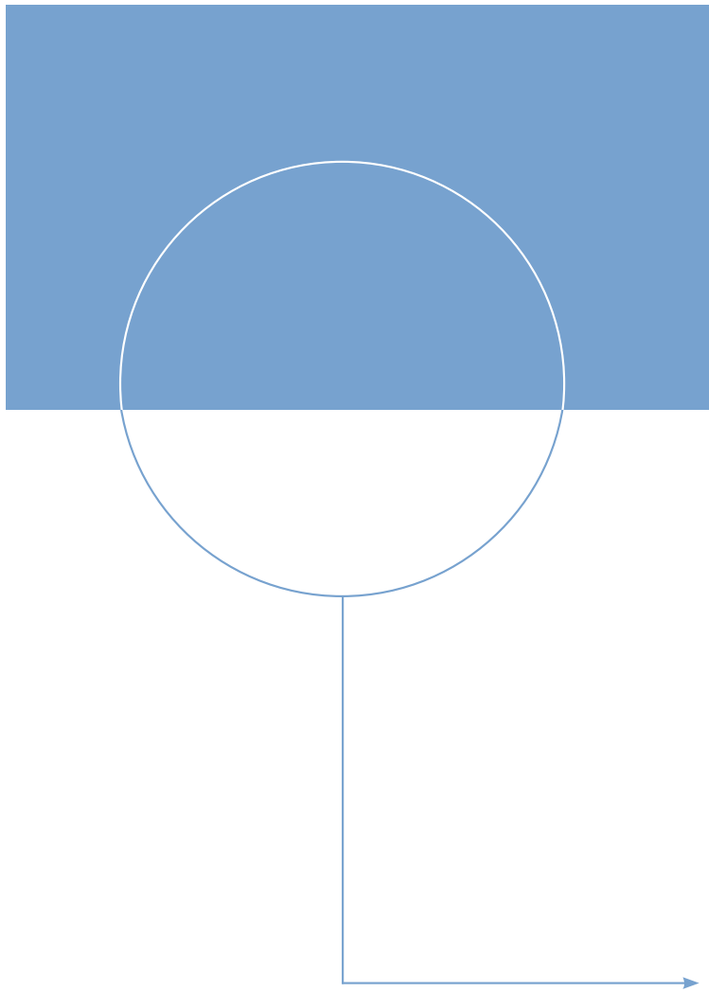

Master's thesis

2020

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Implementation of the Last Planner® System in an Infrastructure Project

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Implementation of the Last Planner® System in an Infrastructure Project

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Master of science in project management
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Abstract

Since the establishment of the Last Planner® system (LPS) by Ballard and Howell, multiple studies have been conducted to evaluate the implementation of the LPS in many construction projects. However, few studies have recorded the implementation process in infrastructure projects. This study investigates the implementation of the LPS in an infrastructure project (Minnevika Bridge project), detect the challenges that arise during the implementation, and suggest measures to overcome these challenges. Several data collection methods were used; namely, a single case study, a literature review, non-participant/participant observations, seven semi-structured interviews and two surveys.

The study revealed that the project followed the best practice process map for the LPS implementation mentioned in the literature. Moreover, the project experienced challenges described in the literature that tend to arise when adopting the LPS, similar to those reported from other construction projects, including, the participants' resistance to the system and participants' commitments towards the new system. The study concludes with suggested measures to overcome these challenges, such as sufficient training, openness towards the LPS, and using the incremental strategy when using the Key Performance Indicators (KPIs). Finally, the author represents challenges that are not clearly described in the literature (e.g. fear of responsibility when making the commitments). In the end, the author suggests a new indicator (Trust-Doubt indicator) which can be utilised to track the doubt and trust attitudes towards the LPS and other participants.

Keywords:

1. Last Planner system
2. Challenges
3. Implementation
4. Infrastructure projects

PREFACE

This research paper has been written to satisfy the requirements of the NTNU subject, TBA4910 Project Management, Master Thesis. The study was supervised by Mr Ola Lædre, Associate Professor at the Department of Civil and Transport Engineering and guided by Mr Brendan Young, a previous master's degree student at NTNU and a current site manager at the company under-study (PNC Norge AS).

This paper is divided into two parts: Part 1 – The Master Thesis, Part 2 – A published research paper, and Part 3 – Appendices. The first part is divided into seven chapters: Chapter 1 – gives an introduction of the research paper and the knowledge gap that was addressed, Chapter 2 – gives detailed information about the method used by the author, Chapter 3 – introduces the extensive literature study that was undertaken, Chapter 4 – a presentation of the findings, Chapter 5 – a presentation of the discussion, Chapter 6 – introduces the conclusion, the lessons learned and the recommendations, Chapter 7 – gives the proposed further work. The second part introduces the research paper published by the author in IGLC28 conference. The third part includes all the appendices.

The topic was selected after a discussion between the author and Mr Ola Lædre, who has good contact with Mr Brendan Young. Mr Young asked Mr Lædre for a student from NTNU to do research either on Last Planner® System or BIM. So, the first proposal by the author was to work with BIM. However, after some time, Mr Young offered a summer training for the author at PNC (the company under-study) to help the project team in the last phase of E18 Rugtvedt-Dørdal project and take the chance of becoming familiar with the company's internal system and to get to know the team members (later the study was made with some of these team members). Mr Young introduced the Last Planner® System to the author and explained its benefits since it was the first time for the author to hear about the LPS. The author read more about the LPS in the literature papers provided by Mr Young, and the passion for studying more about the system has increased dramatically.

The author became aware of the importance of the system and how much it can be useful for companies. PNC decided to implement the LPS in one of their projects as a pilot in order to upskill the project's team members and as a possible start for a Lean transformation, not only in the team members but also in the company in general. So, the author has decided to take part in this transformation and study the LPS. It was not long after that the company offered a six-month full-time contract to the author during the second semester, to help them from one side to implement the LPS and to proceed with the master thesis from the other side.

Based on the results from the study performed in this master thesis, one conference paper was published. A paper titled *Implementation of Last Planner® System in an Infrastructure project* was published in the Proc. 28th Annual Conference of the International Group for Lean Construction (IGLC28), Berkeley, California, USA, in July 2020 (*Kassab et al. 2020*). This conference will be held in visual settings. The author made a pre-recorded presentation which will be presented in 8th of July.

Oslo, 21 June, 2020

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Omar Kassab

Acknowledgement

I would like to acknowledge those who have supported me with their contributions to this study. A sincere thanks to Mr Ola Lædre for his help, patience and existence when I needed him. Thanks to Mr Lædre, I was able to get contact with PNC (the company under-study) which offered the summer training for me later. I also thank Mr Brendan Young for his help and trust in myself. He gave me the chance to go for the summer training and learn more about the Last Planner® System. Mr Brendan played a decisive role in my recruitment within PNC during the second semester which gave me a great opportunity and gained a direct interaction with the participants under-study in their cultural environment which helped me in turn with overcoming some of the limitations occurred during the first semester, such as the time and distance.

Additionally, both Mr Lædre and Mr Young supported me to make the two surveys and the two interview guides. They assisted me a lot with their previous experience in publishing papers, and it was a great honour to have Mr Lædre and Mr Young as co-authors in my publication in IGLC28 conference in the year 2020. The input they added to this study has been invaluable, and I much appreciate that.

I am grateful to the multiple facilitations that PNC Norge AS offered for the successful completion of this research. Thanks to PNC Norge As, I was able to attend the training sessions and the three workshops before the recruitment. Additionally, I was recruited in the company for eight months which facilitated the data collection.

A big thanks to Ms Nina Karliczek and Mr Stephan Steinberger for taking the time out of their busy schedules to allow me to interview them. They gave me the training and valuable information based on their vast experience working with Lean and Last Planner® System. Without that information given by both of them, the data collected would have been much shorter.

I also would like to thank all the project team (PNC project team). As thanks to their cooperation, I was able to collect the required data; they always gave me total support. I would like to thank the representatives from the JV partner and the representatives from the sub-contractors who responded to the two surveys.

I also would like to give a huge thanks to my mother and my brother, as without their support, their love and their prayers I wouldn't have been the person I am today.

Last but not least, I would like to thank my friends, who gave me the full support and motivation to continue, either by word or by action.

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List of abbreviations

LPS – Last Planner® System

LC – Lean Construction

NTNU – Norwegian University of Science and Technology

PNC – PORR Norge construction

PORR – The main organisation for PNC company

IMVP – The International Motor Vehicle Program

LPDS – Lean Project Delivery System

IGLC – International Group for Lean Construction

WWP – Weekly Work Plan

RNC – Reasons for Non-Completion

VM – Visual Mangement

CPM – Critical Path Method

MPP – Milestones and the Phase scheduling

PEP – Production Evaluation and production Planning

ADM – Activity Definition Model

CPS – Collaborative Planning Session

Summary

Based on the literature review conducted, researchers have recorded the implementation process of the LPS in many construction projects, but still, a few numbers of researchers have recorded the LPS implementation in Infrastructure projects. In this master thesis, the author addressed the following three research questions:

- How is PNC going to implement the LPS on the Minnevika Bridge project?
- What are the challenges that arise during the implementation of the LPS?
- What are the measures that PNC can use to tackle these challenges?

By addressing these three research questions, the author will help to fill the gap in the literature related to the lack of research papers introducing the implementation of the LPS in infrastructure projects. Additionally, the author managed to introduce some challenges which were not clearly described in the literature that arose during the LPS implementation on the Minnevika Bridge project (an infrastructure project). Finally, it helped to establish the foundation for the author to suggest some measures for the challenges that arose during the implementation of the Last Planner® System on the project. The measures suggested were a combination of both the suggestions from the project team members and some suggestions from the author.

Chapter 2, METHODOLOGY. The author describes the methods used to collect the data during the first and second semesters, including an extensive literature review, a single case study (PNC Norge AS), seven semi-structured interviews, participant/non-participant observations, document study and two surveys. At the end of Chapter 2, the author gives a summary of the methods utilised to answer each research question.

Chapter 3, LITERATURE STUDY, describes the findings identified from the literature. It consists of a small introduction to Lean thinking and Lean construction and its principles — the definition to the Last Planner® System, its origin and a detailed explanation of the LPS life cycle and its components. Moreover, the author gives an overview of the challenges that arose during the implementation of the LPS in many previous publications and summarises these challenges in one table while concentrating on infrastructure projects. In addition to the challenges, the author presents the measures utilised by the researchers to overcome these challenges. Finally, the author describes what was mentioned in the literature concerning the successful implementation of LPS based on the lessons learned and Critical Success Factors (CSFs) from previous publications.

Chapter 4, FINDINGS, shows the results from a single case study, the seven semi-structured, the observations, the document study and the two surveys.

Chapter 5, DISCUSSION, the findings from Chapter 4 are compared and contrasted to the findings from the literature to find the similarities and variances. Additionally, the author discusses the challenges that emerged during the LPS implementation on the project while introducing the suggested measures. At the end of the chapter, the author suggests a new indicator which can support building the Lean culture inside the weekly meetings for the new adopters of LPS.

Chapter 6, CONCLUSION / LESSONS LEARNED / RECOMMENDATIONS, summarises the results from the study using two different tables. The first table shows the implementation

process of the Last Planner® System on the Minnevika Bridge project, while the second table presents the challenges that emerged on the Minnevika Bridge project with the measures used by the project team to overcome these challenges. Moreover, the author presents the lessons learned from the case study and the recommendations for eliminating the three most critical challenges emerged on the Minnevika Bridge project based on the findings.

Chapter 7, FURTHER WORK, presents the further work suggested by the author in order to build upon and enhance this research.

Part 2 contains one published conference paper that is based on the findings from this study.

Part 3 consists of the appendices.

PART 1 – MASTER THESIS

Implementation of the Last Planner® System in an Infrastructure project

1 INTRODUCTION

1.1 Background

According to the research report conducted by Barbosa et al. (2017), the construction industry lags behind other industries in terms of productivity. This is demonstrated by an annual 1.0 % increase in productivity in the construction industry, compared to 3.6 % for the manufacturing industry over the past 20 years. Teicholz (2013) also shed light on low labour productivity in the construction industry. The secret to the high productivity rates in manufacturing industry lies in many factors; one of those factors is applying the concepts and methods (Lean thinking) utilised in Lean manufacturing for managing the production process; something that sparked a giant revolution.

Koskela (1992) aspired to apply these concepts and methods to the construction industry and was the first to alert the construction industry to this revolution. Later, Howell and Ballard (1998) claimed that Lean is suitable for dynamic projects, as it is the case in construction projects. Tommelein et al. (1999) have reported that complexity, variability and uncertainty are the essential reasons for the low productivity in the construction industry.
Multiple Lean construction tools have been developed in order to improve control over construction projects (Ansah et al. 2016). One of these tools is referred to as the Last Planner® System (LPS). The LPS, which has been developed and invented by Ballard and Howell, is classified as the most advanced tool in Lean construction (Cerveró-Romero et al. 2013).

Howell and Ballard (1998) developed the LPS to enhance the workflow reliability in projects. Increased workflow reliability leads to a reduction in overall waste (Ballard and Tommelein 2016). The main focus of the LPS is to decline the uncertainty or variability in the workflow, which has been neglected in the traditional project management (Ballard and Howell 2003a; Greg Howell and Ballard 1998). The Last Planner® system also seeks to improve the predictability of the planned activities on the construction site (Mossman, 2014).

In Norway, Kalsaas et al. (2009) mentioned that many companies in Norway started to adopt the LPS or showed interests to apply Lean methods in their operations by implementing the system through pilot cases. Demand for the LPS in construction projects by the public employers and the clients is dramatically increasing. That is why it is expected that future contracts will list Lean Construction and the LPS as a requirement. As a part of the construction industry in Norway, PNC Norge AS (the company under-study), like others, has suffered from some productivity issues and unreliable planning. So, they experienced a need for increased workflow reliability. To improve their internal work practices and employees' competencies, they have chosen to introduce the Last Planner® System on one of their projects as a pilot. The project is referred to as Minnevika Bridge.

LPS can help them in turn to improve their productivity, focus on increasing the customer's value, reduce the non-value adding activities, and as a way to distribute ownership of the project to all levels of the project organisation. During the implementation of the LPS on the project, many new-born-challenges started to show up.

This research is an evaluation of the implementation of the LPS on the Minnevika Bridge project, a presentation of the challenges that arise during the implementation, and the suggested measures to overcome these challenges.

1.2 Knowledge gap

Based on a comprehensive literature review, multiple studies have been conducted to evaluate the implementation of LPS in construction projects around the world, but few studies have recorded the implementation process in infrastructure projects. So, in this research, the author focused on the implementation of the LPS in a single case study (an infrastructure project) by contrasting it with the findings from the literature in order to find the similarities and variances.

Additionally, in the literature, more focus has been given by the researchers to improve the LPS components and its integration with other systems. In contrast, less attention has been paid to the behavioural aspects and attitudes of practitioners during the LPS implementation despite its importance and impact on the implementation process. So, the author addresses this point by focusing on the negative attitudes and behaviours of the participants during the LPS implementation. Additionally, the author suggested some measures based on the results of the study to eliminate these negative attitudes and behaviours. At the end of the discussion part, the author suggested an indicator which can help the LPS practitioners to track these attitudes. However, due to time limitations. The indicator was not applied on the project.

Finally, the literature review conducted did not reveal any researchers that have described the Transition Point between the Training Phase and the Execution Phase, that is the point when the LPS Trainers hand over the system (after the training period, which is referred to by the author as the Training Phase) to the project team and specifically to the LPS Facilitator. Note that the Execution Phase is the phase after the Training Phase. In this research, the author highlights the importance of this point which should be chosen carefully. Otherwise, it may influence the implementation process.

The contribution to knowledge is the evaluation of the implementation of the LPS on the Minnevika Bridge project (an infrastructure project) and the suggestion of measures to the challenges that appeared during the implementation of the LPS on the Minnevika Bridge project. Regarding the uniqueness of the project, two challenges were detected by the author, which were not clearly described in the literature. The possible impact on the implementation process, and the suggested measures in order to tackle these challenges were also addressed.

In order to fill the gap, the following research questions were examined:

1- How is PNC going to implement the LPS on the Minnevika Bridge project?
2- What are the challenges that arise during the implementation of the LPS?
3- What are the measures that PNC can use to tackle these challenges?

1.3 Limitations

Many factors have been identified during the study period that formed the limitations of this research. Firstly, this study was limited to the execution phase of the project and did not include the design phase. Additionally, due to the time limitations, the study was just limited to one of the main contractor's perspective; so neither the perspectives of the subcontractors nor the JV partner contractor was included into this study, except for when implementing the two surveys. The attitudes from all of the participants in the weekly meetings and towards the LPS, in general, were observed. The attitudes were not limited in the study to a specific party. So, the objective of this study was to investigate the implementation of the LPS in a single case study (Minnevika Bridge project).

The client (BaneNor) did not plan to use the LPS on this project and did not participate in the LPS implementation process, despite the invitations. So, the client was not a key member in this case study and was not invited to the interviews of the surveys conducted. Due to the limited time, that is four months per semester; the author concentrated on the first two research questions during the first semester and proceeded with the third question during the second semester.

Based on a single case study, the results may lack generalisability. Nevertheless, similar results of the existing literature and assessments by the project team members themselves (by using the interviews and two surveys) could validate the findings of the case study.

The author looked at this case study from different periods. The first period was at the early beginning of this project, and specifically, during and after the initial training, the author gave it the name "the Training Phase". During the first period, the Trainers had the responsibility for the LPS. The second period was when the project team took over the process on their own (after the Training phase). The author referred to this period as " the Execution Phase". During these two periods, many limitations influenced the research process, namely, the delays from the project team concerning the date of the training sessions, the time and distance limitations between the project team and the author, and the outbreak of Covid-19.

Firstly, in the first period, the project team postponed the date of the training sessions, which was planned to be conducted at the beginning of October. Later, The author just had almost one month of observing the process; starting with the training sessions on the 6th of November. During this month, the author managed to attend the two training sessions and two out of the three workshops (due to the time and distance limitations). However, these limitations were solved by having minutes from the workshop. Additionally, the project team members were not acquainted with the LPS, so just two interviews were carried out during the first period.

During the second period, the author was recruited in the company under-study and was present in all weekly meetings, which facilitated observing the project team. Finally, the project team became more familiar with the LPS, which made it much easier to conduct the interviews needed for answering the research questions.

Secondly, the outbreak of Covid-19 made the situation quite challenging, especially when the weekly meetings were suspended, and the communication between the interviewees and the author became complicated. This caused some delays and interruptions. However, the author conducted the interviews over skype and managed to get the needed answers.

The plan was that the author observes the follow-up sessions during the Execution Phase. Nevertheless, the follow-up sessions were suspended during the outbreak of Covid-19, and the author did not get enough information about these sessions and their impact on the implementation process.

At the end of the DISCUSSION chapter, the author suggests a new simple indicator that can be utilised to track the attitudes and behaviours during the weekly meetings. However, due to the time limitations, the author could not apply this indicator on the Minnevika Bridge project. This indicator was, therefore, suggested by the author to be further developed and studied.

2 RESEARCH METHOD

The research questions were addressed by carrying out a comprehensive literature review (by critically analysing a segment of a published body of knowledge), a single case study (Minnevika Bridge project), seven semi-structured interviews, observational research, a document study, and two surveys. The results from the literature study were eventually compared and contrasted with the findings from this case study.

In this chapter, the author describes in detail the different research methodologies and the process utilised to implement each method.

2.1 Literature review

A comprehensive literature review has been conducted in order to study the Last Planner® System theories according to the steps mentioned by (Banister 2015). The author sought to carry out an extensive literature study based on different types of publications; to have a good overview of what the literature mentioned about Lean construction and its meaning; the meaning of Lean culture; the different methods of Lean; the Last Planner® System, its components and its applications; the possible challenges that were detected in the literature; how to overcome these challenges; and how to successfully implement the LPS. Afterwards, the previously collected data was compared and contrasted to the findings from the case study. The results from the literature review also formed a basis to build upon when it comes to defining the knowledge gap. Furthermore, it gave the author a good understanding and breadth of knowledge on the Last Planner® System and Lean Construction.

The publications here are referring to books, articles, journal papers, master theses, dissertations, or conference papers.

Initially, the author relied on a systematic literature review based on the published literature in databases; namely, Scopus, Google scholar, IGLC Papers, ASCE and Web of Science. In addition to the previously mentioned databases, NTNU library (Oria system for publications) was utilised for finding relevant publications. After selecting the publications from the databases, the author later checked the references for the selected publications using forward and backward snowballing and identified the most relevant and the highest cited publications, that is the publications with more than twenty citations.

The author divided the literature review into three different categories; the first one is mainly concentrating on understanding the Last Planner® System and how it was implemented in companies based on different case studies. Whereas, the second category focuses on the definition of Lean Construction and Lean culture. Finally, the third category is a more specific review and focuses on answering the second and third question and by presenting the challenges that arose when implementing the LPS on previous projects and the possible measures for tackling these challenges.

- The first database which the author used was Google scholar, and the following process was carried out:

The first search terms used were “Last Planner System” AND “Implementation” AND “Infrastructure” and sorted by relevance. There was a total of 780 hits, and seven papers were relevant based on the title and the abstract such as:

1. Cerveró-Romero, F., Napolitano, P., Reyes, E., and Teran, L. (2013). Last Planner System® and Lean approach process®: experiences from implementation in Mexico. Paper presented at the 21st Annual Conference of the International Group for Lean Construction, IGLC.
2. Gao, S., and Low, S. P. (2014). The Last Planner System in China's construction industry — A SWOT analysis on implementation. International Journal of Project Management, 32(7), 1260-1272.

The second search terms used were “Last Planner System” AND “Ballard”
Ballard is one of the inventors of the LPS, together with Howell. Therefore, there was a total of 8,080 hits, and many articles were relevant such as:

1. Ballard, H. G. (2000). The last planner system of production control. (PhD Thesis). The University of Birmingham, Birmingham, UK.
2. Ballard, G., and Howell, G. (2003). An update on last planner. Paper presented at the Proc., 11th Annual Conf., International Group for Lean Construction, Blacksburg, VA.

- Then the author utilised the same process with all the databases; namely, Scopus, Oria, ASCE and Web of Science.

The author managed to select more than 30 publications, including conference papers, books, journal articles (peer-reviewed) and PhD dissertations.

- Finally, the author used the IGLC website to find some relevant conference papers, as recommended by MR Ola Lædre.

The author used the term “Last Planner” and managed to find a total of 283 hits and many relevant papers such as:

1. Cano, S., Delgado, J., Botero, L., and Rubiano, O. (2015). Barriers and success factors in lean con-struction implementation: survey in pilot context. Paper presented at the 23rd Ann. Conf. of the Int. Group for Lean Constr., Perth, Australia.
2. Cerveró-Romero, F., Napolitano, P., Reyes, E. and Teran, L. 2013. Last Planner System and lean approach process: Experiences from Implementation in Mexico. In: Proc. 21st Ann. Conf. of the Int’l. Group for Lean Construction. Fortaleza, Brazil, Aug. 31-2

Based on the publications found from the databases, a critical evaluation was undertaken to ensure that each piece of literature included in this study was credible, reliable, relevant objective and recent. A sample of this process and evaluation has been delivered before as an assignment for the course TBA4128 as shown in APPENDIX E – CRITICAL EVALUATION OF LITERATURE.

2.2 Case Study

A single case study has been chosen to justify some findings from the literature study, and all the research questions were answered based on this case study.

PNC is a bridge-building company that has its headquarter in Oslo, Norway and is made up of the main office and the projects. The main office consists of the tender team, and the support team "back office", while the rest of the company is project-based. Furthermore, PNC is part of the main organisation called PORR. PORR is considered as one of the largest and oldest construction companies and has its headquarter in Vienna.

PNC used the LPS for the first time in the company as a way for managing their daily schedules and for controlling the overall work processes in their new project, which is called Minnevika Bridge.

The idea of using the Last Planner® System on the Minnevika Bridge project has been initiated by the project team themselves, and not by the company, for the sake of the improving the participants' skills and enhancing the productivity of the project. Minnevika Bridge was utilised as a pilot project for LPS. This pilot project may form the starting point of a transformation in PNC towards Lean, based on the result of this Last Planner® System implementation.

Mr Ola Lædre has played a decisive role in introducing the author to the company and in specific to Mr Brendan Young who is working as a site manager for the PNC company on the Minnevika Bridge project and is a previous MSc student in PROMAN.

Mr Young offered the author a summer job as an initiative from the company to the author to become familiar with PNC's internal system and procedures and to get to know the working team, since they were the members with whom the author made the study. After the summer job, the author became familiar with all the team members starting from the construction manager and going down the hierarchy to the foremen. This involvement gave the author a great opportunity to proceed smoothly with the case study, observations, document study, the interviews and the surveys.

The author was invited to the training sessions on the 6th and 7th of November 2019. Furthermore, the author managed to attend some of the workshops in-person and got access to the "minutes from the meetings" documents to get to know more about the implementation process. Eventually, from January, the author was based on the project as a full-time employee which gave him a good chance to carry out the observations, the interviews, the surveys and the document study.

Description of the project

PNC Norge AS forms part of the Joint Venture (JV), AFHP, which is the main contractor for the construction of the Eidsvoll Nord-Langset project. As part of this joint venture, PNC is responsible for the Minnevika Railway Bridge. The bridge is 836 metres long, which will become Norway's longest railway bridge. It is a Design-bid-build contract. The LPS was not used during the design phase, nor was there any interest from the client to participate in the process. PNC is the only user of the LPS. However, the JV partner and all the subcontractors were invited to participate in the implementation process.

It is noteworthy of mentioning that this table is presented following the format utilised by Alsehaimi et al. (2009).

Table 2. 1 – Description of Minnevika Bridge project

Project	Contract	Estimated duration	Main contractors	Sub-contractors
Minnevika Bridge	2.2 Billion Nok	4 years	PNC Norge AS and Hæhre	Aarlseff and EB Marine companys

2.3 Interviews

The author based the single case study on semi-structured open-ended interviews. Additionally, the author requested from all the interviewees to keep their answers as case-specific as they could, which means that their answers should be based on their experience from Minnevika Bridge project and not based on generic answers according to any previous experience from other projects.

Thanks to the help of Mr Young and the company that facilitated the research process. Moreover, it was uncomplicated for the author to contact the interviewees. During the first semester, there were some limitations regarding the time and location distance; it was tricky to carry out interviews because of the distant working location and the time commitments for both interviewees and the author, which in turn led to some delays in the dates of interviews.

The table below presents the seven different interviews held by the author. The five different interviewees that participated in these interviews and their positions in the organisation were also described.

Table 2. 2 – The details of the interviews

Interview no.	Name of the interviewee	Position in the oganisation
I	Eveline schnell	The LPS Facilitator
II	Nina Karliczek and Stephan Steinberger	Lean managers (the Trainers)
III	Nina Karliczek	Lean manager (the Trainer)
IV	Katarzyna Zaleska	Site engineer
V	Maciej Kupper	Site manager
VI	Eveline schnell	The LPS Facilitator
VII	Jaroslaw Promorski	The project Planner

The author structured the interviews around the interest in the following questions:

1. What is the reason why PNC is going to use the LPS on the Minnevika Bridge project?
2. How are the project team going to transform the internal system on the Minnevika Bridge project?
3. What are the measurements that they are going to use to track the weekly performance?
4. What are the challenges that will arise during the implementation of the LPS?
5. What are the measures that the project team will utilise to overcome these challenges?

* For more information about the interview questions (see APPENDIX A and B – First and Second interview guides).

Based on an inquiry from the supervisor Mr Lædre, Mr Young was asked by the author to be the co-author for a paper in the International Group for Lean Construction (IGLC2020), so Mr Young was present in *Interview I* and helped the author to analyse the data acquired in the other interviews.

The author conducted the first two interviews in the early beginning of the implementation of the Last Planner® System and precisely before the training sessions. The main reason for conducting the first two interviews was to answer the first research question and to prepare for the second and third research questions. The interview guide utilised in these two interviews was as shown in APPENDIX A – First interview guide.

