. The construction industry has a significant development in information system in recent years that needs to be brought into consideration in LPS.

3.3 TAKT TIME PLANNING

3.3.1 WHAT IS TAKT TIME PLANNING

The term “TAKT” has root in Latin “*tactus*” meaning “*touch, sense of touch, feeling*”. In the 16th century a Takt was defined in German as “*durch regelmäßige Berührung ausgelöster Schlag*” (EN: “beats applied through regular contact”) (Haghsheno et al. 2016). The German word “TAKT” refers to ‘rhythm’ or ‘cadence’ that can be perceived as impulse generator which performs an action or assignment in uniformly sized time intervals (Haghsheno et al. 2016).

Takt time refers as the timespan between two beats of a Takt (Haghsheno et al. 2016) or according to Frandson et al. (2013) "*Takt-time is 'the unit of time within which a product must be produced (supply rate) in order to match the rate at which that product is needed*". Additionally, takt time can be defined as a design parameter in manufacturing or construction that matches the paces of production rate with rate of customer demand (Frandson and Tommelein 2014). The various construction projects with the repetitive process such as bridge construction (incremental launching method), underground construction (slotted walls using pilger rolling), tunnel construction (tunnel boring machines using lining segments) and excavation (digger-truck traffic coordination) can implement the TAKT TIME PLANNING in their frequently repeated identical procedures to utilize the benefits of this planning (Haghsheno et al. 2016) that are explained in the following.

3.3.2 TAKT TIME PLANNING & LPS

Emdanat et al. (2016) stated that "*TTP has the potential of improving LPS implementations because of its focus on the design of predictable flow of materials and resources across clear geographic locations*". Similarly, Frandson et al. (2014) declared that "*The objective of takt time planning is to help create a more stable environment for the Last Planner System by actively designing continuous workflow for trade activities wherever Possible*".

TTP sets the zones in advance that need to be made ready, preparing a vivid lookahead for each task. In addition, TTP helps the project team during the commitment planning to create quality assignments which meet five criteria: definition, size, sequence, soundness, and learning (3.2.4.5). TTP by indicating definition, size and sequence, allows to last planners to concentrate more on identifying the soundness of each commitment (Is the prerequisite work finished? Are the required materials ready? Is the design and drawings accepted? Etc.). Since zones are clearly delineated by task and the desired progressing rates are clear to all, learning process can be improved (Frandson and Tommelein 2014). In other explanation, LPS and TTP are complementary. TTP expands the LPS by introducing continuous flow and LPS makes the mechanism for control and planning where continuous flow is not possible (Frandson et al. 2014). Furthermore, Schöttle and Nesensohn (2019) indicated that "*takt time is a work structuring method to simplify the lookahead process by focusing on standardization and clear batch size in order to create a more stable environment for the LPS. In comparison, the LPS facilitates irregular work variances such as areas with non-repetitive work*".

3.3.3 TAKT TIME STAGES

The development of TTP is the six steps process that provides the production plan based on designed production system (Frandson and Tommelein 2014). These steps include:

1. Gather information,
2. Define areas of work (zones),
3. Understand the trade sequence,
4. Individual trade durations,
5. Balance the workflow,
6. Establish the production plan.

The developments of MPP (milestone and phase plan in LPS) requires the similar steps, except the main difference that exists in the granularity. While in TTP time duration is the main element to harmonize the resources through repetition, MPP can be more unrealistic plan when the future is further away. Besides that, last planners optimize their activity based on the MPP that planned in six week lookahead and weekly work planning. Therefore, integrating takt time in the LPS for repetitive work can be considered as a great opportunity (Schöttle and Nesensohn 2019). Based on the triads of Lean Project Delivery System (LPDS) (Figure 3.1), TTP must begin in the early project definition phase of a project because it is a work structuring method (Frandson et al. 2014).

3.3.4 TAKT TIME PLANNING BENEFITS

TTP aims to achieve a steady stream of predictable works performed in the proper sequence, across the defined geographic areas, and with appropriately planned crew sizes (Emdanat et al. 2016).It is not just only about the workflow on site, but also overall flow of material and information through the supply chain starting in design and moving into detailing, fabrication and delivery processes (Emdanat et al. 2016).TTP can yield significant benefits in regards to time savings, money savings, improved quality, etc (Frandson and Tommelein 2014). In the following some of these benefits are listed:

- Reduce the cycle time for data collection and analysis; the project team can react quickly and decrease the risk of unpredictable variation (Emdanat et al. 2016).
- Ensure uniformity and increase the consistency of data collection and tracking (Emdanat et al. 2016).

- Improve collaborative planning and predict the reliable flow by validating resource assumptions prior to work execution (Emdanat et al. 2016).
- Great tool for improving the efficiency in large projects that span multiple years by defining which information is created, maintained and tracked (Emdanat et al. 2016).
- Create a unique product in a fix amount of time (Frandson et al. 2014).
- Encourage project team to coordinate early on the details of how work can and will be performed (Frandson and Tommelein 2014).
- Provide the tasks of correct size and sequence to the last planner as well as clear outlook for upcoming assignments (Frandson et al. 2014).
- Reduce stress on foreman by having a planned flow in order to clarify his/her target in the project (Frandson et al. 2014).
- Increase focus and standardization of the lookahead process which lead to the clear batches of work (Frandson et al. 2014).
- Provide the opportunity for the entire production team, from detailers to foreman , to develop a understanding on the overall production strategy (Frandson et al. 2014).
- Increase the urgency for make ready analysis because any failure impacts on “Parade of Trades” (Frandson et al. 2014).
- Reduce scope of work in pull planning. The sequences of work were generalized before to one piece of work through areas planned (Frandson et al. 2014).

3.3.5 TAKT TIME PLANNING DIFFICULTIES

It is not always possible to implement TTP which is integrated into LPS as planned. By considering MPP, it is clear that adjustment and re-planning is undeniable for takt areas and specific areas. For instance, reacting of the project team to challenges in achieving the milestones in order to optimize the production process can lead to a re-planning in the main schedule (Schöttle and Nesensohn 2019). TTP may not be always executed according to the plan due to the issues listed below; (Schöttle and Nesensohn 2019).

- Limited availability of resources in the market
- Lack of timely involvement of trades
- Shortage of subcontractor availability
- Variable performance by the different work crews of a trade
- No availability or late delivery of material

- Shortage of labour
- Late change orders by the client
- Delayed decision-making by the client
- No error-free and no on-time delivery of construction documents

In addition, TTP same as LPS need to consider the human factor. The project team consists of participants with different personalities, attitudes, behaviours, experience, and expectations. Therefore, it is a cultural change and way of thinking that needs to be accepted by the members (Schöttle and Nesensohn 2019).

4 FINDINGS

The results of the interviews, document studies, surveys, and observations are presented in this section. The research questions will be answered according to the information obtained from the different methods mentioned. This chapter is divided into three parts. In Section 4.1, the implementation of LPS on the Minnevika bridge project is investigated in order to answer research question number one: "*How is the Last Planner® System practiced on the Minnevika bridge project?*". In Section 4.2, research question number two, "*How do the different involved parties' value/experience the process? What are the strengths and weaknesses of the LPS process on the Minnevika bridge project from participants' perspectives?"* is answered based on information achieved from the survey and interviews. Finally, Section 4.3 measures the attitudes changes towards the detected challenges in the project with one year interval and suggests some solutions to overcome the challenges and improve the process on the Minnevika bridge project.

4.1 LPS ON THE MINNEVIKA BRIDGE PROJECT

As explained earlier in the research, LPS is one of the most popular lean tools being deployed in construction companies across the world. It was designed to improve the gaps that existed in traditional management methods, such as the Critical Path Method. However, according to Dave et al. (2015), the full potential of the Last Planner System is rarely achieved, and the root causes for this are not entirely understood. In this section, LPS implementation on the Minnevika bridge project is examined and an exploration of to what extent it is in accordance with concepts presented in the literature is conducted.

4.1.1 LPS EXECUTION

PNC has adopted the LPS for the first time, not as a requirement in the contract regarding with the Minnevika bridge project but for learning, training, and taking advantages of LPS as a point of departure for the next projects in the future. Therefore, the project team has this opportunity to get familiar with LPS and they will be more efficient and productive in the next project. LPS on the Minnevika bridge project is described in the following sub-sections.

4.1.1.1 MASTER PLAN

The Milestone Plan represents the top of the plan hierarchy and decides the room for manoeuvre in the Look-Ahead Plan and the more detailed Weekly Work Plan (WWP). It is a six-month plan that defines the overall project duration, important milestones, and the key tasks. The main tasks are identified first, and planning is done backwards from the end to the beginning (pull-planning). This kind of planning gives the project team a higher level of view. The Master Plan is a core framework created by the site managers and supervisors at the beginning of the project or new major activity and forms the basis for the more detailed planning such as the Look-Ahead Planning. It is updated sometimes based on reality (what was happened and by considering future plans) by the facilitator or in group and is then presented to other project participants for review.

4.1.1.2 PHASE PLANNING

The process mapping method, an identification of which activities that must be completed to reach each milestone, is applied by PNC in order to map out the construction process by pull principles, from the end to the beginning, during the collaborative meetings. Then, the construction process, which was developed in the process mapping, was transferred to the Milestone and Phase Plan (MPP) to develop a base plan for Look-Ahead Planning and WWP. The mapping includes an identification of which activities that must be completed to reach each milestone. The necessary order, the duration, and the critical path for these activities must also be identified. Then, a backwards planning of the activities and their last date of completion is carried out. The respective first possible start date for the activities and the milestone gives the available time for the activities along the critical path, and hopefully this available time is sufficient.

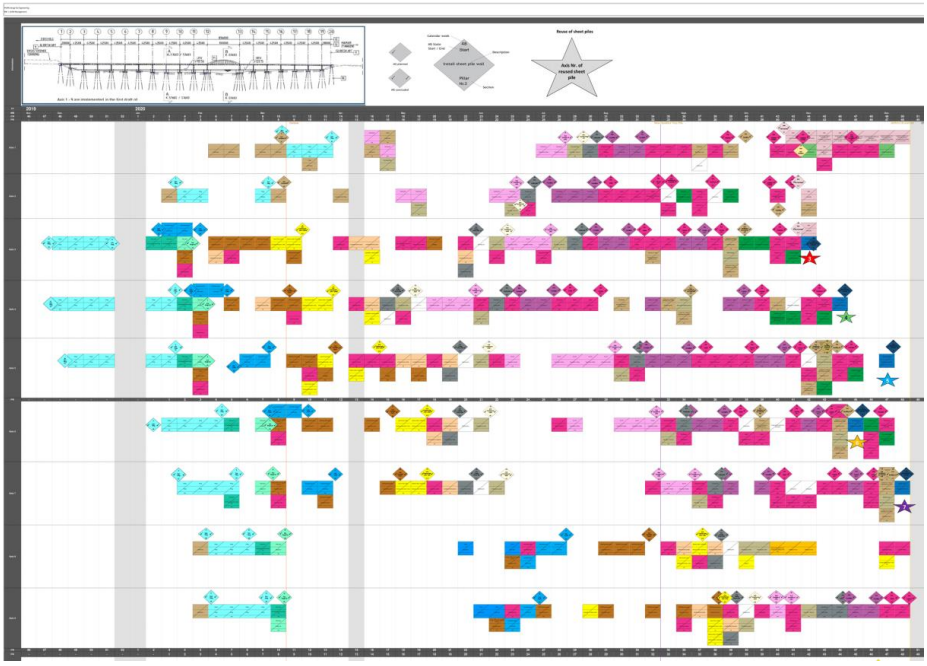


Figure 4.1 Master plan with specified milestones – MPP (Document of PNC)

4.1.1.3 LOOK-AHEAD PLANNING

The backwards/pull planning of the workflow helps the team to develop the Look-Ahead Plan. Look-ahead planning on the Minnevika project is performed using a six-weeks plan based on the Milestone and Phase Plan. Every week the planning for the next six weeks is performed during the weekly meeting that is described below. All contractors and subcontractors including PNC, Hæhre, Aarsleff, Arctic, NRS, and HSE representatives collaborate to identify constraints and find the best path for performing the desired tasks that meet the four quality criteria (well-defined, soundness, sequence and size).

Figure 4.2 Look-ahead planning board (by the author)

4.1.1.4 WEEKLY WORK PLAN

The Weekly Work Plan (WWP), otherwise known as the Production Evaluation and Production Planning (PEP) on the Minnevika bridge project, is a weekly meeting with participation of project members including; Construction managers, site engineers, office engineers, production team, HSE representatives of PNC, representative or supervisors of other contractors and subcontractors, Hæhre, Aarsleff, EB Marine, Arctic and NRS. The PEP meeting begins with an evaluation of the last week of work by going through the different commitments of different trades. Afterwards, uncompleted tasks are categorized by Variance Analysis. Variance Analysis is the same as the Reason for Non-Completion (RNC) measure described in the literature review. The facilitator, with the help of the HSE representative, and by using Order and Safety, define the safety issues related to different axes that have ongoing works on the construction site.

The Risk Matrix is the next tool that is discussed during the PEP meeting. The facilitator coordinates with participants in order to define contingent risks and examines the impacts of these constraints on the process and the probability of their occurrence. If the probability and the impacts of a risk were significant, an action must be defined in the Action Plan. The Action Plan recognizes the need of specific actions with identified responsibilities and deadlines for completion. The look-ahead planning is the main aspect of the meeting. Participants cooperate to create the six-weeks plan in accordance with milestone plan. Then, this look-ahead plan is discussed and clarified by the contractors and subcontractors. At the end, Logistics is discussed by the facilitator to evaluate if there are any logistic constraints on the construction site.

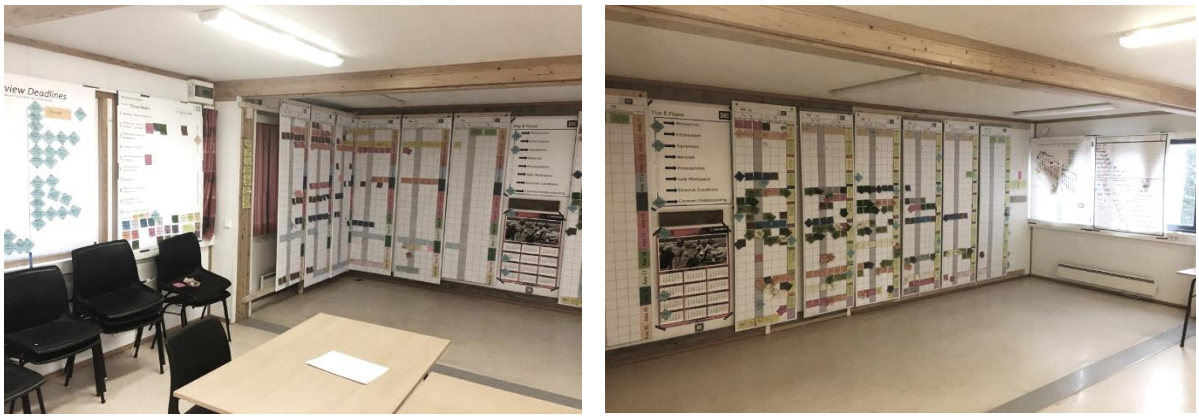


Figure 4.3 PEP meeting place (by the author)

Logistic

When a lot of people work in a tight workplace by receiving several deliveries in the same spot and multiple interfaces, logistics can be a useful tool. In the logistics part, the map and drone footage of the site are displayed on the screen and the main issues surrounding logistics are discussed. For instance, what can be do for the next week? where is the best place for material and machine? the best access ways for executive operations such as casting of foundation axes, access way to pontoon, etc.

4.1.1.5 MEASUREMENT AND LEARNING

As explained earlier, measuring Key Performance Indicators (KPIs) that are described below not only encourages learning among the project team but also provide a clear indication of productivity. These KPIs measured on the Minnevika bridge project include the Percent Plan Complete (PPC) overall, the PPC per trade, Milestone Completion, Variance Analysis (VARA), Top Three Variances, Conclusion Variance Analysis and Problem Solving, and Order & Safety. These indicators, along with the Look-Ahead Plan, risk matrix and action plan are sent to project team every week after the PEP meeting by the facilitator. The indicators are tracked and used in order to increase productivity and learning from mistakes and therefore promote the mindset of continuous improvement. KPIs measure what the team planned compared to the number of commitments that they actually completed during the previous week. In the following sub-sections, the different aspects of KPI are described.

Variance Analysis

This measure on the Minnevika bridge project is defined as the Reason for Non-Completion (RNC). Each week, during the PEP meeting, the previous weekly work plan is reviewed to determine what activities have not been completed. Afterwards, the reasons for non-completion are discussed to take an action that avoids the repetition of these non-completions. The reasons for non-completion on the Minnevika project include: 1) Delayed/defect materials. 2) Preliminary work not finished/available 3) Preliminary work not recognised 4) Change in priority 5) Unforeseen absence of labour 6) Overestimated performance 7) Rework 8) Missing/incomplete information 9) Equipment not available/broken 10) Poor weather conditions.

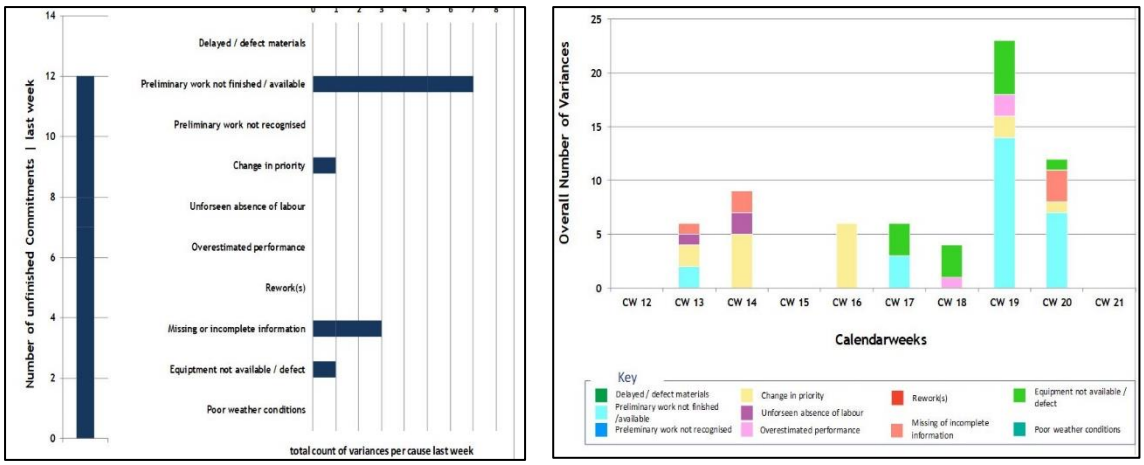


Figure 4.4 Variance analysis on the Minnevika bridge project (PNC document)

PPC overall

As previously described in the literature review section, Percent Plan Complete, is a measure of the percentage of completed assignments in relation to what was planned for these assignments. PPC can be a great tool to clarify the consistency and validity of planning by the team. PPC overall refers to the total of commitments that were completed against planned for that week. The highest amount of PPC overall is 100% that shows all the commitments are fulfilled according to the plan.

Overall PPC Last week was 67% of a total of 36 commitments.

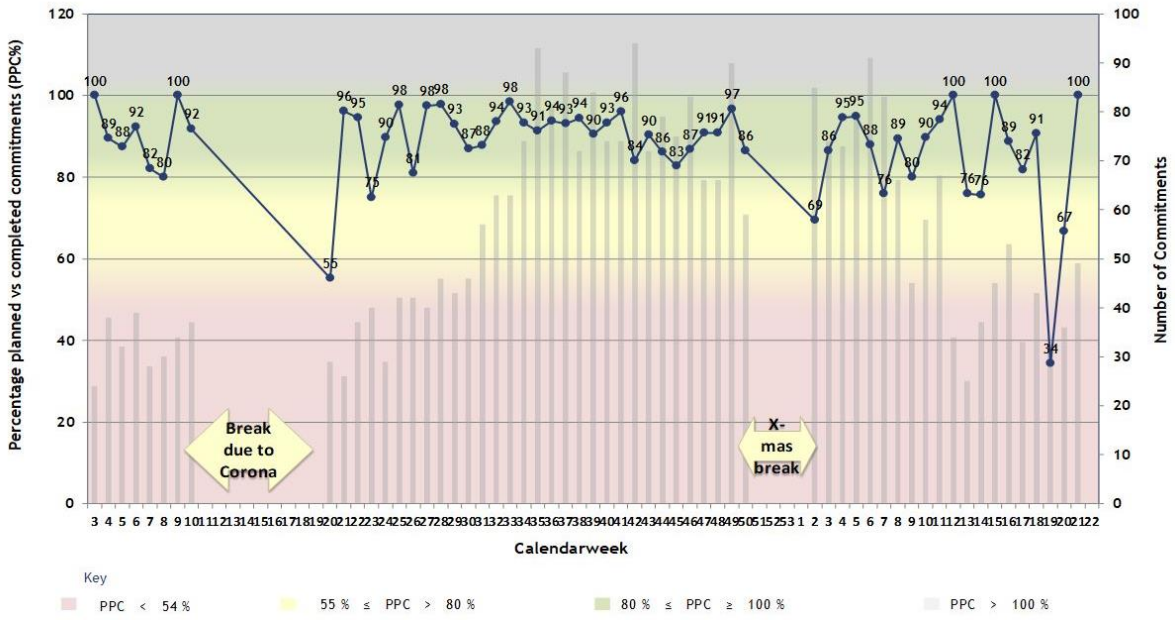
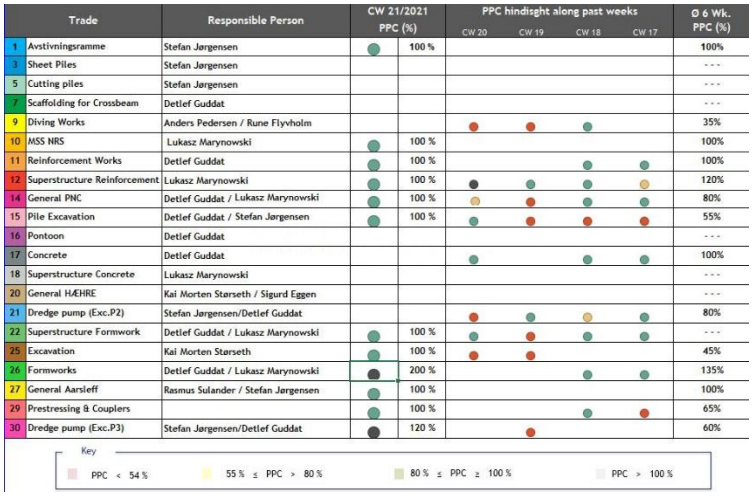


Figure 4.5 PPC measurements on the Minnevika bridge project (PNC document)

PPC per trade

The percentage of completed tasks in relation to the planned tasks is shown per trade. If more tasks were completed than the planned, the value will be more than 100%. PPC per trade indicates the completion percentage of each activity beside the name of responsible person for that commitment. These activities including sheet piling, piling, reinforcement, concreting, etc.



	Trade	Responsible Person	CW 21/2021 PPC (%)		PPC hindsight along past weeks CW 20	CW 19	CW 18	CW 17	Ø 6 Wk. PPC (%)
1	Avstivningsramme	Stefan Jørgensen		100 %					100%
3	Sheet Piles	Stefan Jørgensen							---
5	Cutting piles	Stefan Jørgensen							---
7	Scaffolding for Crossbeam	Detlef Guddat							---
9	Diving Works	Anders Pedersen / Rune Flyvholm							35%
10	MSS NRS	Lukasz Marynowski		100 %					100%
11	Reinforcement Works	Detlef Guddat		100 %					100%
12	Superstructure Reinforcement	Lukasz Marynowski		100 %					120%
14	General PNC	Detlef Guddat / Lukasz Marynowski		100 %					80%
15	Pile Excavation	Detlef Guddat / Stefan Jørgensen		100 %					55%
16	Pontoon	Detlef Guddat							---
17	Concrete	Detlef Guddat							100%
18	Superstructure Concrete	Lukasz Marynowski							---
20	General HÆHRE	Kai Morten Størseth / Sigurd Eggen							---
21	Dredge pump (Exc.P2)	Stefan Jørgensen/Detlef Guddat							80%
22	Superstructure Formwork	Detlef Guddat / Lukasz Marynowski		100 %					---
25	Excavation	Kai Morten Størseth		100 %					45%
26	Formworks	Detlef Guddat / Lukasz Marynowski		200 %					135%
27	General Aarsleff	Rasmus Sulander / Stefan Jørgensen		100 %					100%
29	Prestressing & Couplers			100 %					65%
30	Dredge pump (Exc.P3)	Stefan Jørgensen/Detlef Guddat		120 %					60%

Key

PPC < 54 % | 55 % ≤ PPC > 80 % | 80 % ≤ PPC ≥ 100 % | PPC > 100 %

Figure 4.6 PPC per trade measurements on the Minnevika bridge project (PNC document)

Milestone completion

This measurement tool shows the cumulated number of milestones that were concluded per week throughout the project. The graph below compares the planned milestone (grey area) and the milestones that were achieved (blue line) during the several weeks.

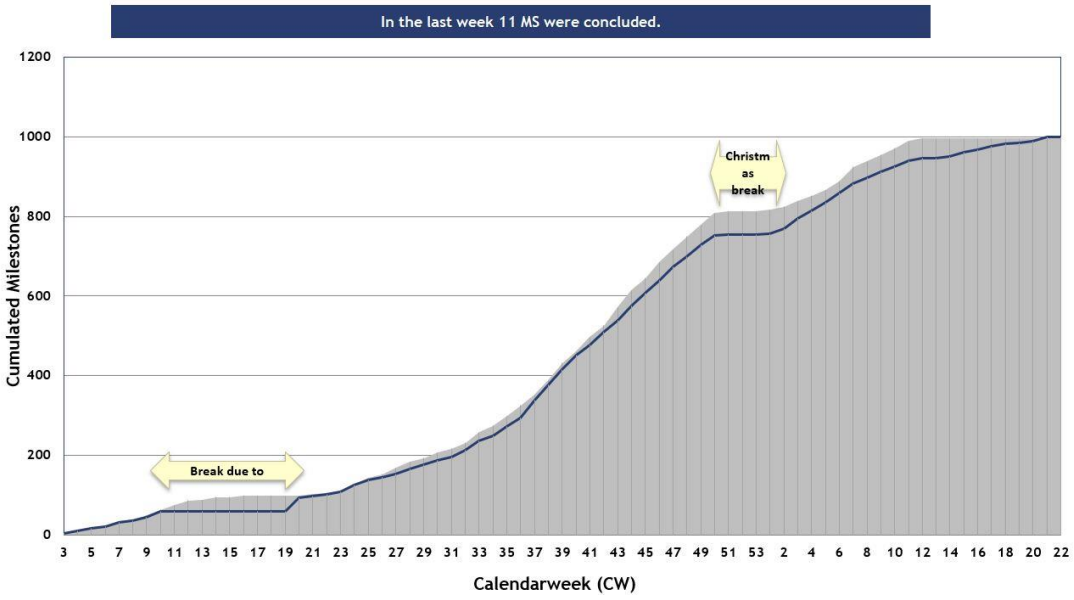


Figure 4.7 Milestone completion (PNC document)

Risk matrix

The risk matrix is a common tool that PNC use to assess the various risks of the workplace hazards. The diagram can help the project team to determine the priority of the risks based on their impacts and occurrence. If the probability of occurrence of a risk and its impact were significant, an action must be defined in the action plan.

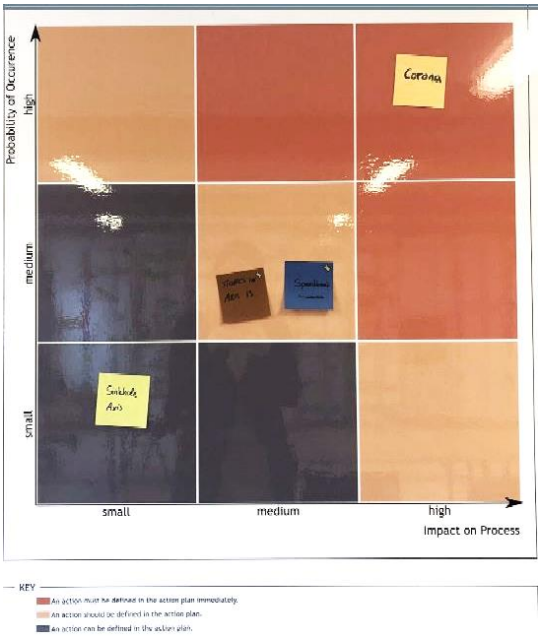


Figure 4.8 Risk matrix (PNC document)

Action plan

The Action plan is a tool that make tasks ready for future action. There are four different situations related to the tasks, action planned, action in process, action in review, and action finished. Action plans have been used to reduce the likelihood or impact of identified risks or to find solutions to issues that arise on the project. The project team recognizes the needs of an action and what must be done in advance.

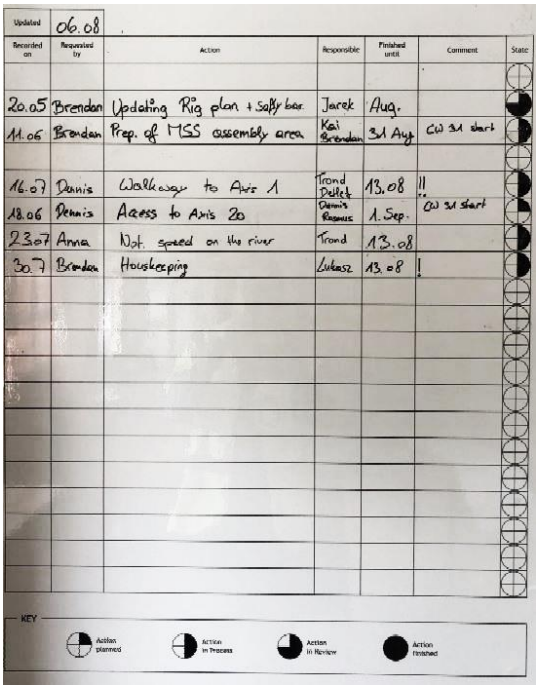


Figure 4.9 Action plan (PNC document)

Order & Safety

This indicator assesses the safety issues on the construction site and informs all the participants about current safety conditions related to each working axis in order to take the necessary actions and accident prevention. A traffic light system is used to represent the different safety conditions at each axis, where red represents an unsafe workplace where immediate action must be taken.

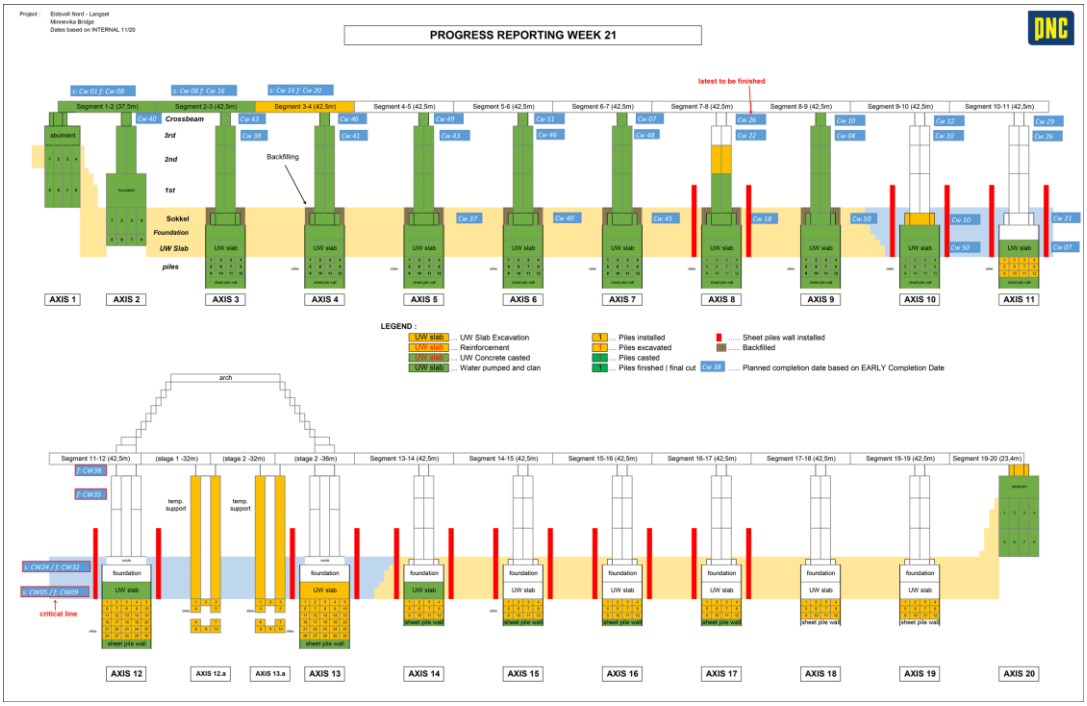


Figure 4.10 Order & safety (PNC document)

4.2 INVOLVED PARTIES' PERSPECTIVE

In this section, the author has examined the different parties' value and their participation experience of the process by using a survey as way of collecting data in reference to Research Question 2 (RQ2). An Interview was adopted to answer the sub-question of RQ2:"*What are the strengths and weaknesses of the LPS process on the Minnevika bridge project from participants' perspectives ?*" In the following, the results from survey and interviews are described.

Results from survey

The survey was conducted on the 19th of Nov 2020 during the PEP meeting in order to include all those who were involved in the LPS process. However, due to current situation and the outbreak of Covid-19, most participants were in quarantine and the author was only able to achieve answers from nine respondents (out of a possible 12 respondents). The survey consisted of three parts: General questions, LPS execution, and Challenges. After consulting with Ola Lædre, it was decided to conduct a survey with more or less similar questions to Kassab et al. (2020) in general and challenges section in order to track attitude changes and measure the development. The findings from the first survey are reported on the 4th of Nov 2019, the day before the first training sessions were conducted with PNC. The results of the survey are presented in the following table.

Table 4.1.Results from first part of the survey 19th Nov 2020

Section 1: General questions

1. What is your impression of Last Planner® System (LPS)?	Negative 1	Undecided 3	Positive 5
1= strongly disagree, 2= disagree, 3= Undecided, 4= agree and 5= strongly agree			
2. Are you satisfied with this transformation/change in the project's system?	Average scale	3.77	
3. Do you think that the LPS is improving the way by which the project is planned?	Average scale	3.91	
4.Would you say that the LPS can lead to a successful project in comparison to traditional project management?	Average scale	3.22	
5. Would you say that it was challenging to adopt the LPS?	Average scale	2.91	

According to the table 4.2, most of the participants have a positive perspective of the LPS. 55.5% of participants (5 out of 9) were satisfied with LPS, compared to 76.9% (10 out of 13) participants who answered "undecided" in the previous survey (4th Nov 2019). This shows a positive improvement to LPS on the Minnevika bridge project. With an average scale of 3.9, the participants believed that LPS has improved the way of management on the Minnevika bridge project, compared to an average scale of 3.6 in the last survey. In addition, whereas the most participants believed that implementation of LPS would be quite challenging, they have changed their minds in the recent survey. The results of the two surveys are listed below.

Table 4.2.Comparison of the survey results (1)

Questions	Survey on 19th of Nov 2020	Survey on 4th of Nov 2019
1.Are you satisfied with this transformation/change in the project's system?	3.77	3.75
2.Do you think that the LPS is improving the way by which the project is planned?	3.91	3.62
3.Would you say that the LPS can lead to a successful project in comparison to traditional project management?	3.22	3.55
4.Would you say that it was challenging to adopt the LPS?	2.91	3.69

Section 2 of the survey was utilised to examine the experience and personal opinions of LPS by the involved parties. The questions regarded different phases of LPS execution. According to the average scale, the value of LPS from the project members' point of view is described in the table below.

Table 4.3.Results from second part of the survey 19th Nov 2020

Section 2: LPS Execution

6. When thinking about the PEP meetings in general ...		
1= Very low, 2= Low, 3=Undecided, 4=High and 5= Very high		
6.1. To what extent is this valuable to you as an individual?	Average scale	3.44
6.2. To what extent is this valuable to your team?	Average scale	3.88
6.3. To what extent is this valuable to overall project?	Average scale	3.77
6.4.To what extent do you look forward to the PEP meeting?	Average scale	3.22
7. When thinking about the Milestone Plan ...		
7.1. To what extent is this valuable to you as an individual?	Average scale	2.88
7.2. To what extent is this valuable to your team?	Average scale	3.11
7.3. To what extent is this valuable to overall project?	Average scale	3.11
8. When thinking about the 6-week look ahead planning performed during the PEP ...		
8.1. To what extent is this valuable to you as an individual?	Average scale	4.00
8.2. To what extent is this valuable to your team?	Average scale	4.44
8.3. To what extent is this valuable to overall project?	Average scale	4.22
8.4. To what extent do you think constraints are identified in the 6-week look-ahead planning?	Average scale	3.77
9.When thinking about the Action Plan ...		
9.1. To what extent is this valuable to you as an individual?	Average scale	3.11
9.2. To what extent is this valuable to your team?	Average scale	3.33
9.3. To what extent is this valuable to overall project?	Average scale	3.33
11.When thinking about the Risk Analysis overview …		
11.1. To what extent is this valuable to you as an individual?	Average scale	2.88
11.2. To what extent is this valuable to your team?	Average scale	3.00
11.3. To what extent is this valuable to overall project?	Average scale	3.22
12. When thinking about the KPI measurements provided during the PEP ...		
12.1 To what extent is this valuable to you as an individual?	Average scale	2.33
12.2 To what extent is this valuable to your team?	Average scale	2.33
12.3 To what extent is this valuable to overall project?	Average scale	2.33
12.4. To what extent do you think the PPC and other KPIs are measured in an accurate way?	Average scale	2.44

According to the achieved results, Look-ahead planning is the most valuable tools of the LPS on the Minnevika bridge project. The highest scale of 4.44, showing the most respondents were in agreement of the validity of 6 weeks look-ahead planning. The majority of responders (3.77) believe that constraints are identified by look-ahead planning. However, the lowest numbers are related to KPI measurements, with the average of 2.33, it seems that KPI is not that much admired by the project team. An average scale of 2.44 (question 12.4) indicates doubts regarding the correct measurement of KPI. It leads to lack of attention to the learning process on the Minnevika bridge project, one of the detected challenges faced on the Minnevika, that is further explained in the research.

4.3 STRENGTHS & WEAKNESSES

By obtaining information from interviews and open-ended questions on the survey (see appendix chapter), the author has attempted to figure out what the strengths and weaknesses of the LPS implementation phases are on the Minnevika bridge project and what solutions can be taken to tackle these challenges. In this regard, the results of the interviews are shown in the tables below.

Table 4.4 Strengths and weaknesses of the Milestone plan

Strengths	Weaknesses
• Higher level management use it to track project progress • Suitable as report to the client • Gives a (6 months) target plan • Can be used when prioritising which activities can be delayed and which can be speeded up	• Does not include all activities on site • Can be forgotten since it is not in everyday use

Table 4.5 Strengths and weaknesses of the Look-ahead planning

Strengths	Weaknesses
• The involved parties cooperate on a reliable detailed plan for decisions, activities and resources with the critical path benefitting the project as a whole. • Planning on hanging boards with colourful sticky notes helps visualize the process and improve understanding • Help participants to reflect and plan clearly	• It sometimes creates a short-term focus • Since Look-ahead planning is time consuming it can lead participants to rush into the actual planning

Table 4.6 Strengths and weaknesses of the Production evaluation and production planning (PEP)/Weekly work plan (WWP)

Strengths	Weaknesses
• A weekly meeting that helps the team coordinate both internally, with partners and with the subcontractors • One meeting substitutes separate meetings with individual subcontractors • Allow discussions on all issues with involved parties • Make the production team commit to the plan • Participation in planning motivates the foremen • Participants with different perspectives provide input to appropriate solutions	• Some supervisors did not attend the meetings • Time consuming (around two hours) • Parts of the meetings were irrelevant to some participants • Rotational working schedules hinders continuous participation

Table 4.7 Strengths and weaknesses of the KPI

Strengths	Weaknesses
• Support communication of lessons learned • Prevent repetition of mistakes • Presentation of progress compared to plan • Reveals reliability of the superior plan	• Hard to attract the participants' attention to the KPI • Participants usually do not analyse and track changes after PEP meetings

4.4 MEASURING THE INVOLVED PARTIES' ATTITUDES DURING THE PROJECT

To measure changes in the participants' attitudes towards the LPS, two surveys were distributed to project participants with around one year interval. Both surveys contains questions based on challenges identified by Kassab et al. (2020) and the findings are reported from the first survey. When distributing the surveys with one year interval, it is possible to observe how attitudes changed when the participants acquainted themselves with the LPS. The changes in average score (from 1= very low to 5= very high on a Likert Scale) from February 2019 to November 2020 are given in table 6.

Table 4.8 Comparison of the survey results (2)

To what extent do you think each of the following challenges is considered as a critical challenge on the Minnevika Bridge project during the Execution Phase?		
Challenges	Survey on 20th of Feb 2019	Survey on 19th of Nov 2020
13. Maintaining people's commitment to be part of the process and to take the system seriously	3.50	3.22
14. Lack of Transparency in the interfaces between project team members	2.25	2.77
15. Resistance to the system	2.25	3.22
16. The language barriers	1.63	2.00
17. Non-participation of critical team members	2.85	3.22
18. The decisions and input are primarily provided by top-level management, such as site managers	3.00	2.88
19. Fear of responsibility (mainly from lower-level management)	3.00	2.22
20. Doubt (doubt about the overall performance and the benefits behind the LPS)	1.63	2.77
21. Misunderstanding of the basic concepts of the LPS	2.00	2.22
22. The time commitment required to participate in the weekly meeting	1.75	2.77
23. The lack of engagement	1.63	2.00
24. Disruption	1.63	2.33

According to the results from Table 4.8, the degree of importance of some challenges decreases among the project members. For example, maintaining the project member's commitment and fear of responsibility. On the other hand, the average scales of most of the challenges have increased, such as disruption, non-participation of critical team members, and resistance to the system. The results indicate that maintaining project member's commitment, resistance to the system, and non-participation of critical team members are the main challenges of the LPS on the Minnevika bridge project.

4.5 MEASURES TO OVERCOME THE CHALLENGES

As previously mentioned, PNC has faced some challenges that are often experienced by every organization at the beginning of implementing a new system. Most of the challenges tend to be related to the softer aspects of execution, such as people, organizational process, and way of thinking. As we can see in the result of last survey (Table 4.8), maintaining people's commitments, resistance to the system, and non-participation of critical team members are considered the most demanding issues. However, it should be noted that the other stated challenges could be considered more critical after a year, as the participants realise that the promised benefits of LPS are not manifesting as quickly as hoped for.

The author has tried to find some measures to overcome the mentioned challenges, described in section 4.3 and 4.4, based on his observation, presence in the project, and interview responses. It is noteworthy to say that achieving a successful LPS as a new system in an organization is a lengthy process and it requires deep change in the project team's mentality and behaviours to adopt it. Therefore, as a general solution, the project team needs to see the benefits of the new system in order to involve and support the process. The following suggested solutions are specific to the Minnevika bridge project.

Milestone planning can be forgotten by the project team as it is not in everyday use. A measure to overcome this challenge that emerged during observations and interviews was to review the milestones periodically. A periodic review would remind the participants about the main milestones in the project and prevent that the short-term look-ahead planning to occupy all attention.

Look-ahead planning sometimes creates a short-term focus. The suggested measure to mitigate this challenge is to increase consciousness about how the six-week look-ahead plan

fits the Milestone plan. The master plan should to a larger extent have been used as a reference for the look-ahead planning.

Since Look-ahead planning is time consuming it can lead participants to rush into the actual planning. The suggested measure is to assign certain people to certain tasks, and thereby increasing consistency in who was responsible for the previous actions before planning. Another solution could be showing the value of the previous duties before planning and how much they can have positive effects on the productivity on the site.

Some supervisors did not attend the meetings. / Maintaining people's commitment to be part of the process and take the system seriously. / Resistance to the system. / Non-participation of critical team members.

It is not easy to ask experienced managers to adopt new ways of management, and that caused these types of challenges. The best way to convince these managers to spend the necessary time is by showing the benefits of the system. During the observations, some benefits appeared. As one of site managers explained: *"The PEP meeting helps us to have one coordination meeting instead of having meetings one by one with all our partners and subcontractors separately. Now we get everyone in the same room and when a problem comes up, we have more people to contribute and look at it from different angles to make better solutions ".*

Parts of the meetings were irrelevant to some participants. /The time commitment required to participate in the weekly meeting Since PNC was responsible for the majority of the commitments on the Minnevika bridge project at this time, the PNC team definitely needed more time to plan compared to the other contractor and subcontractors during the look-ahead planning part of the PEP meetings. The PEP meeting usually begins at 8 am with attendance by all contractors and subcontractors but the PNC team had recently decided to begin half an hour earlier in the meeting to discuss the planning of their task for the upcoming weeks. This solution can prevent "wasting" other contractors' time during the planning (because they do not need to wait a long time for PNC finish the planning) and improve the productivity by using the time efficiently.

Rotational working schedules distort continuous participation. The measure can be putting more efforts into establishing the PEP meeting schedule. The meeting schedule must be aligned with the relevant participants' presence on site, and not at least with which time of the day that

works best for the participant's rotation.

Participants usually do not analyse and track changes (KPI) after PEP meetings.

A suggested measure to overcome the issues is to demonstrate how the measurements of Percent Plan Complete (PPC), Milestone Completion, Variance Analysis (Reasons for Not Completed), and Top Three Variances could be used to improve the workflow for the participants. The participants in the PEP meeting, last planners, have a tight time schedule and they are usually occupied. So, the author, with the cooperation of the facilitator, decided to prepare the KPI documents during the PEP meeting and present it briefly to the participants at the end of the meeting on the big screen in the PEP room. Therefore, participants can keep tracking of the performance of last week (evaluated week) in order to prevent of mistakes and improve the learning.

Doubt (about overall performance and benefits behind the LPS). / Misunderstanding of the basic concepts of the LPS. It is expected that the project team who experiences the LPS for the first time have a vague view of the system. The suggested measure to assist the team is to make an optional short meeting as mentoring every week, or every two weeks, led by the facilitator in order to review the important aspects of LPS, show the benefits of the system compared to the traditional way, answer the raised questions, make the system more understandable and clearer, and increase transparency for the people who have not correctly perceived all principles of LPS.

One of the main challenges that the author faced several times during the observation, was the **Non-participation of one of the critical contractors**. Non-continuous participation of the contractor or its representative led to at least one unfinished task during the evaluation, which no one knew the main reason for the unfulfilled commitment (Variance analysis). Incorrect planning was the result of non-participation of the contractor. Therefore, the only possible way to overcome this challenge was that one person, who could be the facilitator, discussed the contractor’s plans and presented them on their behalf at the next PEP. Then he/she acted as an interface and figured out the planning of the contractor for the next upcoming weeks in PEP meeting.

Lack of attention to the learning process. The author noticed that the participants did not much care about the reasons of unfinished tasks or what PNC called Variance analysis during the PEP meeting. The reason could be that they did not see any benefits. To solve this issue, the facilitator and author decided to focus more on Conclusion Variance Analysis and Problem-

Solving part in KPI document. They analysed the unfulfilled tasks and prepared a complete text every week regarding the questions: what were the main reasons for non-completion? and how can we prevent it from happening again?