The first interview, *Interview I*, with the LPS Facilitator, was held over skype on the 24th of October. During the first interview, it was explicit that the LPS Facilitator was not experienced with the Last Planner® System. During the interview, the answers showed that the LPS Facilitator did not understand the reasons why things were occurring and how things would change. The LPS Facilitator had no previous experience with facilitation of LPS, so the plan was that she learn with the project team.

The second interview, *Interview II,* was held in-person on the day before the training sessions (on 5th of November). The interviewees were very competent and knew what they were saying; based on more than two years of experience in this field, they have also participated in 15 different projects as Trainers. Face-to-face interviews were very beneficial for the author. It was comfortable to ask for more clarifications, and the positive thing was that the Trainers were so experienced that they sometimes expanded the answers; giving some examples based on their previous experience to clarify things.

The purpose of the first two interviews was to examine the LPS implementation process on the project, determine the challenges expected and the measures suggested by the Trainers and the LPS Facilitator.

The author conducted the reset of interviews during the Execution Phase and specifically in February and March. *Interview III* was the only interview held in February and was a face-to-face interview, while the rest was held on March over skype. There were limitations concerning conducting more interviews due to difficulty to reach some of the interviewees. However, the answers from the four respondents, together with the other research methodologies were enough to answer the research questions.

The third interview, *Interview III*, was held in-person during the Execution Phase. During the interview, the author asked the Trainer questions as indicated in APPENDIX B – Second interview guide. The purpose of *Interview III* was to supplement the answers for *Interview II*; there were some answers which were not yet settled. Additionally, the author dedicated a part concerning the results from the second survey; in order to solve the issue of neutral answers from the second survey, detect new challenges, if possible, and to know possible measures for overcoming the challenges detected during the LPS implementation.

Interview VI was held over skype with the LPS Facilitator during the Execution Phase. The purpose of this interview was to monitor the change in answers with respect to *Interview I*. This time, the answers were totally different and indicated a good understanding of the system.

During the interview, the author asked the LPS Facilitator questions as indicated in APPENDIX B – Second interview guide and used the same dedicated part as mentioned in the previous paragraph, but this time from the LPS Facilitator's perspective.

Interview IV, Interview V, and *Interview VII* were held over skype. The same interview guide was used in *Interview III and Interview VI* and with the same purpose, but the difference was that the answers were taken from the participants' perspective.

the outbreak of Covid-19 formed a great obstacle when conducting the last four interviews; many employees were laid off due to the situation, which resulted in some delays. Still, the author achieved the required results.

2.4 Observations

The author carried out – non-participant – observations in an initial training session to record participants' attitudes towards the system. Additionally, the author carried out – participant – observations in three workshops and the weekly Production Evaluation and Planning (PEP)-meetings and managed to observe how the team members' behaviours are going to change before and after the adopting the LPS. The author succeeded in identifying the planning practices for the project team when using the LPS, detecting challenges that arose and suggesting measures for overcoming these challenges.

The author chose to conduct a combination of non-participant observations and participant observations to get the benefits out of both ways; to ask what the participants think about, to observe their reactions in the natural setting and to ask why questions (participant observations) and at the same time having a possibility to look at the meetings from outside and concentrate more on their behaviours and attitudes (non-participant observations).

The recruitment of the author in the company as a full-time employee during the second semester helped with observing the ongoing behaviours and the Last Planner® System application in a natural setting. Additionally, it gave the author a chance to intervene in the environment and to explore the actual causes of behaviours and to determine the validity of the observations gathered.

The limitations to the observation process were the time and distance during the first semester and the outbreak of Covid-19 during the second semester. In the first semester, The author managed to attend two workshops out of three workshops due to the time and distance obstacles, another problem with time was that the project team postponed the process many times which led to some delays in the observations process. In the second semester, the PEP meetings were suspended for two weeks due to the situation which influenced the progress of the observations. However, the observations for five months (one month in the first semester and four months in the second semester) were enough for collecting the data required for answering the research questions.

2.5 Document Study

The document study is treated as a qualitative research method in which the author elaborates what is in the documents "*to give a voice and meaning around an assessment*" (Bowen 2009). The primary purpose of the document study was to identify the implementation process of the LPS, including the dates of the training sessions, workshops and weekly meetings, and the different phases of implementation in general. Moreover, minutes from the weekly meetings, which the author could not attend, in the first semester, due to time and distance limitations, were sent to the author by e-mail for the sake of following the entire implementation process from the beginning.

There were many limitations in the first semester regarding the documents that the author had access to; due to company policy, but this issue was solved during the second semester. The author was recruited on the project as an employee, and the accessibility to the essential documents was uncomplicated.

During the second semester, the author had access to all the documentation from the weekly meetings. Those documentations contained all the records, including the Percent Plan Complete, the reasons for non-completion and many more. The author used these records later in the FINDINGS and DISCUSSION chapters.

2.6 Survey questionnaire

According to Queirós et al. (2017), the survey can be a handy tool when conducting a study on a group of people as according to them it is considered as "*high representativeness of the entire population.*" Additionally, it is a time-saving tool which can be utilised to get responses from different members at the same time.

A first survey – comprised of 14 closed-ended questions and one open-ended question – was answered by 13 respondents. The closed-ended questions were mostly based on a Likert scale method, as indicated in APPENDIX C – The first survey. The first survey was sent before the training sessions. So, both an online and a hard-copy survey (using the same questions) were prepared and sent/distributed to the attendees of the training sessions. The answers from the online copy were anonymous, and the same applied to the answers from the hard copy; the author asked the respondents not to write their names and to leave the paper on a specific desk in order to keep the answers anonymous. The purpose of using anonymous answers was to get the most reliable and honest answers from the respondents.

A second survey – comprised of 22 closed-ended questions and one open-ended question – was answered by eight respondents during Execution Phase (the phase after the Training Phase as will be indicated later in the FINDINGS chapter). The closed-ended questions were mostly based on a Likert scale method, as indicated in APPENDIX D – The second survey. In the second survey, the author utilised just an online form of the survey with anonymous respondents.

The author carried out the two surveys in two previously determined time frames. The first time frame was before the training session to measure how much knowledge about the Last Planner® System the respondents already had from before, to examine openness towards the LPS, and to

record the challenges from the participants' perspective. The second time frame was during the Execution Phase after the participants have already utilised the LPS to evaluate how much their attitudes towards the LPS can change. Moreover, the second survey encompassed a dedicated section (Section 2), using a Likert scale method, to determine critical challenges from the participants' point of view that arose during the Execution Phase.

Limitation to the first survey was the low number of respondents. Many respondents ignored the online survey. To solve this issue, the author had to copy the first survey and deliver it in-hand before the training sessions as a hard copy. The author managed to get 13 responses out of 17 attendees from the first survey. The survey was sent to 24 participants. 13 respondents were not a high number, but still, it was a useful indicator for attitudes and openness towards the LPS.

In the second survey, the author managed to get eight responses out of 12. Still, this was beneficial, especially with the dedicated part for assessing the challenges during the Execution Phase.

The author formed the survey based on what Krosnick (2018) mentioned. So, when using the Likert scale method, the author started with devolping the scale. The scale chosen by the author was five-points scale. The scale range used was 1= strongly disagree, 2= disagree, 3= undecied, 4= agree and 5= strongly agree. 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. Likert scale method can be utilised to measure the attitudes and behaviours (Albaum 1997)

* For more information about the surveys questions and answers, please see APPENDIX C and D – The first and second survey

In summary, in order to answer the three research questions, the author followed the research structure as shown in Table 2.3 below.

Table 2. 3 – Summary of the methods used to answer the three research questions

1) How is PNC going to implement The LPS on the Minnevika Bridge project?

To answer the first question the author carried out:

1- Four different interviews (*Interview I, Interview II, Interview III, and Interview VI*)
2- Document study
3- Observations

2) What are the challenges that arise during the implementation of LPS?

To answer the second question, the author has divided the research process utilised into three steps and they are as follows:

- Preparation of the challenges
  1- Two different interviews (*Interview I, Interview II*).
  2- (Non-participant & participant) observations
  3- Literature study
  4- The first survey (The open-ended question at the end of the first survey as indicated in APPENDIX C – The first survey)

- The challenges arose during the Training Phase
  1- (Non-participant & participant) observations
  2- Five different interviews (*Interview III, Interview IV, Interview V, Interview VI, Interview VII).*

- The challenges arose during the Execution Phase
  1- Participant observations
  2- The second survey (a dedicated section "Section 2", using Likert scale method, to determine critical challenges from the participants' point of view that arose during the Execution Phase, as indicated in APPENDIX D – The second survey)
  3- Five different interviews (*Interview III, Interview IV, Interview V, Interview VI, Interview VII).*

3) What are the measures that PNC can use to tackle these challenges?

To answer the third question the author carried out:

1- Literature study
2- (Non-participant & participant) observations
3- Seven different interviews (*Interview I, Interview II, Interview III, Interview IV, Interview V, Interview VI, Interview VII).*

3 LITERATURE REVIEW

3.1 Lean construction

This section of the chapter defines what is meant by Lean as a philosophy, its origin, and how the term has transferred from the manufacturing industry to the construction industry. However, the primary focus is on Lean Construction, and not Lean Manufacturing.

3.1.1 The origin of the term Lean

"*Lean is a business philosophy and a system for organising and managing corporate processes including product development, design, production, operations, supply chain, and customer relationships to increase value and minimise waste. Lean is a perpetual quest for perfection pertinent to organisational purpose, business processes, and developing people*" (Hamzeh 2011, p. 380).

Lean principles have mainly originated from Japanese manufacturing techniques. As mentioned by Holweg (2007), Mr Taiichi Ohno, a Japanese engineer from Toyota, was responsible for introducing and developing the Toyota Production System (TPS). Mr. Taiichi Ohno introduced the system together with the founder of Toyota, Sakichi Toyoda and his son, who has also participated in the development of the system afterwards. Mr Taiichi Ohno visited the U.S. automobile factories, where he noticed much waste in the production process. Mr Taiichi Ohno thought that over-production had to be eliminated or decreased to the lowest limit possible. So, the new system's main objective was to get rid of any possible waste and to increase the revenues (Holweg 2007).

The term "Lean" was invented by John Krafcik in his article "Triumph of the Lean Production System" in 1988. Moreover, the International Motor Vehicle Program (IMVP) (a five-year research program and its main task was to investigate the future of automobiles) kept working on the system and produced their best-selling book, which was co-authored by James P. Womack, Daniel Jones, and Daniel Roos, and called "The Machine That Changed the World" (Holweg 2007).

The main focus of lean manufacturing is to eliminate waste. Liker (2004) said that the top managers and employees in Toyota used the philosophy of eliminating waste, otherwise known as Muda. Two other terms that are as crucial as Muda for the success of the system are Muri and Mura. Together these 3 M terms form Lean Manufacturing and make it function.

The definitions of the three terms, as indicated by Liker (2004):

• Muda (Non-value added): The activities that lead to a waste in time, increase the expected movements or lead to any time waiting.

• Muri (Overburdening people or equipment): This can be applied when pushing the machines or persons above their abilities which can result in some safety and quality problems, which in turn can cause defects and breakdowns in these machines.

• Mura (Unevenness): It can be formed by the chaotic schedules and the unstable production volumes due to internal issues.

Toyota classified seven types of wastes, with an eighth waste added by Liker (2004):

1- Overproduction
2- Waiting (time on hand)
3- Unnecessary transport or conveyance
4- Over processing or incorrect processing
5- Excess inventory
6- Unnecessary movement
7- Defects
8- Unused employee creativity

The following section describes how Lean transferred from the manufacturing industry to the construction industry.

3.1.2 How could Lean be transferred from manufacturing to construction?

There is a significant difference between the construction industry and manufacturing industry, especially in the "physical feature of the end project" (Koskela and Howell 2002; Salem et al. 2006). In the manufacturing industry, finished products can directly be given to the end customers and repeated again and again, whereas construction projects are unique products and not repeated (or projects we can say) They are even unique in their complexity, since each project has its own complexity (Koskela and Howell 2002; Salem et al. 2006)

It was Dr Lauri Koskela who alerted the construction industry to the revolution in the manufacturing industry. Dr Lauri Koskela wanted to make use of the new concepts and techniques used in manufacturing (lean thinking) and to apply it in the construction industry (Koskela 1992). Despite the massive difference between both industries, lean thinking and techniques have been used in managing construction (Howell and Ballard 1998). Furthermore, Howell and Ballard claimed that lean thinking is suitable for the dynamic projects as Lean thinking is not just a way of standardisation of processes.

The first conference for International group for Lean construction IGLC was hosted by Dr Koskela and a group of other researchers. They made plans to adopt the name of Lean construction (Ballard and Howell 2003a).

But what is Lean thinking? The following section explores this question.

3.1.3 Lean thinking

Ballard and Howell (1998) stated that lean thinking considers the project as a production system. This viewpoint was the opposite of the contract centred perspective.

Lean thinking was prescribed by Womack and Jones (1996) for the elimination of the non-value added activities (Mude in Japanese as mentioned before), and it is a five-step operation as shown:

1- **Specify value**: The definition of the value according to the customers' needs (by the customers themselves). This definition must be adjusted with their capabilities.
2- **The value stream**: All the actions needed to deliver the product to the end customer; namely, the detailed design, engineering, order taking, production scheduling and delivery (Womack and Jones 1997).
3- **The flow**: The flow of resources and information. It is divided into two major types: the controllable flows and uncontrollable flows. The controllable flows are directly dealing with the flow of materials from the warehouses and instructions from management, while uncontrollable flows are suppliers' provisions of resources and design information (Dulaimi and Tanamas 2001).
4- **Pull**: by allowing the customer to pull the product as needed.
5- **Perfection**: looking for perfection by continuous improvement and learning from mistakes.

3.1.4 Lean Project Delivery System (LPDS) Model

Our understanding of the projects has typically been bonded to talking about the project phases; including, predesign, design, procurement and installation (Ballard and Howell 2003a). The essential variations between traditional and Lean project delivery are related to the definition of those phases, the links (overlaps) between them and the participants in each phase.

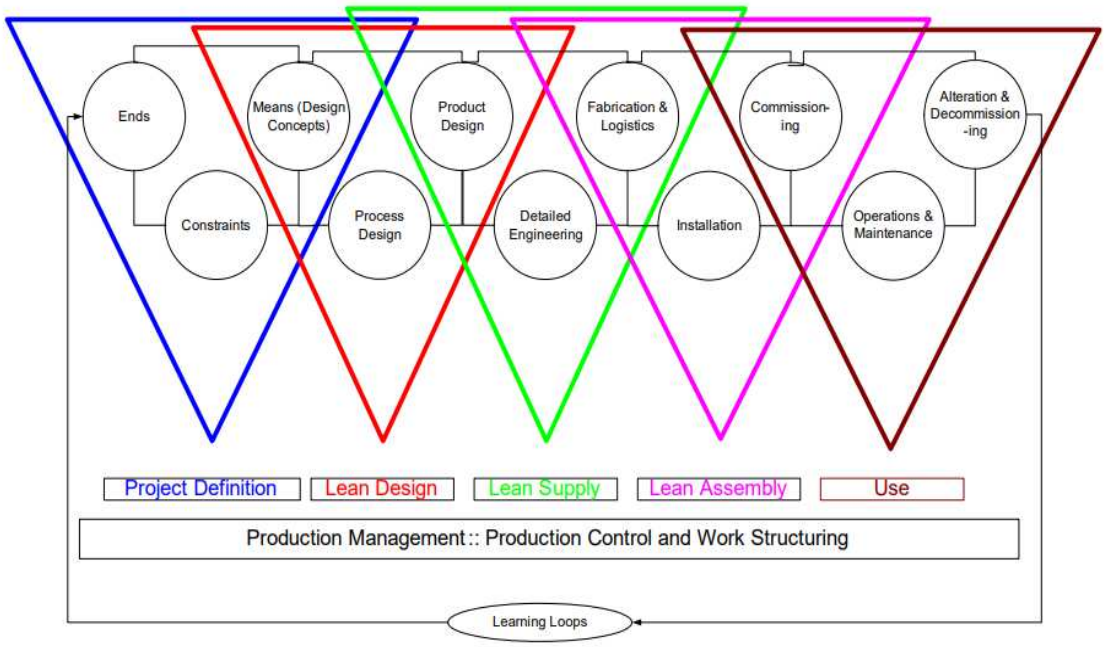

Figure 3. 1 – Lean Project Delivery System (Ballard et al. 2007b)

As shown in Figure 3.1 below, we can notice that the phases are divided in LPDS into five different phases with the relationships between all of them. Each phase and the link between each of them are elaborated as follows.

Project definition: It includes all the purposes and values, the design concept and the design criteria chosen by the customer, and different stakeholders on the project. Each of those elements has a significant influence on the other elements. So, a good relationship has to be

made between various stakeholders in order to understand the project better. The participants of this phase are usually the representatives of every stage in the life cycle of the facility (Ballard and Howell 2003a).

Lean design: According to Ballard and Howell (2003a), the alignment of all the values, concepts and criteria is considered as the gate between project definition and Lean design. In Lean design, we still have the conversation as a central part of the success of this phase. This conversation will be held to align the process design and the product that we get. On contrast to the traditional project delivery method, LPDM postpones the decisions to the last responsible moment for giving the team more time for enhancement and examining the different alternatives possible. In the Lean design phase, "set-based" strategy makes it possible for the interdependent specialists to go beyond the limits of the alternatives they consider while keeping in mind that the decisions have to be made within the lead time for realising the alternatives.

Lean supply: As shown in Figure 3.1, Lean supply is composed of detailed engineering and fabrication, product design and logistics. Before starting the Lean supply phase, the product design has to be finished in order to know what to detail or fabricate and the time of delivery of each component. Ballard and Howell (2003a) added that "*Lean Supply also includes such initiatives as reducing the lead time for information and materials, especially those involved in the supply of engineered-to-order products, which typically determine the pace and timing of project delivery.*" (p. 121)

Lean assembly: Ballard and Howell (2003a) also mentioned that this phase starts with the delivery of material and all the relevant information for its installation. We can say that this phase has ended when the client has the agreed benefit of the facility after commissioning and start-up.

3.1.5 Lean culture

Mann (2017) described the meaning of culture in a company in general as "*an idea arising from experience. That is, our idea of the culture of a place or organisation is a result of what we experience there. In this way, a company's culture is a result of its management system*." (p, 4) Mann (2017) also added that "*culture is critical, and to change it, you have to change your management system.*" (p, 4)

Mann (2017) stated that "*Lean culture emerges as leaders replace the mindset to work around problems today, ignore their causes, and let tomorrow take care of itself—a mindset learned in our careers in conventional processes and organisations*." (p, 9)

Companies have to concentrate on their management system and the targets they can see, including the leader's behaviour, tools, expectations and routine practices. With the use of Lean production systems, all of that will be easier, as "*they emphasise explicitly defined processes and use visual controls*" (Mann 2017, p. 4).

3.1.6 Lean Construction tools

Many different Lean tools used in the construction industry were identified in the literature. However, only 30 tools were declared to be effective and suitable for the construction industry (Ansah et al. 2016). The 30 tools are:

1- Last Planner® System (LPS)

2- Concurrent Engineering

3- Daily Huddle Meetings

4- 5S

5- First Run Studies

6- Visual Management

7- Fail Safe for Quality

8- Construction Process Analysis

9- Kanban (Pull System)

10- Just-In-Time

11- Work Standardisation

12- Value Stream Mapping

13- Statistical Process Control (SPC)

14- Work Structuring

15- Pareto Analysis

16- Poka-Yoke (Error Proofing)

17- Continuous Flow

18- Six Sigma

19- Failure Mode and Effects Analysis (FMEA)

20- Bottleneck Analysis

21- Kaizen

22- PDCA (Plan, Do, Check, Act)

23- 5 Whys

24- Muda Walk

25- Root Cause Analysis

26- Check Sheet

27- Synchronise/Line Balancing

28- Jidoka/Autonomation

29- FIFO line (First In, First Out)

30- Team Preparation

Due to the limited scope of this thesis, the author focuses mostly on the first Lean tool, which is the Last Planner® System. In the following part, the author presents in detail the Last Planner® System and its components.

3.2 Last Planner® System (LPS)

3.2.1 Introduction to the Last Planner® System

What is the LPS?

Glenn Ballard and Greg Howell were the ones that invented the Last Planner® System (LPS) and took the lead for its improvement over the last three decades (since 1992). Several papers have previously been published by Dr Ballard related to this system. The first paper was published in 1993 and was called Improving EPC Performance (Ballard 1993) at the conference of the International Group for Lean Construction (IGLC) in its first year. In this paper, Dr Ballard mentioned the term Last Planner® System for the first time. Since then, the level of implementation of the LPS has been increasing geographically in construction (Daniel et al. 2015).

The Last Planner® System is primarily based on all the principles of Lean Construction, which always seeks for perfection and excellent performance concerning productivity, which can be realised by the improvement of reliability of planning by taking action in several levels in the planning system (Ballard et al. 2007a).

The LPS is "*a structured collaborative process that dramatically improves coordination and the identification of constraints on projects through effective conversations, shared understanding and reliable promising*" (Ebbs and Pasquire 2019, p. 1). The LPS escalate the value on the projects in the form of safety, logistics, quality, team morale (mood), and productivity that in turn reduce schedule and cost (Mossman 2015; Ebbs and Pasquire 2019).

Ballard and Howell were inspired after discovering that construction projects lack "workflow reliability". As a way to enhance the workflow reliability on the projects, they suggested to raise the match between DID and WILL, that is, to learn from our faults and to "learn how to do what we say we are going to do", which can be done by holding meetings in which all the front line supervisors are responsible for producing Weekly Work Plans (WWPs) and reliable assignments. Applying this can lead to reducing overall waste (Ballard and Tommelein, 2016; Howell and Ballard 1998).

The main focus of the LPS is to reduce uncertainty and variability in the workflow that has been neglected in traditional project management which resulted in low performance of the construction projects (Ballard and Howell 2003a; Ballard 2000; Howell and Ballard 1998). The Last Planner® System also seeks to improve the predictability of the planned activities on the construction site (Mossman 2014).

(Ballard and Tommelein 2016; Daniel et al. 2015) have listed the various functions and principles of the Last Planner® System, which are as follows:

1- Specifying what tasks should be done when and by whom, from milestones to phases between milestones, to processes within phases, to operations within processes, to steps within operations.

2- Making scheduled tasks ready to be performed with those who are to execute them

3- Re-planning/planning to complete, to achieve project objectives

4- Selecting tasks for daily and Weekly Work Plans—deciding what work to do next

5- Making release of work between specialists reliable

6- Making visible the current and future state of the project

7- Identify constraints to be removed on the planned task beforehand

8- Ensure promises made are secure and reliable

9- Measuring planning system performance

10- Continuously learn from plan failures that occur when executing tasks to prevent future reoccurrence.

The LPS is being utilised on various applications. Furthermore, the spread of the LPS is not just limited to the construction site and also can be used in the design phase (Ballard and Tommelein 2016; Daniel et al. 2015). However, in this research, the author limited the literature review to just the use of the LPS on the construction sites.

It is noteworthy to mention that many researchers have been working on evolving the LPS and its integration with other systems such as BIM, Takt time planning, and Visual Management planning software (Daniel et al. 2015). The author will not elaborate on this integration process as the company under-study was adopting the LPS for the first time, and no integrations with other system were undergone.

Who is the last planner?

Dr Ballard mentioned that "*The last planner is last in a chain of planners, each providing directives "SHOULDS" to the next. Construction is complex. Planning is not done by one person or group at one time. It is distributed throughout the organi[s]ation and over the life of a project. The "last planner" is the one who produces directives that drive direct work processes, not other planning processes, i.e. assignments. If the planning system fails to produce good assignments, it does not matter how good the upstream planning was. Those plans never get reali[s]ed* " (Ballard 1993, p. 80-81).

Why the LPS?

Since the beginning, Dr Ballard and Dr Howell claimed that traditional project management adopts the system of *project* control and does not take into consideration *production* control (Ballard and Howell 1998; Ballard 2000; Howell and Ballard 1996). "*We need to control management processes, not only project outcomes. Traditional outcome measures such as cost, and schedule can only be used for management decision making on dynamic projects when the project management systems are themselves in control. The primary indicator of such control is the reliability of production planning*" (Howell and Ballard 1996, para. 3).

In several publications, the researchers conducted a comparison between the term project control and the term production control. They always emphasised the dissimilarities between both of the concepts, and said that project control's purpose is to adapt the performance to the plan, in addition to that project control is to align "cost and schedule targets" to the "project scope"

(Ballard and Tommelein, 2016; Howell and Ballard 1996). In contrast, production control was designed to manage complex projects and their variances in order to get the best possible choices and give this beneficial experience back to the parent organisation to make it possible for future learning (Howell and Ballard 1996). They also claimed that production control is considered a missing part in traditional project management and that the construction industry has relied mainly on "project and contract management", while on the other hand, the management of production has been neglected. Moreover, they adopted the idea that projects are "a craft form of production" (Ballard et al. 2007a). Both project and production control are needed for the success of the project, and especially for complex projects. Ballard and Tommelein (2016) said that "*Project controls without production control is like driving while looking in the rear-view mirror. Production control without project controls is like driving with no destination and no awareness of remaining distance or fuel* " (p. 59), and that underlines how necessary it is to get attention on production control for the success of the project.

The Last Planner® System has been evolving since 1992 until it has reached its existing form as a system of production control (Ballard and Tommelein 2016). It is said that "*Last Planner [System] and the entirety of lean thinking applies most directly to projects that are highly dynamic; i.e., uncertain, complex and quick* " (Ballard and Howell 2003b, para. 4).

Ballard and Howell (2003b) also said that the performance of classical project control is not high even in the moderately quick, uncertain, complicated jobs since the information given is not sufficient for making efficient decisions.

Ballard and Howell (2003a) described the main principles for production control as follows:

1. To do the 6-week lookahead planning in order to reduce the uncertainty of the constraints as much as possible.
2. Make quality assignments and put in mind that the assignments that do not fit the criteria should be rejected using the same philosophy of Toyota, i.e. that workers stop the production line if there are any defects.
3. To track the percentage of completed assignments (PPC), and learn from our mistakes.

Difference between traditional project management and the LPS

1- Traditional project management

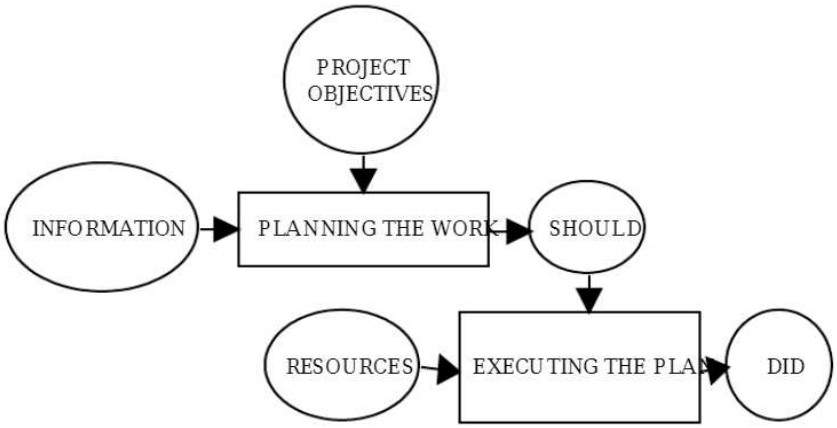

Figure 3. 2 – Traditional project management (Ballard and Howell 1994)

As shown in Figure 3.2 below it is visible that many resources and efforts are dedicated to construction projects to make plans, schedules, budgets etc., which guide project personnel to the SHOULDS- what should be done. In other words, traditional project management gives excellent attention to ensuring the conformance between DID and SHOULD. However, it should be clear that "*Planning and control are two sides of a coin. Planning produces directives that govern processes, while controls measure conformance to directives and provide input for future planning*" (Howell and Ballard 1996, para. 23).