As stated in the survey result, **the language barriers** with average score of 2.00 (where 1 means low impact challenge and 5 means devastating critical) cannot be considered a significant issue. The author also did not see any troubles in this field during the observation.

Similarly**, Lack of engagement** and **Fear of responsibility (mainly from lower-level management)** are not main concerns based on the results of survey and observations. It seems that after one year of the LPS execution, the project team has not any fears in taking responsibility. However, it should be noted that the friendly environment created byPNC has a great impact on solving this issue. The supportive behaviour of the project team gives the lower managers a sense of confidence and makes them more involved in the project. This treat also acted as a measure to overcome lack of engagement.

Disruption was another mentioned challenge, with average score of 2.33 (where 1 means low impact challenge and 5 means devastating critical), that cannot be categorized as a critical issue. During the observation, PNC did not face this challenge significantly. However, it was not completely avoidable. When it happened during the discussions and meetings the facilitator, with smart dialogue such as *"ok, let's back to… "*, tried to avoid disruptions to PEP meetings.

The decisions and input are primarily provided by top-level management, such as site managers. The last planners are vital participants of PEP meeting who make decisions about future tasks, priorities, resources, etc on the site. However, it does not totally mean all decisions are up to the top-level managers. The author usually attended half an hour before the meeting to prepare the required documents and it was a great chance to observe the behaviours of the participant. The remarkable point that had been noticed several times was the coordination between top managers and foremen or lower-level managers right before the PEP meeting in order to make a more reliable plan. So, while top managers may be the ones who put the final papers on the table, lower-level managers had a significant impact on the decisions.

4.6 TAKT TIME PLANNING ON THE MINNEVIKA BRIDGE PROJECT

As stated before, TTP is an attempt to perform work structuring and identify a feasible production strategy that can maximize the number of production activities performed with continuous use of resources (Frandson et al. 2014). Since TTP is a great tool in planning repetitive production procedures that can be integrated with the LPS, PNC has recently decided to implement TTP in order to provide improved coordination and a continuous flow of the repetitive tasks of the superstructure. NRS, the responsible contractor for the launching of MSS on the Minnevika bridge project, has the specific time schedule for the installation of formworks, MSS launching, lowering of MSS for the next span, and other relevant assignments. The Minnevika bridge project consists of 19 spans, all of which have the same design with the exception of spans 1,19, which are shorter in length, and span 12 in the middle, which is where the arch is located. Therefore, PNC by considering its own tasks such as formwork prefabrication, reinforcement installation, post-tensioning activities besides the NRS commitments mentioned above, has provided a cycle plan for MSS installation which can be categorized as repetitive procedures of superstructure activities for the spans. In other definition, it shows the ideal duration of the construction of one typical span including the pre- and post-preparation. The author was the responsible for tracking of span 1 and span 2 in order to collect data in more details to make reliable repetitive procedures for superstructure that can be used in takt time planning in future. The tracking information includes the name of activity with proper details, required duration to complete the task, and amount of manpower. This information is needed to provide the work structure for other spans as takt time planning. However, it should be noted that it is more a learning loop that enables PNC team to follow their improvements at each span and show: how they can achieve the best time schedule (the cycle plan)? What tasks needed more focus? What activities take longer time than usual? What would be the best number of human resources for each specific commitment? The answers can help PNC to increase their productivity and efficiency in their planning and performance.

4.7 SOME POSITIVE POINTS WITH LPS ON THE MINNEVIKA BRIDGE PROJECT

One of the big challenges during the time the author was in attendance on the project was the Covid-19 outbreak, and the government's response that enforced special and strict rules for crossing the borders and meeting people. The new restrictions minimized the number of people at meetings and some people had to attend over Skype. One of the positive points with the PEP meeting was that the contractors and subcontractors discussed their issues during the Action plan, Risk matrix and logistics part in order to achieve the practical solution. Indeed, the PEP meeting, which was held every week in the Big room, provided a great opportunity for the project team to reduce the number of meetings held during the strict constraints of Corona and allow participants to debate all of the topics that needed to be decided.

Additionally, the travelling of the blue-collar workers to their home countries, including being in quarantine for two weeks, was one of the main issues that PNC faced during the Covid-19 situation. The new restriction led to a significant reduction in human resources on the site. Therefore, productivity decreased during that time due to lack of manpower and PNC needed to create a priority list to adapt resources based on the specific commitments. The six weeks look-ahead planning lets the PNC team create an overview of human resource distribution for each task. In look-ahead planning, during the PEP meeting, last planners could specify the required manpower for each trade on the sticky notes on the board. This planning enables the project team to organize the upcoming tasks based on the available resources and optimize the productivity and efficiency on the site.

The other positive point to mention is that after every PEP meeting the site engineers, production controllers or supervisors presented the six-week look-ahead plans and the big boards to the foremen and the responsible people who have the duties to fulfil the specified commitments on the site. The colourful notes related to each task on the big boards make the planning more understandable for blue collars by providing better visualisation.

5 DISCUSSION

5.1 THE LPS ON MINNEVIKA COMPARED TO LPS IN LITERATURE

As mentioned before in the literature review section, the LPS is made up of five main components: milestone planning, phase planning, look-ahead planning, weekly work planning, and learning phase. Similarly, the findings from the case study revealed that the Last Planner® System on the Minnevika bridge project also consists of five components described as essential in literature, namely milestone planning, pull planning, look-ahead planning, weekly work planning and measurements for learning. Even though the contractor only applied LPS in the execution phase and not in the design phase, the core components of LPS were in place. The full implementation of LPS assists PNC in avoiding any failures that could occur as a result of partial adoption of the new system.

Table 5.1 LPS stages on the Minnevika bridge project

	Milestone plan	Phase planning	Look-ahead planning	Weekly work planning	Measurement &Learning
LPS implementation on The Minnevika bridge project	✓	✓	✓	✓	✓

5.2 INVOLVED PARTIES' PERSPECTIVE -

Despite the execution of the LPS on the Minnevika bridge project for almost one year, which is not a sufficient time to achieve success in this lengthy process, the most involved parties have positive perspective towards the process. The results of surveys revealed that most of the participants are satisfied with the LPS on the Minnevika bridge project. In addition, results show that most of the participants with average scores of 3.91 (where 1 means strongly disagree and 5 means strongly agree) see LPS as way of improving planning. It seems that after one year of execution of LPS on the Minnevika project, and getting familiar with the new system, the project team changed their mind regarding the adoption difficulties. The average score has been reduced from 3.69 in first survey to 2.91 in second survey. However, the average score of the question number three, "*would you say that the LPS can lead to a successful project in comparison to traditional project management?*", has been reduced from 3.55 from the first survey to 3.22 in the second survey (where 1 means strongly disagree and 5 means strongly agree). This reduction shows that the project team could not reap the full benefits of the LPS

on the Minnevika project. As a result, they were unable to distinguish distinct aspects of LPS compared to traditional management that were previously mentioned in the research (3.1.4), such as coordination level, CPM versus pull planning, and learning process.

The second section of the survey explored the different involved parties' perspective about LPS stages on the Minnevika bridge project. As shown in the diagram below, look-ahead plan was the most popular component of LPS on the Minnevika with 22%, while KPI at 12% was the lowest.

Figure 5.1 Popularity of LPS stages on the Minnevika bridge project

With an average score of 4.44 and 4.22 (where 1 means strongly disagree and 5 means strongly agree), the majority of participants agreed that look-ahead planning is a valuable tool for their team and overall project respectively. They also believe that look-ahead planning can identify constraints in the planning (3.77 of 5). The main reason for such high popularity of look-ahead planning compared to other components of LPS might be that the project team can see the benefits of this kind of planning. The team is constantly dealing with the six weeks look-ahead planning every week and can easily perceive how this process can help the entire project to achieve the targets. However, KPI with the average score of below 2.5 (where 1 means strongly disagree and 5 means strongly agree) for individual, team, and entire project cannot be considered well admired by the involved parties. The learning process is a component of LPS that has been somewhat neglected on the Minnevika bridge project. The involved parties could not take any advantages of KPI tracking and thus it was considered the least popular stage.

Additionally, PEP is the second most popular stage of LPS on the Minnevika with 19%, showing most of the participants discern it as a great tool. PEP is a functional and practical meeting that individuals, teams, and entire projects can benefit from. Therefore, it is clear that the involved parties have positive vision towards the PEP and look forward to it every week. The remaining stages of LPS on the Minnevika bridge project, milestone planning, action plan- and risk matrix, have been placed in middle of this category with an average score between 2.88 and 3.33. Unlike the PEP and look- ahead planning, milestone planning has not used daily by the project team. Therefore, it is not much tangible and might be forgotten sometimes. This could be the reason why the involved parties consider the milestone planning as a semi-valuable stage of LPS on the Minnevika project.

5.3 STRENGTHS AND WEAKNESSES

After analysing the notes from the participant observations and the transcripts from the interviews with the project team, it seemed that the strengths outweighed the weaknesses. A majority of the project participants' experienced LPS for the first time, and they thought that if LPS were implemented on future projects with the same participants some of the weaknesses would fade away more or less by themselves.

Of those weaknesses identified – both for the Milestone, Look-ahead and Weekly work plan – many of them seemed to be the result of irregular attendance of participants in the meetings. An irritating observation was that it often was repeated which participants attended, and which did not. Put in other words, some participants were not loyal to the plans, and their lack of lloyalty spoiled potential benefits for all. The success of LPS demands that all, or at least most, of the participants act loyal.

Despite some participants not puting sufficient efforts into LPS, the implementation resulted in improved coordination between the contractor and the partners, between the contractor and the subcontractors, and improved tracking and analysis of weekly project progress. With participants acting more loyally, the strengths could probably even have been boosted.

5.4 ATTITUDES HAVE CHANGED TOWARDS THE CHALLENGES

When comparing the scores from February 2019 with the scores from November 2020, it appears that the scores have changed after a year. Three of the challenges originally identified by Kassab et al. (2020) are considered to have become less critical after a year. **Maintaining**

participants' commitment to be part of the process and to take the system seriously was the main challenge during the first stage of LPS implementation and is still one of the three top challenges but has become slightly less significant with time. Similarly, **the decisions and input are primarily provided by top-level management, such as site managers** and **Fear of responsibility (mainly from lower-level management)** have followed the same trend. One reason why these challenges are considered less critical after a year may be that the project team has gained more experience with LPS after one year, and that the participants see that LPS is practiced according to theory.

The comparison of the scores from the first survey with the scores from the second survey reveals, somewhat surprisingly, that nine out of twelve challenges are considered to have become more critical after a year. The nine challenges are **Lack of transparency in the interfaces between project team members**, **Resistance to the system**, **the language barriers**, **Non-participation of critical members**, **Doubt (about overall performance and benefits behind the LPS)**, **Misunderstanding of basic concepts of the LPS**, **the time commitment required to participate in the weekly meeting**, **the lack of engagement** and **Disruption**. These challenges are maybe considered more critical after a year, as the participants realise that the promised benefits of LPS are not manifesting as quickly as hoped for. They need to put in resources to make LPS work, and the resources may outweigh the benefits for projects that implement LPS for the first time. The next project may not need that many resources to realise the benefits.

The second survey revealed that **Maintaining participants' commitment to be part of the process and to take the system seriously, Resistance to the system and Non-participation of critical team members** are considered to be the most critical challenges with an average score of 3.22 (where 1 means low impact challenge and 5 means devastating critical)**.** The project team can have experienced that LPS's charm of novelty has faded during the year, and that implementation of LPS requires persistence. In the below bar chart, comparison of the survey results is illustrated.

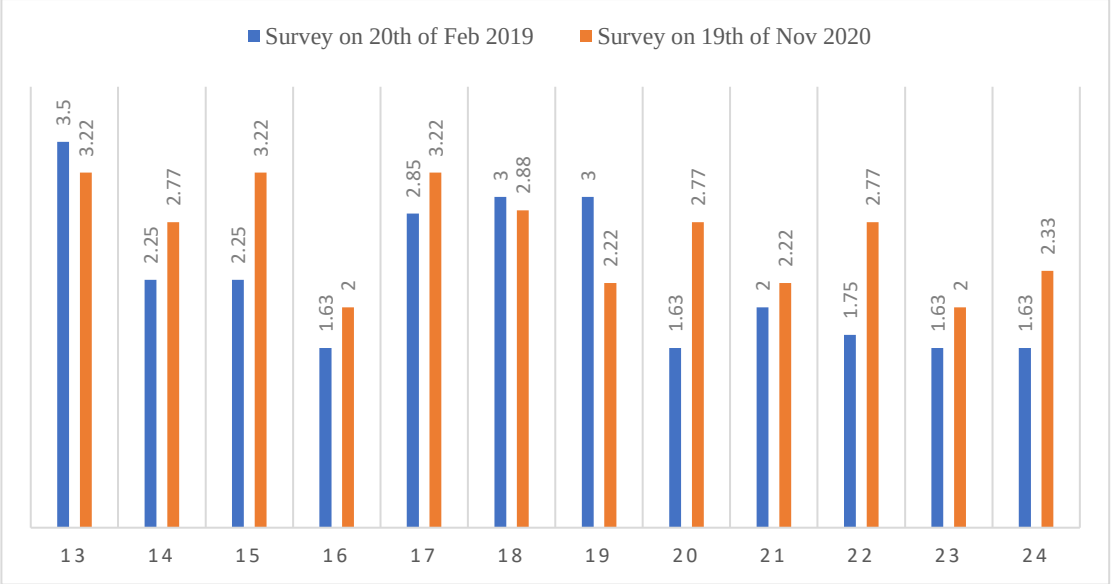


Figure 5.2 Comparison of the survey results according to the table 6

5.5 SOLUTIONS FOR DETECTED CHALLENGES

By introducing a new system to the project that requires a change in the project team attitudes, way of thinking, and openness towards the changes, some difficulties arise that need to be addressed. While the mentioned challenges and solutions that were detected are based on the case study, they can be generalized to the same process of LPS in other construction projects. The mentioned challenges can be analysed from two different perspectives, first from softer aspects and people's perspective, and secondly the challenges that related to the LPS and the process.

As Dave et al. (2015) described, the LPS suffers from lack of standardised training material in implementation and has not yet found a place in textbooks or standard academic curriculum. Therefore, fresh graduates entering the field (who would normally be more perceptible to new ideas) and the senior engineers and those are working in this industry are not all familiar with LPS concepts. This lack of mental preparation and unfamiliarity with the LPS concept lead to non-acceptance and guarding against the newly introduced system.

Some supervisors did not attend the meetings, maintaining people's commitment to be part of the process and take the system seriously, resistance to the system, non-participation of critical team members, doubt (about overall performance and benefits behind the LPS), misunderstanding of the basic concepts of the LPS, non-participation of one of the critical contractors, **lack of engagement** and **fear of responsibility (mainly from lower-level management)** are the challenges faced on the Minnevika bridge project that can be listed on the

softer aspects of implementation and people's perspective.

Since these types of challenges arise not only on the Minnevika project, but also on any project that adopts a new system into its process, the mentioned measures to overcome the challenges can be generalized to other projects that face the same difficulties. The solutions can be defined as showing the benefits of the system and convincing the participants to use it, by providing the proper training and describing the advantages of the system compared to the traditional ways of management, and supporting the team and answering the questions or any doubts regarding the principles of LPS.

However, sufficient time, adequate and proper training, deep changing of participants' mindset and way of thinking are essential in order to tackle the challenges related to softer aspects and people perspective.

The second perspective is related to the LPS itself, where the process can be specific to each project. However, similar problems can occur on other projects that implement LPS. Therefore, the mentioned solutions can be functional to some extent on those projects. These types of challenges on the Minnevika project consist of **milestone planning can be forgotten by the project team since it is not in everyday use, look-ahead planning sometimes creates a short-term focus, since Look-ahead planning is time consuming it can lead participants to rush into the actual planning, parts of the meetings were irrelevant to some participants, the time commitment required to participate in the weekly meeting, rotational working schedules distort continuous participation, participants usually do not analyse and track changes (KPI) after PEP meetings, lack of attention to the learning process,** and **the decisions and input are primarily provided by top-level management.** The suggested measures consider some points, including: reviewing the milestone constantly, defining the explicit information flow from high level plans to short term plans, assigning the responsibility to certain people for planning, effective coordination to use time more efficiently, finding the best time for weekly work meeting according to the participants' plans, defining the more systematic continuous improvement based on tracking task situation in addition to PPC, PPC per trade and variance analysis, and involving more middle positions in planning. These points, at various levels, can be considered when proposing solutions based on the specific status of each project.

6 CONCLUSION AND FURTHER WORK

The Last Planner® System, one of the most famous lean construction tools, is a technique for construction planning and control. PNC, the main contractor on the Minnevika bridge project, has adopted the LPS not as a requirement in the contract but in order to improve planning and control, reduce uncertainty, take advantages of efficient collaboration among contractors and subcontractors, improve learning process, predict resources and measure the weekly project progress. However, there are some challenges that can have negative effects on the productivity of the process. This study set out to answer three research questions, namely, 1) How is the Last Planner® System practiced on the Minnevika bridge project, 2) How do the different involved parties' value/experience the process? with the sub question of what are the strengths and weaknesses of the LPS process on the Minnevika bridge project from participants' perspectives? and 3) How have the involved parties' attitudes towards challenges changed during the implementation of LPS? With the sub question of What are the measures to overcome these challenges? The answers to these questions are based on the findings in one railway bridge construction project but are considered to be valid for other infrastructure projects that plan to implement LPS for the first time.

The answer to the first research question is that the contractor on the Minnevika bridge project has implemented five core components described by literature as essential, namely milestone planning, pull planning, look-ahead planning, weekly work planning and measurements for learning. However, the project team has not managed to exploit the full potential of these five core components yet.

From the involved parties' perspective, all stages of the LPS do not have the same value. It is clear that the participants can see a lot of benefits of the look-ahead planning since it is more tangible. Therefore, look-ahead planning can be counted as the most valuable stage of LPS on the Minnevika bridge project.

The participants recognise the typical strengths of LPS and have experienced improved planning and control during the execution phase. Some project team members did not invest as many resources in following up LPS as the others, but if they had done so, the typical strengths could have been reinforced. The participants believed that if they implemented LPS on their next project, several of the experienced weaknesses would fade because of the training they acquired in the Minnevika project.

The answer to the third research question about how the involved parties' attitudes towards challenges have changed during the implementation of LPS, is that three observed challenges are considered to have become less critical, while nine challenges were considered to have become more critical. Since the project team has gained experience with LPS and seen that it works, the three challenges are less critical. Since the project team also sees that making LPS work demands continuous effort, the other nine challenges were considered more critical after a year. The suggested measures to overcome the challenges are divided into two sections namely, 1) softer aspects of implementation and people's perspective, and 2) LPS difficulties, based on the detected challenges faced on the Minnevika bridge project. Since these challenges can be raised in other construction projects that implement LPS for the first time, the mentioned solutions can be generalized to those projects too.

Successful implementation of LPS is a lengthy process and requires a meaningful participation of all involved parties and a deep change in the members' mindset to adopt the new system, which is not easily achievable for an organization that implements it for the first time. Therefore, the Minnevika bridge project can be a great point of departure for PNC where the project team has had significant opportunity to learn, improve, and become acquainted with LPS. This will lead to having more professionals and experts in this field that can improve the productivity and efficiency of future projects. On the other hand, while it is readily apparent that the execution of LPS is a cultural modification, and the satisfactory degree might be low if the project team uses the system for the first time, adopting the LPS for the first time does not prevent the project team from achieving the set project targets successfully.

The Minnevika bridge will open for traffic in August 2023. To collect more data and quality assure the conclusions in this study, it is recommended to carry out more interviews and distribute a third survey to measure the attitudes towards LPS right before the project is finished. Then, by comparing the results from different surveys with some years interval, developments can be measured as a longitudinal study. Further work can also be to investigate the implementation of takt time planning (TTP) on the project, where PNC has adopted it for the repetitive process of the superstructure construction cycle. Integrating of TTP with LPS on the Minnevika bridge project and how it can help to improve the planning and productivity on the site can be an extensive and interesting topic for future study.

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PART TWO – THE PAPER

THE RESUBMITTED PAPER AFTER FIRST REVIEW IN
29th IGLC CONFERENCE.

LAST PLANNER® SYSTEM ON THE MINNEVIKA BRIDGE PROJECT

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ABSTRACT

Construction companies around the world have adopted the Last Planner® System (LPS) to reduce variability, increase workflow and improve reliability on their projects. This study explains the implementation of LPS in an infrastructure (railway bridge construction) project. Strengths and weaknesses of the implementation were examined and possible measures to overcome the experienced challenges were discussed. Finally, attitude changes towards the LPS during the project were measured.

Data was collected through case-specific observations, semi-structured interviews with open-ended questions, and two surveys. The findings revealed that the project benefitted from implementing LPS, but benefits could have been reinforced if critical team members had participated continuously in the necessary meetings, followed the system without resistance and maintained their commitments. Additionally, LPS on the Minnevika bridge project was the novel start and detected challenges are often experienced by every organization at the beginning of implementation of a new system. Indeed, the Minnevika bridge project can be considered as a point of departure and being persistent will help the parties to benefit even more in the next project.

KEYWORDS

Last Planner® System, Challenges, Infrastructure, attitude.

INTRODUCTION

Since the construction industry plays a vital role in economy, society, environment (Ansah et al. 2016), reducing waste and increasing productivity is important. The existing failures reported in the traditional project management help define the requirements for a new approach. This approach has been adapted to the construction industry, namely lean construction (Pellicer et al. 2015). The Last Planner® System is one of the most popular lean tools which has been used in construction to improve management and control, reduce urgent procurement requests, improve the performance(Alarcón et al. 2011), and for continuous monitoring of planning efficiency (O. AlSehaimi et al. 2014).

Several of the largest construction companies in Norway have shown their interest in LPS or what they call "Collaborative Planning (Veidekke and Kruse Smith), Trimmed Construction (Skanska) and Collaborative Project Execution (Nymo)" in their operations (Kalsaas and

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Grindheim 2014). PNC Norge AS, the company under-study, is one of these organizations that has implemented LPS on their Minnevika bridge project to improve planning and control, reduce uncertainty, take advantages of efficient collaboration among contractors and subcontractors, and measure the weekly project progress. When it comes to LPS implementation, the specific cultural barriers such as attitude to work could show up (Johansen and Porter 2003). However, by considering cultural analysis tools and measurements, it is possible to find out the factors of success or failure of certain practices in cultural conditions (Ravi et al. 2018). A significant number of case studies of implementation of LPS in projects exists, but few have investigated the participants' attitude changes towards LPS implementation on an infrastructure project who have adopted the LPS for the first time. Therefore, the following research questions were formulated:

1. How is the Last Planner® System practiced on the Minnevika bridge project?
2. What are the strengths and weaknesses of the LPS process on the Minnevika bridge project?
3. How have the involved parties' attitudes towards challenges changed during the implementation of LPS?

After the introduction section, the research methods are explained. Then, the literature review concentrates on LPS stages and challenges. The case study findings are presented and discussed before the research questions are answered in the conclusion section.

LITERATURE REVIEW

LAST PLANNER® SYSTEM COMPONENTS

Last Planner® System is a holistic and cascade system that helps construction companies improve planning reliability, production performance, and workflow on construction sites (Hamzeh,2011). The integrated components of this system include milestone planning, phase planning, look-ahead planning, weekly work planning, and learning (Ballard and Tommelein, 2016).

MILESTONE PLANNING

The front-end planning process that, besides defining the project milestones and the required length of time for performing each activity, provides an overview of entire tasks that should be executed throughout the project (Daniel et al. 2017).

PHASE PLANNING

By utilizing the milestone planning and incorporating input from different project parties (direct involvement of the contractors, sub-contractors, clients, and other stakeholders), reliable construction planning will be developed at this stage to cover each project phase as a reverse phase scheduling back from important milestones (Hamzeh et al. 2012).