Ballard et al. (2007a) also mentioned that:

"*Those doing the work, that is: design squads or production crews . . . are being committed by management to doing (WILL) whatever the schedule says SHOULD be done, with no real consideration for what they are actually able to do (CAN) at any specific point in time*." (p. 30)

Everything will be fine until something wrong occurs, then the problems will start to appear, causing some work delays or late deliveries, eventually the slack will gradually fade away until it disappears. Then stress will start to sneak into all the project sides, including the project personnel. Everyone in the chain will have to work more and faster to minimise the delays. Not only will this cause more stress, but also hamper the learning environment, that is, "*directs energy and attention toward getting staff to work with rather than learning how to do work better and faster* " (Ballard and Howell 1994, p. 103). So, the only case where traditional project management works perfectly is whenever there is conformance between SHOULD and DID, that is the work is planned perfectly without any delays; otherwise it will be considered as a failure.

Ballard and Howell (1994) have also mentioned that a significant E/C contractor's project management policy includes the following statement: "*The project management team is*

responsible for finding methods of meeting the control budgets and schedule rather than justifications for not meeting them." (p. 103)
That shows how much it is important for the project team to do the project in time and cost proposed regardless of how much they can learn from their mistakes and experience gained throughout the project period and that run counter to the Last Planner® System principles.

Finally, the way of measuring the performance in traditional project management is by making a comparison between what has been done (DIDS) and the project objectives.

2- Last Planner® System

According to Figure 3.3, we can see that a work environment can be improved and stabilised by making commitments (WILLS). The Last Planner will be the dominant person to keep these commitments to make sure that SHOULDS will be implemented as planned to the extent that the assignments CAN be done. The point here is to proactively control the production units level to reduce uncertainty as much as possible (Ballard and Howell 1994). Finally, Ballard added that practitioners should "*make progressively better assignments to direct workers through continuous learning and corrective action. The function of work-flow control is perhaps evident in its name—to proactively cause work to flow across production units in the best achievable sequence and rate*" (Ballard 2000, ch 3, p. 3).

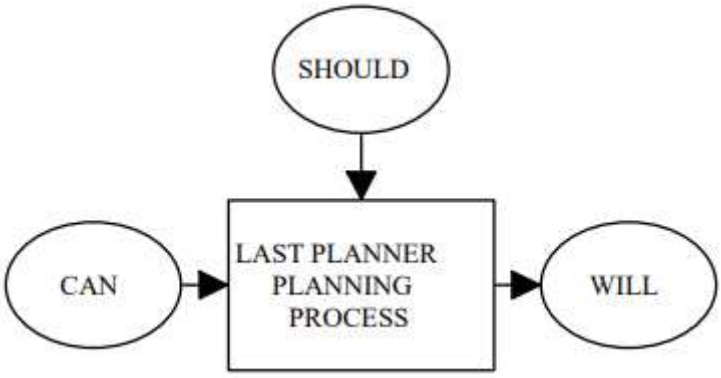

Figure 3. 3 – The Last Planner® System according to Ballard (2000)

Shielding production and pull planning

Before going through the components of the LPS, the author introduces two essential concepts that led to a dramatic transformation towards the LPS by making an effective production control system; namely, shielding production and pull planning.

1- Shielding production

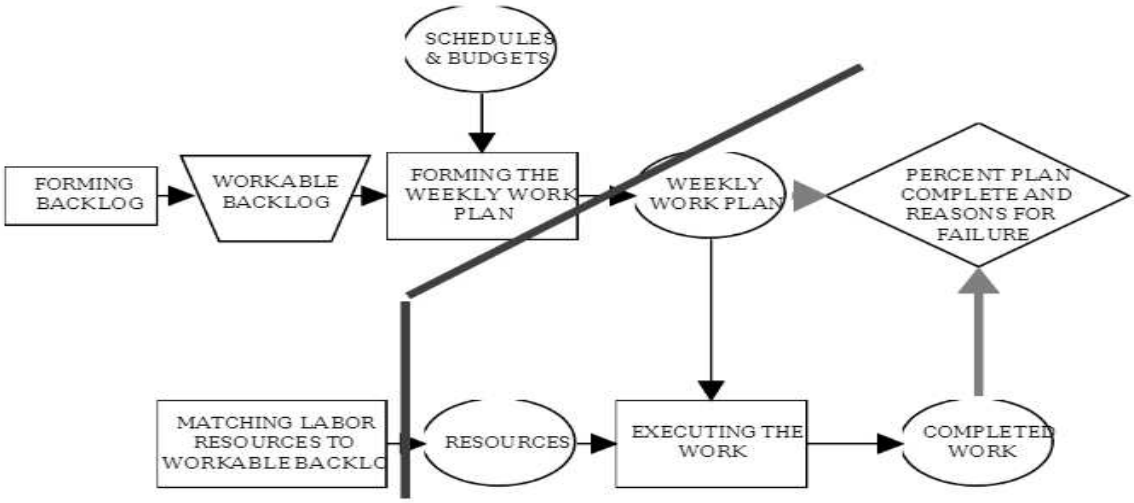

Figure 3. 4 – Shielding production (Ballard and Howell 1994)

According to Ballard and Howell (1994) as seen in Figure 3.4 above, a shield has to be installed for the sake of controlling the complexity and uncertainty. This shield should be comprised of some additional levels in the planning phase, the first of these levels is what some researchers called “the Last Planner commitment”. This commitment to Weekly Work Plans will be to a great extent assured by the use of “commitment plans” that should be selected to meet the following criteria, namely, sound, sequenced, sized and defined (Ballard and Howell 1998) (Covered in more detail in section 3.2.2). After making sure that these criteria have been met, practitioners have to put the first shield to protect the workforce from “upstream variation and uncertainty”.

Ballard and Howell (1998) mentioned that practitioners have to choose the assignments with a high percentage probability that it can be implemented, that is all the material are on hand and the prerequisite work is ready(Ballard and Howell 1998; Ballard 2000). Eventually, to reach the highest level of fitting the shield, practitioners should measure how much is the match between DID and WILL, that is to observe the completed work in comparison to the Weekly Work Plans for analysing the causes of failure, if any, and to learn from the mistakes. This match between WILL and DID can be measured by the use of Percent Plan Complete (PPC), which is discussed in detail in the upcoming section.

The second shield that should be added is to adjust SHOULD to better match CAN and WILL. So, the initial plans can be adjusted to get ADJUSTED SHOULDS that to a great extent can be realised (WILLS). At the end, the result according to the plan can be obtained (DID).

2- Pull scheduling

All the traditional project management schedules are based on the "push method", which is a method "*to push inputs into a process based on target delivery or completion dates*" (Ballard 2000). As shown in Figure 3.5, in push planning the planners start by defining the different activities needed to complete the task and all the dependencies between them. The time and the required resources needed are defined by the use of critical path method (CPM). The schedules are prepared based on the start and the end date of each of these activities and get the overall time required for completing the tasks including some slack time or buffer, by putting an assumption, which may not be fulfilled in most cases, that the material needed will be ready at the start time of each activity. In this case, each activity will passively wait for (instructions, labour, materials, equipment, and space) to be at hand to kick off the beginning of the activity.

The main objective of project control is to adhere to the schedule, and that is referred to as

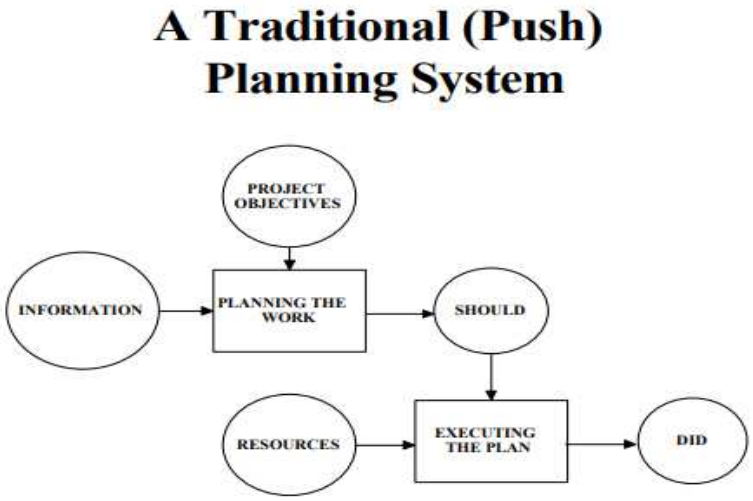

Figure 3. 5 – Traditional (Push) Planning System (Ballard 2000)

"push-driven". Later, the planners may suddenly realise that there would be some delays. An example for delays is the delays from the supplier for some of the activities. These delays would lead the available resources in a waiting time, which can influence the productivity and result in several changes in schedule due to uncertainty (Howell et al. 1993; Thomas et al. 1989; Tommelein 1998).

On the contrary to traditional project management, the Last Planner® System. LPS depends on what is called the "Pull planning method". In the LPS, the material and the information are only allowed to get into the production process if the last planners have the required capability. In order to check the capability, the commitment plans should be utilised (Ballard 2000).

Ballard and Howell (2003a) mentioned that "*[t]he purpose of the pull scheduling is to produce a plan for completing a phase of work that maximises value generation and one that everyone involved understands and supports; to produce a plan from which scheduled activities are drawn into the lookahead process to be exploded into operational detail and made ready for assignment in weekly work plans.*" (p. 128)

Ballard and Howell (2003a) also added that "*[a] Pull technique is based on working from a target completion date backwards, which causes tasks to be defined and sequenced so*

that their completion releases work. A rule of pulling is only to do work that releases work to someone else." (p. 127)

The principal rule of pull planning is to eliminate over-production in the process, which is an essential type of waste in Ohno's definition of waste (Ohno 1988). Additionally, pull planning can help to get rid of the non-value added activities in the overall work process (Ballard and Howell 2003a).

A project team is comprised of those who are going to participate in doing the work in this period and those who can give the needed information, e.g., safety, quality, logistics (Ballard and Tommelein 2016). The first step in pull planning is to define the milestones required to which the team will be pulling from. As indicated by (Ballard and Howell 2003a), the team members start the work structuring by briefly describing on sticky notes what they should do. Those sticky notes should be placed on a wall. Later, the participants can start to "negotiate sequence and batch size" as they will begin to establish the dependencies between different activities.

Moreover, the participants should start to think about some hand-offs between the tasks in the sticky notes on the wall and deeply understand what is exactly required from them. Finally, during the work, there might be some room for multiple changes in the plan, but still, the primary purpose for the pulling planning to build up a flexible team able to respond to any changes (Ballard and Tommelein 2016).

Ballard and Howell (2003a) talked about the team members that are responsible for setting up the schedules, the meetings can generally comprise of the general manager, the subcontractors and some of the stakeholders including the designers, client and regulatory agencies.

The next section covers the cycle of the Last Planner® System and the LPS most popular components in the literature.

3.2.2 LPS components / LPS planning cycle

LPS components

Daniel et al. (2015) conducted research which encompassed most of the components of the Last Planner® System, as shown in Figure 3.6 below. Daniel et al. (2015) concentrated on 57 papers published at the IGLC (the International Group for Lean Construction, www.iglc.net) about the LPS implementation in 16 different countries. The main focus of this study was to recognise how the LPS had developed over 21 years (from 1993 to 2014).

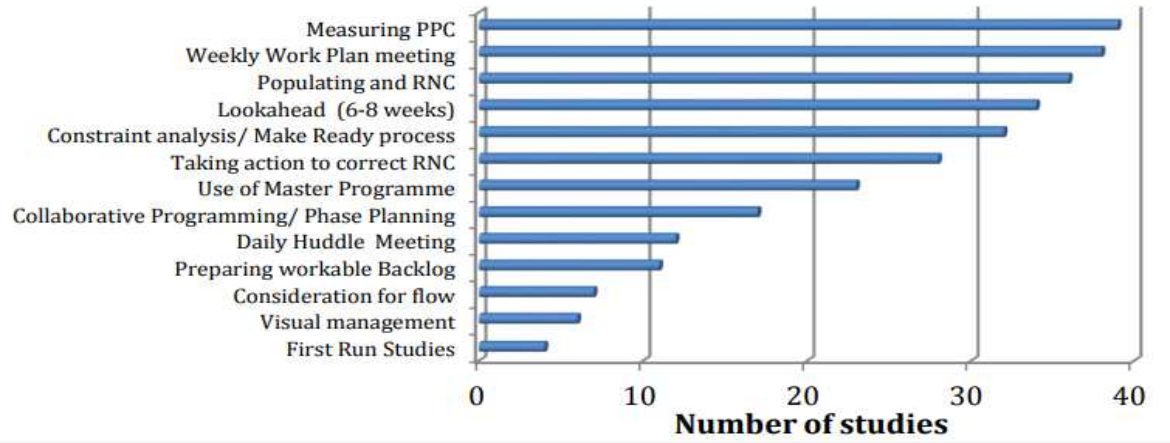

Figure 3. 6 – The Last Planner® System components (Daniel et al. 2015)

Based on the selected papers, Daniel et al. (2015) managed to count 13 different components of the LPS. Percent Plan Completed (PPC), Weekly Work Plan (WWP) and recording Reasons for Non-Completion (RNC) are the most implemented components of the LPS, while on the other hand, the First Run Studies and Visual Management (VM) came in last place. First Run Studies has been mentioned in earlier reports of Ballard, however, it is not well-known (Daniel et al. 2015). It is noteworthy to mention that Visual management (VM) was not fully described in the earlier papers of Ballard, but VM could clearly be embedded in the LPS (Daniel et al. 2015).

Daniel et al. (2015) used another figure to describe the LPS elements used over the 21 years. From Figure 3.7, we can grasp that the implementation of the LPS elements is variable over the years. However, it is noticeable that the implementation of the LPS elements is in a progressive increase with some exceptions, such as the First Run Studies and the workable backlog.

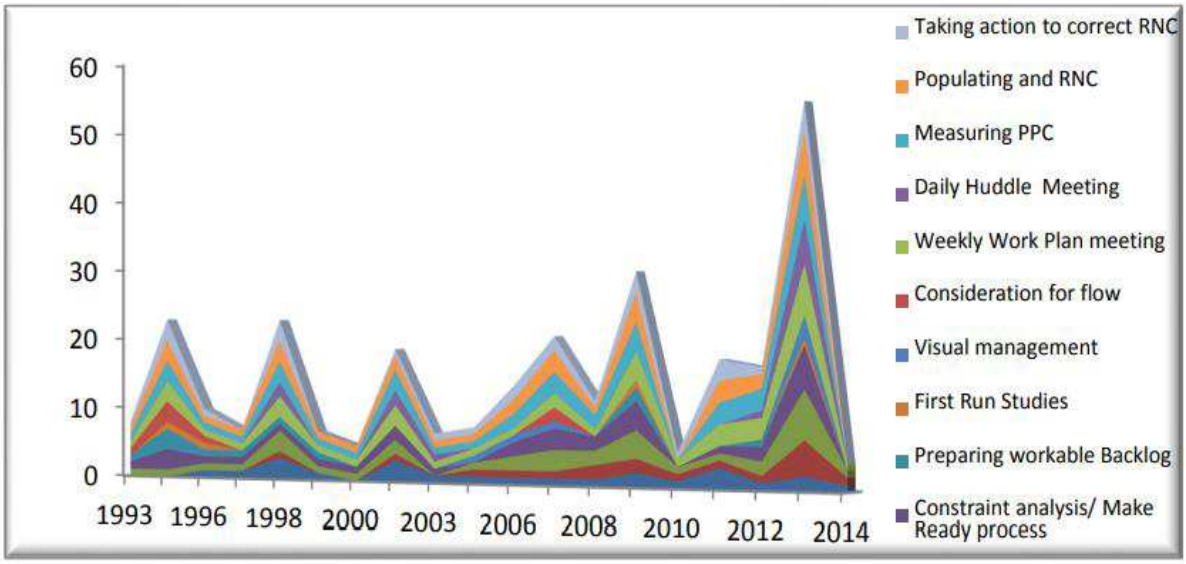

Figure 3. 7 – LPS elements used over 21 years (Daniel et al. 2015)

LPS planning cycle (general overview of the LPS implementation)

As shown in Figure 3.8, the Last Planner® System planning cycle (implementation process) is made up of four different levels; namely, the master schedule level, the phase schedule level, lookahead planning level, and finally the Weekly Work Plan level (Ballard et al. 2007a).

The master and phase schedules are part of a planning phase called front-end planning. The

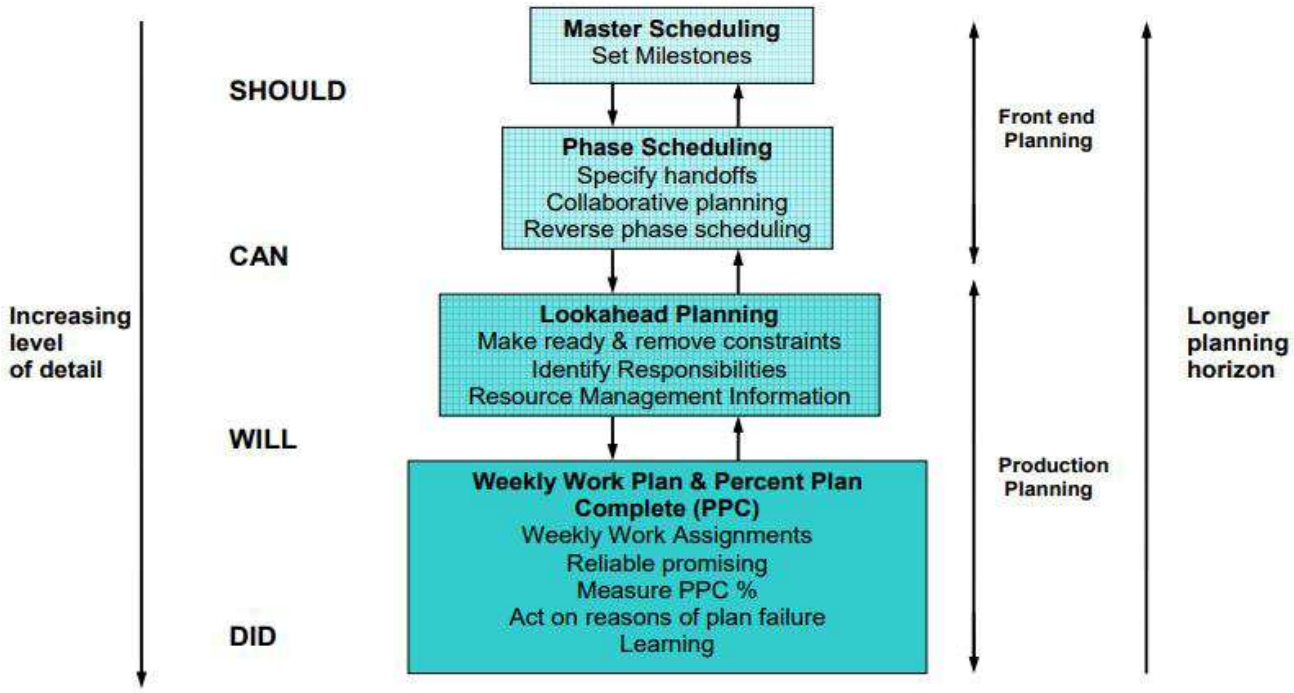

Figure 3. 8 – LPS planning cycle (Ballard et al. 2007a)

lookahead planning and the WWP are part of another planning phase called production planning. The construction process starts with front-end planning. In this phase, the master schedule is prepared, which means setting up the milestones and conducting the Critical Path Method (CPM) in order to recognise the overall project duration and budget. After carrying out the master schedule, comes the more detailed scheduling, the phase schedule. The phase schedule defines the connection between the work structuring and production control. The plan in the phase schedule improves during the lifetime of the project. In order to conduct the phase schedule, collaborative planning and reverse-phase scheduling (pull technique) should be utilised (Ballard et al. 2007a).

Once the phase schedule ends, the production planning phase begins. In this phase, activities are transferred from the phase schedule to the more detailed lookahead plan (a process called explosion). A working plan should be made for the upcoming six weeks (the typical number of planning weeks to have a reliable plan). Any constraints that threaten the workflow should be studied to be removed (referred to as constraints analysis). The constraints analysis should be carried out every week, followed by an update tweeweeo the lookahead plan. Every participant of the team should identify their responsibilities, make assignments ready (this is called make-ready), and finally analyse the resource management information (Ballard et al. 2007a). Subsequently, the WWP can be carried out; this plan is considered as the most detailed plan compared to all the previous plans. Ballard et al. (2007a) mentioned the WWP in their research

and said that “It directly drives the production process”. The quality assignments and reliable promises are then conducted so as to have more reliable plans; as a result, the production unit now is shielded by those quality assignments form the uncertainty in the upstream. Finally, The participants have to analyse Reasons for Non-Completion (RNC) and learn from that for future work; this can be obtained by performing a root cause analysis. Additionally, The participants can utilise some key performance indicators such as the Percent Plan Complete (PPC) to measure the system performance. Note that the all the above mentioned terms are elaborated in detail in the upcoming sub-sections.

Finally, in their publication, Perez and Ghosh (2018) presented the recommended best practice process map for the LPS implementation (based on an extensive literature review). This best practice process map was identical to the planning cycle mentioned by Ballard et al. (2007a).

1- LPS training and workshops

Ballard et al. (2007b) mentioned that companies utilise two different mechanisms for training their personnel in the LPS; some of them learn by doing, while other firms require a certain amount of training (classroom training).

Alarcón et al. (2002) defined the meaning of the workshops as “*training sessions that use a methodology based on learning in action that enables step by step implementation of the concepts and tools*” (p. 3). After the application of the training workshops in projects, workshops proved efficiency in altering the vision of the participants in the implementation process of the LPS.

Ballard (1994) presented the team workshop in order to develop the LPS process (Lim et al. 2006). The workshops and the training sessions have been applied in many projects, according to the following research papers (Alsehaimi et al. 2014; Lim et al. 2006).

Villego® Last Planner® System Simulation

New adopters of the LPS are using the Lego® simulation as a good method of elaboration the benefits of the Lean thinking using the key Lean concepts, namely, flow, pull, Plan-Do-Check, Act, continuous improvement, detailed short term planning and Lean behaviours. In the Lego simulation game, “*Participants build a small Lego villa in each round. The first round uses traditional planning methods – plan the way you normally plan. The second round uses key elements of the LPS. Financial performance of each team is calculated after each round based on schedule, quality and safety performance* ” (Ebbs and Pasquire 2019, p. 7).

There are many benefits behind the use of the Lego® simulation. Still, the essential benefit is that this simulation creates a secure learning environment by the use of a simple Lego project. The point in the Lego simulation game is to teach the participants the Lean principles by doing or from the “Aha” moments experienced through the simulation (Ebbs and Pasquire 2019).

2- Master schedule

According to (Ballard et al. 2007a; Ballard et al. 2007; Hamzeh et al. 2008; Tommelein and Ballard 1997), the project team members form the master schedule during the "front end planning" by carrying out the critical path method (CPM). CPM logic can be represented in different forms such as Gantt, Program Evaluation Review Technique (PERT), or line of balance. (Hamzeh et al. 2008).

Milestones can be in the form of "start" or "finish" dates but are not activities. The typical form for those milestones is represented by a diamond shape, and it should be identified by all the project stakeholders. Those milestones are related to either key contract milestones or last planner's milestone (Ebbs and Pasquire 2019).

The tasks in the master schedule are partly approximate. The main purpose of the master schedule to make sure that all the milestones and the whole project, in general, can be executed in time. As mentioned before, the master schedule shows the start and end dates of the tasks and how they proceed in terms of flow. The concentration here in this schedule is on the most important tasks, whereas the less important tasks, such as the tasks with short durations should not be included into the master schedule or can be included as the work content of other tasks (Junnonen and Seppänen 2004). Since it is an approximate plan, errors in estimating cost and quantities of work should be considered.

The master schedule begins the strategic planning of the project and defines the timing of different phases of that project while putting into consideration that the master schedule has the lowest level of detailing as seen from Figure 3.9. It is also referred to as the milestone level of project planning, and it shows the different activities "at a course-level" over a long planning period. Furthermore, this schedule can be considered as a reflection of the main milestones, which are defined by the project objectives and constraints. The master schedule is a part of the work structuring and can be broken down by function, area, or product (Ballard and Tommelein 2016; Ballard et al. 2007a). In master plans, the overall progress of the whole construction project is planned and controlled.

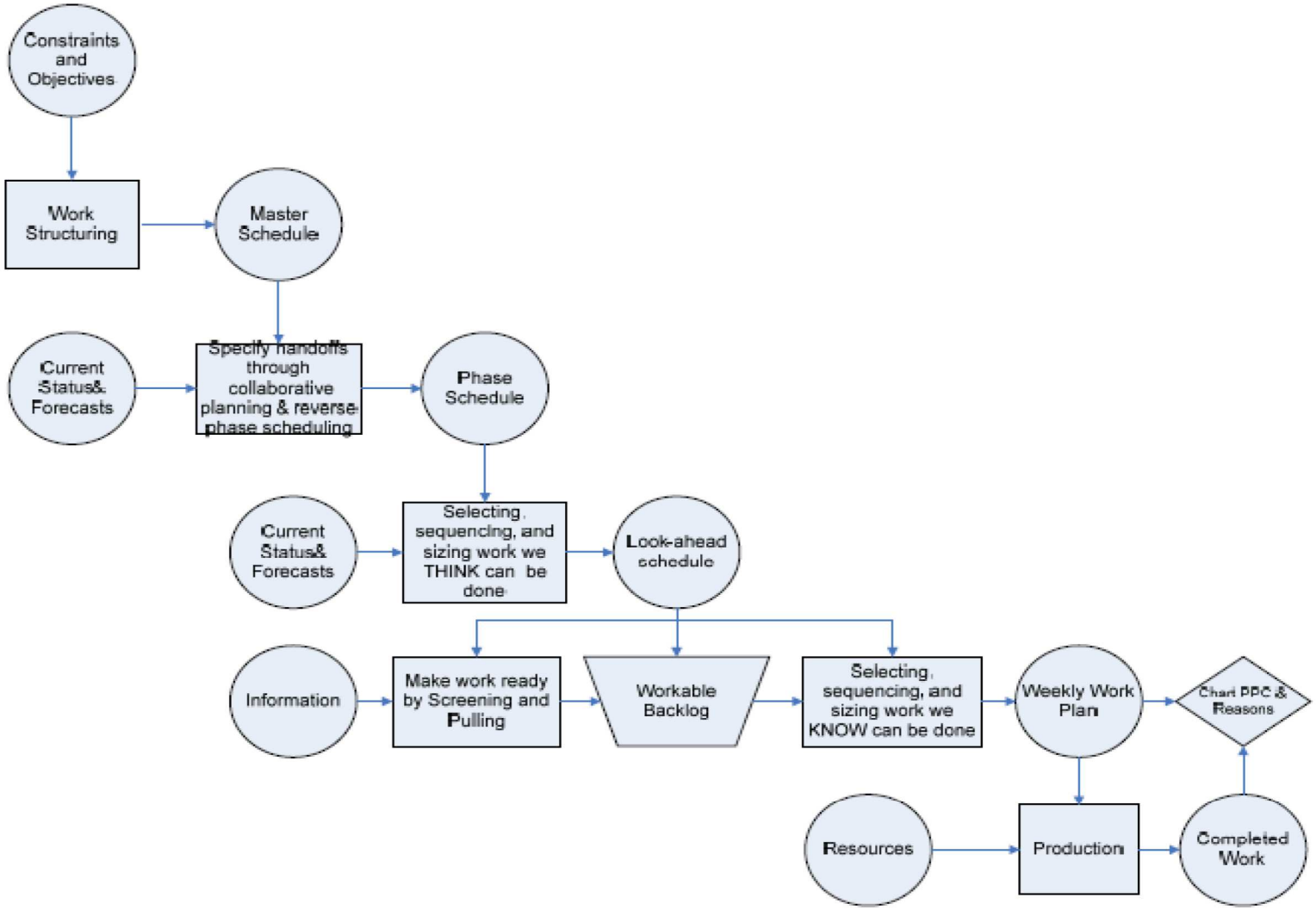

Figure 3. 9 – The Last Planner® System life cycle by Ballard et al. (2007a)

3- Phase schedule

As shown in Figure 3.9, phase scheduling defines the connection between the work structuring and production control. The major role for phase scheduling is to make sure that the correct work is prepared and will be done in the correct time to accomplish the final objective of the project (Ballard and Howell 2003b; Ballard and Tommelein 2016; Ballard et al. 2007a).