LOOK-AHEAD PLANNING

It is medium term planning approximately six weeks in advance and screens for constraints in eight flows, which includes resources, information, equipment, material, prerequisites, safe workplace, external conditions (Koskela 2000) and common understanding (Pasquire and Court 2013) before passing the activities into production on site in order to increase construction flow. (Daniel et al. 2017).

WEEKLY WORK PLANNING

The weekly work planning takes place every week with the involvement of last planners in order to review the commitments planned in the previous week. It involves making a schedule for the week ahead and defining the detailed assignments that should be performed during that week (Pellicer et al. 2015).

LEARNING

Measuring the reliability of the plan that is directly related to the productivity (Pellicer et al. 2015) is possible by applying measurement indicators such as; Percentage Plan Complete (PPC) for evaluating the proportion of commitments that are delivered on time and the reason for non-completion (RNC) in order to learn from the mistakes and avoid them in future (Ballard and Tommelein 2016).

LAST PLANNER® SYSTEM CHALLENGES

Many construction companies have made attempts to take advantage of the LPS. However, it should be noted that besides the numerous benefits of this tool, many organizations face significant implementation obstacles (Ballard et al. 2007; Viana et al. 2010). As Hamzeh (2011) stated *"researchers in the field of change management and lean have reported attempts of many organizations to implement lean practices. However, most companies either failed or only partially achieved lean production in its true form*". According to Hamzeh (2011), both general and local factors can impact implementation of LPS. General factors relate to the execution of a new method and include: human resources, organizational inertia, resistance to change, technological barriers. Local factors relate to project circumstances and include; relatively new experience in lean methods, traditional project management methods, the newness of LPS to team members, lack of leadership, and team chemistry. Similarly, Porwal et al. (2010) categorized the challenges into two parts; 1. Challenges faced during the implementation phase such as lack of training, partial or late implementation of LPS, lack of support and contractual structure. 2. User challenges, for instance, lack of commitment and attitude toward the new system, lack of collaboration, extra resources or time consuming, and lack of understanding of new system. It should be noted that the most LPS challenges tend to be related to the softer aspects of implementation including organizational process and people (Dave et al. 2015). Kassab et al. (2020) followed the initial implementation of LPS on the Minnevika Bridge Project and Table 6 lists the challenges they identified.

RESEARCH METHODS

To answer the research questions, data was collected through case specific observations, semi-structured interviews with open-ended questions, and two surveys. An initial literature study was carried out to identify the core components of LPS and the challenges related to implementing LPS. Findings from literature were used when establishing an interview guide and formulating the survey questions.

The Minnevika bridge project was selected as a case study since it is one of the first infrastructure projects in Norway to implement LPS. It consists of 2 abutments and 18 piers standing on 268 Ø1016/20 mm steel tube friction piles. When opening for traffic in August 2023, this 836m long concrete bridge will be the longest in Norway. It is part of the Norwegian railway operator BaneNor's Eidsvoll Nord-Langset 4.5 kilometer double-track rail development that in addition to the Minnevika bridge includes a short tunnel and three short

bridges. A joint venture was established between Hæhre AS and PNC Norge AS to deliver the total project. Within the joint venture, PNC Norge acts as the main contractor for the Minnevika bridge.

The first author was employed as a trainee on the Minnevika project and supported the LPS facilitator both in the weekly work meetings and with preparing the LPS documentation. The first author was an participant-observer who followed the guidelines of Saunders et al. (2009) while conducting observations. Notes were taken from the observations of 9 weekly work meetings. The second author was an ordinary participant in these meetings, but not an observer. These two authors' participation led to an in-depth knowledge about the project but may also have led to a biased analysis despite attempts to avoid it.

Three semi-structured interviews were collected during the LPS implementation with two site managers and one project planner. The interview questions were structured after the three research questions.

Two more or less similar surveys were distributed in February 2019 and November 2020 with the same participants. The first survey was answered by 8 participants and the second by 9. Findings from the first survey are reported by Kassab et al. (2020). Collecting data with the two surveys conducted with an interval of one year allowed for a longitudinal study to be presented here.

FINDINGS

LPS IMPLEMENTATION ON THE MINNEVIKA BRIDGE PROJECT

The implemented LPS on the Minnevika bridge project consists of a Milestone plan, Look-ahead plans and the Weekly work plans. The contractor's site managers and supervisors established the Milestone plan at the beginning of the project. The milestones are tied to the major activities in the project. The Milestone plan represents the top of the plan hierarchy and decides the room for manoeuvre in the Look-ahead plan and the more detailed Weekly work plan.

With the Milestone plan as the starting point, the Look-ahead plans were established. The contractor used the milestone plan to map the bridge construction activities from the beginning to the end by pull planning principles. The mapping included an identification of all activities that had to be completed to reach each milestone. The necessary order, the duration and the critical path for these activities were identified. Then, a pull planning of the activities from their last date of completion was carried out. The respective first possible start date for the activities on the critical path gave the available time. Hopefully the available time is sufficient. The team used this backwards – or reverse – planning of the workflow to establish the Look-ahead plan from the milestone plan. Look-ahead plans on the Minnevika bridge project were for six weeks ahead and required representatives of the main contractor and the subcontractors to plan reliably and identify constraints.

The construction managers, site engineers, production team, HSE representatives, partners and subcontractors participated in the Weekly Work Plan (WWP) meetings. On the Minnevika bridge project, the term Production Evaluation and Planning (PEP) is used for the activities that correspond to the LAP and WWP described in literature. The agenda in the PEP meeting had standard headings: evaluation of the previous week, checking the Reason for Non-Completion (RNC) of trades (part of handover management between the trades, and the Minnevika project use the term Variance Analysis), Order and safety **(**analyse the safety issues on the construction site), Risk matrix (risks/constraints with corresponding probability and consequences), Action Plan (with responsibles and deadlines, to mitigate risks and promote opportunities), LAP, WWP, and Logistics.

The contractor measured the following Key Performance Indicators (KPI): Percent Plan Complete (PPC) overall, PPC per trade, Milestone Completion, Variance Analysis (or RNC), Top Three Variances, and Problem Solving. The indicators were tracked and used in order to increase productivity and learning from mistakes.

THE LPS ON MINNEVIKA COMPARED TO LPS IN LITERATURE

The Last Planner® System on the Minnevika bridge project consists of five components described as essential in literature, namely milestone planning, backwards planning, look-ahead planning, weekly work planning and measurements for learning. Even though the contractor only applied LPS in the execution phase and not in the design phase, the core components of LPS were in place.

Table 1: LPS components on the Minnevika bridge project

	Milestone plan	Phase planning	Look-ahead planning	Weekly work planning	Measurement & Learning
In place	✓	✓	✓	✓	✓

STRENGTHS AND WEAKNESSES OF LPS – EXPERIENCES FROM MINNEVIKA

To understand the productivity and efficiency of LPS on the Minnevika bridge project, it is vital to determine the benefits and drawbacks of the system from the participants' perspective who were involved in implementation of LPS. After analyzing the notes from the participant observations and the transcripts from the interviews with the project team, it seemed that the strengths overweighted the weaknesses. A majority of the project participants' experienced LPS for the first time, and they thought that if LPS were implemented on future projects with the same participants some of the weaknesses would fade away more or less by themselves. During the interviews, the strengths and weaknesses of the LPS execution as well as possible solutions for the shortcomings were examined. The results related to the milestone plan, lookahead plan, weekly work plan and KPIs are described in table 2-5 below, respectively. Each table is followed by a discussion.

Of those weaknesses identified – both for the Milestone, Look-ahead and Weekly work plan – many of them seemed to be the result of irregular attendance of participants in the meetings. An observation was that it often was the same participants that did attend and and the same that did not. Put in other words; some participants were not loyal to the plans, and their unloyalty spoilt potential benefits for all. The success of LPS demands that all – or at least most – of the participants act loyal.

A measure to overcome the challenges related to the Milestone plan in table 2 – that emerged during the observations and interviews – was to review the milestones periodically. A periodic review would remind the participants about the main milestones in the project and prevent that the short-term look-ahead planning occupied all attention.

Table 2: Strengths and weaknesses of the Milestone plan

Strengths	Weaknesses
• Higher level management uses it to track project progress • Suitable as report to the client • Gives a target plan on the entire project • Can be used when prioritising which activities can be delayed and which can be speeded up	• Does not include all activities on site • Can be forgotten since it is not in everyday use

Table 3: Strengths and weaknesses of the Look-ahead planning

Strengths	Weaknesses
• The involved parties cooperate on a reliable detailed plan for decisions, activities and resources with the critical path benefitting the project as a whole for. • Planning on whiteboard with colourful sticky notes helps visualize the process and improve understanding • Helps participants to reflect and plan clearly	• It sometimes creates a short-term focus • Since Look-ahead planning is time consuming it can lead participants to rush into the actual planning

Suggested measures to mitigate the challenges in table 3 related to Look-ahead planning at the Minnevika bridge project included to increase consciousness about how the six-week look-ahead plan fits the Milestone plan. The milestone plan should to a larger extent have been used as a reference for the continuous look-ahead planning, as the milestone plan was not always consulted when the look-ahead plan was updated to match progress on site. The result was that the updated look-ahead plan was not fully aligned with the milestone plan. However, since the updated look-ahead plans were not substantially changed, the missing alignment was not expected to cause future problems. Another suggested measure was to assign people to activities, and thereby increase consistency in who was responsible for the planning.

Table 4: Strengths and weaknesses of the Production evaluation and production planning (PEP)/Weekly work plan (WWP)

Strengths	Weaknesses
• A weekly meeting that helps the team coordinate both internally, with partners and with the subcontractors • One meeting substitutes separate meetings with individual subcontractors • Allow discussions on all issues with involved parties • Make the production team commit to the plan • Participation in planning motivates the foremen • Participants with different perspectives provide input to appropriate solutions	• Some supervisors did not attend the meetings • Time consuming (around two hours) • Parts of the meetings were irrelevant to some participants • Rotational working schedules distort continuous participation

It is not easy to ask experienced managers to adopt new ways of management, and that caused the weaknesses of the PEP meetings listed in table 4. The best way to convince these managers to spend the necessary time is by convincing them of the benefits of the system. During the observations, some benefits appeared. As one of site managers explained: *"The PEP meeting helps us to have one coordination meeting instead of having meetings one by one with all our partners and subcontractors separately. Now we get everyone in the same room and when a problem comes up, we have more people to contribute and look at it from different angles to make better solutions"*. Another measure that appeared during the observations and the

interviews is to put more efforts into establishing the PEP meeting schedule. The meeting schedule must be aligned with the relevant participants' presence on site, and not at least with which time of the day that works best for the participant's rotation, their tasks on site, and their meeting schedule.

Table 5: Strengths and weaknesses of the KPI

Strengths	Weaknesses
• Supports communication of lessons learned • Prevents repetition of mistakes • Comparison of progress compared to plan • Reveals reliability of the superior plan	• Hard to attract the participants' attention to the KPI • Participants usually do not analyse and track changes after PEP meetings

The KPIs were measured, but as identified in Table 5, the participants in the PEP meetings were not eagerly embracing the entailing opportunities. A suggested measure to overcome the weaknesses was to demonstrate how the measurements of Percent Plan Complete (PPC), Milestone Completion, Variance Analysis (Reasons for Non-Completion), and Top Three Variances could be used to improve the workflow for the participants.

MEASURING THE INVOLVED PARTIES' ATTITUDES DURING THE PROJECT

To measure changes in the participants' attitudes towards the LPS, two surveys were distributed to project participants with around one year interval. Both surveys contains questions based on challenges identified by Kassab et al. (2020), who reported the findings from the first survey. When distributing the surveys with one year interval, it was possible to observe how attitudes changed after the participants acquainted themselves with the LPS. The changes in average score (from 1= very low to 5= very high on a Likert Scale) from February 2019 to November 2020 are given in Table 6.

Table 6: To what extent do you think each of the following challenges is considered as a critical challenge on the Minnevika Bridge project during execution phase (average scores from 1-5)? (developed from Kassab et al. (2020))

Challenges	Feb 2019	Nov 2020
1. Maintaining people's commitment to be part of the process and take the system seriously	3.50	3.22
2. Lack of transparency in the interfaces between project team members	2.25	2.77
3. Resistance to the system	2.25	3.22
4. The language barriers	1.63	2.00
5. Non-participation of critical team members	2.85	3.22
6. The decisions and input are primarily provided by top-level management, such as site managers	3.00	2.88
7. Fear of responsibility (mainly from lower-level management)	3.00	2.22
8. Doubt (about overall performance and benefits behind the LPS)	1.63	2.77
9. Misunderstanding of the basic concepts of the LPS	2.00	2.22
10. The time commitment required to participate in the weekly meeting	1.75	2.77
11. Lack of engagement	1.63	2.00
12. Disruption	1.63	2.33

ATTITUDES HAVE CHANGED

When comparing the scores from February 2019 with the scores from November 2020, it appears that the scores have changed after a year. Three of the challenges originally identified by Kassab et al. (2020) are considered to have become less critical after a year. **Maintaining participants' commitment to be part of the process and to take the system seriously** was the main challenge during the first stage of LPS implementation and is still one of the three top challenges. It has become slightly less significant with time. Similarly, **the decisions and input are primarily provided by top-level management, such as site managers** and **Fear of responsibility (mainly from lower-level management)** have followed the same trend. One reason why these challenges are considered less critical after a year may be that the project team has gained more experience with LPS after one year, and that the participants see that LPS is practiced according to theory.

The comparison of the scores from the first survey with the scores from the second survey reveals – somewhat surprisingly – that nine out of twelve challenges are considered to have become more critical after a year. The nine challenges are **Lack of transparency in the interfaces between project team members**, **Resistance to the system**, **The language barriers**, **Non-participation of critical members**, **Doubt (about overall performance and benefits behind the LPS)**, **Misunderstanding of basic concepts of the LPS**, **The time commitment required to participate in the weekly meeting**, **The lack of engagement** and **Disruption**. These challenges are maybe considered more critical after a year, as the participants realise that the promised benefits of LPS are not manifesting as quickly as hoped for. In addition, the project team might have experienced that LPS's charm of novelty has faded during the year, and that implementation of LPS requires persistence. They need to put in resources to make LPS work, and the resources may outweigh the benefits for projects that implement LPS for the first time. The next project may not need that much resources to realise the benefits.

The suggested explanations for why three challenges have become less critical (more experience and LPS practiced according to theory) could have been used to explain a decrease in the nine remaining challenges as well. However, the nine other challenges increased. The other way around, the suggested explanations for why nine challenges have increased (promised benefits not manifesting, charm of novelty has faded out, implementation requires persistence and resources outweigh benefits) could have been used to explain an increase in the three. The exact reasons for why three challenges decreased, and nine challenges increased were not in-depth investigated.

CONCLUSIONS AND FUTURE WORK

This paper set out to answer three research questions, namely, 1) how is the Last Planner® System practiced on the Minnevika bridge project, 2) what are the strengths and weaknesses of the LPS process on the Minnevika bridge project from participants' perspectives and 3) how have the involved parties' attitudes towards challenges changed during the implementation of LPS. The answers to these three research questions are based on the findings from studying the implementation of LPS on one railway bridge construction project and are considered valid for other infrastructure projects that plan to implement LPS for the first time.

The answer to the first research question is that the contractor on the Minnevika bridge project has implemented five core components described by literature as essential, namely milestone planning, phase planning, look-ahead planning, weekly work planning and measurements for learning.

The participants recognise typical strengths of LPS and have experienced improved planning and control during the execution phase. Some project team members did not invest as much resources in following up LPS as others, but if they had done so the typical strengths could have been reinforced. Despite that some participants did not put sufficient efforts into LPS, the implementation resulted in improved coordination between the contractor and the partners, and between the contractor and the subcontractors. The participants believed that if they implemented LPS more faithfully on their next project, several of the experienced weaknesses would fade and strengths could probably even be boosted because of the training they acquired on the Minnevika project.

The answer to the third research question about how have the involved parties' attitudes towards challenges changed during the implementation of LPS, is that three observed challenges are considered to have become less critical while nine challenges are considered to have become more critical. Since the project team has gained experience with LPS and see that it works, the three challenges are less critical. Since the project team also sees that making LPS work demands continuous effort, the other nine challenges are considered more critical after a year. Successful implementation of LPS not only relies on the application of the full version of the tool, but also on changes in mindset and project team participation. LPS does not represent a quick fix.

The Minnevika bridge will open for traffic in August 2023. To collect more data and quality assure the conclusions in this study, it is recommended to carry out more interviews and distribute a third survey to measure the attitudes towards LPS right before the project is finished. The third survey should look for the exact reasons why some challenges decrease and some increase by time.

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PART THREE - APPENDICES

APPENDIX A – SPECIALIZATION PROJECT

ABSTRACT

Nowadays construction projects experience more complexity, uncertainty, and interfaces. By introducing the Last Planner® System (LPS), one of the most effective lean construction tools in reducing variability and improving reliability, many construction companies around the world have adopted this method of management. PNC is one of these companies that has implemented LPS, on their Minnevika bridge project in Norway. The following report examines the LPS on the Minnevika bridge project while considering the three research questions.

1. What measures have PNC used to practice LPS?
2. How do the different involved parties' value/experience the process?
3. How can PNC improve the practice of LPS?

It should be noted that, the third research question due to the limitations will be studied further in the next semester.

The different methods of obtaining information are described in chapter 2, research method. It is noteworthy to mention that, besides the literature review which is the main part of this report, three interviews and one survey have been conducted during this semester in order to achieve more accurate results. Chapter 3, literature studies, describes the findings from related papers regarding lean concepts, lean thinking, lean in construction, lean construction tools, introducing Last Planner® System, Last planners, LPS stages, and benefits and barriers of LPS.

The findings chapter shows the results from the different research methods, i.e., interviews, survey and document studies that have been used in answering the research questions. The obtained information is categorized as LPS implementation on the Minnevika bridge project, investigation of involved parties' experience about LPS, strengths and weaknesses of the different stages of LPS on the Minnevika and finding possible solutions to overcome the challenges. The majority of this part will be examined later in the next semester.

In the conclusion part, an attempt has been made to explain an overview of the achieved results in terms of answering the research questions.

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1. INTRODUCTION

1.1. BACKGROUND

A project is a set of activities performed to achieve a specific purpose or goal or in another definition based on Ansah et al., (2016) "Projects have been considered as temporary based production systems which need to be designed, produced, and delivered within a specified time". It is generally accepted that the management of projects must attempt to achieve the goals of projects that were defined before the start of the project. In order to be able to complete projects on time, it is necessary to deploy the tools, skills, techniques and available resources. Productive and efficient project management is a great tool in meeting and exceeding the expectations of the customer. The optimal use of available resources; be it time, money, human, space, and endeavour for a successful completion of a project within budget and on time are some of the features of an effective project management.

However, according to Ansah et al., (2016), there have been observations and evidence that have indicated that, the models behind construction management and project management tools like; critical path method; work break down; and earned value management; have failed to complete project within budget on time and the quality desired for the project. It has been asserted by several researchers that fast, complex and uncertain projects that are features of construction projects cannot be managed by controversial methods and that fast-track projects with long, intricate supply chains involving many performers and tasks, extensive process design changes have complicated flow management that have failed miserably (Ballard and Howell, 1994). These existing failures in the current management method become reasons and requirements for defining the new approach. This approach has been adapted to the construction industry by Koskela (1992), being called lean construction. The construction industry has a direct impact on the economy, society, and the environment, so appropriate policies and decisions will be an effective step towards achieving sustainable development standards. Since this industry plays an important role in the growth and development of a nation; reducing waste along with more efficiency in less time would lead to significant cost savings for the industry as well as the society. A key part of lean construction is defined using tools. Several tools have been developed over the past decade to manage construction projects and among them, the Last Planner® system (LPS), which is known as the most famous tool that has been used for the management of the construction process and the continuous monitoring of planning efficiency.

According to Kalsaas et al,(2009), several of largest construction companies in Norway show their interest in apply lean construction methods in their operations. PNC is one of these construction companies that has adopted LPS, on their Minnevika bridge project. In this report, an attempt has been made to evaluate the use and practice of LPS on the Minnevika bridge project by PNC, one of the largest bridge construction companies in Norway. The strengths and weaknesses of LPS execution on the Minnevika project and possible solutions for the arising challenges beside the investigation of involved parties' experience are studied in the report.

1.2. KNOWLEDGE GAP

Since Last Planner® System has been introduced for about 30 years, most of its technical part have been discussed in different papers during these years. Based on comprehensive literature review, few studies have been conducted about the practice of Last Planner® System and its evaluation in an infrastructure project, while the most papers have been studied about practical issues of LPS. In addition, the main focus of the reviewed papers is to identify challenges in the implementation of LPS and LPS improvements. However, in this research, an attempt has been made to evaluate the individual and behavioural aspects of people participating in LPS including the experience of individuals, how they deal with this method and their perspectives. To address the identified research gap, the following research questions were formulated.

4. What measures have PNC used to practice LPS?
5. How do the different involved parties' value/experience the process?
6. How can PNC improve the practice of LPS?

1.3. LIMITATIONS

Some cases were identified as limitations during the course of the report. First of all, the research is based on single case study named the Minnevika bridge project. Therefore, conclusive cases are related to this project and it may not be possible to generalize them. Secondly, due to the time limitation in this semester, studies and in particular the issues to be considered in relation to the research question No. 2 as well as the interviews, are limited to a specific group of participants and involved parties. In addition, the number of respondents of the survey was less than the author expected, due to some issues,i.e., Covid-19, the busy work program of the project team, and their rotational work schedule. Finally, as mentioned before, the most extent of the third research question will be studied during the next semester due to the time limitation.

It should be noted that, the possibility of physical presence on the project due to the outbreak of Covid-19 was quite challenging, but thanks to Mr Brendan Young, the site manager of PNC, who created this opportunity for the author.

2. RESEARCH METHOD

The research questions were addressed by performing a thorough literature review, document study, case study (Minnevika Bridge project), observations (over skype) and interviews. At the end, the results of these methods are used to answer the research questions.

Using a combination of a literature study and document study gave a theoretical insight into Last Planner® System. With the theoretical background in place, interviews were performed to gain practical insight. The combination of theoretical and practical insight helped to analyse how Last Planner® System improved the planning on the Minnevika project.

2.1. LITERATURE REVIEW

A literature study was conducted in over two months (Aug & Sep 2019) and constitutes an important part of this research. It is a great method for obtaining necessary qualitative information. The findings from literature review and comparing them with a case study not only formed the knowledge gap section but also could be a great function in defining the meaning and the concept of lean construction and the Last Planner® System. The purpose of the literature review is to obtain the required information about Lean construction and Last Planner® System, which will be categorized and mentioned later in this section. Lots of the papers have been reviewed and studied in order to reach an understanding of the Lean and the theory behind it, Lean thinking & production, the origin and the emergence of Lean construction, reasons of choosing Lean construction over traditional management, introducing Last Planner® System as one of the Lean construction tools, underlying Last Planner® System principles ,and Last Planner® System benefits & challenges.

A combination of both journal articles and conference papers was used to get a broad perspective of the current views of the topics. The reliable resources in order to access relevant literature include Google scholar, ResearchGate, International Group for Lean construction (IGLC) papers.

After consulting with Professor Ola lædre & Brendan Young (site manager of the Minnevika bridge project), the references of Omar Kassab's thesis, the previous student who studied the LPS (Kassab,O., 2020, Master's thesis), were used as a point of departure to get acquainted with the concept of Lean construction and Last Planner® System. Since LPS has been introduced from 1900s, lots of papers have been presented until now. Therefore, finding the most appropriate and relevant literatures is quite challenging and time consuming.

The literature review is divided into two main categories. The focus and purpose of the first part is to understand the concept of Lean and the theory behind it, Lean thinking & production, Lean construction, and Lean construction tools.

The papers of this section can be used as a starting point for answering part of the first research question and introductory part of the report. The important keywords used in this section were "Lean construction " with more than 1 million hits on Google scholar. "Lean construction foundations " was more specific with 290.000 related papers on Google scholar that helped the author to find the papers related to Lean definitions and its theory, "Howell & Ballard & Lean " was another search with about 6,430 results that were more accurate due to the names of the inventors and developers of Lean construction. "Kosekela & Lean construction " another prominent researcher in the Lean presented about 9000 hits on Google scholar. By considering the systematic literature review, research questions, and evaluation of the related papers, the author has attempted to narrow down the scope of the research as much as possible.

After the final review, twenty papers were selected for this section at the first stage, which was later reduced to the eleven papers according to the evaluation factors that presented in the project management advance course (TBA 4128). The following are two examples of the papers.

3. Koskela, Lauri & Ballard, Glenn & Howell, Gregory & Tommelein, Iris. (2002). The foundations of lean construction. Design and Construction: Building in Value.

4. Howell, Gregory & Ballard, Glenn. (1998). Implementing Lean Construction: Understanding and Action.

The second part is concentrating on the definition of Last Planner® System, Implementation and principles of Last Planner® System, LPS stages, and the benefits and barriers of LPS . The papers related to this section could be efficient in responding to question No. 1 & 3 by introducing LPS as the most important Lean construction tools that has been adopted on the Minnevika bridge project. The most important search terms used were "Lean construction tools & Last Planner System" with about 33.500 results could give the general information about LPS definitions and principles. "Practice & LPS & Construction" was second keyword for finding the papers to follow up the practice of LPS on real project as a case study. "Implementing LPS & Infrastructure " another term that represented lack of LPS research in infrastructure projects. About 130.000 results and the papers with low number of citations are proof of this claim.

Eighteen papers were selected for this part at the final stage, which was diminished to the eleven papers by the method of evaluation that previously explained. The following are two examples of these papers.

3. AlSehaimi, A.O., Fazenda, P.T. and Koskela, L., 2014. Improving construction management practice with the Last Planner System: a case study. Engineering, Construction and Architectural Management.

4. Salem, O., Solomon, J., Genaidy, A. and Luegring, M., 2005. Site implementation and assessment of lean construction techniques. Lean construction journal, 2(2), pp.1-21.

(The list of the related papers used in the report is provided in the reference section)

2.2. CASE STUDY

The Minnevika bridge project is the chosen case study.It will be the longest railway bridge in Norway once built at 836 metres long. The Minnevika railway bridge is located in Minnesund, an hour's drive from Oslo. The 836m long concrete bridge will be standing on 288 pcs Ø1016/20 mm steel tube friction piles in installation lengths up to 58 meters, and foundations consisting of 2 abutments and 18 piers, four of which will be installed offshore. The Minnevika project is part of Norwegian railway operator Bane Nor's Eidsvoll double-track rail development that includes the construction of a 4.5 km double-track section, with a short tunnel, three shorth bridges and the 836-meter Minnevika railway bridge.

The Norwegian railway infrastructure manager, Bane Nor, has awarded the Hæhre – PNC ANS joint venture a NOK 2.2 billion contract for the construction of a double-track section between Eidsvoll North to Langset, on the InterCity main line, in eastern Norway. PNC, a tunnelling, and bridge construction company with the motto "innovative constructions connect people" is the main contractor responsible for the construction of the Minnevika bridge. PNC Norge consists of headquarters in Oslo and several projects in Norway. In addition, PNC (PORR Nordic Construction) is part of the main organization named PORR, which is a well-known

Austrian construction company headquartered in Vienna. The Minnevika bridge project is the first project of PNC where the Last Planner® System has been adopted as a managing method in order to control the overall work process and workflow of the project. This pilot project in regards with the results from implementation of LPS, could be a departure point for PNC to adopt LPS as planning method in future projects.

2.3. OBSERVATION

After consulting with Mr Ola Lædre and get acquainted with Last Planner® System and the Minnevika bridge project, Mr Brendan Young, the site manager of the project, offered non-participant observations in the weekly Production Evaluation and Planning (PEP)-meetings over the Skype. The PEP meetings were held every Thursday from 8.00 am to 10.00 am in the big room and the project team get together to discuss about the work process, collaborate, look ahead planning, and other aspects of LPS on the Minnevika bridge project that are explained in the following.

It was a great opportunity for the author to learn about the implementation of the Last Planner® System on the Minnevika bridge project. The key points and important aspects that were considered during the non-participant observations include,1. Familiarity with the implementation process of LPS on the Minnevika project. 2. It was a great chance to look at the meetings from outside and concentrate more on behaviours and reactions of the participants.3. Familiarity with project team members and observing their interactions, attitudes, and level of cooperation during the meetings.4. Tracking the process of the project. However, physical presence on the project for observation was not possible due to limitations such as prevalence of Covid-19,distance obstacles and lack of time in this semester ,but the author was able to attend the project once before the Christmas 2021 to do the interviews and the survey. The other related issues contain; 1. Low quality of sound and video in some cases due to internet connections problem 2. Impossibility of follow- up in some cases (look ahead planning & some boards on the wall) due to movements of the project members in the room and fixed host laptop camera. Therefore, not every step of the process and the project members could be observed.

2.4. DOCUMENT STUDY

The document study is written materials that contain information about the phenomena the researcher is interested in studying. The results of examining the document studies are used later in the Findings chapter. The related document studies of the Minnevika bridge project consist of milestone & phase planning, look ahead planning, action plan, risk matrix and KPI measurement such as PPC, variance analyses, order and safety. These documents were sent every Friday (the day after the PEP meeting) by Eveline Schnell, the LPS facilitator of the project, to the project team members' emails.

The main purpose of the document study is to get acquainted with the process of LPS on the Minnevika bridge project. The other information that can be obtained from these documents, including defining the upcoming tasks, identifying the different risks on the project and estimating the percentage of project progress. One of the basic advantages of the document

study is that it allows familiarity and reviews of the process of LPS on the Minnevika bridge project to the author that does not have easy physical access due to outbreak of Covid-19, time and distance limitations. However, at the beginning, reviewing, and examining the document studies was very confusing and ambiguous, but this issue was gradually solved by attending the weekly PEP meetings over the Skype and obtaining more information about the LPS process on the Minnevika bridge project.

2.5. INTERVIEWS

An interview is typically a qualitative research method that involves asking open-ended questions to collect data about the subject and converse with respondents. It is a great technique for obtaining in-depth information about the behaviour, attributes, opinions, attitudes, and experiences of interviewees who are experts in their operation fields. Thanks to Professor Ola Lædre and Mr Brendan Young who facilitated the process and provided the condition for face-to-face interviews. Undoubtedly, attending the project and conducting face-to-face interviews had a great impact on obtaining the better results and more accurate answers. In total, the three interviews were conducted on 18th and 19th of Nov 2019 during the autumn semester. The names and the positions of interviewees are listed in the table below.

Table 2.1.The interviews 1

Interview no.	***Name of Interviewee***	***Position on the project***
1	Jaroslaw Pomorski	Planner/ Planlegger / Technical Support
2	Brendan Young	Site Manager/ Anleggsleder
3	Maciej Kupper	Site Manager/ Anleggsleder

The interview questions were arranged as semi-structured and open-ended interviews that were a great help for the author to obtain the most accurate and detailed qualitative information. This semi-structured interview offers a considerable amount of flexibility to the author to probe the respondents along with maintaining basic interview structure. In addition, this structure could make a great chance for the author to express the interview questions in the format he preferred to get extra information. However, finding a proper time for the interview due to the outbreak of Covid-19, distance limitation, and tightly schedule of the interviewees, who are the key members of the project team, was quite challenging.

The interview questions consist of three sub-questions for each part of LPS implementation on the Minnevika bridge project in order to get information about the process of LPS on this project and to answer the first and the third research questions. The lists of the questions and the results of the interviews are included in the Appendix and Findings chapters, respectively.

2.6. SURVEY

A survey is one of the research methods used in this report for collecting data from predefined group of respondents to gain information and insights into various aspects of research questions no. 2 & 3. The survey included 45 questions, both close-ended and open-ended, in order to obtain accurate qualitative and quantitative information. The survey consisted of three parts (general, implementation and challenges) and the author has built upon the Omar's questionnaire (Kassab,O., 2020, Master's thesis) for the first and third sections as way to measure the developments and attitudes changes towards the LPS during the project.

The survey was conducted on 19th of Nov 2019 during the PEP meeting in the forms of hard copy with 9 participants. The Likert scale method, that can be utilised to measure attitudes and behaviours (Albaum 1997), was chosen for close-ended questions in order to achieve more precise quantitative data, present the results as graphs, analyse the answers, and compare the results with Omar's survey to measure development.

The scale range used was 1= very low, 2 = low, 3 = undecided, 4 = high and 5 = very high. The total score was calculated for each question that depended on Likert scale method and was divided by the number of respondents from the survey. The final result was the average scale.

The advantages of the survey included improved accuracy, because of the higher number of respondents compare to interviews, it is quick and easy to analyse, makes for an easier comparison to attain more accurate conclusion, and potentially more reliable answers due the survey's anonymity. However, achieving more precise results require more participants and convincing them to take their time, which is not very easy. All the details, questions and responds related to the survey were described in the appendix and finding chapters.

3. LITERATURE REVIEW

3.1. LEAN CONSTRUCTION

In this section, the information obtained from the literatures in regard to Lean, lean thinking & production, lean construction and its background is studied.

3.1.1. LEAN & LEAN PRODUCTION

Lean is a way to design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value (Koskela et al., 2002). In another definition Hamzeh (2011) said "Lean is a business philosophy and a system for organizing and managing corporate processes including product development, design, production, operations, supply chain, and customer relationships to increase value and minimize waste. Lean is a perpetual quest for perfection pertinent to organizational purpose, business processes, and developing people". Therefore, it is clear that increasing value and minimizing waste were the main focuses of Lean since its inception. These outstanding features of Lean led to its introduction to the industry by Mr Taiichi Ohno for the first time in the Toyota. Mr Taiichi

Ohno was a Japanese industrial engineer who inspired the Lean Manufacturing in the U.S. Engineer Ohno shifted attention to the entire production system from the narrow focus of craft production on worker productivity and mass production on machine(Howell 1999).Toyota in order to cope with capital constraints and low production volumes after world war II introduced Toyota production system (TPS) that can be seen as synonym to Lean production . TPS is described as a production which "uses less of everything compared with mass production, half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a product in half the time" (Holweg 2007). As Howell(1999) explained, the main concentrate of the lean production is to optimize performance of the production system against a standard of perfection to meet unique customer needs. It is a way to design and make things differentiated from mass and craft forms of production by objectives and techniques applied in design and along supply chains.

3.1.2. LEAN THINKING

The origin of lean thinking takes its roots from the Japanese auto industry as lean manufacturing (TPS) that was described in the section 3.1.1. and is still used widely today to guide modern Lean manufacturing practices. Lean thinking forces attention on how value is generated rather than how anyone activity is managed (Howell and Ballard 1998). In another definition, lean thinking is a concept to describe the process of making value or business in a lean way. Ballard and Howell (1998) stated that lean thinking considers the project as a production system. Where current project management views a project as the combination of activities, lean thinking views the entire project in production system terms, that is, as if the project were one large operation. James P. Womack and Daniel T. Jones (1997), founders of the Lean Enterprise Institute (LEI), laid out the five key principles of lean thinking as follows (Womack and Jones 1997).

1.Define value: It is important to define customers' needs and understand what value means for them. Value is defined by Womack & Jones as "capability provided to customer at the right time at an appropriate price, as defined in each case by the customer".

2.Value stream: Identifying all the process and steps that transforms raw materials to working products. Womack & Jones described value stream as set of all "specific activities required to design, order, and provide a specific product, from concept to launch, order to delivery, and raw materials into the hands of the customer".

3.Flow: According to Womack & Jones (1997), It defines as "progressive achievement of tasks along the value stream so that a product proceeds from design to launch, order to delivery and raw materials into the hands of the customer with no stoppages, scrap or backflows" or establishing a smooth flow that work is not impeded.

4. Pull: It creates desirable setting for customers to pull products when they need to. Womack & Jones (1997) said "the system of cascading production and delivery instructions from downstream to upstream in which nothing is produced by the upstream supplier until the downstream customer signals a need".

5.Perfection: The pursuit for the perfect product is never-ending process. Therefore, it is needed a to have a system to encourage everyone to improve the process. This means that Lean

Thinking must be embedded in the company's culture. The goals of lean thinking according to Howell and Ballard (1998) is to redefine performance against three dimensions of perfection: (1) a uniquely custom product, (2) delivered instantly, with (3) nothing in stores. This leads to increase value and decrease waste.

3.1.3. TRADITIONAL MANAGEMENT

Traditional management by scheduling and controlling activities, endeavours to utilize output measures. From the first moments, construction projects are managed by breaking them into pieces or activities, estimating the time and money to complete each, applying the critical-path method (CPM) to identify a logical order, and then either contracting externally or assigning internally to establish responsibility (Koskela et al., 2002). As Salem et al., (2006) stated the main feature of the traditional construction management is in "Planning distribute and combine the available resources during a specific time for each of the project tasks, optimizing cost and keeping a right level of quality". Despite these aspects of construction management, The US Bureau of Labour Statistics reported that the construction industry is facing a severe decrease in labour productivity. But why does this approach, which sounds reasonable, so often fail in practice? Current research shows that complexity, variability, and uncertainty are the major causes of this decrease in the productivity (Porwal et al., 2010).

Construction projects nowadays are so complex, uncertain, and quick. There is always pressure for shorter duration that adds to the burden. Complexity and uncertainty arise from multiple contending and changing demands of clients, the marketplace and technology. It is a dynamic environment that activities are not often linked together in simple sequential chains. Alternatively, work within and between tasks is connected to others assignment by means of shared resources or depends on work underway in others (Koskela et al., 2002). This traditional method of management ignores the workflow and misses the creation and delivery of the value. As Ballard et al., (2002) presented, "In traditional project management, it is assumed that variability is independent of management action and consequently that the trade-off between time and cost is fixed, the only discretion for decision making is in finding the exact point where the trade-off can best be made". Therefore, uncertainty and variability are the main struggles that project managers who rely on these kinds of schedules might encounter, but the managers rarely see the problem arising from their reliance on the project level planning and control activities (Koskela et al., 2002).

The failures of traditional project management help to define the requirements for a new approach. There is a mismatch between the conceptual models of traditional management and the reality. Therefore, the need for a new management method is quite clear in order to optimize performance, increase productivity, create value, and flow at projects.

3.1.4. LEAN IN CONSTRUCTION

As explained in the section 3.1.3, the traditional project management in construction industry suffers from some deficiencies and there is lack of a new approach to solve these issues. In addition, by introducing lean to the industry as a successful and effective method in achieving the objectives, minimizing the waste, and creating the value, now is the time to introduce this way of management to other industries, including construction. But how can this method that

is tailored to the structure of the manufacturing industry, be adapted to the construction industry?

In the long term, both construction and manufacturing strive to add value to their products via high returns on investment; however, each employs different means to achieve this objective.

On the one hand, there are significant differences between manufacturing and construction industry. Physical features of end product are one of these differences. While in manufacturing finished goods can be moved as a whole to end customers, deals cannot be transported in construction. In manufacturing, the lifecycle of a product on the market is long enough to develop related research and training capabilities, whereas a product's lifecycle is the relatively short project duration with more difficulty to justify research and training in construction (Salem et al., 2006). The way of realising work is another differentiation. Work is released, moves down the line, in manufacturing based on the design of the factory. However, in construction work is released by an administrative act, planning. In this sense, construction is directive driven in contrast to manufacturing which is routing driven. In addition, the construction industry has features that distinguish it from manufacturing: on-site production, one-of-a-kind projects, and complexity that can be hardly managed compared to manufacturing industry (Howell and Ballard 1998).

On the other hand, Lean manufacturing and lean construction techniques share many common elements despite the obvious differences in their assembly environments and processes (Salem et al., 2006). As Howell (1999) explained "Waste in construction and manufacturing arises from the same activity-cantered thinking".

After introducing the Japanese techniques that were part of new production system (known as Lean production), the scope of the technique was not limited to the manufacturing. Having the characteristics of both "production" and "service" systems, the construction industry has also taken some steps toward applying the lean production concept (Salem et al., 2006). According to Howell and Ballard (1998), lean thinking views the entire project in production system. Howell & Ballard as pioneers of lean construction after exploring the underlying nature and implications of lean thinking, described it: "Lean thinking is a new way to manage construction. Many people object on first exposure because lean thinking appears to be the application of a manufacturing technique to construction. One response to the arguments that "construction is different" is to make construction more like manufacturing through greater standardization. It can even be argued that manufacturing is a special case of construction because it alone is characterized by multiple copies of the same product. Both construction and manufacturing require prototyping, that is the design of both product and delivery process."

In addition, it is noteworthy to mention that Lean is as much a philosophy and culture as a set of principles or methodologies that could be addressed in any industry. Therefore, the principles of lean are equally applicable without considering the differentiation between construction and manufacturing industry (Ansah et al., 2016). Despite these explanations, the extension of manufacturing techniques to construction industry is still an open question. Although, it is important to determine set of tools in order to achieve higher performance outcomes in construction industry.

3.1.5. LEAN CONSTRUCTION TOOLS

As explained in the section 3.1.4, Lean construction was born out of the success of the lean philosophy that developed in the manufacturing industry. This management approach has been adapted to the construction industry by Koskela (1992) in 1990s and since that time, lean construction has emerged as a new concept, both in construction management and practical sphere of construction(Ansah et al., 2016).

According to Koskela et al. (2002) Lean construction can be described as "an approach to design the system of production to reduce waste of time, materials, and effort with a specific end goal to generate the most conceivable amount of value". Lean construction is a project management methodology that is based on the principles of lean thinking and lean production in industry. Therefore, Lean Construction shares same objectives as lean production; reduction of cycle time, continuous improvements, pull production control, waste elimination, reduction of variability, continuous flow (Ansah et al., 2016). The application of production control throughout the life of the product from design to delivery, aimed at maximizing performance for the customer at the project level, simultaneous product and process design, and a clear set of objectives for the delivery process are the key features of managing construction under lean (Howell 1999).

There is no doubt that lean construction is the way forward for construction industries around the world. Several lean production techniques and tools have been introduced over the past decade to manage construction projects. These tools can be described as procedural, conceptual, and embedded in programming. The tools include but are not limited to: Last Planner® System, Visual Management, 5S Process, Value Stream Mapping, First Run Studies, Daily Huddle Meetings, Plan-Do-Check-Act, Fail Safe for Quality and Safety, A3 Reports, Target Value Design and Concurrent Engineering. Whereas some of these tools are simple to adopt, complexities revolve around the others, i.e., Last Planner® System (LPS) (Sorooshian et al., 2016).Sorooshian et al.(2016) also indicated that "Danish contractors had increased productivity by 20%, minimized project duration by 10%, expanded efficiency by 20%, and enhanced profitability 20% - 40% on projects where lean principles are adopted" .

3.2. LAST PLANNER SYSTEM

3.2.1. INTRODUCTION TO LAST PLANNER® SYSTEM

The Last Planner® System was introduced by Ballard (1993) to members of first meeting of the International Group for Lean Construction named IGLC-1. Ballard mentioned the Last Planner® System term for the first time in the paper that was published as Improving EPC Performance (Ballard 1993). The principles of the LPS were developed at IGLC- 2 in 1994 (Ballard, 1994), and further elaborated at IGLC-5 in 1997 (Ballard, 1997) and made ready to introduce (Zaeri et al., 2016). The Last Planner® system has emerged as one of the most important lean construction tools since its inception. It is one of the first steps taken by the construction organization that embarks their lean journey in order to tackle the challenges of production management on construction sites(Koskela et al., 2015).This cascade planning technique has taken its roots from lean thinking with the principles of supporting management through the reduction of performance variabilities, continuous monitoring the production,

enhanced reliability, and improvement of project performance in order to allow better control and planning(Zaeri et al., 2016).

According to Hamzeh (2011) and Ballard et al.(2007), LPS has five key principles which are listed below,

6. Planning in greater detail as time gets closer to executing the work
7. Developing the work plan with those who are going to perform the work
8. Identifying and removing work constraints ahead of time as a team to make work ready and increase reliability of work plans
9. Making reliable promises and driving work execution based on coordination and active negotiation with trade partners and project participants
10. Learning from planning failures by finding the root causes and taking preventive actions

The LPS has been implemented in a large number of projects in several countries since its inception. Many reports and research papers have confirmed these successes in the construction industry and LPS became gradually a powerful tool for the management and planning of construction. In the following, some benefits of LPS are well documented by Koskela et al. (2015).

- Tackling variability, ensuring task availability, and compressing duration
- Smooth production flow
- Improving flow, making waste visible and continuous improvement
- Building collaboration and trust amongst project participants
- Supply chain integration

One of the primary benefits of LPS is the collaborative planning process that involves last planners for planning in greater detail in order to successful implementation of project plans. But who are the last planner?

3.2.2. LAST PLANNER

Construction consists of different tasks that require planning by different people,in different work posts of the organization. Eventually, somebody decides what specific job will be done (assignment) and by whom the following day. “Ballard and Howell (1994) called this person or group the “last planner”; usually these persons or organizations are: site supervisors, foremen, subcontractor, supplier, etc” (Pellicer et al., 2015). In the same definition, Koskela et al. (2014) described last planner as “the person or group accountable for production unit control, that is, the completion of individual assignments at the operational level”.

3.2.3. LPS VS TRADITIONAL PROJECT MANAGEMENT

Traditional project management was described in the section 3.1.4. The main difference is that planning, and control are separated in traditional construction project management, while these can be seen as an integrated process in the LPS of construction management. This feature makes the plan more predictable and reliable that leads to reduction in lead time in the

construction phase (Daniel et al., 2017). The following table shows the principles differences between LPS and traditional project management.

Table 3.1.Comparison of Principles of LPS and Traditional Project Management. (Kalsaas et al., 2014).

LPS	*Traditional*
Non-deductive: Decentralised decisions to remove constraints and realize the plan. Continuous control.	Deductive: Centralised master plan without systematic focus on removing constraints. Control afterwards
Horizontal involvement	Limited involvement. Expert planning
Vertical involvement	Limited involvement. Expert planning
Continuous improvement through continuous learning, measuring of PPC, casual analysis and sharing of experience	Monthly reports, e.g., on earned value. Lesson learned after completion of projects
Pull based project control through reversed scheduling and removal of constraints towards construction	Centralized critical path method in planning and pushing the work towards downstream activities
Simple and manual planning technique	Computer based expert planning

Identifying the more fundamental differences between lean production and traditional management is beyond the scope of this report.

3.2.4. LPS STAGES

The Last Planner® System is a holistic system that means each of its parts is necessary to support lean planning and execution. According to Daniel et al. (2017), The LPS integrated components include, master planning, phase planning, make-ready process, weekly work planning, and learning

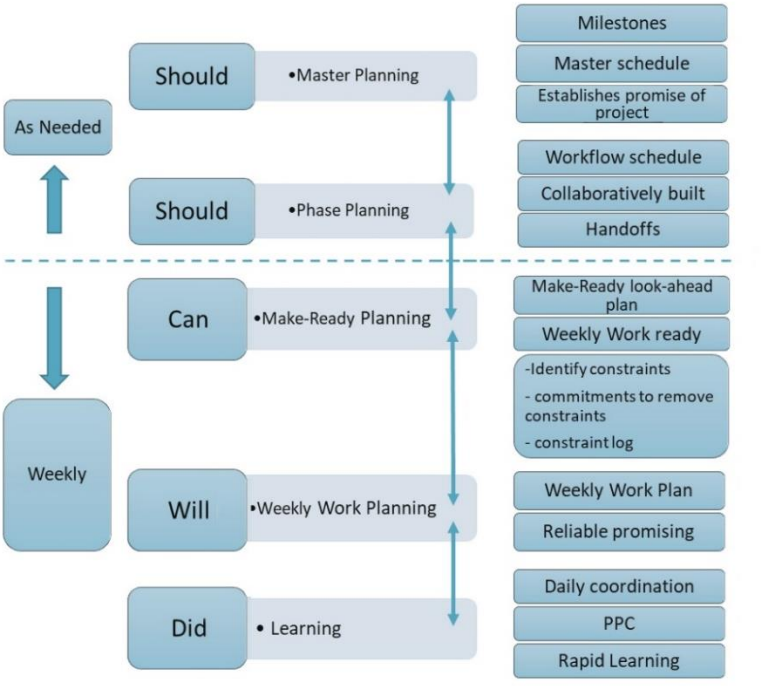

Figure 3.1. Summary of Last Planner® System of production control (Ballard and Tommelein 2016).