The main reason for implementing phase scheduling is to have integration and coordination between different specialists' operations (Ballard et al. 2007a). The phase schedule is a plan for a specific phase of work which maximises the value generation while putting in mind that it should be understandable and supported by the team members (Ballard and Howell 2003b; Ballard and Tommelein 2016).

"*The level of detail in the phase schedule is determined by the requirement that the phase schedule specifies the handoffs between the specialists involved in doing the work in that phase*" (Ballard and Howell 2003b, p. 6). These handoffs then are transformed to be goals to be accomplished through production control (Ballard et al. 2007a; Ballard and Howell 2003b; Ballard and Tommelein 2016). Phase scheduling is collaborative planning between the team members that will do the work in the phase by using the pull planning technique (Ballard and Tommelein 2016).

Knapp et al. (2011) indicated that teams involved in the phase planning process managed to better understand their project, the individuals on the project, and the requirements for the success of the projects. (Kalsaas et al. 2009) said that when applying phase planning (which is the input for the lookahead plan), a more reliable plan can be obtained.

The correct order for forming the phase schedule:

After breaking down the master schedule, the participants should define the work included in the phase, e.g. substructure, superstructure, etc. The participants use "post-it notes" on which the required task will be written considering the prerequisites and the upcoming works (Ballard and Howell 2003b). Additionally, the end date of the phase should also be defined. Then, logical links between the different tasks should be considered when starting to make the phase schedules by using reverse-phase schedule (working backwards from the completion date). The following step is to set up the different durations for each task in the phase schedule and check if there is any buffer between the estimated start date and the possible start date. When making the master plan, time buffers should also be considered so that the schedules are resilient against any unanticipated delays (due to uncertainties) and allow some variability during the implementation. On the other hand, in the phase schedule, there should be no contingency (as much as possible) in the duration estimates (Ballard et al. 2007a; Ballard and Howell 2003b; Ballard and Tommelein 2016).

The next step is to reexamine the schedule for logic and intensity (application of resources and methods) for the sake of shortening the overall duration. Any excess time can be utilised by one of the following:

1- Use it on the task with the highest uncertainty,
2- Postpone the start as an investment in prerequisite work, or
3- Accelerate the completion date of the phase

Finally, "*If the gap cannot be made sufficiently positive to absorb variability, the phase completion date must slip out, and attention turns to making up that time in later phases. The key point is to deliberately and publicly generate, quantify, and allocate schedule contingency* " (Ballard and Howell 2003b, p. 7).

Mossman (2014) summarised the benefits behind the phase scheduling process as follows:

1- Prepares team members for action together
2- Team members discuss details and risks much sooner
3- Sorts out sequencing & other issues that would be difficult to change later; issues sorted on paper rather than at the workplace
4- Enables the team to test options to improve workflow, buildability and program reduction
5- Identifies unclear design details
6- Builds commitment to program, and
7- Reduces overall program period

As previously mentioned, the most important participants of the scheduling process are the ones that have work responsibilities in this phase and the ones that implement the work. The team responsible would consist of the main contractor, the subcontractors and other stakeholders; namely, the designer and the client (Ballard and Howell 2003b; Ballard and Tommelein 2016).

4- Lookahead planning

As shown in Figure 3.9, the lookahead planning process is located right in the middle of the Last Planner® System planning hierarchy, and it directly occurs after the front-end planning (after the master schedule and the phase schedule). Lookahead planning represents the first step in the production planning phase, and it links the long term and short term planning (Ballard 1997; Ballard et al. 2007a; Hamzeh 2009; Hamzeh et al. 2008).

Lookahead planning adds greater details and some adjustments to the schedules. Lookahead planning "pulls the needed resources into play" and screens the activities that may have some shortage of resources. Lookahead planning is mainly conducted to control the workflow in the production system (Ballard et al. 2007a; Ballard 2000).

(Ballard 1997; Ballard and Howell 2003a; Ballard 2000) highlighted the main functions of lookahead planning:

1) Shape workflow in the best achievable sequence and rate for achieving project objectives that are within the power of the organisation at each point in time.
2) Match labour and related resources to the workflow.
3) Produce and maintain a backlog of assignments for each frontline supervisor and crew, screened for design, materials, and completion of prerequisite work at the CPM level.
4) Group together work that is highly interdependent, so the work method can be planned for the whole operation.
5) Identify operations to be planned jointly by multiple trades.

On the contrary to the master schedule, which covers all the activities included on the project from start to the finish, the six weeks lookahead plan is typically a plan for six weeks from the planning date (Ballard 1997; Ballard et al. 2007a; Hamzeh 2009). The period of the lookahead plan ranges from 3 to 12 weeks, depending on the nature of the work that is going to be executed , and the responsiveness of the suppliers to different activities (The reliability of plans can differ from one work to another). Suppliers here is not just limited to the suppliers of resources, but also the participants themselves or anyone that supplies input, including the prerequisite works (Ballard et al. 2007a).

Which activities should the participants include in the lookahead plan? The following three steps mentioned by Ballard et al. (2007a) can answer this question:

- **Explosion**: By making more specific activities from the master and phase schedule, which can be achieved by carrying out the activity definition model. During lookahead planning, a larger amount of detail is required concerning the inputs and outputs for all the activities in order to make the next step (screening) in the correct way. The participants should take into consideration the real conditions in which affect the project, including the weather conditions, the market conditions, etc. During the planning process, participants should be confident to a great extent that these activities CAN be executed.

- **Screening**: The participants check the status of tasks concerning the constraints with each task and see if it is suitable to be advanced in the lookahead plan or be retarded back to the master schedule. This depends on the probability of removing the corresponding constraints before the start date of the task. Participants can advance these activities to the lookahead plan, but they should make sure that these constraints will be eliminated before the start time of the task in the schedule.

- **Make-ready**: To take the required actions and remove the constraints from the activities in order to get them ready for the last planner at the designated time in the Weekly Work Plans.

And now, what are the steps required to implement the lookahead plan? The implementation process of the lookahead plan was developed over several years by (Ballard 1997; Ballard and Howell 2003b; Ballard et al. 2002; Ballard 2000; Hamzeh et al. 2008; Tommelein and Ballard 1997) until it reached its final form by (Hamzeh et al. 2012). The implementation process of the lookahead plan is as presented in Figure 3.10.

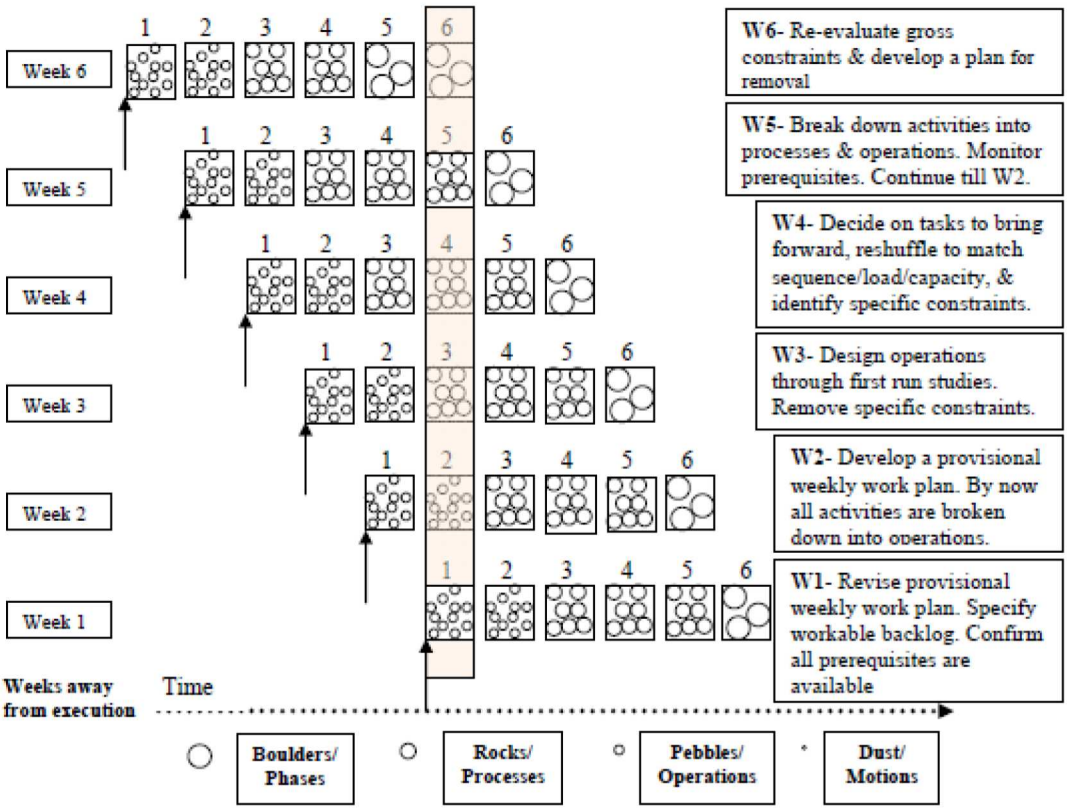

Figure 3. 10 – Changes made in the lookahead Plan (Hamzeh et al. 2012)

Hamzeh et al. (2012) mentioned that the lookahead plan is comprised of five different steps which strengthen compatibility between the master schedule and Weekly Work Plan:

Step 1: In this step, the participants execute the lookahead plan (in this case, it is six weeks lookahead plan). The tasks enter the lookahead plan come directly from the phase schedule (or the master schedule if the phase schedule has not been implemented). Gross constraints (the constraints that affect the whole phase or the main work in that phase, such as materials and design information) are evaluated, and a plan for eliminating these constraints is developed. It is advisable by (Hamzeh et al., 2008) to eliminate those constraints two weeks before execution.

Step 2: In the period between five weeks and four weeks ahead of execution, the Phase-level tasks should be decomposed into smaller parts (activity break down). As shown in Figure 3.10, the "boulders" are representing phases, such as superstructure, "Rocks" are processes, such as building walls, "Pebbles" are operations, such as lay formwork, and finally "Dust" are the steps required to make up operations or elemental motions as indicated by (Hamzeh et al. 2012). Elemental motions may be suitable analytical units for the design of the tasks with high repetition executed under controlled conditions, but they are not represented (up to now) in the current forms of the LPS. Steps are defined in the design of operations. Steps are tasks assigned to individuals or sub-teams within workgroups.

Activity breakdown starts with defining the work needed to be done, achieve the most optimal work sequence, coordinating activities among project stakeholders, loading with resources, sizing to match load capacity, and check soundness (discussed more into detail in the sub-section – screening / quality criteria) (Ballard 2000; Hamzeh et al. 2008).

Step 3: Three weeks ahead of execution, participants design operations using first run studies, identify the constraints and screen out tasks that they are not confident can be made ready in time (the different steps will also be defined in detail later).

Step 4: Two weeks ahead of execution, the lookahead plan activities are decomposed to the level operations/steps as participants are getting closer to execution. The level of detail of this week will match the level of detail required for production in the Weekly Work Plan. All the constraints for all the tasks should be removed before the execution week. There might be some non-critical tasks in the plan which are constraint-free. Those tasks can join the fallback/follow on worklist or what is referred to as workable backlog (will be discussed later).

Step 5: One week ahead of execution, the tasks on workable backlog can be included in the Weekly Work Plan if they meet five quality criteria, namely, definition, soundness, sequence, size, and learning. Tasks that are critical and made ready or can be made ready in the upcoming week can be involved in the Weekly Work Plan (Ballard 2000; Hamzeh et al. 2008).

5- Screening/quality criteria

In the screening process, five quality criteria should be met by each activity before advancing into the lookahead plan (The same quality criteria for the shielding process in the Weekly Work Plan are used) (Ballard et al. 2007a; Ballard and Howell 1994; Ballard and Howell 1998; Ballard 2000). These quality criteria are:

- **Definition**: Make sure that the assignments chosen are specific enough so that the right information and material needed can be easily collected, and that final form is well-defined in order to make it possible to know if that assignment has been completed at the end of the week.

- **Soundness**: make sure that the assignments are workable, and the last planner understands what is needed to finish that assignment, the prerequisite work has been executed, the material needed for completing the task is on hand. The point is to get the work done before the scheduled time.

- **Sequence**: The correct order of working according to the working process should be decided upon. Also, it must be ensured that the finished assignments will release work required by another person, in order to have the needed workflow. In case of assignment failures or achieving higher productivity than expected, the tasks concerned should be replaced with what is called “workable backlog”, illustrated in the following sub-sections.

- **Size**: Ensure that the assignments are chosen according to the productive capability of the individuals or groups and still can be achieved according to the schedule.

- **Learning**: Make use of the failures and learn from them and ask for reasons for the deviation occurred.

The activities that do not meet the quality criteria must be made ready in the first point before advancing them to the lookahead plan (Ballard et al. 2007a).

The screening process during lookahead planning can be seen as "less restrictive" in comparison to the shielding process during the weekly work planning (Ballard et al. 2007a).

6- Constraints analysis

For the sake of assuring that the work will be executed in a specific time (SHOULDS) and with high efficiency, this work has to be performed (CAN) without any interruption. In this case, the interruptions are referred to as constraints (Ballard and Tommelein 2016). According to Ballard et al. (2007a), a constraint is "*anything that stands in the way of a task being executable or sound. Constraints concern directives, prerequisites, or resources*" (p. 19). Actions have to be taken in order to eliminate those constraints (Ballard and Howell 2003a).

Ballard et al. (2007) said that "*Typical constraints on construction tasks are the completion of design or prerequisite work; availability of materials, information, directives, and labo[u]r or equipment resources*" (p.19). There are also some other constraints related to the design tasks, including the inputs from others, clarity of criteria for what to be provided, approvals and finally design and engineering resources in general (Ballard et al. 2007a). Ballard and Tommelein (2016) stated that "*Constraints can be either physical (availability of plotter before printing, rebar installation prior to concrete placement) or informational (soils report before foundation design, engineering details before fabrication, permit before hazardous work).*" (p. 67)

A model has been developed to define the different categories of the constraints. This model is referred to as "Activity definition model (ADM)", and it forms a robust framework to understand the construction process (Ballard and Tommelein 2016).

Ballard and Howell (2003a) mentioned the essential categories for ADM, and they are as follows:

- **Directives part**: "*provide guidance according to which output is to be produced or assessed. Examples are assignments, design criteria and specifications*." (p. 123)
- **Prerequisite work part**: The needed activities and work before or during the implementation process (e.x. the materials, funding, information and previous work).
- **Resources part**: includes the labour and the equipment used.

Ballard et al. (2007) described constraint analysis and mentioned that "*the Constraints Analysis [f]orm depicts a table with rows listing potential assignments and columns listing outstanding constraints if there are any. Each constraint category provides an indication of who may be involved in removing a constraint. These constraints remain to be resolved for the corresponding assignment to be considered sound (one quality criterion).*" (p. 19)

As mentioned previously, Hamzeh et al. (2008) recommend that removing the constraints, especially the ones related to the prerequisite work part, should be done two weeks before the execution of the activity.

7- Make-ready

Ballard (2000) defined the make ready process as the process of taking the required actions to eliminate the constraints from the assignments to make them sound. Ballard et al. (2007b) said that the make-ready process is a vital piece of the LPS, and they described it as the criteria for making sure that an activity is ready to start.

Ballard et al. (2007b) said that " *the key to make ready is making sure that the activity is ready in all ways to be started. This includes the availability of labour, equipment, materials and anything else "required" for the activity to be started. For instance, if an activity is ready to begin, and scheduled to begin, but an important piece of equipment was absent, that activity would not be considered to be an assignable activity. The resources that would be taken up by this activity would be put to other uses until everything required for that activity was ready and waiting for the construction work to start*." (p. 258)

It is the responsibility of the planner to eliminate the constraints from the tasks and make them ready for assignment (Ballard et al. 2007a; Hamzeh 2009).

Make-ready process can be done through three steps, and they are as follows:

- Assuring that any assignments into the first two weeks in the lookahead plan are made ready by analysing the constraints connected with each activity and making them sound (Ballard 1997).
- Conducting the screening process to all the remaining weeks and screen out all the activities that can not be made ready (Ballard 1997)
- Record the actions needed to make the assignments ready in the plan (Ballard 1997).

So, as we can notice the constraints analysis process and the screening process are part of the make-ready process, which forms a vital step in the LPS implementation.

8- Weekly Work Plan (WWP) and Commitment Planning

(Ballard et al. 2007a; Hamzeh et al. 2008) defined the meaning of the weekly work planning as the final form of the planning, which includes the highest level of detail.

The responsible persons for making these plans are the designers, construction supervisors, foremen, site managers and numerous others (Ballard et al. 2007a).

In the beginning, the last planners have the responsibility of choosing the activities that are ready to be implemented (meet the five quality criteria mentioned before). Those activities can be put into the first week of the lookahead plan, or what is referred to as the Weekly Work Plan. The activities that do not fulfil the requirements have to be made ready first (Ballard et al. 2007a). The main objective of this process is to make the most reliable plan possible (Ballard 2000). Fulfilling the quality criteria can shield the production units from uncertainties in the workflow (Ballard et al. 2007a; Ballard 2000; Hamzeh et al. 2008). The shielding process has already been mentioned before, so the author will not discuss it again (for more information kindly go back to Shielding production in section 3.2.1)

Every week, the plan is reviewed for completeness so as to measure its reliability, analyse reasons for plan failures and act on these reasons to learn (Ballard et al. 2007a; Ballard 2000; Hamzeh et al. 2008)

The Weekly Work Plans may contain two types of plans; namely, Plan A and Plan B. Plan A is tasks which other last planners require to be finished within the planned period. On the other hand, Plan B contains fallback/follow on tasks, in case of Plan A tasks cannot be implemented, or as if Plan A tasks are finished earlier than anticipated (Ballard and Tommelein 2016).

9- Workable backlog

The workable backlog is a list of tasks that can be done without influencing the work of any other trade (Mossman 2015). Ballard et al. (2007a) defined the meaning of workable backlog as "*ready work that cannot be assigned* " to the Weekly Work Plans. If the workers did not manage to finish any assignment in time (due to any reason) or even in case they completed the work sooner than planned, they could make the workable backlog instead.

But when do we use the workable backlog?

The workable backlog can be utilised when capacity limitations exist. Some of the ready activities that fulfil four quality criteria; namely, definition, sequence, and soundness must also satisfy the sizing criterion (Ballard et al. 2007a; Ballard and Tommelein 2016). The capacity limitations of the workers and the tools should be considered. If these activities were put into the schedules without considering the sizing criterion, the last planners would be overloaded. This may influence their performance. Ballard et al. (2007a) explained that when he mentioned that "*assigned work that remains incomplete counts against the plan reliability measure*" (p. 39).

Over the years the term workable backlog has been utilised in two ways; the first is used to describe the tasks in the Weekly Work Plans that have been released for commitment, and it is referred to as the workable backlog, whereas the second term is known as " Plan B" and it means that the tasks can be available as fallback options if the participants are not able to complete the commitments in the first week in the six weeks lookahead plan, or the tasks can be utilised as follow on work options if the participants can do more tasks than planned (Ballard and Tommelein 2016)

As shown in Figure 3.11, the workable backlogs are tasks that are not critical, which means they are not included in SHOULD in the left-hand side, but still CAN be done and WILL be done.

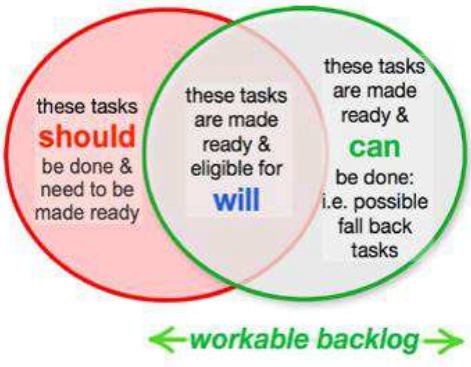

Figure 3. 11 – Workable backlog (Ballard et al. 2007a)

Ballard et al. (2007a) said that "*the Last Planner aims at creating a reliable workflow for the immediate production unit that will execute the Weekly Work Plan as well as production units downstream. This plan reliability is key to system performance.*" (p. 39)

On the other hand, work has to be underloaded for the production units to less than 100% of their capacity to have a release of time for more improvement, learning and training for the workers and more maintenance for the equipment.

10- PPC (Measuring system performance)

In order to continuously improve, system performance should be measured. Practitioners should measure how much work has been executed from the Weekly Work Plan in comparison to the planned work or to measure the quality of each Weekly Work Plan (Ballard and Howell 1994; Ballard et al. 2007a). (Ballard and Howell 1994; Ballard 2000) highlighted the importance of using a quality measurement which they called Percent Plan Complete (PPC) for the sake of the enhancement of the project and continuous improvement. If the PPC was used and the per cent of completed work is low, then practitioners can realise that they are not in the right track and that the Reasons for Non-Completion (RNC) should be identified.

According to Ballard et al. (2007a) "*PPC is the number of actual completions divided by the number of assignments for a given week.*" (p. 40)

"*Measuring PPC allows us to distinguish between failures rooted in plan quality and failures to execute plans. Currently, that distinction cannot be made because the quality characteristics of plans are not made explicit, and it is assumed that all failures are execution failures*" (Ballard and Howell 1994, p. 108).

So, this tool can be used to evaluate if the team and specifically the last planner was able to expect the finished work correctly during the Weekly Work Plan or to see if WILL matches DID (Ballard et al. 2007a). This process is indicated in Figure 3.12.

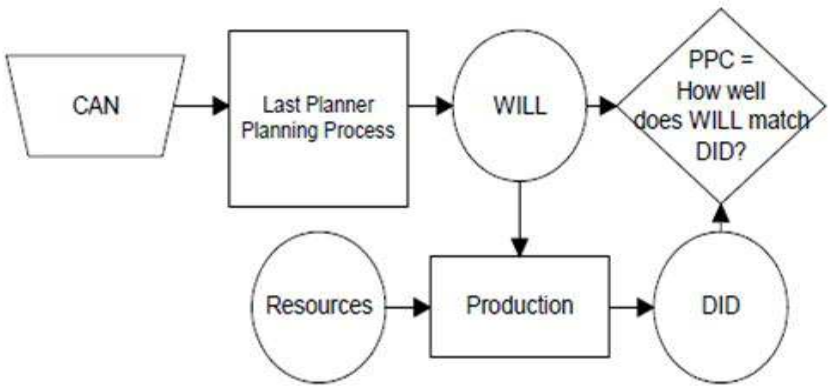

Figure 3. 12 – Percent Plan Complete (Ballard et al. 2007a)

Finding the Reasons for Non-Completion and learn from mistakes is part of the PPC measurement process (Ballard 2000). This indicates that the PPC does not only present the plan

reliability, but it can be a good indicator of performance and productivity on the project (Daniel et al. 2015). After knowing the Reasons for Non-Completion, the root cause should be traced and eliminated (RNC and root cause analysis are elaborated in the next sub-section).

11- Learning from mistakes and Reasons for Non-Completion (RNC)

As a part of the PPC measurement process, the Reasons for Non-Completion of assignments in the weekly plan have to be recorded for the sake of learning from our mistakes (Ballard et al. 2007b; Mossman 2015). The Reasons for Non-Completion are divided into four categories, namely, the directives, prerequisite work, resources, and process/output failures. Some examples for each category are presented in Figure 3.13, which also encompasses the design phase.

	DESIGN	CONSTRUCTION
Directives	changes in design criteria unaware of code requirements	changes in directives from superintendent not informed of performance standard
Prerequisite Work	information needed from owner waiting for vendor confirmation	need submittal approval materials did not arrive request for information unanswered other contractor still in area no access to work area
Resources	equipment failure unavailability of lead designer to grant approval	lack of tools and equipment labor shortage
Process or Output	insufficient time discovered calculation error	insufficient time no craft coordination weather emergency

Figure 3. 13 – Possible examples for Reasons for Non-Completion of tasks (Ballard et al. 2007a)

Ballard et al. (2007a) mentioned that RNC can be plotted, as shown in Figure 3.14, which represents the frequency of occurrence of each failure. Subsequently, actions should be made to the failure with the highest frequency of occurrence in order to reduce its effect and enhance our way of dealing with it.

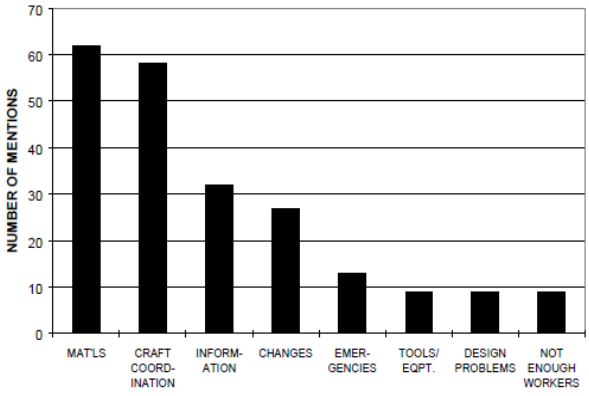

Figure 3. 14 – An example showing how Reasons for Non-Completion of tasks are presented in projects (Ballard et al. 2007a)

After detecting the Reasons for Non-Completion, the participants should perform the root cause analysis. The main cause for doing that is to recognise the source of the action or the event

chain that led to the non-completion of the tasks. The point here is to learn from mistakes and know the root cause, but all the participants have to be aware that the purpose is not to blame other parties, but to help understanding how changing their actions might stop future plan failure (Ballard et al. 2007a).

Ballard et al. (2007a) recommended a quality management technique which is referred to as "The five whys" in order to solve the issues by finding the root causes for these issues. The five why method can be implemented by asking at least five consecutive questions in order to identify an actionable root cause. The five whys method proved a success, according to Ballard et al. (2007a), to know the root causes of the non-completed tasks.

3.2.3 The LPS Facilitators Role

The LPS Facilitator is a person responsible for guiding the Weekly Work Plan (Ebbs and Pasquire 2019). The facilitator plays various critical roles during the implementation of the LPS by guiding the project team members. "*The role of these people [referring to the LPS Facilitators] has reinforced the implementation and consolidation of the Lean planning tools in the companies*" (Alarcón et al. 2002, p. 7).

It is recommended by Alarcón et al. (2002) to train and prepare more Facilitators within companies in order to achieve a high degree of autonomy and decline the need for external aid.

Ebbs and Pasquire (2019) mentioned some vital characteristics which are highly recommended to be presented in the LPS Facilitator. These characteristics are summarised in Table 3.1.

Table 3. 1 – Vital characteristics that should be presented in the LPS Facilitator

1- Previous experience co-facilitating lean simulations and every element of the LPS.
2- Competency guiding the sessions they are facilitating.
3- Good time management skills; start and finish on time.
4- Ability to train and coach other team members.
5- Possess the authority to set up sessions, create specific agendas and coordinate all necessary logistics (rooms, food, materials, project information, critical attendees) in enough time.
6- Ability to help the team set goals and agree on ground rules and then gently remind last planners of the agreed ground rules if old behaviours begin to return.
7- Recognise when a new role appears and assign someone to role-play if necessary.
8- Ensure the names, roles and contact details of all last planners are known for all participants
9- Be a good observer and listener in order to recognise when a change of approach is needed.
10- Allow people to slowly learn how to use the system without criticising every mistake made.

3.2.4 The LPS in Norway

The Last Planner® System has been implemented internationally in the construction industry, and its impact on the production system seems to be significant and rapid (Daniel et al. 2015).

In Norway, the interest towards the LPS has increased dramatically over the years, since it first entered the Norwegian industry around the mid-2000s (Ravi 2018; Ravi et al. 2018). However, the construction practitioners in Norway have implemented the LPS under different names, such as “collaborative planning” in (Veidekke and Kruse Smith), “Trimmed Construction” in (Skanska) and “Collaborative Project execution” in (Nymo) (Daniel et al. 2017; Kalsaas et al. 2014). It is noteworthy to mention that these different versions or translations did not fully support the development of the system, but, on the contrary, led to some cases which are not fully implementing all the elements or only a few elements of the LPS (Daniel et al. 2017). Several of the largest construction companies in Norway started to adopt the LPS or showed interests to apply Lean methods in their operations by implementing the system through pilot cases; an exception might be the two large contractors, namely, Veidekke and Skanska. Those two companies incorporated the LPS into their project management system and decided to go for full implementation of their version of the LPS (Kalsaas et al. 2009; Ravi 2018; Ravi et al. 2018).

Multiple publications have been conducted to present the topic of the LPS in Norway. However, the author concentrated on three publications that encompassed the implementation of the LPS in eight different case studies.

The first publication was written by Haarr and Drevland (2016). In this study, the researchers introduced one case study, which was referred to as the rehab project. The goal of the project was to execute a building which is a part of the Norwegian University of Life Sciences and is located at Campus Ås, 30 km south of Oslo, Norway. The building has three stories with an additional basement and attic. The total gross area was about 8190 m^2. The project was organised as a lump sum prime contract, while the design group had a unit price contract. The prime contractor was contracted after the completion of the detailed engineering. The Norwegian government property developer – Statsbygg – was planning to implement Lean Construction by mandating, in the tender competition, that the prime contractor and the designers use Lean Construction principles and Pull planning and production control based on the Last Planner® System’s plan hierarchy (Ballard 2000). LC culture, principles and methods were new for almost all actors on the project. The study revealed that the Last Planner® System’s plan hierarchy did not work as intended. The project team failed the project control, and that was due to the lack of previous experiences with the lookahead process. The participants did not do the needed preparation before meetings, and this made it hard to maintain a sufficient workable backlog. Additionally, many unforeseen challenges started to show up, which hindered the required preparations.

The second publication was written by Kalsaas et al. (2009). In this study, the researchers also presented a pilot project, Havlimyra, in which the implementation of the LPS was initiated by the general contractor, Skanska, in a construction project of 6800 m^2 made up of a kindergarten, junior high school and sports and cultural centre. The owner of the project is the Municipality of Kristiansand. Havlimyra is a suburb in Kristiansand, which is the capital of the South Coast region of Norway.

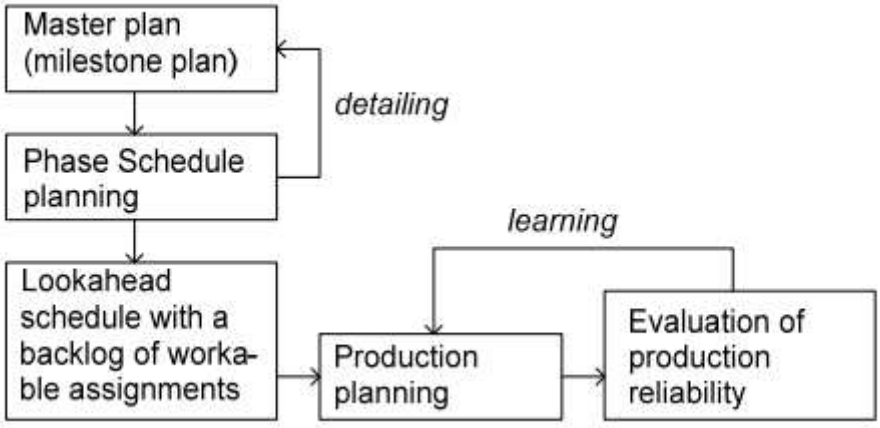

Figure 3. 15 – Overview of the LPS planning hierarchy on the Havlimyra project

Figure 3.15 gives an overview of the LPS planning hierarchy, which was partially implemented on the project. For production planning, the project team used PPC as an indicator for performance and Pareto charts for expressing the Reasons for Non-Completion of different tasks. For phase schedule planning, multiple phase schedules have been executed at different times. Firstly, they made the first phase scheduling collectively in week three. The participants included three technical subcontractors (electrical contractor, plumber and sprinkling, and ventilating) and the general contractor (project manager). The method of reverse scheduling was applied, and the milestone was identified. Later, several joint phase schedule processes were conducted using the same technique as discussed before. At one occasion, the general project manager had already made up the phase schedule individually, but they turned back again later to the collective phase planning as the individual planning led to a serious problem. Furthermore, the project team implemented just two lookahead schedules covering three weeks beyond the Weekly Work Plan, but the lookahead plan was not utilised during the weekly planning meetings for making the work ready, and that was due to the insufficient support to the general project manager. The need was to form the link between the phase schedule and the production planning (presented in the Weekly Work Plan), but unfortunately, that did not occur. The real success point recorded was that the project team managed to implement multiple phase processes, in which the subcontractors were involved in the collective organised planning process.

The third publication was written by (Ravi 2018; Ravi et al. 2018). In this study, the researchers managed to collect the data from six case studies for two major contractors in Norway - Veidekke Entreprenør and Skanska Norway, which have both built the LPS into their management system. The study revealed that companies are implementing the LPS with similar conceptualisation. At the beginning of the projects, the two companies start with introductory courses and training, where all the project team members go through four modules, namely strategic planning- master and phase scheduling, Lookahead planning, Legal binding plans, making commitments and Weekly and Daily planning. After the training sessions, they present the different phases of implementation by conducting the master schedule. Moving to the

lookahead plans, the two companies conduct it differently; Skanska uses the PPD (production-procurement-design) coordination meeting as a lookahead planning meeting, while Veidekke does a short term (2-4 weeks) and a long term (5-9 weeks) lookahead planning meetings. The Weekly Work Plan is done at the end of each week by subcontractors and foreman. During the weekly meeting, the two companies utilise PPC and present the Reasons for Non-Completion to learn from mistakes. Skanska uses the constraint analysis during their PPD meeting, and Veidekke uses MS Project schedule linking every activity to each of the seven pre-requisites with a YES/NO column for constraint analysis, but the workable backlog is not used to a great extent by both the contractors. Finally, Skanska used the daily huddles by a briefing to all the crew the list of assignments for the day. On the other hand, Veidekke does not use daily huddles.

Regarding the meetings' structure, the two companies are using different structures for planning the project. Starting with Viedekke, the company has four weekly planning meetings, and they are as follows:

1- The first meeting which takes place on Monday. The participants of this meeting are the subcontractors in order to plan their weekly work and the workforce they need.
2- The second meeting takes place on Tuesday. The purpose of this meeting is to discuss the lookahead plan with a time frame of 2-4 weeks. The participants of this meeting are the foreman and subcontractors.
3- The third meeting which takes place on Wednesday. This meeting is also a lookahead plan meeting, but with a longer time frame of 5-9 weeks. The participants of this meeting are the site manager and project manager. The purpose of this meeting is to discuss the information status, such as drawings and workforce. In this meeting, the make-ready process of the work by constraints analysis and workable backlog. uses MS Project schedule linking every activity to each of the seven pre-requisites with a YES/NO column for constraint analysis
4- The fourth meeting which takes place on Friday. The participants of this meeting are all subcontractors meet the foreman to discuss the work done for the previous week. The activities which have not been done can be removed to the next week.

Moving to the Skanska, the company has three mandatory weekly meetings and one more small meeting for daily job briefing. The three weekly meetings are as follows:

1- The first meeting takes place on Monday. The participants of the meeting are all the trades that have activities that week to plan the work.
2- The second meeting is on Friday. In this meeting, all the foremen are required to participate. The point is to achieve the required coordination between the foremen. Additionally, the PPC is calculated as a performance indicator.
3- The third meeting is referred to as Production-Procurement-Design (PPD) coordination meeting for in-house managers. The primary purpose of this meeting to plan activities for 5-9 weeks and to identify the materials and resources needed to be ordered early.

By presenting those publications, the author concludes that most of the case studies presented are similarly implementing the LPS. The companies in Norway are trying to fully implement the LPS with all components of the LPS, including, the master schedule, the phase schedule, the lookahead plan and the Weekly Work Plan. The different meetings' structures have been

presented for just the last publication, and the review illustrated that the two companies are using a different structure with some similarities.

3.2.5 LPS is not just a tool

According to Fauchier and Alves (2013), the LPS is dealt with by some of the researchers and practitioners as a tool or as segregated components of the LPS; for instance, (Hamzeh and Bergstrom, 2010; Liker 2004) asserted that the LPS is just a tool in the way of carrying out production planning. They also said that in order to transform the system into measurable performance, the organisation responsible for the implementation must be committed to changing, learning and concentrating on participants and philosophy, instead of concentrating on tools and methods. That seems correct to some extent, but when implementing the LPS in organisations, such as projects, there can be some behaviours that emerge from the LPS implementation. Participation in the LPS teaches-by-doing and leads to increasing the highly desired lean behaviours (Fauchier and Alves 2013).

According to Fauchier and Alves (2013), several behavioural benefits lie behind the implementation of the LPS in construction projects. The author will briefly discuss the three main sets of behaviours, as mentioned by Fauchier and Alves (2013):

- Building social networks
- Addressing multiple needs in a dynamic environment
- Treating construction projects as production systems

BUILDING SOCIAL NETWORKS

1- LPS builds **collaboration** between all the involved participants, which is not only limited to the foremen and supervisors but also the client, designers and consultants.
2- One of the main benefits to the LPS is to **identify the value to all the customers**. The customer here in this context is not just referring to the client or the end-user, but it also includes the trades that perform the predecessor activity/activities.
3- **Open participation/communication, transparency**. Transparency is needed so as to make reliable promises. During the initial stages of the LPS implementation, parties are often dealing with each other without trust and disclosing all the actual needs and assumptions. However, this can change over time; the LPS help to build the trust, and as a result, the transparency increases.
4- LPS helps to **build trust and reliable promising**. Reliable promising is an inherent characteristic of the LPS. However, participants still need time to make reliable promises (last planners do not necessarily begin making reliable promises). They will begin to make reliable promises when they see the value of it and the impacts of others not making reliable promises.

ADDRESSING MULTIPLE NEEDS IN A DYNAMIC ENVIRONMENT

1- **Goal-driven behaviour**. When last planners make reliable promises (meeting commitments) in the WWP, a behaviour which drives the project to the milestones/goals will become visible.

2- **Making clear commitments (understood by all).** Last planners should utilise a language that is clear for everyone in the meeting and especially to those who perform the predecessor activity/activities. Later, the last planners can learn how to make clearer commitments.
3- **Systemic thinking and deep analysis of cause.** The last planners ask why questions in order to reach the root causes of failure of tasks. This is also an inherited component of the LPS, and it is referred to as "the five whys".
4- **Learning and continuous improvement**. Last planners learn from their mistakes and try to improve continuously.

TREATING CONSTRUCTION PROJECTS AS PRODUCTION SYSTEMS

1. **Establishing clear production goals.** Those production goals are presented in clear customer's goals. The last planners should define the required milestone to achieve those goals.
2. **Long-term and short-term planning.** The LPS is fully time-scale integrated.
3. **Promotion of flow and predictable handoffs between different trades.** The LPS can help to achieve the highest possible sequence of tasks in weeks and days.
4. **Definition of clear metrics.** Metrics can be considered as the wake-up call in order not to get lazy when succeed.
5. **Promote flow and creating a clear, visual workplace**. The clear visual workplace is an inherent characteristic of the LPS, and this can be presented using the coloured post-its.
6. **The value of flow.** Last planners begin to appreciate the value of flow when experiencing it after several weeks of using the WWP.
7. **Identification of waste**.

3.3 Challenges that arise during the LPS implementation and the suggested measures

The Last Planner® System has multiple advantages, but still, many organisations confront sufficiently significant challenges when implementing the system. Hamzeh (2009) mentioned that "*Although the Last Planner™ System may seem intuitive and realistic for creating collaborative schedules, refining tasks as they get closer to completion, using quality 100 assignments, removing constraints to make activities ready, and emphasising reliable promising, practical applications of the system may face many challenges*." (P. 99-100)

A wide range of literature has already examined and evaluated the Last Planner® System performance in different countries over the last years. Some of them highlighted success stories of the implementation of the LPS in several projects. In contrast, the other part of the literature indicated the challenges that arose during the execution through a complete or partially failed stories of the implementation. The author has noticed two types of challenges that tended to appear during the implementation of the LPS. One of them is related to the LPS itself, that is

challenges related to the LPS components and practical use of the LPS, which is called "the practical challenges". The other type is associated with the transformation process or to the team members attitudes and behaviours, which called soft (intangible) challenges (Hamzeh and Bergstrom 2010). In this literature review, The author concentrated on both of the challenges. This research is mainly based on the challenges in general and not limited to a specific type.

Several challenges appear during the implementation process related to organisational change, and there are so many publications from the researchers in the field of change management and Lean construction that included a trial of various organisations to conduct Lean practices. Some of these organisations have proved a failure, while other organisations did not manage to reach the correct form of lean production and achieved it to a certain degree (Ballard et al. 2007b; Hamzeh and Bergstrom 2010; Kotter 2012; Liker 2004).

Teamwork and continuous improvement are the major components of lean production. Unfortunately, many organisations fail to work with them, especially in the construction industry, which includes several "self-interested parties" who are not motivated to develop. They do not know each other and do not have the trust between each other. Nevertheless, when comparing the construction industry to the manufacturing industry, we can observe that the secret of the significant success of Toyota way was thanks to the creation of active connections between individuals and cooperation towards a specific goal (Liker 2004).

Every company have to know how to get that level of trust and functional connections between individuals to have an excellent atmosphere to achieve the required goals. Lean thinking emphasises that the way work is viewed and carried out should be changed drastically by the individuals in the organisation (Liker 2004). This change will result in breaking this independence between the team members, shifting the focus towards the "larger integrated team goals" instead of the focusing on the individual tasks. However, practitioners should put in mind that changing the existing state is not just tricky for the company, but also for those who have been working in a successful system "based on their conviction" for many years, in fact, they may consider it as a threat. So, team leaders have to thoroughly prepare these team members to be willing to learn, to work in a better way and to make great efforts for continuous improvement (Hamzeh and Bergstrom, 2010).

What are the most critical challenges that arose in organisations when implementing the LPS (according to literature)? Moreover, what are the possible measures to eliminate these challenges or to mitigate the impact of these challenges? These two questions are answered in the following paragraphs.

In the following paragraphs, the author presents the challenges mentioned in the literature. The author summarised what the researchers introduced concerning the challenges and the measures for overcoming these challenges. Still, it is noteworthy to know that not all the publications incorporated measures for the challenges.

1)

Ballard et al. (2007b) conducted a study on the implementation of the LPS on several construction projects. The researchers mentioned various challenges that encountered the projects teams during the implementation of the LPS, and they are as follows:

1. People resisted the change
2. Lack of commitment from the top management level or other stakeholders of the project
3. Top-down mandates without active support
4. The lack of leadership
5. Contractual structure on the project

The researchers mentioned that lack of leadership was mostly connected with less effective implementation. They added that a top-down approach through mandates from top management could result in the resistance from lower-level management. So, in order to tackle these challenges, good leadership is required by involving all the stakeholders responsible for the different commitments. The stakeholders should be the ones, in addition to the top management, to provide input into the selection and design of the solution. The researchers also said that there should be an agreement on the problem so as to have an agreement on the solutions. In some of the projects mentioned by the researchers, the lack of commitment from different stakeholders on the project and specifically from the upper-level management; they were not believing in the idea of lean and did not want to change, so they did not give lean a chance, and that formed a great challenge. Finally, the contracting process also formed a significant challenge in some of the projects, especially when the contractors were not present during the design of the project. If that occurred, some of the lean concepts, such as target costing could not be applied. The earlier the contractors are involved in the process, the higher the opportunity to apply lean concepts

2)

Hamzeh (2009) divided the factors that can cause challenges, during the implementation of the Last Planner® System specifically and by adopting new processes in general, into two types, namely the local factors and the general factors. The local factors (emerged in the case study mentioned in the dissertation) which are related to the project conditions and the project team members, while the general factors (did not emerge in the case study mentioned in the dissertation) affect the adoption of a new process in general and not specific to the LPS. The local factors are as follows:

1- Fairly new experience in Lean methods,
2- Utilising traditional project management methods,
3- Novelty of the LPS to team members,
4- Fragmented leadership, and
5- Team chemistry

Hamzeh (2009) asserted that periodic training sessions could be used to mitigate the challenges associated with experience factor, whereas the other challenges need a longer-horizon plan.
The point is to build a collaborative team that shares both pains and gains. In the case study presented by Hamzeh (2009), the team members relied on Integrated Form of Agreement (IFOA), that is a contract model used which, according to Hamzeh (2009), had a significant impact on the collaboration of team members (kindly review what Lichtig (2006) mentioned, for further information about IFOA).
While, on the other hand, the general factors are:

1- Human capital,
2- Organisational inertia,
3- Resistance to change,

4- Technological barriers, and
5- Climate

The general factors did not emerge on the project mentioned by Hamzeh (2009). However, Hamzeh mentioned that studying these factors is necessary to highlight the challenges that may hinder the implementation of a novel planning process on a construction project. So, the author briefly elaborates what each of these factors means based on what Hamzeh (2009) said.

Human capital is connected with human skills and experience required on a project. It emphasises the need to continuously evolve new skills, such as new technologies, policies and processes. **Organisational inertia** is related to the resistance to change, and it can be divided into two types, namely, internal structural agreement and external environment. The internal factors include (1) investments, equipment, and personnel, (2) incomplete information reaching decision-makers, (3) internal political constraints such as fear that change may disrupt internal political equilibrium, and (4) constraints generated by an organisation's history such as standard procedures and normative agreements. External factors include (1) barriers to enter and exit from markets (e.g. legal setting), (2) incomplete information about external environment (demands, threats, and opportunities), (3) legitimacy constraints arising when a new norm challenges/changes established legitimised norms, and (4) common rationality problems (e.g. a strategy found the rationale for a certain decision-maker may not necessarily be rational for a large number of decision-makers) (Hamzeh 2009; Hannan and Freeman 1977). **Resistance to change** is directly correlated to the organisational inertia. **Technological barriers** may have a significant effect on the success of failure of the new systems. There can be a lack of experience with new technologies or incompatibility of this technology with the current systems. Finally, **the climate** is the organisational characteristic that employees live through and experience while working for an organisation. The climate shapes their behaviour, performance, and the way they perceive the organisation.

3)

In their article, Alsehaimi et al. (2014) reported challenges to the implementation of the LPS in two different projects. Regarding the first project, the significant barriers identified were Lengthy approval procedure by the client, Cultural issues, "Commitment and attitude to time" and Short-term vision. In the second project, the researchers reported the same barriers as the first project, in addition to one more hurdle, which was due to the high number of subcontractors on the project. It is noteworthy that "commitment and attitude to time" can differ dramatically depending on the culture people came from, and the location of the implementation of the LPS. In other words, what we call a barrier in a country can be neglected in another country.

4)

Dave et al. (2015) managed to make a study on five different companies (four from the UK and one from Finland). The five companies are five large-size companies, and all of them are main contractors that had previous experience with Lean construction principles and the LPS on their projects. Based on the observations made on the five companies, in addition to the literature review conducted, they managed to categorise five different challenges that may arise during the implementation of the LPS; namely, Inability to effectively deploy collaborative aspects, partial deployment of the LPS, reduced importance of robust phase and master plans, missing continuous improvement and missing the links between detailed and high-level plans. Regarding the last challenge, some companies were not using the phase schedule or the

lookahead and took the schedules directly from the master schedule which resulted in suboptimal plan performance; as detailed constraints analysis was not implemented, and tasks were not analysed for appropriate sequencing logic.
In order to overcome these challenges, the researchers recommended understanding these challenges from two different perspectives, firstly from people and process perspective and this can be tackled by training and change management, while secondly as a needed update in the LPS in general and this is a broader challenge which reflects the practical needs of the industry.

The lack of standardised training on the LPS implementation is the leading cause of the first perspective. The issue can be that the consultants, who are giving the training, are from different backgrounds, and may have different forms of the LPS. Some of them emphasise the use of the Weekly Work Plan, neglecting the lookahead plan and phase scheduling which is challenging to be understood at the beginning. Additionally, fresh graduates entering the construction field are not familiar with the LPS, as it has not yet found a place in textbooks or academic curriculum. So, it is needed to have more standardised training material on the LPS implementation.

Regarding the second challenge, the author will not go into details, but it is vital to know that more improvements in the LPS are still needed by integrating the system with other product modelling systems.

5)

Porwal et al. (2010) made an extensive literature survey on 17 distinct publications, in a timeframe between 2000 and 2009, to examine the various challenges which the construction professionals face during the implementation of the LPS. The researchers managed to detect 12 various challenges that occurred during the implementation of the LPS in projects included in the publications. Six of these challenges, which they gave the term “IMPLEMENTATION CHALLENGES”, were related to the challenges that appeared during the first introduction to the LPS as pilot projects, which is relevant to the research scope.

IMPLEMENTATION CHALLENGES:

1. Lack of training
2. Lack of leadership/failure of management commitment/organisational climate
3. Organisational inertia & resistance to change- (This is how I have always done it) attitude
4. Stakeholder support
5. Contracting and legal issues/contractual structure
6. Partial implementation of the LPS & late implementation of the LPS

The researchers also added some other challenges. These challenges mostly occurred with experienced team members. Porwal et al. (2010) termed these challenges as “USER CHALLENGES”.

USER CHALLENGES

1. Human capital and lack of understanding of the new system; difficulty making quality assignments/human capital–skills and experience
2. Lack of commitment to use the LPS & attitude toward the new system
3. Bad team chemistry and lack of collaboration

4. Empowerment of field management/lengthy approval procedure from the client and top management
5. Extra resources/more paperwork/extra staff/more meetings/more participants/ time
6. Physical integration

6)

Alarcón et al. (2002) highlighted multiple challenges that arose during the implementation of the LPS in 12 Chilean construction companies. The researchers mentioned that lack of time for the participants was considered as the primary challenge during the training sessions. Moreover, the LPS and the new weekly meeting made it hard and surpassed the project team's capacity. In addition to these challenges, the researchers identified four more challenges which were associated with human factors, namely, the resistance to change, short-term vision, misunderstanding of PPC and lack of self-criticism.
In order to motivate people to change, the researchers recommended an incentive strategy which is discussed in detail in section 3.4.2. Secondly, for eliminating the short-term vision challenge, the researchers advocated the importance of implementing the lookahead plans and utilising the make ready process at least six weeks ahead of execution. Finally, the researches highlighted the value of self-questioning for continuous improvement of the team.

7)

Perez and Ghosh (2018) conducted a single case study to investigate the implementation of the LPS in a construction project and to find the challenges and lessons learned from the studied project. The challenges presented by the researchers were as follows:

(1) Incomplete PPC process: the project team identified the Reasons for Non-Completion of tasks, but they did not use the root-cause analysis and did not effectively utilise the information acquired from the Reasons for Non-Completion process. The participants did not address the constraints or develop an action plan despite conversations regarding how this would be addressed in the immediate future. According to Hamzeh (2009), the PPC process requires "*non-completed tasks to undergo root-cause analysis to uncover the root cause for non-completion and develop preventative actions to inhibit the same failure from recurring*." (p. 91)

(2) The underutilisation of lookahead plans: The lookahead plans were directly developed from the master schedule, which resulted in "suboptimal plan performance" (Dave et al. 2015). The project team and the trade contractors should collaboratively work together to identify the most suitable sequence and apply the lookahead plan.

(3) Lack of guideline/standard practice for updating the higher level schedules, such as the master schedules and the phase schedules. The lack of flow back to high-level plans hindered the overall production control.

In the following tables (Table 3.2 and Table 3.3), the author has summarised the most critical challenges faced by the construction industry professionals when implementing the LPS in construction projects (using 16 case studies). It is noteworthy to mention that these tables are presented following the format utilised by Fernandez-Solis et al. (2013).

Table 3. 2 – List of case studies presented in previous publications

Case No.	Reference	Projects	Project type
C1	(Ballard et al. 2007b)	Air Products: Large chemical plant	Industry
C2	(Ballard et al. 2007b)	Heathrow Terminal 5 building: civil phase	Commercial
C3	(Hamzeh 2009)	Cathedral Hill Hospital project	Health care
C4	(Alsehaimi et al. 2014)	Faculty of business and administration building	Institutional
C5	(Alsehaimi et al. 2014)	General classrooms and laboratories	Institutional
C6	**Kim et al. (2007)**	**Seoul subway project**	**Infrastructure**
C7	**Kim et al. (2007)**	**Busan subway project**	**Infrastructure**
C8	**Ansell et al. (2007)**	**3 miles of carriageway renewal**	**Infrastructure**
C9	**(Jang et al. 2007)**	**Seoul Ring Road project**	**Infrastructure**
C10	**(Cerveró-Romero et al. 2013)**	**GDL project**	**Infrastructure**
C11	**(Cerveró-Romero et al. 2013)**	**Los Cabos project**	**Infrastructure**
C12	(Ballard et al. 2007b)	AP39 Global pharmaceutical re-search and development centre	Institutional
C13	**(Cerveró-Romero et al. 2013)**	**Torre México 1 project**	**Infrastructure**
C14	**(Cerveró-Romero et al. 2013)**	**Celaya project**	**Infrastructure**
C15	**(Cerveró-Romero et al. 2013)**	**Torre México 2 project**	**Infrastructure**
C16	(Perez and Ghosh 2018)	A five-story educational building with a basement level	Institutional

Table 3. 3 – Reported challenges and the corresponding case studies

TY	Challenges	In which case?
Soft (intangible) challenges	Participants resisted the change "this is how I'have done it' attitude	C1, C3, **C6**, **C7**, **C8**, **C11, C13**
	Lack of commitment from the top-management level or from participants themselves	C1, C3, **C6**, **C7**, **C9**, **C11**
	Organisational inertia	C3, **C6**, **C7**, **C8**
	Lack of Leadership or weak/fragmented leadership	C1, C2, C3, **C9**
	Limited success in getting participation by all the sub-contractors or managers	C12, **C15**
	Bad team chemistry between participants	C3, **C9**
	Cultural issues (e.g. "Commitment and attitude to time")	C4, C5
	Doubt of the new system and concern over results	C12
Practical challenges	Novelty of the LPS to the participants and lack of understanding of the new system and lean thinking	C3, **C6**, **C7**, **C8**, **C9**
	Human capital (lack of skills, training and experience)	C3, **C8, C14**
	Lack of defined roles and responsibilities	**C14, C11**
	Short term vision	C4, C5
	Lengthy approval procedure by the client	C4, C5
	The language barriers	**C10**
	Inconsistent WWP review	**C13**
	The LPS and new weekly meeting which made it hard and surpassed the project team's capacity	C12
	Involvement of many subcontractors	C5
	In complete PPC process (e.g. no root-cause analysis)	C16
	The underutilisation of look-ahead plans	C16

3.4 How to successfully implement the LPS?

In this part, the author introduces the lessons learned and the critical success factors of projects or companies when implementing the LPS based on what was mentioned in the literature. Additionally, the author examines a publication which gives a guideline for a successful implementation of the LPS. Finally, the author presents incentive strategies that can be used to motivate project teams to change and to decrease the resistance towards new systems.

3.4.1 Lessons learned and Critical Success Factors (CSFs)

The first step towards a successful implementation of the LPS is to fully implement the LPS on the project by utilising all the components of the LPS, namely, the master schedule, the phase schedule, the lookahead plan, and the Weekly Work Plan. However, the full implementation of the LPS is not the only factor for success, and there are many other factors and measures to implement the LPS successfully. According to Ravi et al. (2018), "*it is difficult to directly correlate LPS implementation with project success based on LPS metrics*" (p. 378). Lean experts from Veidekke and Skanska companies asserted that project success could be obtained despite poor LPS implementation, while on the other hand, failure of projects can occur despite successful implementation of the LPS. So, it is vital to be aware of the lessons learned and critical success factors from other different projects (based on the literature) in order to get the highest possible potential of the LPS implementation

Many researchers in previous publications highlighted the importance of the active presence, commitment, involvement, and strong leadership of upper-level management. Alarcón et al. (2002) mentioned that support and leadership from project administrators were considered as a fundamental aspect that made the difference between success and failure in LPS implementation in many projects. Strong leadership and the involvement of the upper-level management are very crucial, especially in some of the key activities such as the planning meetings in large projects. These large meetings can gather project managers, foremen, subcontractors, and other participants, which make it difficult to be organised.