3.2.4.1. MASTER PLAN

As an output of the "pull session" meeting that last planners participate; a master plan is provided with the commitment of all parties. The master plan or milestone planning captures the entire task to be implemented throughout the project and at the same time shows the required time for each task to be completed. It identifies the project milestones and initiates the means for achieving them (Daniel et al., 2017).

Pull session is the key stage of this phase because a committed group of decision-makers and those who work behind the plan, define milestones and perform planning as a team. They have face to face discussions of every important task to make a backward plan and creating a schedule buffer that is allocated to critical and risky tasks in the plan which forcing the participants to think out of the box (Pellicer et al., 2015). The initial output is a logic network showing the temporal dependence of tasks to be performed in the phase, process, or operation being planned. A schedule can be produced by estimating task durations (Ballard and Tommelein 2016).

The pull session must be driven by an external facilitator, beside the involving the site manager and the site superintendents in the session, but they do not lead it. The participants must have to be invited formally. The expectations of meeting are: (1) identify tasks, including time and resources needed; and (2) identify constraints to perform those tasks .There are some physical provisions requirements in order to have a successful pull session, 1) A wide room with a proper arrangement of the tables to accommodate the participants; (2) A big blackboard to display the different tasks; (3) Sheets of colour paper (post-it or similar) to stick it to the blackboard; (4) Colour markers; and (5) A camera (Pellicer et al., 2015).

In addition, the pull session generally follows these steps (Pellicer et al., 2015):

9. The facilitator writes down the end date of the project (as a milestone) in the right side of the Board.
10. The facilitator asks what is the last task that it should be carried out in order to reach that milestone (end date).
11. The last planner responsible for this task writes down the needed information in the different colour post-it which contains the information about organization, task, time scheduled, human resources needed, and constraints. Then, facilitator sticks it on the board on the left side of the milestone. Different colour can be used to modify every contribution.
12. This process should be done for each task; Overlapping has to be considered too.
13. The construction site manager and the superintendent must monitor the logic of the construction and ask questions to the other participants, if needed, to check time and resources.
14. When there are no more tasks that precede the last one stick on the board, the schedule is over.
15. The facilitator, with the help of the site manager and the site supervisor, reviews all the tasks to ensure that everyone agrees and are committed to this schedule.
16. The site manager introduces the schedule and distributes it to every stakeholder involved.

3.2.4.2. PHASE PLANNING

It is a process used in developing a reliable construction programme from the master plan by direct involvement of the subcontractors, contractors, suppliers, designers, and other stakeholders on the project including the client. The project's workflow is determined and the participants together to form a more concrete schedule for the project. That is the reason, why this process is also called Collaborative programming (Daniel et al., 2017).

Collaborative planning: As Howell and Ballard (1998) explained "Collaborative planning refers to the act of bringing all subcontractors to the same meeting and planning in a true collaborative fashion at each stage, i.e. phase, lookahead and weekly aspects". This is one of the main focus of LPS that involves the last planners and who are responsible for planning in greater details in order to have effective program for executing. Another aspect is that collaborative planning is another name of LPS in Norway. LPS has been implemented under different names and in Norway, construction practitioners call the LPS names such as "collaborative planning (CP)", and "collaborative project execution" among others (Daniel et al., 2017), (Kalsaas et al., 2014).

3.2.4.3. LOOK-AHEAD PLANNING

The look-ahead planning is a medium-term plan for project activities. This plan identifies the constraints and introduces a path to avoid or eliminate bottlenecks. Look-ahead plan forecasts six weeks in advance approximately and looks forward to increase the construction flow. Within the master plan, the look-ahead plan is produced by the construction site manager assisted by the last planners if needed (Pellicer et al., 2015). One of the differences between LPS and traditional management is look- ahead planning where Daniel et al (2017) mentioned that "in the traditional way of managing projects, the look-ahead plan (master programme) only provides advance notice of the start date of an activity and does not consider the complex network of flows, their sequence, matching work flow with capacity, or maintaining a backlog of workable activities".

According to Ballard et al (2002), the functions of lookahead planning including;

- Shape workflow sequence and rate
- Match workflow and capacity
- Maintain a backlog of ready work (workable backlog is explained in following)
- Develop detailed plans for how work is to be done.

The lookahead windows may be shorter or longer than six weeks, depending on the rapidity of the project and the lead times for information, materials and services. On the one hand, the extending lookahead window can offer the possibility of better control over workflow. On the other hand, the ability of controlling workflow on site can be affected by pulling too far in advance. In consequence, period of the lookahead window is a matter of local conditions and judgment (Ballard et al., 2002).

3.2.4.4. MAKE READY PROCESS

The works that break down into detailed tasks need to be considered as make-ready process in order to match the available resources for execution based on realities on construction site. Therefore, the make-ready process is used to eradicate the constraints or blockers to planned activities identified in the look-ahead planning before they are passed into production on site (Daniel et al., 2017).

3.2.4.5. WEEKLY WORK PLAN

The weekly work plan is scheduled every seven days named as the weekly meeting with the involvement of participants such as last planners. The plan which, is produced during the meeting, established the detailed assignments that should be done during the following week through promises of the last planners. WWP is done to review the task planned in the previous week in order to plan for the week ahead collaboratively with the team. At this point, only tasks that meet the four criteria of production are entered onto the WWP (Daniel et al., 2017). These criteria including (Ballard and Tommelein 2016);

Well-defined: One of these requirements is tasks should be defined so that performer can understand what should be done, where, when and by whom. In addition, it can determine the necessary resources, what is needed by way of materials, information, tools, and equipment to perform the task.

Sequence: This feature can be described as the order in time of a set of tasks. Performing the tasks at the current moment without incurring a penalty later, is a necessary factor for inclusion on weekly work plan.

Soundness: For involving a task into weekly work plan, it should be removed from all possible constraints before starting the execution. The purpose is to perform the task according to schedule.

Size: According to this feature, the task should be sized to the capability of those who are responsible for performing that. This improves workflow reliability. More works is assigned to performers who increase their capabilities and capacities.

The tasks which do not included these criteria must be made ready in the first point before advancing them to the lookahead plan. In addition, tasks meeting the four criteria but not entered onto the WWP are held in a “workable backlog” or Plan B. “The workable backlog enables the workforce to drop onto these tasks if for any reason they are unable to complete work on the WWP” (Daniel et al., 2017). As Ballard and Tommelein (2016) recommend, “workable backlog refers to tasks that have been released for commitment, and “Plan B” for tasks included on commitment plans to serve as fallback or follow-on work”.

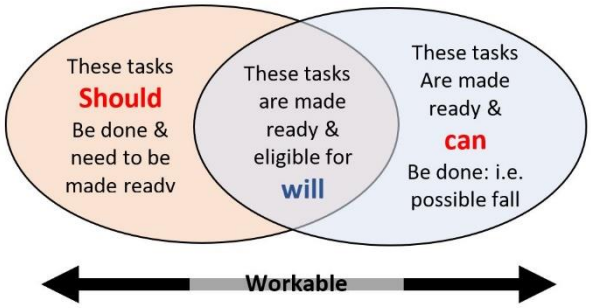

Figure 3.2 Commitments plans 11

Tasks that are not critical and not included in SHOULD side (Fig 3.2 above), may be placed into workable backlog under two conditions.1) If they can be implemented now without incurring a penalty later.2) If there is more capacity. There are two plans in regards of commitments, plan A and plan B. The tasks of plan A are those which are truly speaking commitments, which are SHOULD be done; other tasks are depending on them to be completed. Plan B consists of fallback/follow-on tasks in case Plan A tasks cannot be completed, or as follow-on work in case Plan A tasks are completed earlier than expected (Ballard and Tommelein 2016).

Daily huddle is another aspect that should be considered when it comes to weekly work plan. Daily huddle meeting is used to monitor how activities planned for the week are performing each day. The main focus of this meeting that held by participation of groups of interdependent players, is to guide the planned production from deviation and to re-plan when is predicted. In other words, they share what commitments they have completed or need help with them (Daniel et al., 2017).

3.2.4.6. MEASUREMENT AND LEARNING

The key metrics measured of learning are, percentage plan complete (PPC), the reason for non-completion (RNC) and a developing reliability index using metrics from tasks made ready (TMR) and tasks anticipated (TA) In practice, PPC measurement, and recording of RNC not only encourage learning but also could be a positive tool in increasing productivity (Daniel et al., 2017). These three metrics (PPC, TMR, TA) involve comparison of task sets in different weeks of the lookahead window. A six week lookahead window is assumed in the figure below (Ballard and Tommelein 2016),

Figure 3.3. Six weeks ahead (Ballard and Tommelein 2016).

3.2.4.6.1. PERCENT PLAN COMPLETE (PPC)

As Koskela et al (2014) described PPC is “a measure of the proportion of promises made that are delivered on time. It is calculated as the number of activities that are completed as planned divided by the total number of planned activities, presented as a percentage”. PPC measures workflow reliability; i.e., PPC compares the tasks that were completed (Week-1 in figure above) to the tasks in the weekly work plan for that week (Week0)11. Increasing PPC means increasing performance, both in the production unit that executes the Weekly Work Plan and the production units downstream for better planning. Moreover, identifying upcoming resource needs let the managers to pull those resources from upstream supply to where they needed to be available (Ballard et al., 2002).

3.2.4.6.2. TASKS MADE READY (TMR)

This metric is the same as PPC but performed earlier in the look ahead process, comparing the weekly work plan (Week0) against an earlier week in the lookahead window (Week n) in the figure 3.3. TMR measures the ability of the project team to determine and remove constraints ahead of the schedule that planned for the specific tasks (Ballard and Tommelein 2016).

3.2.4.6.3. TASKS ANTICIPATED (TA)

TA is another metrics that measures the percentage of tasks for a specific week. Those tasks were anticipated in an earlier plan for that target week. Providing a relative measure of how the project team can cause what is going to happen on the project in the weeks ahead, is the main objective of this indicator. The right work cannot be made ready without this critical planning (Ballard and Tommelein 2016).

3.2.4.6.4. REASON FOR NON-COMPLETION (RNC)

Each week, last week’s weekly work plan is reviewed to determine what tasks were completed. Those not completed when planned are assigned to a category which describes the reasons for non-completion. If a task has not been performed, then a reason is provided. These categories are generally established prior to the start of the project and show the possible reasons that might be expected during execution of the project. However, as the project evolves the new reasons might be added to this category based on the different project situations (Ballard and Tommelein 2016). Reasons are examined to find main causes and action taken to avoid repetition. These failures can be, lack of materials, equipment, technical issues etc. Whatever the cause, continued tracking of reasons of failure will measure the efficient of remedial actions. If action could not help to eradicate the root cause of the failures, then different action is required to be taken (Ballard et al., 2002). In the figure below, as an example, RNC are compared in two different projects.

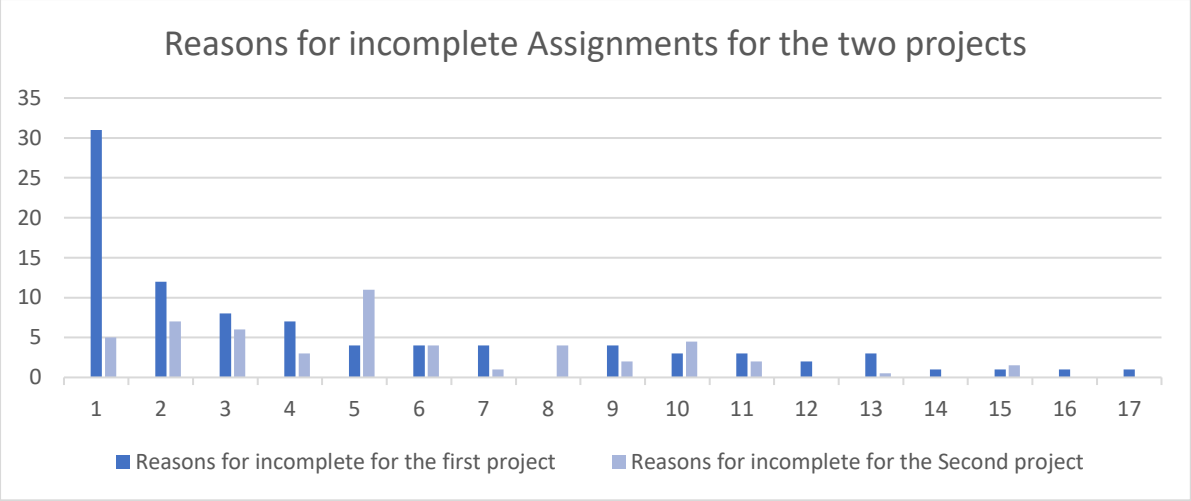

Figure 3.4 Reasons for Incomplete assignments for the Two Projects (Koskela et al., 2014).1)Prerequisite work.2) Material. 3) Approval. 4) Changed priority. 5) Labour. 6) Equipment 7) Design. 8)Late request for inspection. 9) Overestimate achievement. 10) Incomplete information. 11) Defects require rework 12) Scheduling/ coordination. 13) Interface with other packages. 14) Space. 15) Weather. 16) Other (technical specification). 17) Other (rock under floor).

3.2.5. LPS CHALLENGES & BENEFITS

Many construction companies try to use lean tools at level of operations through use of WWP and other tools of LPS to take advantages of this new management method. It is noteworthy to mention that the implementation of LPS beside the numerous benefits also has barriers and challenges. As Hamzeh (2011) stated “researchers in the field of changing management have reported many failures and partially achieving of lean production by organizations that have attempted to implement LPS. However, most companies either failed or only partially achieved lean production in its true form”. The softer aspects of execution, such as organisational processes and people are the majority of these barriers that is explained in the following (Koskela et al., 2015). Earlier in this report, the benefits and advantages of adopting LPS compared to traditional project management were repeatedly mentioned.

According to Zaeri et al (2016), there are various benefits attributable to LPS implementation on construction projects, including,1) Identifying the main reasons for project variances. 2) Achieving continuous improvement through PPC measurement.3) Successful completion of projects through weekly planning by project team and 4) Decreasing problems due to the project structure. Further benefits can be mentioned as: avoidance of repetitive project mistakes, fulfilment of promises made by team members to each other, and identification of the reason of broken promises.

In spite of the benefits outlined above, there are some challenges in implementation of LPS that has adopted on construction projects. These challenges can act as barriers to full implementation of LPS in organizations. In some case, the result of lack of leadership during the process can be considered as implementation challenge. In other cases, lack of commitment by upper management is the main issue. There are two sets of factors, local and general that impact the execution of new methods such as LPS. Local factors are potential challenges related to project circumstances and the team including, the relatively new experience in lean

methods, traditional project management methods, newness of LPS to team members, lack of leadership and team chemistry. The impacts of general factors can be listed as; human resource, organizational inertia, resistance to change, technological barriers. In addition, climate of organization can be another factor. Climate is "an organizational characteristic that employees live through and experience while working for an organization. The climate shapes their behaviour, performance, and the way they perceive the organization" (Hamzeh 2011).

Based on Porwal et al (2010) the challenges of construction professionals fall into two categories;1) implementation stage, when LPS introduce to the project team and pilot projects are in progress. Senior and mid-level management face these organizational problems in the initial stages.2) Using stage, LPS is used by a professional team and technical challenges related to human capital that is needed for using LPS are introduced. Listed below are these challenges.

IMPLEMENTATION CHALLENGES

- Lack of training
- Lack of leadership/failure of management commitment
- organizational climate
- Organizational inertia & resistance to change
- Stakeholder support
- Contracting and legal issues/contractual structure
- Partial implementation of LPS & late implementation of LPS

USER CHALLENGES

- Human capital & lack of understanding of new system
- Difficulty making quality assignments/human capital–skills and experience
- Lack of commitment to use LPS & attitude toward new system
- Bad team chemistry & lack of collaboration
- Empowerment of field management/lengthy approval procedure from client and top management
- Extra resources/more paperwork/extra staff/more meetings/more participants/ time
- Physical integration

In addition, Koskela et al (2015) described several challenges that emerges from literature and observation from organisations practicing LPS.

- Inability to effectively deploy collaborative aspects
- Partial deployment of LPS
- Reduced importance of robust phase and master plans
- Missing continuous improvement
- Missing the links between detailed and high-level plans

The following table listed the benefits and barriers of LPS implementation in two projects.

Table 3.2..Benefits & barriers of LPS implementation (Koskela et al., 2014).

Project	*Benefits*	*Critical success factors*	*Barriers*
1	Enabling site supervisors to plan their workload	Top management support	Lengthy approval procedure by client
	Improving learning process	Commitment to promises	Cultural issues
	Improving planning and control practice	Involvement of all stakeholders	Commitment and attitude to time
	Enabling accurate prediction of resources	Communication between parties to achieve teamwork	Short-term vision
	Reducing uncertainity	Close relationship with suppliers	
	Preparing team members to collaborate	Motivating people to make change	
2	Enabling accurate prediction of resources	Commitment to promises	Involvement of many subcontractors
	Improving planning and control	Communication and coordination between parties	Lengthy approval procedure by client
	Enabling site supervisors to plan their workload	Involvement of all stakeholders	Commitment and attitude to time
	Improving site management	Top management support	Cultural issues
	Improving learning process	Close relations with suppliers	Short-term vision
	Reducing uncertainty	Managing resistance to change	

What are the measures to overcome?

These challenges can be analysed from two perspectives. First from people and process perspective i.e. the need for training and change management, and secondly that LPS itself may need updating to fulfil the essential needs of the industry. In regards with the first problem, there is lack of training material on the LPS implementation. Several consultants with different backgrounds have vary opinions with execution of LPS. Some consultants emphasise the use of weekly planning while neglecting the aspects of lookahead and reverse phase planning. In addition, it should be noted that LPS has not yet found a place in textbooks or standard academic curriculum. Therefore, many graduates have no idea about LPS. The second issue needs a much deeper investigation with theoretical basis. Some broad suggestions are mentioned below (Koskela et al., 2015);

- The collaborative part of the planning needs to be considered with a fresh perspective. Much of the time during collaborative meeting is used for collecting information Using an information system can minimise this time and help the team for efficient planning.

- The information flow from high level plans to short term plans, and more importantly from short-term plans to the Master level plans needs to be explicitly determined in the LPS.
- In addition to PPC and RNC, more systematic continuous is needed to achieve better and more accurate analysis and tracking of task conditions.
- The role of information systems and product modelling systems (such as BIM) should be integrated/considered in the new LPS model. The construction industry has a significant development in information system in recent years that needs to be brought into consideration in LPS.

These were some measures to analyse and overcome the specified challenges. However, finding the proper solutions for the challenges related to LPS is beyond the scope of this report and will be examined in the next semester.

4. FINDINGS

The results of the interviews, document studies, surveys and observation are studied in this section. The author has attempted to answer the research questions according to the information obtained from the different methods mentioned. This chapter is divided into three parts. In the section 4.1, the implementation of LPS on the Minnevika bridge project is investigated in order to answer the research question number one which is "What measures have PNC used to practice LPS?" .In the section 4.2 , the research question number two (How do the different involved parties' value /experience the process?) is answered based on information achieved from the survey .Finally, the author in the last section 4.3 provides information based on interviews to answer the last research question to some extent(How can PNC improve the practice?) Due to the time limitation in this semester, the last research question will be further explored along with another, yet to be clarified topic, as part of the master thesis next semester.

4.1. LPS ON THE MINNEVIKA BRIDGE PROJECT

As explained earlier in the report, LPS is one of the most popular lean tools being deployed in construction companies across the world. It was designed to improve the gaps that existed in traditional management method such as the Critical Path Method system. However, according to Koskela et al(2015), the full potential of the Last Planner System is rarely achieved, and the root causes for this are not entirely understood.In this section,LPS implementation is examined and has been realized to what extent it is in accordance with concepts presented in the literature.

4.1.1. LPS EXECUTION

PNC has adopted the LPS for the first time, not as a requirement in the contract regarding with the Minnevika bridge project but for learning, training, and taking advantages of LPS as a point of departure for the next projects in the future. Therefore, the project team has this opportunity

to get familiar with LPS and they will be more efficient and productive in the next project. LPS on the Minnevika bridge project included.

4.1.1.1. MASTER PLAN

It is a six-month plan that defines the overall project duration, important milestones, and the key tasks. The main tasks are identified first, and planning is done backwards from the end to the beginning. This kind of planning gives the project team a higher level of view. Master plan is a core framework created by the site managers and supervisors at the beginning of the project or new major activity and forms the basis for the more detailed planning such as look-ahead planning. It is updated sometimes based on reality (what was happened and by considering future plans) by the facilitator or in group and is then presented to other project for review.

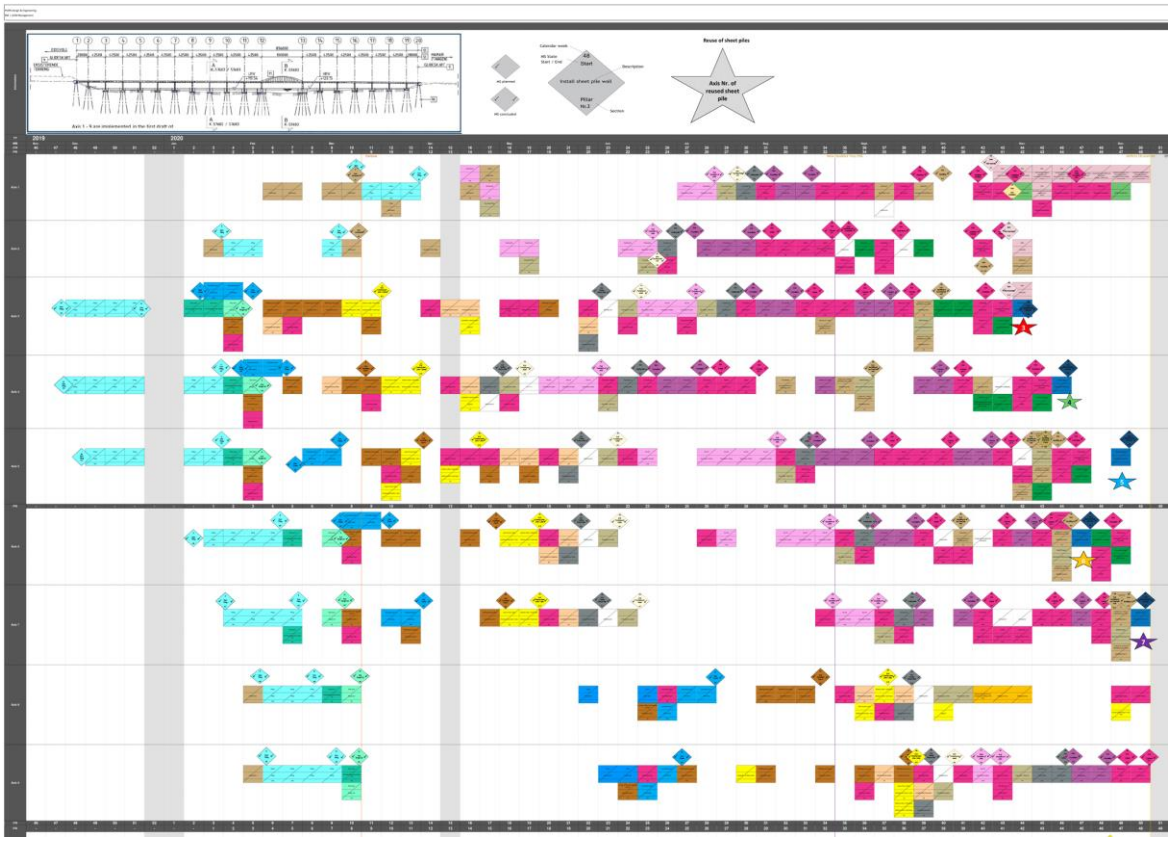

Figure 4.1 Master plan with specified milestones(Document of PNC)

4.1.1.2. PHASE PLANNING

The process mapping method is applied by PNC in order to map out the construction process by pull principles, from the end to the beginning, during the collaborative meetings. Then, the construction process, which was developed in the process mapping, was transferred to the Milestone and Phase Plan (MPP) to develop a base plan for Look-ahead planning and WWP. The reverse phase planning is used to determine the workflow of the project. (Kassab,O., 2020, Master's thesis).