Ballad et al. (2007) also mentioned that commitment and leadership of management are two of the most vital factors for the successful lean implementation.

Moreover, Hamzeh (2009) asserted that strong leadership is considered as "*[o]ne of the success factors in driving the implementation of LPS and in leading continuous improvement efforts*." Additionally, Jang et al. (2007) stated that "*strong Lean commitment from the general contractor is necessary for successful implementations*" (p. 472). Finally, Alsehaimi et al. (2014) have also highlighted the importance of top management support as a critical success factor to the LPS implementation. The people in charge must be willing to lead the change that occurs within the company. The top managers should be aware of when and how to use their knowledge and oversight. They should be able to see the mistakes and learn from them. "*Leadership must be willing to deal with the successes, as well as the inevitable mistakes"* (Ballard et al. 2007b, p. 264). The commitment is not only required from the high-level management, but also from all the levels of the organisation. So, high levels of commitment and involvement from all the participants are required for the implementation of the Lean methodologies inside the organisation (Coffey 2000). The top managers should establish a sense of urgency of what all the participants are doing, and this can be done by making everyone stakeholder (Ballard et al. 2007b; Alsehaimi et al. 2014). So, the relationship to the suppliers

(as external stakeholders) should also get enhanced (Alsehaimi et al. 2014). According to Hamzeh (2011), "*applying LPS on a project is a lengthy process and requires a strong commitment from the owner, top management, and all others involved*." (p. 385)

Training activities to all the team members, including the Facilitator, the supervisors, the foremen, the top-level managers, the subcontractors, and many more, is also a key in the success factor of the LPS implementation according to many researchers (Alarcón et al. 2002). As mentioned before, there are two different mechanisms for training personnel; some of them learn by doing, while other firms require a certain amount of training (classroom training). "*Education [classroom training] creates awareness and works towards understanding. Training [learning by doing] enables further understanding and begins to develop capability. Education and training supported by experience results in competency*" (Ballard et al. 2007b, p. 206). Not only the company's personnel (if we are talking about the main contractor), but also the subcontractors, A good communication, support and training should be given to the subcontractors to enhance the working atmosphere and to reverse the subcontractors' reluctance to implement Lean (Jang et al. 2007; Alsehaimi et al. 2014). Training can promote commitment and generate greater participation. In order to achieve higher quality lean implementation, all the team members' lean knowledge, including the subcontractors, should be high, and that will need both, effort and capital (Jang et al. 2007).

Researchers also emphasised the importance of the "Incremental implementation strategy" by introducing the components of the LPS gradually. According to (Alsehaimi et al. 2014; Perez and Ghosh 2018), the incremental introduction of the LPS can assist with stabilising the introduction and minimising the resistance to change. (Howell and Ballard 1998; Womack and Jones 1997) asserted the importance of the change agent. The change agent is the person who makes the things happen, encourages the participants and gives them confidence that changes are going to occur.
Perez and Ghosh (2018) called this person the champion and highlighted how much it is important for maintaining and ensuring the intent of the system.

3.4.2 Incentive strategies to motivate project teams to change / Guideline for a successful implementation of the LPS

In this section, the author summarises two papers which present two methods for successful implementation of the LPS:

1) Developing Incentive Strategies for Implementation of Lean Construction

The summary:
Alarcon and Seguel (2002) mentioned a methodology that has been evolved by a group of Chilean construction companies. The methodology involved employee and organisational incentives in order to increase the participation and commitment towards the LPS implementation and decrease the resistance towards the system.

The researchers concluded that when implementing the LPS, there are eight main points that practitioners have to be aware of in order to implement the LPS successfully, and they are as follows:

1- **Motivation**: In order to make changes within an organisation, the participants should be motivated. The researchers concluded that economic rewards are not the priority element for motivation. However, many other elements have also to be considered, namely, personal recognition, active participation, training to enhance on-the-job-growth, and security (having stability when working).

2- **Training**: Which is one of the main factors of change or for implementing improvement inside an organisation. Training workshops can result in higher commitment and participation in the change of improvement. The researchers mentioned an example of conducting the training workshops in one of the companies mentioned, and the result was that these training workshops facilitated the implementation process.

3- **Leadership:** Strong leadership can also result in a proper implementation process. The leadership here is referring to the commitment from the top-level management by participating in the improvement programs and creating the right conditions for their subordinates to participate in those programs. A strong leader should have sufficient competence to lead the process.

4- **Information:** All the participants in the organisation should be aware and have the same level of information regarding the progress of the improvement project which according to the researchers have a great impact on the behaviour and attitudes on the persons.

5- **Knowledge:** The goals and the objectives agreed upon for improvement should be thoroughly known for all project managers and the professional in companies.

6- **Resources:** Practitioners have to put in mind that time is a very vital resource and that economic resources are not priority action for improvement. At the beginning of the LPS implementation process, more work will be needed in order to prepare, order and analyse new information which can be utilised for the decision-making process and the subsequent follow-up and control of the process. As a result, the time will be scarce, and that should be considered.

7- **Commitment:** The point is to increase the degree of participation by all of the team members, which can generate commitment towards the system.

8- **Organisation:** The operation of a special organisation that supports the development is required in order to implement new improvements in the organisation.

2) The Lean Transformation: A Framework for Successful Implementation of the Last Planner™ System in Construction

The summary:

Hamzeh and Bergstrom (2010) suggested a framework for integrating the LPS into a project. The framework was drawn based on experiences from previous LPS implementations and research in change management. Still, it should be tailored to the project circumstances. The researchers recommended seven steps that should be followed by new adopters of the LPS:

1- **Harness the support of the project's owner and the organisation's top management.** A strong commitment is required from all the organisation levels, including, from the head of each organisation, the division managers, and even middle-level managers in order to achieve the planned change.

2- **Establish a cross-functional nucleus team and develop goals to accomplish.** The project team should establish goals and perform the required adjustments and improvements to achieve this goal, such as by identifying the training needs and carrying out training programs. The team should involve all the levels of the organisation starting from the top-level managers and ending with the last planners, such as foremen and superintendents.

3- **Evaluate and map the current planning process.** The project team should use the process mapping to understand the deficiencies and valuable steps in the current process.

4- **Develop a go-to process.** Adjust the LPS to the current project by building on the existing valuable steps and removing prodigal steps.

5- **Identify challenges and opportunities for implementing the new process.** The project team should identify the possible challenges to deal with them correctly and grasp the opportunities.

6- **Develop and perform a train-the-trainer program.** Training programs should be implemented to all the project team members and train the future trainers who are mostly the last planners, such as the foremen and the superintendents. All members should feel that the system both useful and possible to be achieved.

7- **Create a positive team experience during initial implementation and regularly evaluate achievements.** During the initial implementation stages, the project team should see evidence of success so as to build upon later. The project team should introduce incremental improvements to the process in order to meet the end goals.

4 FINDINGS

In this chapter, the findings from interviews, observations, document study and the surveys are presented below.

The chapter is divided into two major parts. The first part directly answers the first research question, “How is PNC going to implement the LPS on the Minnevika Bridge project?”, while the second part of this chapter addresses the second and the third questions, “What are the challenges that arise during the implementation of LPS?“ and “What are the measures that PNC can use to tackle these challenges”.

4.1 Last Planner System on the Minnevika Bridge project

This part has been divided into three major sections. The first section is a general overview of the LPS implementation process on the Minnevika Bridge project and some essential definitions which the author uses later in section two, three and four. The second section is a detailed description of the LPS implementation on the Minnevika Bridge project during the Training Phase, the Transition Point, and the Execution Phase. Section three encompassed a description of the meetings concerning the LPS, a description of the Key Performance Indicators (KPIs), the results from the PPC and the reasons for non-completion of tasks recorded during the LPS implementation, and finally an elaboration of the change in openness towards the LPS during the implementation process (the results from the two surveys).

4.1.1 Overview of the LPS implementation on the Minnevika Bridge project

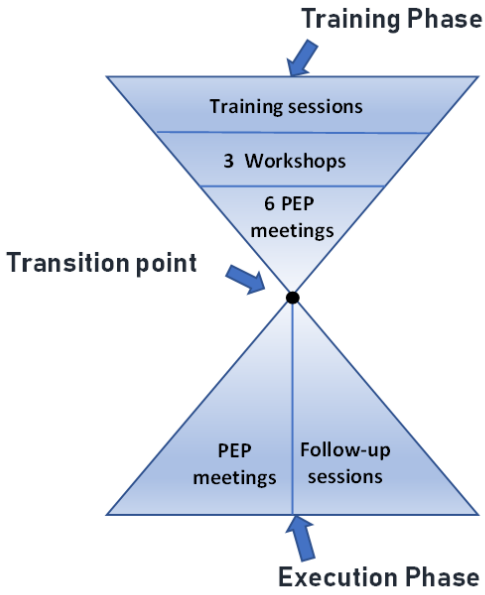

Figure 4. 1 – The LPS implementation on the Minnevika Bridge project

IMPORTANT TERMS

Training Phase:
As indicated in Figure 4.1, the Training Phase expressed the first LPS implementation on the Minnevika Bridge project. This phase was comprised of three different steps, namely, two training sessions, three workshops and 6 PEP meetings. The responsible persons during the Training Phase are the Trainers.

Transition Point:
After the Trainers had become sure that the project team were able to run the system by their own, they handed over the system to the project team and specifically to the LPS Facilitator and the process expert. This handing over process is considered the Transition Point.

Execution phase:
After the Transition Point, the LPS implementation transferred to another phase, referred to as the Execution Phase. In the Execution Phase, the LPS Facilitator and the process expert supervise the project team so as to successfully implement the LPS.

Production Evaluation and production Planning (PEP) Meeting:
This meeting is well-known in the literature as the Weekly Work Plan (WWP) meeting; however, in this case, the Trainers utilised their own terminology to express it.

The Trainers:
PNC contacted the top management of the PORR organisation (located in Vienna) and engaged the two Trainers in order to supervise the project team when implementing the LPS on the Minnevika Bridge project during the Training Phase. The Trainers introduced the project team to Lean history, concepts, principles, and methods in general and the LPS components in particular. After the Transition Point, the Trainers handed over the LPS to the project team and specifically to the LPS Facilitator and the process expert.

LPS Facilitator:
After handing over the system to the project team (after the Transition Point), the Facilitator was responsible, with the help of the process expert, for the facilitation of the PEP meetings. During the PEP meetings, the Facilitator presents and interprets the KPIs, establishes a conversation culture, defines the level of risks by using the risk matrix, using the action plan, and supports the project team to plan their activities and milestones. After the PEP meeting, the Facilitator documents the progress and updates the MPP.

Process expert:
A person that supports the LPS Facilitator with the facilitation of the PPE meetings, captures the KPIs' evaluation, introduces the KPIs, if needed, supports the Facilitator with the discipline regarding the conversation culture during the meeting, and supports the project team to plan their commitments and milestones.

Milestone and Phase Plan (MPP):
MPP is the base production plan for the lookahead plan and the Weekly Work Plan. In this plan, the optimal sequence, which was developed using the process mapping, was transferred to a weekly based schedule. Additionally, the constraints analysis was carried out in order to develop a sound production plan. The project team chose a milestone and worked backwards

(using the pull planning method) from the date of this milestone until the day of the workshop. The project team mapped out the activities based on processes and predecessors. Then they optimised it by resources. In the end, the project team managed to map out all the activities during this timeframe.

4.1.2 Implementation of the LPS on the Minnevika Bridge project

The Trainers introduced the LPS on the Minnevika bridge project using the following sequence:

The Training Phase

1- The training sessions

Two training sessions were held on the sixth and seventh of November (the same training for different participants for more flexibility). The Trainers utilised a theoretical explanation to elaborate on what is meant by Lean Construction and the Last Planner® System and their origins. Seventeen participants attended these training sessions in the two days; including, the site managers, the construction manager, the construction foremen, the supervisors, the LPS Facilitator and the representatives from both the sub-contractors. The client and the JV partner were invited to the training sessions. However, neither the client nor the JV partner participated in any of these training sessions.

The introduction to the LPS included a production control game, called "Villego Simulation game", to teach the attendees about the meaning of production planning and elaborate on the difference between traditional project management and the LPS.

The Villego Simulation game consisted of two rounds. In the first round, every participant was assigned a certain role (general contractor, trade and data analyst). Furthermore, the participants were introduced to the simulation rules. In this first round, the team had 25 minutes to prepare for construction of the Lego® house. In this round, the preparation phase and the construction process were supported by the traditional project management by using the same methods the participants are accustomed to from before.

After the first round, the Trainers introduced the concept of collaborative planning. In the second round, the participants built a similar house, but this time the construction process was supported by the Lean methodology (the Last Planner® System)
A Collaborative Planning Session (CPS) was held in two parts. In the first part, an optimal construction workflow was developed. In the second part, the workflow has been optimised to meet everybody's needs and objectives. Then, the project team started to build the house. It was noticed that the erection duration reduced by a factor of around eight and all key figures changed positively.

Applying the collaboration planning into the game reflected positively on most of the attendees as they started to understand the benefits of the Last Planner® System.

2- The three workshops

After carrying out the training sessions, three workshops have been conducted to train the participants more on the Last Planner® System by using "learning in action method" and for setting up the framework for the implementation of the system during the Training Phase. The three-day workshops included the first three levels of the Last Planner® System mentioned by Ballard, namely, the phase schedule, the six weeks lookahead planning and the weekly work planning.

During **the first workshop**, the project team sought to map out and analyse the overall construction process by utilising process mapping. The Trainers initiated the day with an introduction to the five Lean principles, including, value, optimisation, flow, pull and continuous improvement and used another production planning game to facilitate the understanding of these principles. Before starting the process mapping, the team developed some team rules, which were applied as a guideline for their meetings.

The team rules are as follows:

1- Be on time
2- One conversation at a time
3- Be respectful to all other participants
4- Keep the conversation in English inside the meeting
5- Use different languages only if it was really necessary
6- No electronic devices should be used during the meetings

Later, the participants were introduced to the idea of process mapping, and different colours were assigned to different trades, work steps or companies. In the next step, repeating patterns were identified. Then, the team started the process mapping for the project. The construction process was mapped using the pull principle, from the end to the beginning without getting into small details. Sticky notes were used for this process.

It was observed during the process mapping that the participants frequently tended to get lost in the details of the construction process. However, in the end, the participants succeeded to complete the process mapping, to define the different roles and responsibilities as well as the dependencies between all the team members.

In **the second workshop**, the participants continued with the process analysis and started to transfer the process onto a timeline. In the beginning, the team started by defining the project gates and important milestones. Later, the participants conducted the MPP with an objective to develop a base plan for the weekly lookahead. They also used the collaborative planning process and the reverse phase scheduling for developing these plans.

Furthermore, for developing a sound production plan, known constraints were considered. The project team tried to define as many constraints as possible to eliminate them or find some solutions for them generally. A risk matrix has also been conducted to evaluate the possibility of occurrence of the constraints and the influence on the reliability of the work plan. Finally, Action plans have been used for lowering the risks or for working out solutions for certain issues.

The third workshop was conducted on the 16th of January in order to set up the six weeks lookahead plan and was carried out based on the same steps mentioned by Ballard, namely,

explosion, screening and make-ready. In this meeting, the Trainers generated a common understanding of the different processes and the common goal. Due to the fact that the third workshop was conducted after approximately one month from the second workshop, the Trainers used some time reminding the team members of the journey until then. The project team reviewed the collaboratively agreed process map again and refined their milestones and phase plan (MPP) and incorporated some small adjustments to it. Finally, they started planning the six weeks lookahead depending on the milestones and phase plan (MPP). They also applied what they learnt during the second workshop and utilised the risk matrix after defining the constraints for all the different tasks and examined the impact of these constraints on the process and the probability of their occurrence. If the probability of occurrence of a constraint and its impact were high, an action must be defined in the action plan. Finally, the project team assured that all the tasks in the first week of the six weeks lookahead could be done and were meeting the four quality criteria (Definition, soundness, sequence and size).

3- The 6 PEP meetings

The final step in the Training Phase was the Production Evaluation and Planning meetings (PEP meetings). The first PEP meeting was held one week after setting up the first six weeks lookahead plan during the third workshop. The Trainers started to evaluate the first week of working by going through the different commitments of different trades.

The Trainers used the risk matrix and the action plan as a way to make tasks ready. Then, the team evaluated the weekly performance using the Key Performance Indicators (KPIs). Regarding KPIs, the Trainers used standard indicators (was elaborated in detail in the sub-section "Measurements for tracking the weekly performance and safety on-site"). In the end, the project team established the Weekly Work Plan (WWP) and modified the six weeks lookahead plan under the supervision of the Trainers.

The Trainers recommended implementing the first 6 PEPs together with the project team. During this period (6 weeks), they coached the LPS Facilitator and the process expert on-site, then after this period, they handed over the system to both of them, but first, they had to make sure that they were able to run the system themselves. For all the 6 PEP meetings, the Trainers followed the same sequence; starting with the last week evaluation and ending with establishing the new Weekly Work Plan and an overall modification in the six weeks lookahead.

The Transition point

Once the Trainers ascertained that the Facilitator, the process expert, and other team members obtained the required knowledge concerning the LPS implementation and attained an adequate level of maturity that qualifies them to run the system independently, the Trainers handed over the LPS system to the project team. The Transition Point describes the handing over process between the Trainers and the project team members. This point is undoubtedly critical and should be chosen carefully by the Trainers and the project team. In the DISCUSSION chapter, the author describes in detail the importance of this point and how it can influence the LPS implementation.

The Execution Phase

After handing over the system to the project team and specifically to the LPS Facilitator and process expert, the Execution Phase began. As shown in Figure 4.1, two processes coincided during the Execution Phase, namely, the PEP meetings and the follow-up sessions.

1- The PEP meetings

In the PEP meetings, the Facilitator used the same steps learned in the 6 PEP meetings performed during the Training Phase. Again, the project team established the Weekly Work Plan (WWP) and modified the six weeks lookahead plan under the supervision of the Facilitator and the process expert. The Facilitator also used the action plan and a risk matrix as a way to make tasks ready. Then, the team evaluated the weekly performance using the Key Performance Indicators (KPIs). As a way of improvement, the Facilitator incorporated some new processes and a new indicator to those mentioned by the Trainers (See section "Measurements for tracking the weekly performance and safety on-site")

4- The follow-up sessions

The Trainers suggested carrying out follow-up sessions simultaneously with PEP meetings. Two weeks after the last PEP meeting in the Training Phase, one of the Trainers carried out the follow-up sessions in order to assure that the project team did not deviate from the drawn path. The plan was that one of the two Trainers would physically be presented during the PEP meetings on a fortnightly basis. Then later, the Trainers planned to attend the meetings over skype. However, the follow-up sessions were interrupted due to the outbreak of Covid-19.

4.1.3 Practical work with the LPS / Openness towards the LPS

Meetings

Based on the interviews and the observations, the following results have been obtained:

The company kept doing the same regular construction meetings as they used to do before implementing the Last Planner® System, such as meetings for tracking the progress and cost, or meetings for solving technical issues. The only meeting that was added and was directly related to the Last Planner® system is the PEP meeting. The purpose of the PEP meeting, according to the Trainers, is to investigate the process itself and give an evaluation of the work process, not to solve technical issues. So, all the technical issues should be solved outside the PEP meeting.

Referring to the importance of discussing the technical issues outside the PEP, the Trainers mentioned that:

"*If the technical issues were discussed during the PEP meetings, it will be like two people are discussing with each other, while the other people are looking at them and waste their time. In the PEPs, they will talk about the constraints, but they will not solve the constraints inside the meetings they (the people having the technical issues) will take it outside and solve it in a separate meeting, solving the technical issues outside the PEP meetings can save much time*".

Tracking the weekly performance, safety and logistics on-site

Based on the results from the interviews, the observation and document study, the Trainers and the Facilitator deployed five different Key Performance Indicators (KPIs) in order to track the weekly performance of all the trades involved and the safety status on-site. Additionally, the Facilitator incorporated a talk about the logistics on-site in the PEP meetings.

1) The Trainers had a standard collection of Key Performance Indicators (KPIs) for tracking of weekly work planning, including, the Percent Plan Complete (PPC) overall, the PPC per trade, Milestone Completion, Variance Analysis, and Top Three Variances.

   - PPC overall: Percentage of completed commitments in relation to planned commitments. The PPC shows the consistency and reliability of the planning of the team. The maximum PPC overall is 100%. The team cannot achieve more than 100%, even though they have completed commitments earlier (more commitments than planned in that week). The result is a trend for the project.

   - PPC per trade: Percentage of completed commitments in relation to planned commitments shown per trade. Here the value can be more than 100% if trades manage to complete their tasks earlier than planned.

   - Milestone Completion: Shows the cumulated number of milestones per calendar week throughout the project (planned).

   - Variance Analysis: shows a standard set of reasons, which may vary from project to project. On the Minnevika Bridge project, the participants have chosen ten possible reasons for non-completion of commitments that suited the project. Later, the project team can select one of these ten reasons as the reason for non-completion. Note that the participants should choose just one reason for each un-finished commitment.
     The Trainers chose to limit the number of reasons in order to facilitate the documentation process and to make it easier for the participants to find the reasons for non-completion.

   - Top Three Variances: The top Variances between all trades cumulated over the period of the project.

2) The Facilitator invited the HMS (Health, Safety and Environment) coordinator to participate in the PEP meetings in order to help the project team to track the safety status on-site. Furthermore, the Facilitator added a new indicator for tracking the safety status on-site, which is referred to as the "Order and Safety" Indicator. By this indicator, the project team assess subjectively how well-organised the site is, presented as a traffic light with red, blue, green. The red colour indicates an unsafe workplace, while the green is for a safe workplace.

3) At the end of each PEP meeting, the Facilitator included a small talk about the logistics on-site by presenting a general overview picture of the construction site. The attendance of the foremen and the supervisors were recommended in this talk. However, the foremen and the supervisors rarely attended the PEP meeting.

The Percent Plan Complete (PPC) results

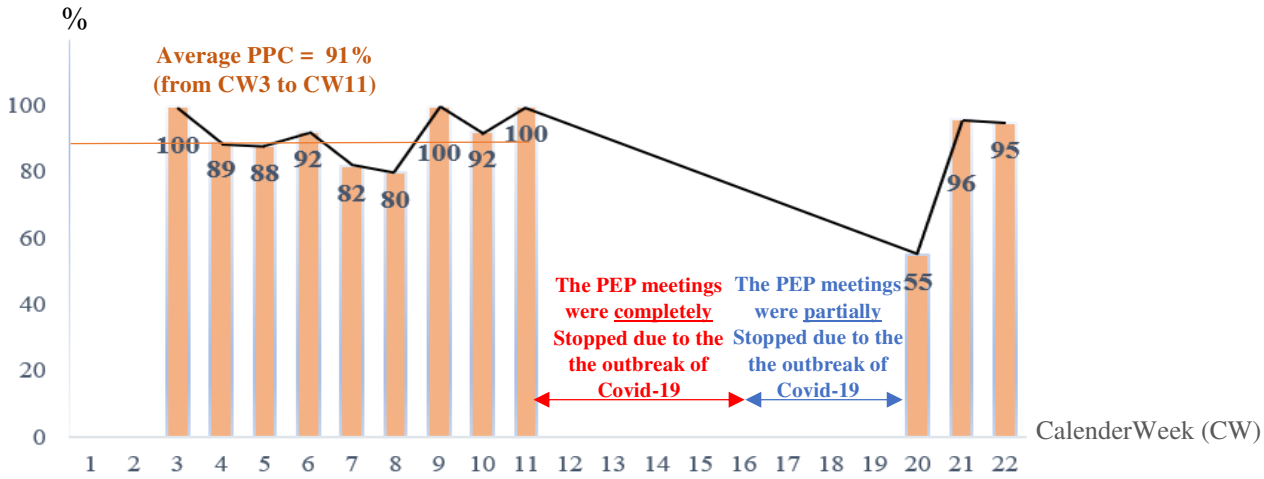

Figure 4. 2 – The PPC results from CW3 to CW22 On the Minnevika Bridge project

According to Figure 4.2, the graph shows a great start with high PPC results, which ranged from 100 to 80 % in the first nine weeks. Last Planners managed to finish all the commitments which they have committed to and achieve a perfect score (100% PPC) on many occasions (e.g. CW3, CW9, and CW11). The project team was also close to the 100% PPC in many situations (e.g. CW6, CW10, CW21, and CW22). Most of the PPC results indicate a good performance during the LPS implementation. As it is indicated in Figure 4.2, the outbreak of Covid-19 resulted in the interruption of the PEP meetings completely from CW11 to CW16. From CW16 to CW20, some of the participants carried out the PEP meetings, but without the attendance of the LPS Facilitator or the process expert. The PPC results were not calculated, and the KPIs were not utilised. The first PEP meeting after the outbreak of Covid-19 was on CW20. In this meeting, the Facilitator and the process expert calculated the PPC. The PPC results dropped significantly to be just 55% PPC, from an average PPC equal to 91% in the first nine weeks (from CW3 to CW11). One week later, the PPC results started to get back on track with two consecutive successful weeks.

The Reasons for Non-Completion (RNC)

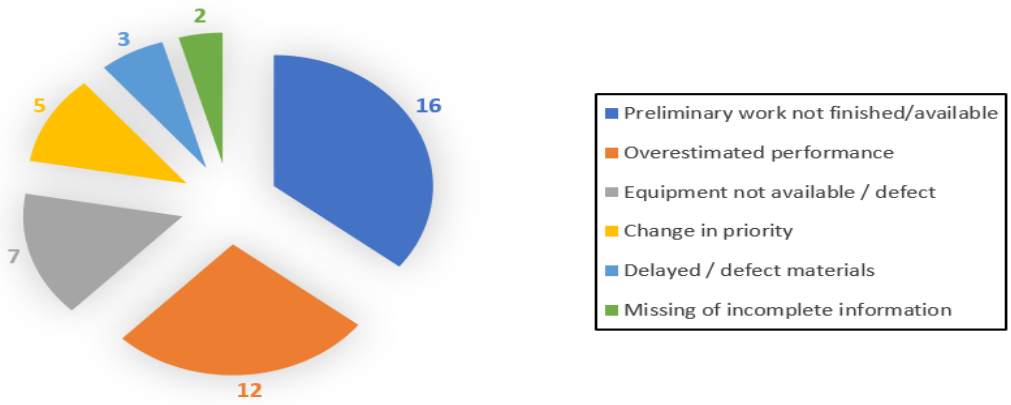

Figure 4. 3 – The RNC of commitments from CW3 to CW22 On the Minnevika Bridge project

Figure 4.3 indicates the reasons for non-completion of commitments on the Minnevika Bridge project. The most critical two reasons for non-completion were the preliminary work not finished, and the overestimated performance; 30 commitments were not finalised due to these two reasons. Equipment was not available on some occasions, which resulted in seven non-completed commitments. Delayed/defect materials did not influence the planning process. Just three unfinished commitments were due to the delayed material. Incomplete information came in the last place concerning the impact on the completion of the commitments. Note that the four remaining reasons for-non completion did not influence on the completion of the commitment on the Minnevika Bridge project, including:

1- Reworks
2- Poor weather conditions
3- Unforeseen absence of labour
4- Preliminary work not recognised

Openness towards the LPS (The results from the two surveys)

2- Results from the first survey

The first survey was given to the respondents prior to the training sessions. The two surveys were carried out in order to track the change in openness towards the LPS during the implementation process. According to the results from the first survey, as shown in Table 4.1 below, almost 62% of the respondents (8 out of 13) declared that they have never heard about the LPS before, while 85% of them (11 out of 13) have not worked with the LPS before. This indicates how critical it was for PNC to conduct a Training Phase for all the participants to know how to utilise the LPS during the implementation process. Since few participants had heard about the LPS from before, many of the participants (10 out of 13) had undecided impressions about the LPS. However, the responses showed openness towards the LPS and satisfaction towards the change. Many of the participants responded positively to most of the survey questions; they believed in the success of the LPS implementation on the Minnevika Bridge project.

An average scale of 3.69 in survey question number 10 shows that many of the participants believed that the LPS implementation would be a challenging task to achieve.

Table 4. 1 – Results from the first survey

Survey question	Survey answers		
1- Have you heard about Lean Construction before?	Yes 85%		NO 15%
2- Have you heard about the Last Planner® System (LPS) before?	Yes 38%		NO 62%
3- Have you worked with the LPS before?	Yes 15%		NO 85%
4- What is your impression of the LPS?	Positive 3	Negative 0	Undecided 10
5- Would you say that in general, you are open to new ideas?	Average scale		4.15
6- Would you say that you are ready to be part of the LPS?	Average scale		3.92
7- Are you curious to know more about the LPS?	Average scale		4.23
8- Are you satisfied with this transformation/change in the project's system? (Applies to PNC employees)	Average scale		3.75
10- Would you say that it will be challenging to change to the LPS?	Average scale		3.69
11- Do you think that the LPS is a waste of time and effort?	Average scale		2.15
12- Do you think that the LPS will improve the way by which the project will be planned?	Average scale		3.62
13- Would you say that traditional project management is enough for the success of infrastructure projects?	Average scale		3.25
14- Would you say that the LPS can lead to a successful project in comparison to traditional project management?	Average scale		3.55

3- Results from the second survey

The second survey was conducted during the Execution Phase. According to Table 4.2, the impressions towards the system were more positive than the first survey; five respondents gave a positive answer, while the other three respondents gave an undecided answer. Most of the participants were still curious and motivated to be part of the LPS implementation and had even more satisfaction. An average scale of 2.88 in survey question number 5 indicates that many of the participants believed that the LPS adoption on the Minnevika Bridge project was not a challenging task.

Table 4. 2 – Results from the second survey

Survey question	Survey answers		
1- What is your impression of Last Planner® System (LPS)??	Positive 5	Negative 0	Undecided 3
2- Are you still motivated to be part of the LPS?	Average scale 4.50		
3- Are you still curious to know more about the LPS?	Average scale 4.00		
4- Are you satisfied with this transformation/change in the project's system? (Applies to PNC employees)	Average scale 4.00		
5- Would you say that it was challenging to adopt the LPS?	Average scale 2.88		
6- Do you think that the LPS is a waste of time and effort?	Average scale 2.00		
8- Do you think that the LPS is improving the way by which the project is planned?	Average scale 4.00		
9- Would you say that traditional project management is enough for the success of infrastructure projects?	Average scale 3.13		
10- Would you say that the LPS can lead to a successful project in comparison to traditional project management?	Average scale 3.50		

4.2 The challenges arose during the LPS implementation

This part has been divided into three main sections. The first section, describes the methods used to prepare a set of challenges (expected challenges) that formed the basis for finding the challenges during the LPS implementation on the Minnevika Bridge Project. The second section presents the challenges that occurred during the Training Phase, while the third section outlines the challenges that arose during the Execution Phase.

4.2.1 Preparation of the challenges

The first step towards answering the second research question was to prepare a set of challenges that might arise during the LPS implementation on the Minnevika Bridge project. The preparation process took place essentially before the Training Phase. However, the author's observations endured for five months. As mentioned in the RESEARCH METHOD chapter, the author relied on three different methods to achieve this objective:

1- Two different interviews (*Interview I, Interview II*),
2- (Non-participant & participant) observations, and
3- The first survey.

1- The results from the interviews

Interview I revealed that the LPS Facilitator had no experience in facilitating the LPS from before. The Facilitator was acquainted with Lean thinking and how it can be executed inside organisations. During the interview, the author asked her multiple questions, but the answers indicated a lack of knowledge with the system and implementation process. As a result, "**to have a Facilitator with little experience in the LPS"** was recorded as a possible challenge in the implementation process. How is she going to deal with the LPS challenges? Will she take support from the Trainers? Will the challenge influence the implementation process? Those questions were put into consideration when observing this challenge.

In *Interview II*, the two Trainers expected some challenges to arise during the Training Phase, including:

5- **Doubt.** Some negative questions and ideas might come to the mind of the new adopters of the Last Planner® System, such as "What are the Trainers doing here?" "Why are we changing the traditional system?" "Is it meaningful to stay here?" "Am I wasting my time?" "I know my process", "I know what I need to do", and "I have done it a thousand time that way".
6- **Lack of engagement.** The participants may realise that they have to be in the meeting/training, so they just set down without any engagement.
7- **Disruption.** The participants might interrupt the training/meeting by telling jokes or by discouraging the team and distracting them from the main goal.
8- **Culture and organisational issues.** Trainers thought it would be hard to get the participants to change their cultures and open up their minds, as people typically do not want to change.
9- **Transparency & honesty.** One of the most significant challenges from the Trainer's point of view during the implementation process was to make the participants transparent and honest. Due to the construction industry atmosphere, the participants might be opaque; they usually make a shield from the attacks of other contractors or the client and always try to be the winners.
10- **The time commitment required to participate in the weekly meeting.** The participants might think that they are wasting their time and adding one more meeting to their already tight schedules.
11- **The non-participation challenge of critical team members.** If someone is missing, it would be challenging to plan their work correctly. It would be challenging to know what they are doing and what are the challenges (they are the ones that knows better).
12- **Typical technical challenges.** If the team do not know what to do, they will not manage to make the phase planning or the process mapping; everybody has to be prepared as it is hard to implement something if they do not know what they should do.
13- **Fear of responsibility (mainly from lower-level management).** In the Last Planner® System, everybody is responsible. So, the responsibility will be divided between the whole team and higher responsibility will be given to persons who did not have it from before, some people will be relieved, and some others will have a higher burden.

2- The results from the first survey

In the first survey, the author dedicated an open-ended question at the end of the survey (as shown in APPENDIX C – The first survey) to explore the challenges from the participants' perspective. Eight of the participants answered the open-ended question, while the other participants did not manage to expect any challenges since they did not know so much about the system. The most critical challenges presented by the participants were as follows:

1- **Maintaining participants' commitment to be part of the process and to take the LPS seriously.**
2- **Acceptance of the LPS from all the participants**, including all the project organisation-level and every responsible team member in the system, and change the way of thinking.
3- **Participants resistance to the system.**
4- **Lack of Transparency in the interfaces between the team members.**

3- The results from the observations (during the training sessions).

1- The language formed a great challenge for some of the attendees.
2- Some participants were not convinced by the LPS, while some others could not see the real benefit of the pull planning method.
3- The author observed that the traditional way of doing the work in the planning process was controlling the atmosphere; the decisions were concentrated in the top management. It was also recorded that one of the foremen said, *"I could not find the point of involving me during the planning meetings"*; the foremen or the supervisors always took the orders from the top management and obeyed.

In the end, the author summarised the set of challenges, as indicated in Table 4.3.

Table 4. 3 – Summary of the expected set of challenges

Soft (intangible) challenges	The practical challenges
Doubt (doubt about the overall performance and the benefits behind the LPS)	The non-participation challenge of critical team members (due to circumstances beyond their control).
Lack of engagement.	The language barriers.
Lack of Transparency in the interfaces between the team members.	To have a Facilitator with little experience in the LPS.
Participants' resistance to the system.	Typical technical challenges.
Maintaining participants' commitment to be part of the process and to take the LPS seriously.	The time commitment required to participate in the weekly meeting.
Fear of responsibility (mainly from lower-level management).	Participants do not understand the LPS or some of its components.
The non-participation challenge of critical team members (refuse to attend).	The decisions and input are primarily provided by top-level management, such as site managers.
Disruption.	
Culture and organisational issues.	

4.2.2 The challenges arose during the Training Phase

The second step to answer the second research question was to utilise the prepared set of challenges (mentioned in Table 4.3) as a reference/guide: first when observing the project team during the Training Phase, and secondly when doing the five interviews (*Interview III, Interview IV, Interview V, Interview VI, Interview VII*).

Based on the observations and the five interviews, eight different challenges arose during the Training Phase. The eight challenges are described in detail in the upcoming paragraphs.

1) **Doubt (doubt about the overall performance and the benefits behind the LPS).** Many interviewees declared that they had doubt towards the LPS during the Training Phase and specifically during the training sessions and the three workshops. Some others had broad experience with other systems, which made it unnecessary to change. The author observed that the Trainers did not convince many of the participants during the training sessions.
2) **Disruption.** In the second training session, there were some participants that resisted to work with the Trainers, and someone (one representative from the subcontractors) was disrupting the training actively. It was challenging for the Trainers to keep the rest of the participants with them.
3) **Language barriers.** During the Training Phase, the language formed a significant barrier against the implementation process; gathering almost seven different nationalities, speaking five different languages in the same room could result in some challenges. It was mentioned by one of the site managers that " *you cannot take it for granted that everyone understands the same thing when something is said* ." In *Interview VI*, the interviewee said that "*language is always a barrier, especially in an international atmosphere like here. Not just now, but it will also be a challenge in the future. Sometimes there are misunderstandings*."
4) **The non-participation of the JV partner in the training sessions and workshops.** The author observed that the non-participation of the JV partner affected the process negatively, especially in the part of developing the milestones and the phase scheduling (MPP) as the inputs regarding duration for JV partner's work were taken from the schedule and incorporated into the MPP considering the known restraints. Later, they have to bring the representative again and introduce the MPP to him and ask him for confirmation for the process, which led to some waste of time due to repetition.
5) **Newcomers to the PEP meetings.** A new representative for the JV partner started to attend the PEP meetings (from the first PEP meeting) which resulted in some challenges associated with the level of knowledge they had compared to the other participants.
6) **Fear of responsibility when making the commitments from lower-level management (the site engineers).** It was observed more than once the difficulty to take decisions when top-level managers were not present in the PEP meeting. Due to some urgent meetings, the site managers could not attend some of the PEP meetings, which resulted in some hurdles making the weekly plans and commitments with the required reliability.
7) **The non-participation of critical participants due to circumstances beyond their control.** Critical team members include the site managers, the site engineers, the JV partner, the supervisors, foremen and the subcontractors. This challenge can frequently occur in construction projects; new circumstances may occur suddenly, resulting in the absence of critical participants.

8) **The non-participation of the supervisors or foremen.** On the Minnevika Bridge project, two supervisors and several foremen were responsible for the execution process. It was observed that one of the supervisors did not show up - on purpose - in any of the meetings during the Training Phase. Further investigation revealed that the supervisor had a troublesome experience with the Last Planner® System from a previous project. The other supervisor participated in the training session, the workshops and some of the PEP meetings. Some foremen attended the training sessions. Still, none of them showed up again in any of the other meetings during the Training Phase.

4.2.3 The challenges arose during the Execution Phase

The set of challenges mentioned in Table 4.3 were finally utilised to identify the challenges that emerged during the Execution Phase. The author first observed all PEP meetings during the Execution Phase. Later, the author carried out the second survey, which included a dedicated section on the challenges during the Execution Phase. Finally, the author conducted the five interviews to solve the problem of the neutral answers from the survey results and to search for possible new challenges that may not have been detected.

Table 4. 4 – Results from the second survey (Section 2)

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

Table 4.4 shows the results from the second survey regarding the most critical challenges that emerged during the Execution Phase. As indicated before in the RESEARCH METHOD chapter, the author relied on a five-point Likert scale method to find the most critical challenges from the participants' perspective. The author excluded all the challenges that got an average scale lower than 3, except for "**Non-participation of critical team members"** challenge,

which was mostly a neutral answer. All the neutral answers acquired (answers with average scale 3) were later used in the five interviews to assure whether or not these challenges are still critical during the Execution Phase.

Thanks to the observations, the second survey and the five interviews that were carried out, the author managed to find eight different challenges that arose during the Execution Phase. The eight challenges are described in detail in the upcoming paragraphs.

1) **Maintaining participants' commitment to be part of the process and to take the system seriously.** As indicated from in Table 4.4, this challenge was considered as the most critical challenge during the Execution Phase due to the ramifications it has on the implementation process. It was clear-cut when the site manager said that "*Without the commitment of the participants, it would be very hard to take any benefit from the system, it is based on the commitment from all the parties."* In *Interview VI*, the LPS Facilitator said that "*if one of the parties is not committed to the LPS, it would be very hard to get a reasonable plan and information*."
2) **The non-participation of critical participants due to circumstances beyond their control.** As indicated before, this can continuously be a challenge; whether in the Training Phase or the Execution Phase.
3) **Fear of responsibility when making the commitments from lower-level management (the site engineers).** Two of the interviewees declared that this challenge is still critical to the implementation of the LPS due to the lack of experience of some of the participants (e.g. the site engineers) and the difficulty to make reliable promises without the guidance of the critical team members (e.g. the site managers or the supervisors)
4) **Difficulty in analysing and understandingthe KPIs by the participants.** This challenge was also observed during the Execution Phase; less attention was given to the KPIs, and more focus was given on the preparations for the weekly plan. Three of the interviewees expressed how difficult it was to understand and analyse the KPIs.
5) **The non-participation of the supervisors or the foremen.**
6) **Disruption**
7) **The decisions and input are primarily provided by top-level management.**

Challenges 6, 7 and 8 were directly correlated. One of the supervisors did not accept the LPS. As a result, the supervisor did not attend all the meetings during the Execution Phase, except for one PEP meeting. In this meeting, it was clear that the supervisor was trying actively to disrupt the other participants. During this meeting, a disagreement between the supervisor and one of the site managers occurred, which led the supervisor to leave the PEP meeting.

The other supervisor moved to another project. So, none of the supervisors attended the PEP meetings. Furthermore, the foremen were prioritising other work over the PEP meetings, so they did not attend either. Despite the implementation of the LPS, the decisions and inputs were still provided by top-level management.

8) **Carrying the PEP meetings without the support of the Facilitator or the process expert.** As mentioned before in Figure 4.2, some of the participants conducted the PEP meetings without the supervision of the LPS Facilitator or the process expert. As a result, the PEP meetings were not performed as usual. Moreover, none of the key performance indicators was utilised.

4.3 The measures used to overcome these challenges.

This part is comprised of two main sections. In the first section, the author presents the measures used by the team members to overcome the challenges emerged during the Training Phase, while the third section outlines the measures used by them to overcome the challenges arose during the Execution Phase.

4.3.1 The measures applied during the Training Phase

In this section, the author presents the challenges and the corresponding measures used by the Trainers, the LPS Facilitator, or the participants to overcome the challenges that emerged during the Training Phase. The measures presented are based on the observation and the five interviews conducted.

1) **Doubt (doubt about the overall performance and the benefits of the LPS).** In order to overcome the doubts, sufficient training was given to the participants. Additionally, the Trainers introduced the benefits of the LPS during the training sessions. The Trainers asked the participants to give their feedback for resolving their doubts. Finally, the participants learned by doing during both the workshops and the 6 PEP meetings.
2) **Disruption.** The Trainers dealt with the person that disrupted the room during the training session, they reminded him, in front of the other participants, the importance of what they are doing.
3) **Language barriers.** In order to overcome the language barriers, the project team defined the team rules during the training sessions. One of these team rules was to "keep the conversation in English inside the meeting". Additionally, at the end of each PEP meeting, the Last Planners presented all of their commitments to assure understanding of what they have committed to.
4) **The non-participation of the JV partner in the training sessions and workshops.** The Trainers escalated the issue to top-level management. Then, the representative from JV partner was changed, and another person attended the meetings. The Trainers explained in detail the LPS to the newcomer.
5) **Newcomers to the PEP meetings.** The Trainers illustrated the LPS to the newcomers into detail to reach an equivalent level of knowledge with other participants.

6) **Fear of responsibility when making the commitments from lower-level management (the site engineers).** Internal agreement/discussion within different companies about the minimum experience needed to be in the PEP meetings in order to make reliable weekly plans.
7) **The non-participation of critical participants due to circumstances beyond their control.** The Trainers requested him/her to inform the other participants about the executed work and the planned work for the next week (by email for example), or by sending a delegate who had the same responsibility to make the commitments in the PEP meeting.

8) **The non-participation of the supervisors or foremen.** The supervisors and foremen were invited to the PEP meetings. However, it was hard to convince them to attend the meetings.

4.3.2 The measures applied during the Execution Phase

In this section, the author presents the challenges and the corresponding measures used by the Trainers, the LPS Facilitator, or the participants to overcome the challenges that emerged during the Execution Phase. The measures presented are based on the observations and the five interviews conducted.

1) **Maintaining participants' commitment to be part of the process and to take the system seriously.** Building up the real trust to the LPS and between all of the participants (building a positive environment) by consistently elaborating the benefits behind the LPS to the different parties.
2) **The non-participation of critical participants due to circumstances beyond their control.** The same measures as in the Training Phase.
3) **Fear of responsibility when making the commitments from lower-level management (the site engineers).** The same measures as in the Training Phase.
4) **Difficulty to find the real reasons for non-completion.** The plan was to use Pareto charts to analyse the root causes of non-completion for different commitments. However, the project team did not use any method to find the root causes.
5) **The decisions and input are primarily provided by top-level management.**
6) **The non-participation of the supervisor or the foremen.**
   In challenges 6 and 7, it was vital for the Facilitator to get all the participants presented in the PEP meetings, including the supervisors and the foremen. The point was to decentralise decision making. The Facilitator invited all foremen and supervisors, but none of them attended.
7) **Disruption from the supervisor.** The Facilitator tried to convince the supervisor of the system, but no further measures were taken.

5 DISCUSSION

The author divided the chapter into two main parts. In the first part, the author compared the findings obtained and the literature. In the second part, the author analysed the challenges and the suggested measures from a broad perspective and suggested some measures for the untackled challenges.

5.1 The Last Planner® System Implementation process

5.1.1 Comparing the literature to the case study

The following tables identify the similarities and differences between what was mentioned in the literature concerning the implementation of LPS different components and the findings from the single case study. Additionally, the table validates things that have been mentioned in the literature.

Table 5. 1 – Training and workshops (literature vs. Minnevika Bridge project)

Theoretical Background	LPS implementation on the Minnevika Bridge project	Similar/ Different
Training and workshops: Ballard et al. (2007b) mentioned that companies utilise two different mechanisms for training their personnel in the LPS; some of them learn by doing, while other firms require a certain amount of training (classroom training). Alarcón et al. (2002) defined the meaning of the workshops as "*training sessions that use a methodology based on learning in action that enables step by step implementation of the concepts and tools*." (p. 3). New adopters of the LPS are using the lego® simulation as a good method of elaboration the benefits of Lean thinking. This lego® simulation creates a secure learning environment by the use of a simple Lego project.	The Trainers carried out two training sessions (classroom training) and three workshops ("learn by doing" training). The Trainers utilised a theoretical explanation to elaborate on what is meant by Lean Construction and the Last Planner® system and their origins. The introduction to the system included a production control games, which called "Villego Simulation game", to teach the attendees about the meaning of production planning.	Similar

Comment:

As shown in Table 5.1, the Trainers utilised similar training strategy as mentioned in the literature.

Table 5. 2 – The master schedule (literature vs. Minnevika Bridge project)

Theoretical Background	LPS implementation on the Minnevika Bridge project	Similar/ Different
The master schedule: The project teams form the master schedule during the "front end planning" by carrying out a CPM (Ballard et al. 2007a). CPM logic can be represented in different forms such as Gantt, Program Evaluation Review Technique (PERT), or line of balance (Hamzeh et al. 2008). The main purpose of the master schedule to make sure that all the milestones and the whole project, in general, can be executed in time. The master schedule shows the start and end dates of the tasks and how they proceed in terms of flow**.**	The tendering team prepared the overall project schedule (the master schedule) during the tendering process by the use of CPM, and overall project duration and important milestones were defined. Just the construction manager that was involved in the process of making the schedules together with one representative from the JV partner. However, most of the tasks were independent for both companies, and that reduced the collaboration between both of them. The master schedule consisted of all the milestones from the start date to the end date of the project.	Partially similar

Comment:

As shown in Table 5.2, the real difference here is that the master schedule was not prepared as a part of the Last Planner® System on the Minnevika Bridge project, since the client (BaneNor) did not request that the LPS should be implemented on the project and it was an initiative from the project team.
The real start of the implementation process of the LPS on the project was almost half-year after the start date of the project. Until then, the project team used the traditional project management with an intention to utilise the Last Planner® System. Nonetheless, the results in both cases are the same; both used the CPM logic and had the important milestones with no detailed tasks.

Table 5. 3 – The phase schedule (literature vs. Minnevika Bridge project)

Theoretical Background	LPS implementation on the Minnevika Bridge project	Similar/ Different
The phase schedule: The project teams break down the master schedule into different phases, e.g. substructure, superstructure, etc. The project teams use "post-it notes" on which the required task will be written considering the prerequisites and the future work (Ballard and Howell 2003b). Additionally, the end date of the phase should also be defined, and logical links between the different tasks should be carried out using the reverse-phase schedule and collaborative planning techniques.	During the first workshop, the Trainers applied "the process mapping method". The participants assigned different colours to different trades, work steps or companies. Later, the repeating patterns were identified. Then, the team started to map out the construction process by pull principles, from the end to the beginning without getting into small details using the sticky notes. The construction process, which was developed in the process mapping, was transferred to the Milestone and	Partially similar

The major participants of the scheduling process are the ones who will have work responsibilities during this phase. During the preparations, they can bring the drawings and the contract, if needed (Ballard and Howell 2003b; Ballard and Tommelein 2016).	Phase Plan (MPP) to develop a base plan for the six weeks lookahead plan. They used the reverse phase scheduling and collaborative planning to optimise the overall schedule concerning all the constraints. Additionally, constraints were defined, and the risk matrix was used to evaluate the possibility of occurrence of the constraints and its influence on the reliability of the work plan. Finally, Action plans have been used for lowering the risks of these constraints or working out solutions for any other issues.	

Comment:

As indicated in Table 5.3, in literature, the phase schedule was taken directly from the master schedule, but in Minnevika Bridge project, the project team formed a middle step between the master and phase schedules and applied the process mapping method. This method made it easier later when preparing the phase schedule.

The process mapping method has also been identified as vital for the LPS implementation by Hamzeh and Bergstrom (2010).

Additionally, in literature, the constraints analysis was conducted during the lookahead planning, while, in Minnevika Bridge project, the project team carried out the constraints analysis during the phase scheduling. It was still the beginning, and many constraints were still unknown. However, the early definition of constraints (during phase scheduling) is still important for establishing reliable plans. Apart from the constraints analysis and the process mapping method used during phase scheduling, the implementation process was pretty much the same with what mentioned in the literature.

Table 5. 4 – The lookahead plan (literature vs. Minnevika Bridge project)

Theoretical Background	LPS implementation on the Minnevika Bridge project	Similar/ Different
The lookahead plan: It adds greater details and some adjustments to the schedules (Ballard et al. 2007a; Ballard 2000). The period of the lookahead plan ranges from 3 weeks to 12 weeks, depending on the nature of the work that is going to be executed. The lookahead plan is comprised of three different steps, namely, explosion, screening, and make ready. It is the responsibility of the planner to eliminate the constraints from the tasks and make them ready for	Every week, the project team modify the six weeks lookahead plan during the PEP meetings. They carry out the six weeks lookahead plan based on the same steps mentioned by Ballard, namely, explosion, screening and Make-ready. They plan the six weeks lookahead plan by the use of the milestones and phase plan (MPP). They also utilise the risk matrix after defining the constraints for all the different assignments and examined the impact of these constraints on the process and	Similar

assignment (Ballard et al. 2007a; Hamzeh 2009).	the probability of their occurrence. In case the probability of occurrence of a constraint and its impacts were high, an action must be defined in the action plan. Finally, the project team assure that all the tasks in the first week of the six weeks lookahead can be done and meet the four quality criteria (definition, soundness, sequence and size).	

Comment:

As shown in Table 5.4, the preparations for the six weeks lookahead plan on the Minnevika Bridge project are similar to what was mentioned in the literature, without any additional or missing steps.

Table 5. 5 – The Weekly Work Plan (literature vs. Minnevika Bridge project)

Theoretical Background	LPS implementation on the Minnevika Bridge project	Similar/ Different
The Weekly Work Plan: The final form of the planning, which includes the highest level of detail (Ballard et al. 2007a; Hamzeh et al. 2008). Last planners choose the activities that are ready to be implemented. These activities can be put into the first week of the lookahead plan, or what is referred to as the Weekly Work Plan. In the weekly work planning, the last planners can use the workable backlogs as fallback options. In order to continuously improve, the project team can measure system performance by means of PPC. Then, the Reasons for Non-Completion (RNC) of assignments in the weekly plan have to be recorded for the sake of learning from our mistakes. Finally, "The five whys" method can be used to identify the possible root causes for non-completion of assignments (Ballard et al. 2007a). Ready work that cannot be assigned to the Weekly Work Plans can be as workable backlog or Plan B tasks (Ballard et al. 2007a).	The project team prepare the Weekly Work Plans during the PEP meetings. The Trainers utilised the term "PEP meetings" instead of weekly meetings. In the PEP meetings, the project team evaluate the last week of working by going through the different commitments of different trades. The Trainers/Facilitator use/uses the risk matrix and the action plan as a way to make tasks ready. Then, the team evaluated the weekly performance using the Key Performance Indicators (KPIs). The KPIs include a bunch of standard indicators, namely, the Percent Plan Complete (PPC) – overall, the PPC – per trade, Milestone Completion, Variance Analysis, and Top Three Variances. The Facilitator integrated a new tool ("Order and Safety" Indicator) for evaluating the safety on the construction site. At the end of each PEP meeting, the Facilitator include a small talk about the logistics on-site The project team was not introduced to the workable backlog concept, and it is not used on the Minnevika Bridge project.	Partially similar

Comment:

As shown in Table 5.5, the project team utilise the same steps mentioned in the literature by Ballard. However, there still some differences. They did not utilise the workable backlog concepts, as it was not introduced to them by the Trainers.

They also apply the Variance Analysis as a way to recognise the RNC. Additionally, as observed, it was challenging for the participants to know the RNC of some commitments on many occasions. A possible reason for the issue was that the project team did not employ any tools to know the root causes for non-completion of commitments. During the Execution Phase, it was planned to use Pareto charts, but later no tools were utilised. The incomplete PPC process was also identified in the literature review by Perez and Ghosh (2018).

According to Hamzeh (2009), the PPC process requires "*incomplete tasks to undergo root-cause analysis to uncover the root causes for non-completion and develop preventative actions to inhibit the same failure from recurring*." However, no root cause analysis was undergone during the implementation process.

On the other hand, the project team utilised elements which were not clearly described in the literature, such as the "Order and Safety" indicator and the talk about logistics.

The new elements validate the point of view which indicates that the LPS escalate the value on the projects in the form of safety, logistics that in turn reduce schedule and cost (Mossman 2015; Ebbs and Pasquire 2019).

"The Order and Safety" indicator and the talk about logistics are highly recommended especially for highly complicated projects. The Last Planner® System made it much easier to gather many participants at the same time and facilitated the communication of information between the project team members. The attendance of the supervisors and foremen is a requirement for making these new elements more efficient; they are the closest, between all the participants, to the construction site. So, they should participate.