4.1.1.3. LOOK-AHEAD PLANNING

Look-ahead planning on the Minnevika project is performed using a six week plan based on the milestone and phase plan. Every week the planning for the next six weeks is performed during the weekly meeting that is described below. All contractors and subcontractors including PNC, Hæhre, Aarsleff, EB Marine, Arctic and NRS collaborate to identify constraints and find the best path for performing the desired tasks that meet the four quality criteria (well-defined, soundness, sequence and size).

Figure 4.2 Look-ahead planning board (by the author)

4.1.1.4. WEEKLY WORK PLAN

The Weekly Work Plan (WWP), otherwise known as the Production Evaluation and Production Planning (PEP) on the Minnevika bridge project, is a weekly meeting with participation of project members including; Construction managers, site engineers, office engineers, production team, HSE representatives of PNC, representative or supervisors of other contractors and subcontractors, Hæhre, Aarsleff, EB Marine, Arctic and NRS. The PEP meeting begins with an evaluation of the last week of work by going through the different commitments of different trades. Afterwards, uncompleted tasks are categorized by Variance Analysis. Variance Analysis is the same as the Reason for Non-Completion (RNC) measure described in literature review. The facilitator, with the help of the HSE representative, and by using Order and Safety, define the safety issues related to different axes that have ongoing works on the construction site.

The Risk Matrix is the next tool that is discussed during the PEP meeting. The facilitator coordinates with participants in order to define contingent risks and examines the impacts of these constraints on the process and the probability of their occurrence. If the probability and the impacts of a risk were significant, an action must be defined in the Action Plan. The Action Plan recognize the need of specific actions with identified responsibilities and deadlines for

completion. The look-ahead planning is the main aspect of the meeting. Participants cooperate to create the six-week plan in accordance with milestone plan. Then, this look-ahead plan is discussed and clarified by the contractors and subcontractors. At the end, Logistics is discussed by the facilitator to evaluate if there are any logistic constraints on the construction site.

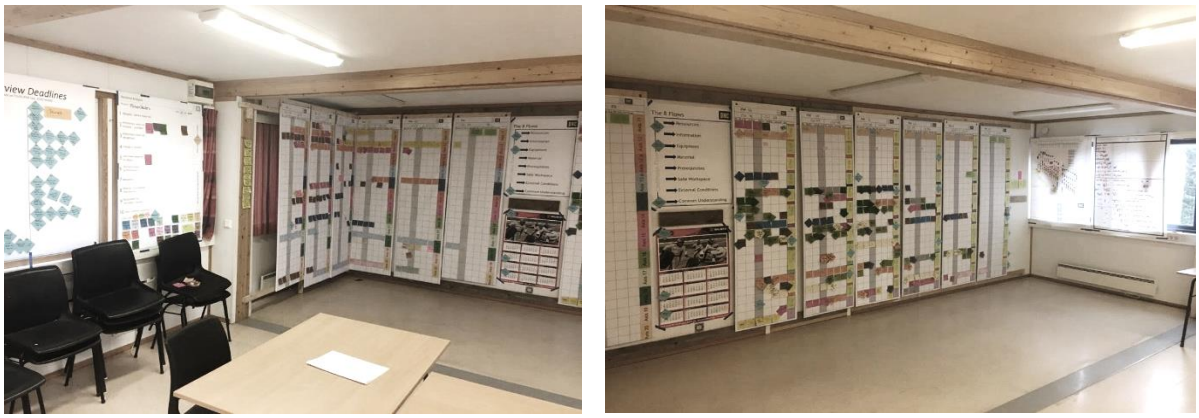

Figure 4.3 PEP meeting place (by the author)

Logistic

When a lot of people work in a tight workplace by receiving several deliveries in the same spot and multiple interfaces, logistics can be a useful tool. In the logistics part, the map and drone footage of the site are displayed on the screen and the main issues surrounding logistics are discussed, ie, what can be do for the next week? where is the best place for material and machine? the best access ways for executive operations such as casting of foundation axes, etc.

4.1.1.5. MEASUREMENT AND LEARNING

As explained earlier, the measurements not only encourage learning among the project team but also provide a clear indication of productivity. These measurements on the Minnevika bridge project known as Key Performance Indicators (KPI) include; the Percent Plan Complete (PPC) overall, the PPC per trade, Milestone Completion, Variance Analysis (VARA), Top Three Variances, Conclusion Variance Analysis and Problem Solving, and Order & Safety. These indicators, along with the look-ahead plan, risk matrix and action plan are sent to project team every week after the PEP meeting by the facilitator. The indicators are tracked and used in order to increase productivity and learning from mistakes. KPIs measure what the team planned compared to the amount of commitments that they actually completed during the previous week.

Table 4.1. LPS stages on the Minnevika bridge project

	Milestone plan	*Phase planning*	*Look-ahead planning*	*Weekly work planning*	*Measurement &Learning*
LPS implementation on The Minnevika bridge project	✓	✓	✓	✓	✓

Variance Analysis

This measure on the Minnevika bridge project is defined as the Reason for Non-Completion (RNC). Each week, during the PEP meeting, the previous weekly work plan is reviewed to determine what activities have not been completed. Afterwards, the reasons for non-completion

are discussed to take an action that avoids the repetition. The reasons for non-completion on the Minnevika project include: 1) Delayed/defect materials. 2)Preliminary work not finished/available 3) Preliminary work not recognised 4) Change in priority 5) Unforeseen absence of labour 6) Overestimated performance 7)Rework 8)Missing/incomplete information 9)Equipment not available/broken 10)Poor weather conditions.

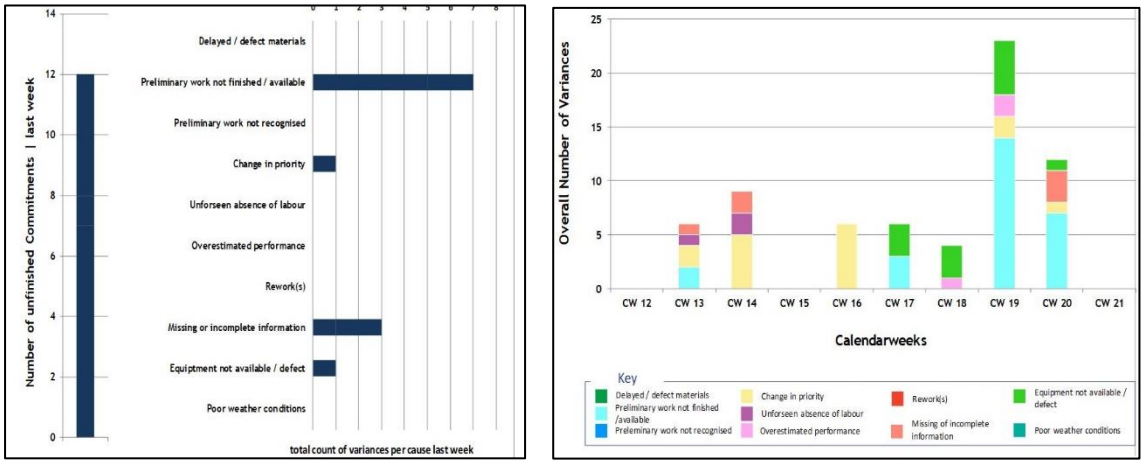

Figure 4.4 Variance analysis on the Minnevika bridge project(PNC document)

PPC overall

This is exactly explained in the literature review section, the Percentage of completed assignments in relation to what planned before for these assignments. PPC can be a great tool to clarify the consistency and validity of planning by the team. PPC overall refers to the total of commitments that have planned for that week. The highest amount of PPC overall is 100%.

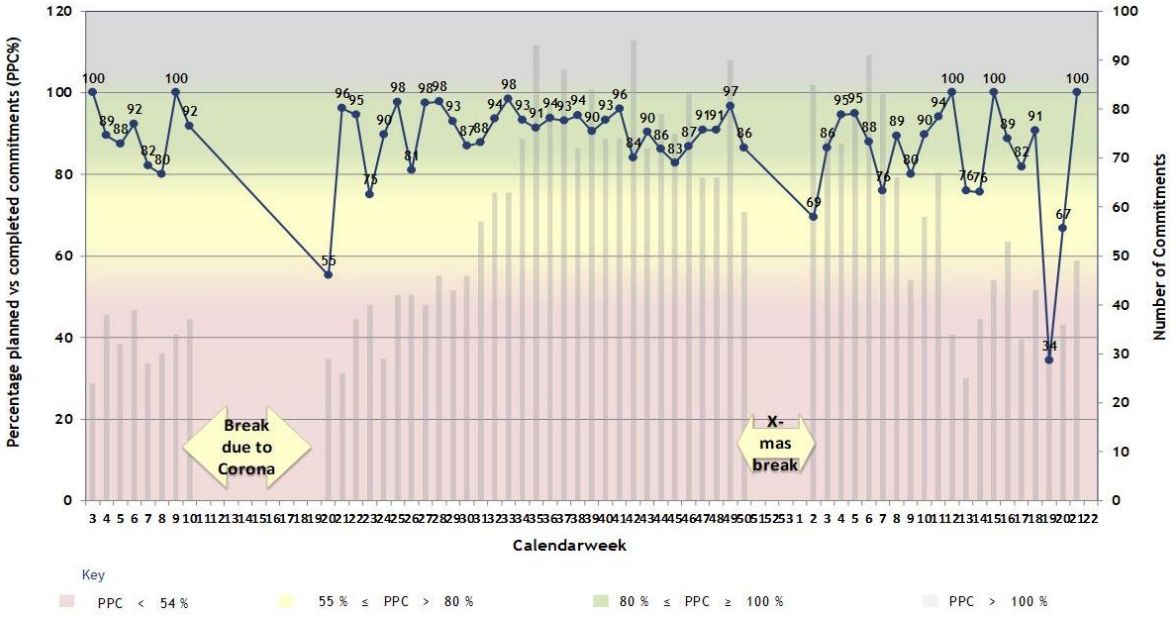

Figure 4.5 PPC measurements on the Minnevika bridge project (PNC document)

PPC per trade

The Percentage of completed tasks in relation to what planned the tasks shown per trade. If the tasks are completed earlier than the plan, the value will be more than 100%.PPC per trade indicates the completion percentage of each activity beside the name of responsible person for that commitment. These activities including sheet piling, piling, reinforcement, concreting, etc.

Milestone completion

This measurement tool shows the cumulated number of milestones that were concluded per week throughout the project. The graph below compares the planned milestone (grey area) and the milestones that were achieved (blue line) during the several weeks.

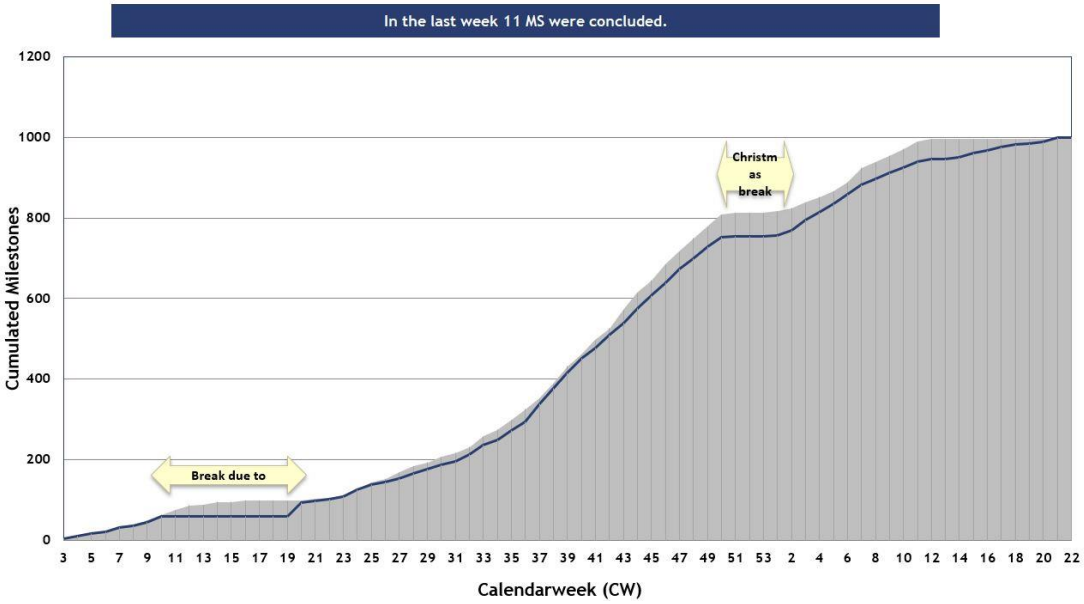

Figure 4.6 Milestone completion (PNC document)

Risk matrix

The risk matrix is a common tool that PNC use to assess the various risks of the workplace hazards. The diagram can help the project team to determine the priority of the risks based on their impacts and occurrence. If the probability of occurrence of a risk and its impact were significant, an action must be defined in the action plan.

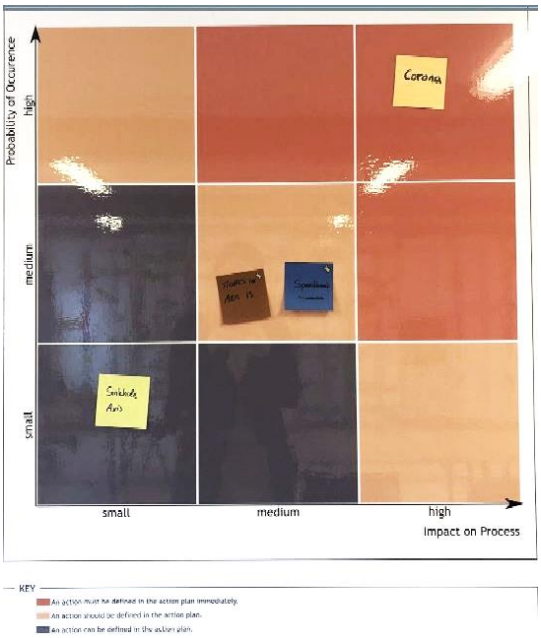

Figure 4.7 Risk matrix (PNC document)

Action plan

The Action plan is a tool that make tasks ready for future action. There are four different situations related to the tasks, action planned, action in process, action in review, and action finished. Action plans have been used to reduce the likelihood or impact of identified risks or to find solutions to issues that arise on the project. The project team recognizes the needs of an action and what must be done in advance.

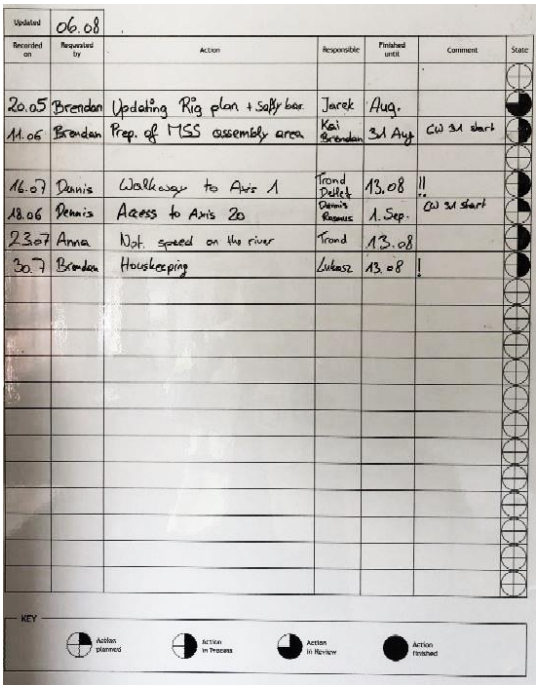

Figure 4.8 Action plan (PNC document)

Order & Safety

This indicator assesses the safety issues on the construction site and informs all the participants about current safety conditions related to each working axis in order to take the necessary actions and accident prevention. A traffic light system is used to represent the different safety conditions at each axis, where red represents an unsafe workplace where immediate action must be taken.

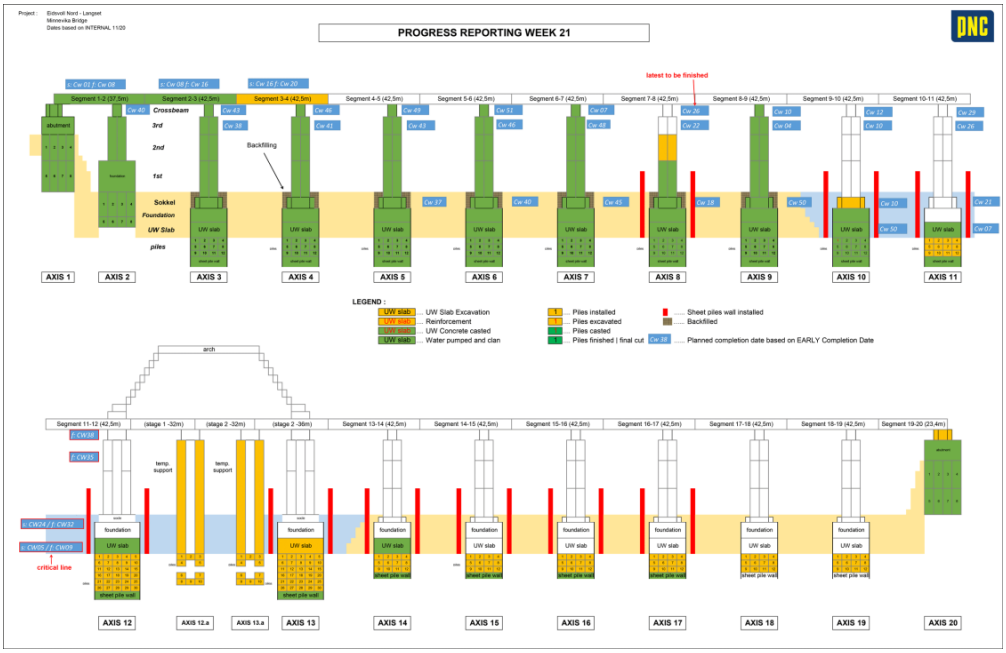

Figure 4.9 Order & safety (PNC document)

4.2. INVOLVED PARTIES' PERSPECTIVE

The author has attempted to examine the different parties' value and experience of their participation in this process by use of the survey.

Results from survey

The survey was conducted on the 19th of Nov during the PEP meeting in order to include all those who are involved in the LPS process. However, due to current situation and the outbreak of Covid-19 most participants were on quarantine and the author was only able to get answers from nine respondents. The survey consisted of three parts: General questions, LPS execution, and Challenges. After consulting with Ola Lædre, it was decided to mention the same questions (General & Challenges) that the previous student named Omar had asked in his master thesis in order to track changes and measure the development. He carried out the first survey on the 4th of Nov 2019, the day before training sessions. The results of the survey are presented in the following table.

Table 4.2.Results from first part of the survey

Section 1: General questions			
1. What is your impression of Last Planner® System (LPS)?	Negative 1	Undecided 3	Positive 5
1= strongly disagree, 2= disagree, 3= Undecided, 4= agree and 5= strongly agree			
2. Are you satisfied with this transformation/change in the project's system?	Average scale	3.77	
3. Do you think that the LPS is improving the way by which the project is planned?	Average scale	3.91	
4.Would you say that the LPS can lead to a successful project in comparison to traditional project management?	Average scale	3.22	
5. Would you say that it was challenging to adopt the LPS?	Average scale	2.91	

According to the table 4.2, the most of the participants have positive perspective to the LPS.55.5% of participants (5 out of 9) were satisfied with LPS, compared to 76.9% (10 out of 13) participants, who answered "undecided" in the previous survey, showing the improvements of LPS on the Minnevika bridge project. Most of the participants by the average scales of 3.9 believed that LPS has improved the way of management on the Minnevika bridge project,while this number was 3.6 in the last survey. In addition, whereas the most participants believed that implementation of LPS would be quite challenging, they have changed their minds in the recent survey. The results of the two surveys are listed below.

Table 4.3. Comparison of the survey results (1)

Questions	*Survey on 19th of Nov 2020*	*Survey on 4th of Nov 2019*
1.Are you satisfied with this transformation/change in the project's system?	3.77	3.75
2.Do you think that the LPS is improving the way by which the project is planned?	3.91	3.62
3.Would you say that the LPS can lead to a successful project in comparison to traditional project management?	3.22	3.55
4.Would you say that it was challenging to adopt the LPS?	2.91	3.69

The following bar chart compares the trend differences between the two surveys,

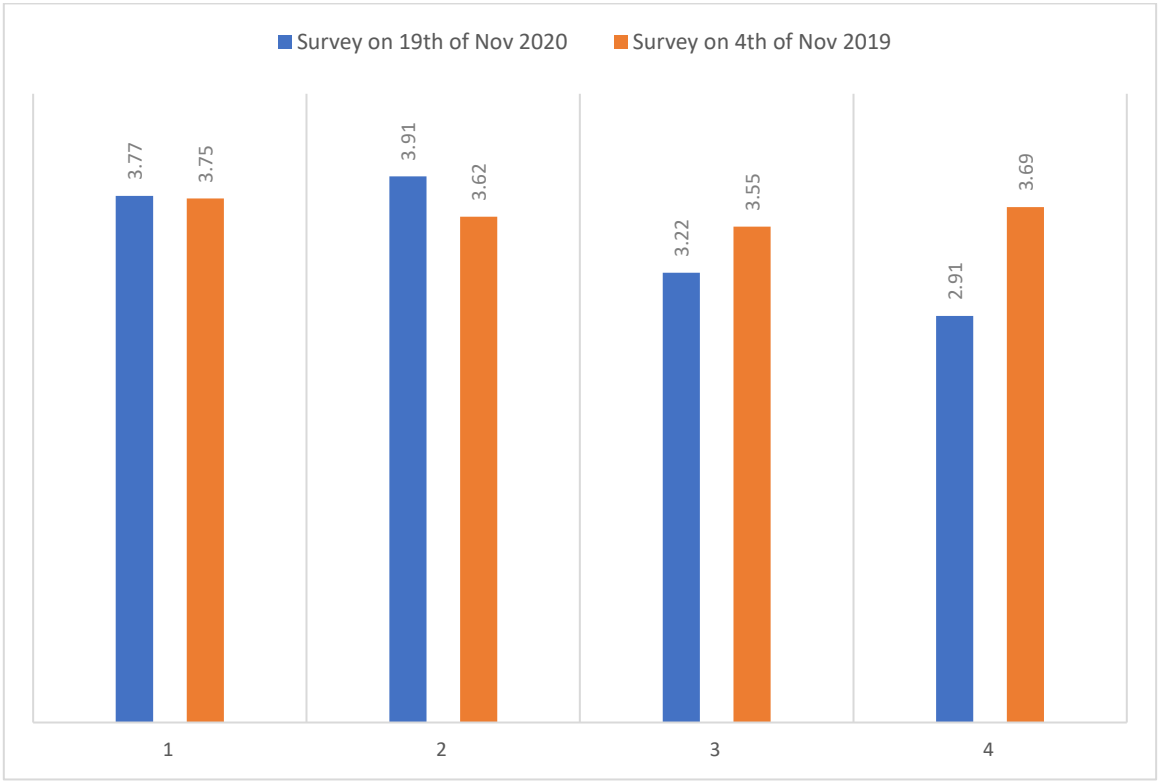

Figure 4.10 Comparison of the survey results (2)

The section 2 of the survey was considered in order to examine the experience and personal opinions of involved parties about LPS. The questions were regarding different phases of LPS execution. According to the average scale, the value of LPS from the project members' point of view is described in the table below.

Table 4.4.Results from second part of the survey

Section 2: LPS Execution		
6. When thinking about the PEP meetings in general ...		
1= Very low, 2= Low, 3=Undecided, 4=High and 5= Very high		
6.1. To what extent is this valuable to you as an individual?	Average scale	3.44
6.2. To what extent is this valuable to your team?	Average scale	3.88
6.3. To what extent is this valuable to overall project?	Average scale	3.77
6.4.To what extent do you look forward to the PEP meeting?	Average scale	3.22
7. When thinking about the Milestone Plan ...		
7.1. To what extent is this valuable to you as an individual?	Average scale	2.88
7.2. To what extent is this valuable to your team?	Average scale	3.11
7.3. To what extent is this valuable to overall project?	Average scale	3.11
8. When thinking about the 6-week look ahead planning performed during the PEP ...		
8.1. To what extent is this valuable to you as an individual?	Average scale	4.00
8.2. To what extent is this valuable to your team?	Average scale	4.44
8.3. To what extent is this valuable to overall project?	Average scale	4.22
8.4. To what extent do you think constraints are identified in the 6-week look-ahead planning?	Average scale	3.77
9.When thinking about the Action Plan ...		
9.1. To what extent is this valuable to you as an individual?	Average scale	3.11
9.2. To what extent is this valuable to your team?	Average scale	3.33
9.3. To what extent is this valuable to overall project?	Average scale	3.33
11.When thinking about the Risk Analysis overview …		
11.1. To what extent is this valuable to you as an individual?	Average scale	2.88
11.2. To what extent is this valuable to your team?	Average scale	3.00
11.3. To what extent is this valuable to overall project?	Average scale	3.22
12. When thinking about the KPI measurements provided during the PEP ...		
12.1 To what extent is this valuable to you as an individual?	Average scale	2.33
12.2 To what extent is this valuable to your team?	Average scale	2.33
12.3 To what extent is this valuable to overall project?	Average scale	2.33
12.4. To what extent do you think the PPC and other KPIs are measured in an accurate way?	Average scale	2.44

According to the achieved results, Look-ahead planning is the most valuable tools of the LPS on the Minnevika bridge project. The highest scale of 4.44, showing the most respondents were agreed upon the validity of 6 weeks look-ahead planning. The most responders (3.77) believe that constraints are identified by look-ahead planning. However, the lowest numbers are related to KPI measurements, with the average of 2.33, it seems that KPI is not that much admired by the project team. An average scale of 2.44 (question 12.4) indicates doubts regarding the correct measurement of KPI. The following graph represents the different involved parties' perspective about LPS stages on the Minnevika bridge project.

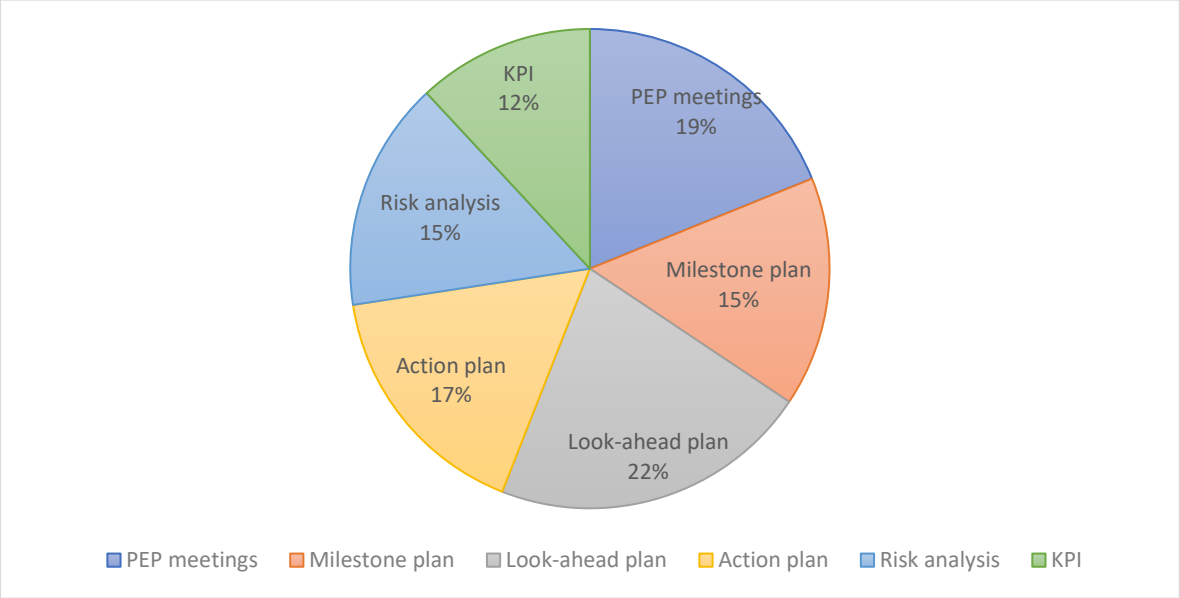

Figure 4.11 Popularity of LPS stages on the Minnevika bridge project

4.3. STRENGTHS & WEAKNESSES

By obtaining information from interviews and open-ended questions on the survey (see appendix chapter) the author has attempted to figure out what are the strengths and weaknesses of the LPS implementation phases on the Minnevika bridge project and what solutions can be taken to tackle these challenges? In this regard, the results of the interviews are shown in the table below.

Table 4.5.Results from the interviews

<table>
<tr><th colspan="2"><u>Milestone plan</u></th></tr>
<tr><th>Strengths</th><th>Weaknesses</th></tr>
<tr><td>Good tool for comparison in order to track the project by higher level of management.
Used as a report to the client
Having a target plan for a specific period (6 months)
Presenting a higher level view of the project;i.e., What is the current situation of the project? What kind of activities can be delayed? What must be done first? what are the priorities?</td><td>The plan does not include all the situation that happens on the site
Since it is not used continuously, it can be forgotten.</td></tr>
<tr><th colspan="2">The measures to overcome the challenges</th></tr>
<tr><td colspan="2">Reviewing important milestones at specific times to remind participants.</td></tr>
<tr><th colspan="2"><u>Look-ahead planning</u></th></tr>
<tr><th>Strengths</th><th>Weaknesses</th></tr>
<tr><td>Making a reliable plan with details by cooperation with involved parties and get agree upon what should to be done? what resources are needed? what is the critical plan? what is the best for the project?
Planning on big scale board with colourful sticky notes and visualization is a great help in better understanding
Help participants to think and realize clearly</td><td>It sometimes creates a short-term focus
Being time consuming can lead to rush in the process of thinking appropriately</td></tr>
<tr><th colspan="2">The measures to overcome the challenges</th></tr>
<tr><td colspan="2">The project team should be conscious of how this six-week look-ahead plan fits into the big picture
Considering the master plan as reference in look-ahead planning.
Assigning certain people to certain tasks so that there is more consistency in who is doing the planning</td></tr>
<tr><th colspan="2"><u>PEP meeting</u></th></tr>
<tr><th>Strengths</th><th>Weaknesses</th></tr>
<tr><td>Weekly coordination meeting.Not only it helps the team internally but also lets them to coordinate among the subcontractors and partners</td><td>Not every supervisor attends the meeting
Spending a lot of times, around two hours of every participants. It is not always related to all participants.</td></tr>
</table>

• Prevention of additional meetings with each contractor separately • Better environment for coordination and discussing all issues with involved parties. • Great opportunity to make a reliable plan in the presence of production team. • By attending of foremen, they can feel as they are part of planning that leads to increase of motivation • Getting more input from participants with different perspective on finding appropriate solutions	• The problem of constant attendance of participants due to the rotational working schedules of the members.
The measures to overcome the challenges	
• It is not easy to ask the top managers with many years' experience to adopt the new way of management. The best way is to convince them by showing the benefits of the system. • Finding a suitable time schedule for the relevant presence of the participants • Treating participants flexibly to motivate them to attend consistently • Choosing the meeting based on which day of the week or which part of people's rotations to make it more and more accountable	
<u>KPI</u>	
Strengths	**Weaknesses**
• Lessons to learn • Prevention of repeating mistakes • Help to improve the process • It is a representation of how accurate plan is processing. It shows the accuracy and weaknesses of the current plan.	• Lack of attention by participants. They are not into details • Participants usually do not analyse and track the changes and developments after EP meeting.
The measures to overcome the challenges	
• By demonstrating the benefits of KPI analysis that can have positive impacts on the workflow, the participants can be persuaded to track these measurements.	
<u>Action plan</u>	
Strengths	**Weaknesses**
• Great tool for participants to reminder what is the necessary action in regards of completing a specific task • Big opportunity to consider all participants ideas • It mobilises participants to remember the necessary actions and keep these fresh in their memories.	• Some actions that mentioned on the board have already been take care of.

The measures to overcome the challenges	
• Participants should adhere to their commitments and attend the meeting to avoid possibility of forgetting their assigned tasks.	
Order & Safety	
Strengths	**Weaknesses**
• Great tool because safety is the most important issue on the construction site • Explaining the safety conditions related to the axis	• The figures and tables are not clear • What specific criteria should be considered in measuring the safety?
The measures to overcome the challenges	
• There should be specific measurements to identify the safety issues regarding axes. • The table should be more precise and inform participants what does it mean exactly? What actions need to be taken? And when we should change the colour?	

The section three of the survey was conducted with exact questions of the second Omar's survey (Kassab,O., 2020, Master's thesis) on the 20th of Feb 2019 during the execution phase in order to measure the developments of the project in terms of dealing with problems. The following table comparing the results (average scale) of the surveys.

Table 4.6. Comparison of the survey results (2)

To what extent do you think each of the following challenges is considered as a critical challenge on the Minnevika Bridge project during the Execution Phase?

Challenges	*Survey on 20th of Feb 2019*	*Survey on 19th of Nov 2020*
13. Maintaining people's commitment to be part of the process and to take the system seriously	3.50	3.22
14. Lack of Transparency in the interfaces between project team members	2.25	2.77
15. Resistance to the system	2.25	3.22
16. The language barriers	1.63	2.00
17. Non-participation of critical team members	2.85	3.22
18. The decisions and input are primarily provided by top-level management, such as site managers	3.00	2.88
19. Fear of responsibility (mainly from lower-level management)	3.00	2.22
20. Doubt (doubt about the overall performance and the benefits behind the LPS)	1.63	2.77
21. Misunderstanding of the basic concepts of the LPS	2.00	2.22
22. The time commitment required to participate in the weekly meeting	1.75	2.77
23. The lack of engagement	1.63	2.00
24. Disruption	1.63	2.33

According to the results from the table 4.6 , on the one hand, the degree of importance of some challenges decrease among the project members. For example, maintaining the people's commitment and fear of responsibility. On the other hand, the average scales of most of the challenges have increased such as disruption, non-participation of critical team members and resistance to the system. The results indicate that maintaining people's commitment, resistance to the system and non-participation of critical team members are the main challenges of the LPS on the Minnevika bridge project. In the below bar chart, comparison of the survey results is illustrated.

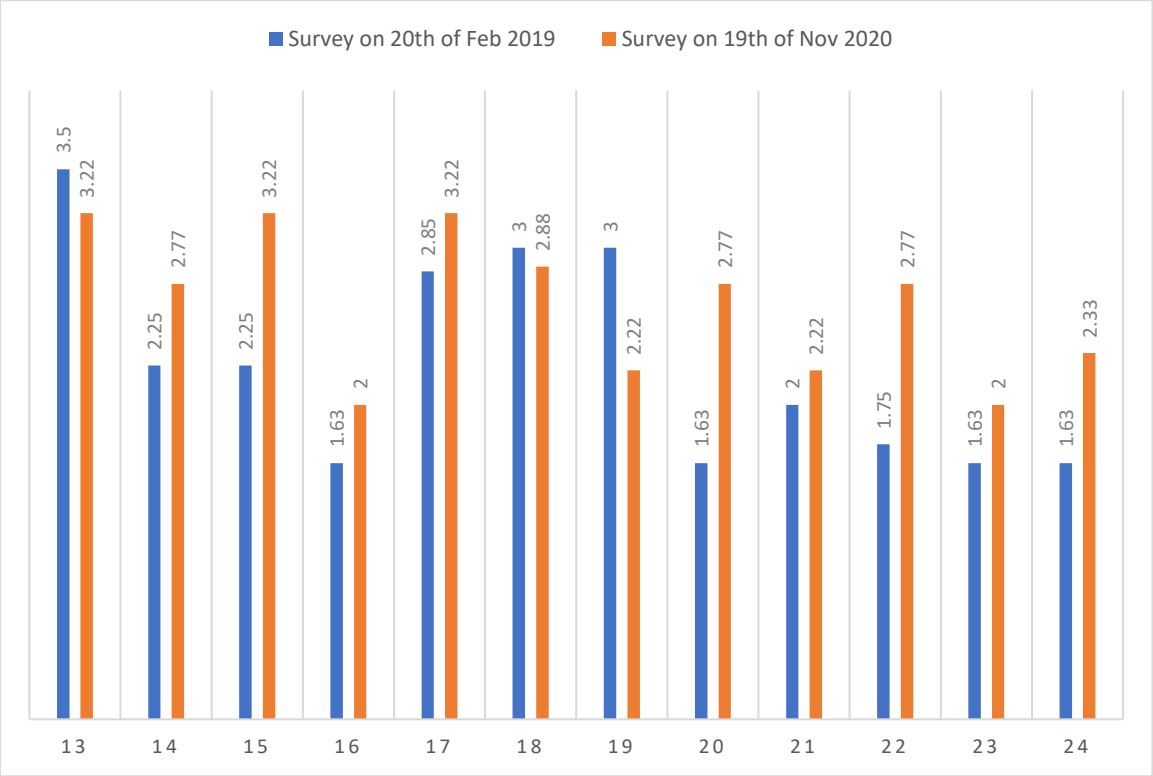

Figure 4.12 Comparison of the survey results (2)

These challenges, the measurements to overcome and further factors will be examined in the next semester due to the time limitation.

5. CONCLUSION

The Last Planner® System as one of the famous lean construction tools is a technique for construction planning and control that is concentrated on the decision makers called last planners. The last planners are the key members of providing initial phase named pull session that establish master plan with milestones. Look-ahead plan is the next phase of the process that represent by the site manager and collaboration of last planners during the weekly work meeting in order to remove constraints and improve the production flow in the weeks ahead. The weekly meeting can be a great tool to identify issues and propose solutions by reviewing the tasks performed in the previous week and at the end, the results are presented every week in order to learn and avoid repeating mistakes. The benefits of LPS implementation in PNC include efficient collaboration among all contractors and subcontractors, weekly measurement of the project progress, improved learning process, reduced uncertainty, improved planning and control, precise prediction of resources, and etc. However, there are also some challenges that can have negative effects on the productivity of the process. Commitments of the participants to the process and resistance to the system are the main challenges that not only PNC faces, but also every organization that wants to change the way of management and implement a new system. It is not just applying a tool to the project, but it is more about changing the way people think, behave, and perform. It is worth mentioning that despite these challenges, according to the achieved results, the most involved parties have the positive experience with the process. Look-ahead planning is the most popular stage of LPS on the Minnevika bridge project. Most of the participants have a positive attitude towards it, while KPI and measurement tools are neglected by the project team. Therefore, it is needed to show the benefits of these learning tools to the project members in order to avoid repetition mistakes and increase productivity of the project. encouraging the participants and convincing them to attend regularly by demonstrating the advantages of the LPS and how it improves the reliability of workflow can be one of the main approaches to tackle the challenges.

It should be noted that the challenges mentioned in the report are related to the Minnevika bridge project which is the first experience for PNC with LPS in Norway.Successful implementation of LPS is a lengthy process and requires a meaningful participation of all involved parties and deeper change in the members' mindset to adopt the new system which is not easily achievable. Therefore, the Minnevika bridge project can be a great point of departure for PNC where the project team has significant opportunity to learn, improve, and become acquainted with LPS.This will lead to having more professionals and experts in this field that can improve the productivity and efficiency of future projects.

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APPENDIX B – INTERVIEW QUESTION

I am Sajad Daliri, a last year master student at NTNU in project management with civil engineering specialization. I have a bachelor's degree in civil engineering and have about 2 years work experience in the construction industry on one of the big projects in my country, Iran mall. The subject of my master thesis is the Last Planner System on the Minnevika bridge project. I continue Omar's work by focusing more on the practice of LPS on the Minnevika project. In order to achieve the desired result, the research questions include the following,

1. What measure PNC has used to practice?
2. How do the different involved parties' value/experience the process?
3. How PNC can improve the practice of LPS?

At first, I want to ask permission for recording the interview and writing down what the interviewee will say in my report. The interview consists of three parts. Part one includes introductory questions to get to know the interviewees better. The second part includes technical questions to obtain the answers for research questions and the third part contains appreciation and request for further cooperation if needed.

Introductory questions (warm up)

1. Explain yourself, name, role in the project, how many years' experience do you have in the construction industry? What about PNC?
2. Did you have any experience with LPS before Minnevika project? Where? How long?
3. Why has PNC adopted the LPS?

Part 2

Milestone plan

1. What do you do with the milestone plan? What does it include on the Minnevika project?
2. What are the strengths and weaknesses of the Milestone plan? What are the challenges?
3. What are the measures to overcome these challenges? How can PNC improve?

Look ahead planning

1. What do you do in Look ahead planning? What does it include on the Minnevika project?
2. What are the strengths and weaknesses of Look-ahead planning? What are the challenges?
3. What are the measures to overcome these challenges? How can PNC improve it?

WWP

1. What do you do in WWP? What does it include on the Minnevika project?
2. What are the strengths and weaknesses of WWP? What are the challenges?
3. What are the measures to overcome these challenges? How can PNC improve it?

KPI

1. What do you do in KPI? What does it include on the Minnevika project?
2. What are the strengths and weaknesses of KPI? What are the challenges?
3. What are the measures to overcome these challenges? How can PNC improve it?

Action Plan

1. What do you do in AP? What does it include on the Minnevika project?
2. What are the strengths and weaknesses of AP? What are the challenges?
3. What are the measures to overcome these challenges? How can PNC improve it?

Order & Safety

1. What do you do in Order & safety? What does it include on the Minnevika project?
2. What are the strengths and weaknesses of Order & safety? What are the challenges?
3. What are the measures to overcome these challenges? How can PNC improve it?

Logistics

What do you do in Logistics? What does it include on the Minnevika project?

Part 3

- Thank the interviewee for attending the interview
- Ask permission to make a phone call if a question arises
- Ask the interviewee for further cooperation with future questions and explain if something is forgotten or unclear during the interview.

APPENDIX C – SURVEY

EXECUTION PHASE SURVEY

Questions	*Answers*				
Section 1: General questions					
1. What is your impression of Last Planner® System (LPS)?	Negative		Undecided		Positive
1= strongly disagree, 2= disagree, 3= Undecided, 4= agree and 5= strongly agree					
2. Are you satisfied with this transformation/change in the project's system?	1	2	3	4	5
3. Do you think that the LPS is improving the way by which the project is planned?	1	2	3	4	5
4.Would you say that the LPS can lead to a successful project in comparison to traditional project management?	1	2	3	4	5
5. Would you say that it was challenging to adopt the LPS?	1	2	3	4	5
Section 2: LPS Execution					
6. When thinking about the PEP meetings in general ...					
1= Very low, 2= Low, 3=Undecided, 4=High and 5= Very high					
6.1. To what extent is this valuable to you as an individual?	1	2	3	4	5
6.2. To what extent is this valuable to your team?	1	2	3	4	5
6.3. To what extent is this valuable to overall project?	1	2	3	4	5
6.4.To what extent do you look forward to the PEP meeting?	1	2	3	4	5
6.5. Do you see any ways to improve this?					
7. When thinking about the Milestone Plan ...					
7.1. To what extent is this valuable to you as an individual?	1	2	3	4	5
7.2. To what extent is this valuable to your team?	1	2	3	4	5
7.3. To what extent is this valuable to overall project?	1	2	3	4	5
7.4. Do you see any ways to improve this?					
8. When thinking about the 6-week look ahead planning performed during the PEP ...					
1= Very low, 2= Low, 3=Undecided, 4=High and 5= Very high					
8.1. To what extent is this valuable to you as an individual?	1	2	3	4	5
8.2. To what extent is this valuable to your team?	1	2	3	4	5

8.3. To what extent is this valuable to overall project?	1	2	3	4	5
8.4. To what extent do you think constraints are identified in the 6-week look-ahead planning?	1	2	3	4	5

8.5. Do you see any ways to improve this?

9.When thinking about the Action Plan ...					
9.1. To what extent is this valuable to you as an individual?	1	2	3	4	5
9.2. To what extent is this valuable to your team?	1	2	3	4	5
9.3. To what extent is this valuable to overall project?	1	2	3	4	5

9.4 Do you see any ways to improve this?

10.When thinking about the Logistics ...					
1= Very low, 2= Low, 3=Undecided, 4=High and 5= Very high					
10.1. To what extent is this valuable to you as an individual?	1	2	3	4	5
10.2. To what extent is this valuable to your team?	1	2	3	4	5
10.3. To what extent is this valuable to overall project?	1	2	3	4	5

10.4. Do you see any ways to improve this?

11.When thinking about the Risk Analysis overview …					
11.1. To what extent is this valuable to you as an individual?	1	2	3	4	5
11.2. To what extent is this valuable to your team?	1	2	3	4	5
11.3. To what extent is this valuable to overall project?	1	2	3	4	5

11.4. Do you see any ways to improve this?

12. When thinking about the KPI measurements provided during the PEP ...					
12.1 To what extent is this valuable to you as an individual?	1	2	3	4	5
12.2 To what extent is this valuable to your team?	1	2	3	4	5
12.3 To what extent is this valuable to overall project?	1	2	3	4	5
12.4. To what extent do you think the PPC and other KPIs are measured in an accurate way?	1	2	3	4	5

12.5. Do you see any ways to improve this?

Section 3: Challenges

To what extent do you think each of the following challenges is considered as a critical challenge on the Minnevika Bridge project during the Execution Phase?

1= Very low, 2= Low, 3=Undecided, 4=High and 5= Very high

13. Maintaining people's commitment to be part of the process and to take the system seriously	1	2	3	4	5
14. Lack of Transparency in the interfaces between project team members	1	2	3	4	5
15. Resistance to the system	1	2	3	4	5
16. The language barriers	1	2	3	4	5
17. Non-participation of critical team members	1	2	3	4	5
18. The decisions and input are primarily provided by top-level management, such as site managers	1	2	3	4	5
19. Fear of responsibility (mainly from lower-level management)	1	2	3	4	5
20. Doubt (doubt about the overall performance and the benefits behind the LPS)	1	2	3	4	5
21. Misunderstanding of the basic concepts of the LPS	1	2	3	4	5
22. The time commitment required to participate in the weekly meeting	1	2	3	4	5
23. The lack of engagement	1	2	3	4	5
24. Disruption	1	2	3	4	5

25. Are there any other challenges you would like to add (which are not mentioned in the previous challenges) that you expect to show up in the upcoming weeks?

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