Table 5. 6 – The daily huddles (literature vs. Minnevika Bridge project)

Theoretical Background	LPS implementation on the Minnevika Bridge project	Similar/ Different
The daily huddles: The front line supervisors have a small talk with the workers that are going to execute the work in their workgroup. The main objective of that meeting is to: 1. Identify the make-ready actions needed within the day 2. Identify problems requiring re-planning 3. Share the commitments they have completed 4. Discuss the commitments that need extra support from other workgroups 5. Issues with deliveries 6. Evaluate the factors	In a specific period, a daily stand-up meeting was held on the construction site to discuss the daily plans, the material, the machinery and the human resources in the site. The attendees included: two site engineers, the LPS Facilitator, and the process expert. However, this was not always the case on the project; the daily meetings were just held for two weeks, and it was stopped later. Additionally, the supervisors were gathering every working day with the	Similar

influencing resources, such as (machine breakdowns, absenteeism, weather, etc.) 7. Take the needed adjustments (Ballard and Howell 2003; Koskela and Howell 2002; Ballard et al. 2007).	workers that are going to execute the work to give the instructions. However, these meetings did not have something to do with the Last Planner® System. This meeting was held even before the application of the LPS on the project. Since the supervisors and the foremen were not attending the weekly meetings regularly, the commitments needed to be done were directly taken from the site managers or the site engineers.	

Comment:

As shown in Table 5.6, the daily huddles were employed on the Minnevika Bridge project, despite not being mentioned during the training sessions or the workshops. The participation of the supervisors and the foremen in the PEP meetings are therefore required. The point is that the supervisors should be aware of the commitments needed to be finished based on the information presented during the weekly meetings and participate in developing these commitments.

General overview:

So, based on the comparison undergone, the LPS implementation on the Minnevika Bridge project was notably similar to what was mentioned in the literature. The study indicated that the implementation had many similarities to the best practice process map mentioned by Ballard et al. (2007a) and Perez and Ghosh (2018); project team tended to completely implement all the different components of the LPS, namely, the master schedule, the phase schedule, the lookahead plan and the Weekly Work Plan with some small changes. The supervisors also carried out the daily huddle meetings without the supervision of the LPS Facilitator or the Trainers. Finally, since the company is new to the LPS, no integration with other systems, such as BIM, Takt time planning, and Visual Management planning software was undergone.

The literature review conducted revealed that the companies in Norway are tending to implement LPS with all components of LPS, and that was in the same line with what was mentioned in the case study. It is correct that not all of the companies succeed to fully implement the LPS, but still many have a similar tendency.

5.2 LPS implementation challenges and the suggested measures

During the implementation of the LPS on the Minnevika Bridge project, several challenges arose. However, just two main challenges had the greatest impact on the implementation process in both phases. During the Training Phase, the resistance to change was considered as the leading challenge, while during the Execution Phase, a challenge was placed on the Facilitator to maintain the commitment (towards the system) obtained during the Training Phase. The main focus for the Trainers during the Training Phase was to reduce, as much as possible, the doubts that every participant had towards the LPS, whereas the main focus for the Facilitator was to

maintain the level of commitment towards the LPS obtained during the Training Phase and even increase it during the Execution Phase.

Figure 5.1 shows the relationship between two attitudes, namely, trust and doubt with time when implementing the LPS on the Minnevika Bridge project.

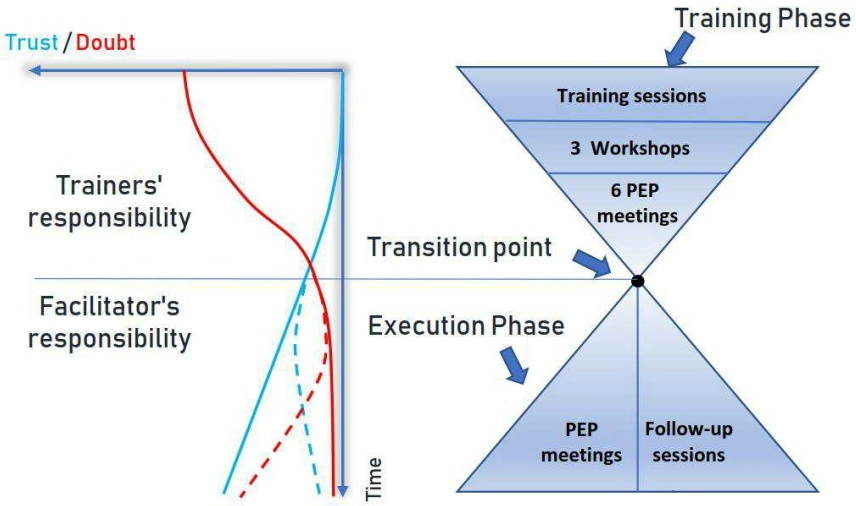

Figure 5. 1 – Trust-Doubt relationship with time on the Minnevika Bridge project

In Figure 5.1, the solid red line indicates the change of the "doubt attitude" of participants towards the system with time, while the solid turquoise line indicates the change of trust attitudes of participants towards the system and other participants with time. Firstly, the doubt of participants was at its highest point at the beginning of the implementation process. During the training sessions, doubts towards the system slightly decreased as most of the participants were not really convinced about the LPS. Doubts towards the system have dramatically decreased during the rest of the Training Phase and especially during the PEP meetings after the participation of most of the participants.

Secondly, the trust towards the system was not really improved during the training sessions or the workshops, but it started to improve after holding the PEP meetings. The trust towards the LPS and other participants requires more time to be built, and it depends for sure on the participants themselves.

In order to eliminate the resistance towards the system, the doubt should be reduced to the lowest value possible before entering the Execution Phase. So, before handing over the system to the project team, or more precisely before transferring from the Training Phase to the Execution Phase, it was the responsibility of the Trainers to make sure that the project team members and specifically the LPS Facilitator and the process expert have acquired sufficient training and knowledge towards the LPS. As indicated in Figure 5.1, the Facilitator took the lead after the Transition Point. The Transition Point is critical and should be chosen carefully. At this point, doubts should have been diminished to the lowest value possible before entering the Execution Phase. Furthermore, the participants' trust towards the LPS should have increased. And this what exactly occurred on the Minnevika Bridge project.

It is tricky to measure the participant's trust towards the system and other participants, but it can be translated into another attitude, which is the transparency between participants when

making plans. So it is the responsibility of the Trainers and the Facilitator to monitor the transparency between the participants, which is an indicator for the trust.

Later in this chapter, a way for measuring doubt towards the LPS is elaborated. Nevertheless, first and foremost, the participants should be aware that they are responsible for expressing their doubts towards the LPS to make it more manageable for the Trainers to specify the transition point precisely.

After the transition point, there may be two possible routes: the first is to continue on the same line and improve more and more as presented in the figure with the solid lines, while the second route is to deteriorate back again as indicated in the figure with the dash lines; the red dash line represents the possible increase of doubt after entering the Execution Phase, while the turquoise represents the possible decrease of trust towards the LPS and other participants during the Execution Phase. These two possibilities may occur if the LPS was not managed in the correct way by the LPS Facilitator during the Execution Phase.

More detailed elaboration of these two main challenges and the possible routes will be elaborated upon in the next sections.

5.2.1 During the Training Phase

Resistance to the system

According to the literature review in Table 3.3, participants' resistance to the system and lack of commitment towards the LPS have been challenging for many construction projects, irrespective of the type of the project (e.g. infrastructure projects or other construction projects). **"**Participants resisted the change "this is how I'have done it' attitude" challenge was mentioned in cases *C1, C3, **C6, C7, C8, C11, C13***, while "Lack of commitment from the top-management level or participants themselves" challenge was mentioned in cases *C1, C3, **C6, C7, C9** and **C11***. That is not something strange according to Ballard et al. (2007b). Whenever there is organisational change into the management system that involves individuals (such as adopting Last Planner® system for the first time in a pilot project)), it would be vital that participants accept this change. The change process of individuals will most likely be associated with psychology and different behaviours of individuals, and one of those behaviours is resistance to change (Ballard et al. 2007b).

On the Minnevika Bridge project, resistance to change materialised during the Training Phase in many forms, namely, "the non-participation of the JV partner in the training sessions and workshops", "the non-participation of the one of the supervisors in any of the meetings held during the Training Phase", "the non-participation of the foremen in the three workshops or the six PEP meetings", and " disruption during the training sessions."

The resistance may be a result of **doubt** towards the LPS. According to the interviews and the two surveys, there are three root causes for the doubt: 1. The novelty of the system for most of the participants 2. Broad experience with other systems makes it unnecessary to change 3. Troublesome experiences with the LPS for some of them from previous project. So, in order to minimise the resistance towards the LPS implementation, the doubt towards the LPS should be minimised in the first place.

In order to minimise the doubts towards the LPS, the following points should be considered:

a) Diminishing the doubts connected with the first two root causes needs openness from all the participants, sufficient training, and time (depending on the human capital). Firstly, every participant involved should be open towards the new system, including, the construction managers, the site managers, the site engineers, the supervisors, the foremen, the JV representatives and the subcontractors' representatives. This happened in the case study, as according to the first survey, more than 80% of respondents showed openness towards the system. The commitment from all the participants is also required; all the participants should participate in all the meetings. On the Minnevika Bridge project, it was challenging at the beginning to get all the participants involved, especially the JV representative. However, the issue of the JV representative was solved later, as indicated in the FINDINGS chapter.

b) The Trainers should expect trials of disruption from some of the participants, especially the participants with broad experience with other systems. The Trainers should be prepared to deal with this type of resistance, for example, by replacing this person with another person, if possible, to have a better work environment. Another solution could be to escalate the issue to a higher level or the next level. So, before the training sessions, an agreement on the levels of escalations, and whom to contact in such cases within the team should be established.

c) Diminishing the doubts connected with the third root cause is a bit tricky and needs efforts from many parties. In order to remove this challenge, the person that has a bad experience with the LPS should firstly participate in the meetings, which is the responsibility of the top-level managers. Then, it is the responsibility of the Trainers to listen to his/her doubts, remove these doubts in a proper way, and make him/her see the benefits of the system. Nevertheless, this was not the case on the project. As mentioned, one of the supervisors had troublesome experience with the LPS from a previous project. The top-level management was a bit lax with him during the Training Phase; they just invited him to the meetings without insistence. It is vital to make sure that all the critical persons participate in the meetings.

   The solutions can be strong leadership, good internal team communication between the top-level management and lower-level management, and finally massive efforts from the Trainers. In the first place, the supervisors should feel that the top-level managers are putting their suggestions and ideas into consideration; otherwise, the solutions will be in vain. The issue in this case study was not connected with strong leadership, but with a lack of communication between the two levels. Fauchier and Alves (2013) mentioned that the LPS opens communication and transparency between team members over time. The author agrees with this point of view, but before that, all the participants should be ready to open the communication, and especially the top-level managers. Once good team communication between the team members is established, it may be easier to get the supervisor involved.

d) Once the team is ready to learn about the system, it is the responsibility of the Trainers to provide sufficient training, and to start building up the trust of the people towards the system and towards each other. The trust towards the system can gradually increase by continuously working with it while learning its benefits. However, more time will be needed for those who had broad experience with other systems. The trust towards each other,

especially when the participants are from different companies like in this case study, will be built with the help of long term efforts.

Ballard et al. (2007b) mentioned that companies utilise two different mechanisms for training their personnel in the LPS; some of them learn by doing, while other firms require a certain amount of training (classroom training). Training sessions help to create a better understanding of the system (Ballard et al. 2007b). The lack of training in *C3* and ***C8*** that was identified in the literature review impacted negatively on the participants' understanding of the system. The study was in the same line with what was identified in the literature. On the Minnevika Bridge project, the Trainers utilised two different mechanisms of training, namely, the training sessions (classroom training), the three workshops and the 6 PEP meetings ("learn by doing" training). After the training sessions, many participants gave positive feedback about how they benefitted from the training sessions and learned more about the system and its components. Finally, regarding "Learning by doing" training, the three workshops and the 6 PEP meetings represented the final step to reduce the doubts before handing the system over to the project team.

As mentioned in the Findings, the participants started to learn by operating the system under the supervision of the Trainers who trained them, guided them, and showed them the benefits of the system and how to utilise its tools. Subsequently, many of them started to change their minds towards the LPS; and that was quite clear when **many newcomers started to show up during the last PEP meeting in the Training Phase**. On the other hand, this formed a new challenge as the newcomers were not on the same level of training with other participants. The introduction of new participants, if not handled correctly, could change the atmosphere of the sessions and lead to some members forming a bad image of the system. It is a requirement to elaborate the system into greater detail for them in the beginning until they get up to speed with the others. This is how it was handled on the Minnevika Bridge project.

The language barriers

In addition to the previously stated challenges, **language** formed a significant challenge during the Training Phase, similar to that which occurred in ***C10***. Moreover, Fauchier and Alves (2013) declared that when using the LPS, clear commitments (understood by all) should be made, but if the language is a challenge that could be unfeasible. To address this, at the end of the meeting, the Facilitator should make sure that everybody understood what they committed to by presenting those commitments to the other participants in the room. Additionally, the presence of various languages in the same room could lead to a mess. It is therefore advisable to form team rules, such as the one carried out by the project team in this case study, to create a more stable environment, for example by using the rule "*all discussions in English. The use of other languages only permitted if it is really necessary to explain a difficult topic*". This rule seems simple but can have a positive impact on the working environment during the meeting.

5.2.2 During the Execution Phase

Maintaining participants' commitments

After diminishing the doubts and acquiring participants' commitment towards the LPS, the next area of focus is to maintain this commitment. It was mentioned in the findings that

"**maintaining participants' commitments"** was considered as the most critical challenge between all the other challenges during the Execution Phase. In order to maintain the participants' commitment towards the LPS in this phase, trust towards the system and between the participants should remain stable, or even be improved. Fauchier and Alves (2013) detected that the system contributes to building trust between participants by making them more transparent, but this occurs over the long term. The author supports this point of view, but it is also vital to consider the short time and maintain the level of trust established. This is where the responsibility of the Facilitator arises. The Facilitator should be cautious when using the KPIs, at least in the beginning of the Execution Phase, regardless of the value KPIs add to the system. On the other hand, KPIs can act as a reason for shaming and blaming inside the PEP meeting, and that can result in destroying the established trust between participants, and by extension, towards the LPS. The Facilitator should show the results to the participants as usual, but he/she can be a bit "soft" when dealing with those results. On the Minnevika Bridge project, PPC records have shown very high results, before the outbreak of Covid-19. However, the Facilitator followed a similar LPS implementation strategy.

The findings from the case study were similar to that found in the literature. The researchers also emphasised the importance of the "Incremental implementation strategy" by introducing the components of the LPS gradually. According to (Alsehaimi et al. 2014; Perez and Ghosh 2018), the incremental introduction of the LPS can assist with stabilising the introduction and minimising the resistance to change.

However, this strategy had some defects on the Minnevika Bridge project. The incremental strategy concerning the KPIs during the implementation process, in both phases, was somehow slow. Firstly, the KPIs were not often used during the Training Phase. However, this can be justified; KPIs were not frequently used during the Training Phase due to the lack of KPIs results and records; the team still did not experience so much in the process yet, and that is typical at the beginning of the LPS implementation process; no real trend yet was established to analyse.

At the beginning of the Execution Phase, the Facilitator did not go more in-depth and analyse the Top Three Variances. The reason for this was the use of the incremental strategy to build trust towards the system. However, it was just observed once when the Facilitator started to analyse in-depth the Top Three Variances with the team during the Execution Phase. As a result, many participants started to feel that the KPIs were not an essential part of the LPS implementation.

Additionally, It was **confusing for many participants to analyse and understand the KPIs.** Similar results were also found in *C3, **C6**, **C7**, **C8**, **C9**.* The reason for that is quite apparent; the project team have not experienced so much of the process yet. The Facilitator's goal was to build the trust more towards the system, and the results and a good understanding KPIs were expected to come with time. However, the incremental strategy with respect to the KPIs should be carried out a bit faster, especially during the Execution Phase comparing to the Training Phase.

An additional measure which can be taken into consideration during the Execution Phase is the follow-up sessions. The Trainers suggested this measure for ensuring that the participants had

understood the process and did not deviate from the drawn path. However, due to the outbreak of Covid-19, the follow-up sessions were suspended on the Minnevika Bridge project.

Partial implementation of the lookahead planning and the WWP (during the the outbreak of Covid-19)

The results in Figure 4.2 indicated a massive drop of PPC records from an average PPC 91% in the first nine weeks to 51% in CW20. Indeed, the resources, including the workforce, equipment and material dramatically declined during the outbreak of Covid-19 due to the suspension of air traffic in Norway and Europe in general. However, many of the participants have also declared that the PEP meetings were not well-organised during the outbreak of Covid-19. When the Variance Analysis was carried out in CW20, the following results were obtained:

1- Three un-finished commitments due to issues with equipment.
2- Two un-finished commitments due to overestimated performance.
3- Seven un-finished commitments were because of the preliminary work was not finished as a result of the issues with the equipment.

The reason for the massive drop in PPC records can be that the participants implemented the Weekly Work Planning and the six weeks lookahead planning partially and not completely. Before the outbreak of Covid-19, the project team accustomed to conducting the constraints analysis and make-ready process in the form of the action plan and the risk matrix. Additionally, they conducted the Variance Analysis and PPC. Nonetheless, during the outbreak of Covid-19, none of these components was utilised.

Ballard et al. (2007a) mentioned that the last planners have the responsibility of choosing the activities that are ready to be implemented and meet the quality criteria, namely, definition, soundness, sequence and size. Those activities can be put into the Weekly Work Plan. The activities that do not fulfil the requirements have to be made ready first. The point here is that we require the most reliable plan possible (Ballard 2000).

For the sake of assuring that the work will be executed in a specific time (SHOULDS) and with high efficiency, this work has to be performed (CAN) without any interruption. So, the **constraints analysis** should also be carried out (Ballard and Tommelein 2016).

Apparently, the participants had issues with the make-ready process. Constraints analysis was not carried out to make the assignments sound two weeks before the implementation. For example, the issues with the equipment could have been solved sometime before execution and actions could have been taken to make the assignments ready. The project team have to make sure that the assignments (CAN) be made before advancing them to the Weekly Work Plan.

Once the project team started to implement the weekly work planning and the six weeks lookahead planning completely in CW21, the PPC records get back to its natural course. The project team should always remember to completely implement the LPS components (as learned during the Training Phase). This is again the responsibility of the Facilitator. The Facilitator should assure that the project team fully implement the LPS components in order to maintain and ensure the intent and the success of the system—this what referred to in the literature as the champion (Perez and Ghosh 2018).

5.2.3 During the Training and Execution Phases

Fear of responsibility from lower-level management (the site engineers)

"Fear of responsibility when making the commitments (mainly from lower-level management)" was also recorded as a critical challenge during the implementation. This seems to be conventional due to lack of experience. The point here is to have a minimum level of experience inside the room in order to make reliable promises; the attendance of critical participants (e.g. site managers, supervisors and especially foremen) is always a requirement to have the most reliable commitments. Otherwise, should a critical member not be available, preparation in advance with a representative (e.g. site engineers) should be executed to ensure as many reliable plans as possible are committed to in the PEP meetings.

Lack of experience in the LPS from the Facilitator

During the preparation of challenges, in the beginning, the author anticipated that the lack of experience in the Last Planner® System from the Facilitator could be a significant challenge to the implementation process in Minnvika Bridge project. However, it was quite the contrary; The Facilitator managed to support the LPS implementation and succeeded to maintain the participants' commitment towards the LPS and even attracted some newcomers. The Facilitator was acquainted with Lean thinking and how it can be executed inside organisations. Moreover, the Trainers managed to transform the LPS within each participant, which facilitated the duties of the Facilitator inside the project. Sufficient training in Lean thinking and the LPS components (the responsibility of the Trainers), understanding the duties and responsibilities from the Facilitator and the support from other participants are **the key factors to make a successful Facilitator.**

The non-participation of critical team members

It was mentioned in the findings that one of the supervisors had troublesome experience with the LPS from a previous project. The other supervisor moved to another project. Finally, the foremen were not participating in any of the PEP meetings, despite being invited. This was the case both in the Training Phase and the Execution Phase. So, they did not participate in the decision-making process during the planning process. As a consequence, The decisions and input concerning the weekly plans were primarily provided by top-level management.

The supervisors and the foremen are the ones that know the best of what is going on site. Their input is also vital for the planning process. They are the last planners, and they have to know what to expect and what work is needed to be done next week. So, they have to participate in all key decisions. Nonetheless, the participation of the supervisors and foremen in the weekly meetings did not occur. The non-participation challenge was also recorded before in the literature; Ballard et al. (2007b) also reported the difficulty to bring all the participants to the weekly meetings.

A possible solution, suggested by the author for tackling this challenge, is to invite the supervisors and foremen to **attend the last part** of the meeting to help with the planning, give their opinions about the safety and the logistics on-site. The second solution can be to let the supervisor or the foremen facilitate the meetings themselves; they would own it, and they will have the impression that they are leading the meeting and that the top-level managers are listening

to them. The second solution might be tricky to be accomplished, but let us analyse this solution. A possible reason (in addition to the doubts towards the system mentioned before) why the supervisors and the foremen are not attending the meetings is that they are feeling that they are overruled in that meeting, and no one is listening to them—this what exactly happened. When the supervisor attended the PEP meeting (for the first and only time), he felt that no one is listening to his ideas. This ended up with the supervisor leaving the PEP meeting upset.

As mentioned before, it is a matter of lack of communication and trust between the two levels, and good communication and trust can also be established if we managed to let the supervisor or one of the foremen to be the Facilitator while putting into consideration the same **key factors to make a successful Facilitator.**

Not only the supervisors and foremen, but also all the stakeholders should participate in the PEP meetings. The site managers, the site engineers, the project planner, the supervisors, the foremen, the representatives from the JV partner, the representatives from the subcontractors, and many others should participate in the PEP meetings. However, the attendance of all the stakeholders may occur just in ideal circumstances, but it is not in construction sites.

In construction sites, new challenges can occur in a blank which requires quick actions. So, some of the participants may not manage to attend all the PEP meetings. The Trainers and the Facilitator, however, used a suitable measure to remove this challenge. The Trainers and the Facilitator requested him/her to inform the other participants about the executed work and the planned work for the next week (by email for example), or by sending a delegate who had the same responsibility to make the commitments in the PEP meeting. By following these measures, the challenge was totally eliminated during the Execution Phase.

5.2.4 Trust-Doubt Indicator

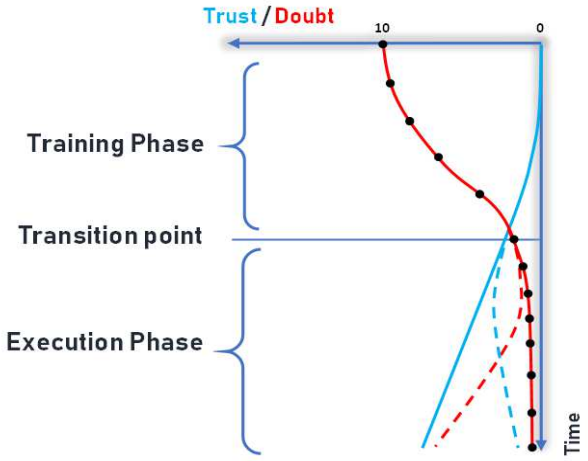

Figure 5. 2 – Trust-Doubt indicator

As shown in the discussion, "the trust towards the LPS and other participants" and "doubt" are the most vital attitudes that Trainers and Facilitators should keep an eye on while implementing the LPS on projects. The following graph (Figure 5.2) is a simple way of presenting and a valuable way of monitoring these two most significant attitudes, namely, trust and doubt during the LPS implementation.
Trust and doubt are two human attitudes that are tricky to measure, thus the graph is as uncomplicated as possible.

When presenting the "trust attitude" towards the system, the term "monitor the trust" can be more precise than the term "measure the trust" in this situation. So, during the entire implementation process, it is possible for the Trainers to monitor the trust towards the LPS and other participants by capturing the behaviours of participants, such as the transparency when dealing with each other, the willingness to cooperate, or the engagement during meetings. These behaviours should be obvious and easily monitored by the Trainers or the Facilitator.

On the other hand, doubts towards the system can be measured by means of a survey. As stated previously, the Likert scale method can be utilised to measure the attitudes. A possible approach to determine a value for doubt is to use a simple survey that encompasses straightforward questions based on the 11-point Likert scale method to measure the change in doubt over time. The choice of a multipoint scale makes it easier later when recording the results.

The survey should be answered by the participants at the beginning of every second meeting. The results from this survey can then be plotted on the graph, as shown in Figure 5.2. During the LPS implementation process, the Trainers and the Facilitators can have a good overview of the doubt attitude of participants towards the LPS.
Trust is preferred to be monitored than measured. Measuring the trust of participants towards other participants, for example, by using a survey, could be tricky and will most likely not indicate the real image. However, the behaviours of participants should give an indication. It is correct that it is hard to draw the trust line, but the essential goal is to assure that the trust is improving with time by means of a simple sketch. Trust towards the LPS and sufficient training

can be the keys to diminishing the doubts. However, in Figure 5.2, the trust curve is flatter than the doubt curve. This is due to the fact that the curve is a representation of both the trust towards the LPS, **in addition to** the trust towards the other participants, which takes longer time to be built.

Finally, the participants should be aware of the importance of the graph and take the survey seriously. That is why the author recommends that the Trainers or the Facilitator elaborate the value and benefits of the indicator weekly to the participants in order to have reliable results.

Following are the benefits and the disadvantages from the Trust-Doubt indicator:

Benefits of the graph

1- Warning sign if there is an increase in doubt.
2- Encourage the Facilitator or the Trainers to keep monitoring the behaviours and attitudes of the participants on the meetings and not just concentrate on the LPS components.
3- With the help of the graph, the Transition Point can be easier defined; when having experience with the graph, the Trainers can specify a value for doubt on the graph after which the transition becomes more feasible.
4- In case the trust started to decrease, and doubts started again to increase, as indicated with the dash lines, the need for follow-up sessions can be considered by the Facilitator.
5- Can help with building the Lean culture inside the organisation, by tracking the trust and doubts of participants. Better control over the resistance and commitments on projects can be established. This, in turn, can support with better building a good lean culture.
6- Can be used for further improvement in the system.
7- Can be a good measure for the new adopters of LPS.

Disadvantages of the graph

1- The graph depends mainly on the transparency of the participants; the participants should be transparent when answering the survey to get the best possible outcome of the graph.
2- The use of the graph is not enough for specifying the Transition point; as the Trainers should assure that the Facilitator and the project team had understood the work required and the responsibilities, so it might take a bit longer than the specified point.
3- To collect the data, participants must complete a survey every 2 weeks which may be considered as a new commitment for the participants.

The author did not utilise the Trust-Doubt indicator during the LPS implementation on the Minnevika Bridge project due to the time limitations. Nonetheless, the author recommends that graph to be further studied.

6 CONCLUSION / LESSONS LEARNED / RECOMMENDATIONS

This thesis supplements the existing body of knowledge by answering the following questions:

1- How is PNC going to implement the LPS on the Minnevika Bridge project?
2- What are the challenges that arise during the implementation of the LPS?
3- What are the measures that PNC can use to tackle these challenges?

The Last Planner® System has been in a development since Ballard and Howell first invented it in the early 1990s. Since then, several studies have been carried out to evaluate the implementation of the LPS in construction projects worldwide. Nontheless, few studies have recorded the implementation process in infrastructure projects. Additionally, more focus has been given to improve the LPS components and its integration with other systems. In contrast, less attention has been paid to the behavioural aspects of practitioners during the LPS implementation despite its importance and impact on the process. Finally, no previous studies have clearly described the importance of the Transition Point between the Training Phase and the Execution Phase. Therefore, this study has contributed to filling these three gaps.

Based on the single case study, literature study, interviews, non-participant / participant – observations, seven interviews, two surveys, and document study conducted as part of this research,the author has described the LPS implementation process on the Minnevika Bridge project, the emerged challenges, and the measures required to takle these challenges.

Many Factors were identified during the study period that formed the limitations of this study. Based on a single case study, the results may lack generalisability. Additionally, the outbreak of Covid-19 interrupted the implementation of the follow-up sessions on the Minnevika Bridge project. Addressing these limitations can be recommended for further research.

6.1 LPS implemenetation on the Minnevika Bridge project

Table 6.1 presents the implementation process of the LPS on the Minnevika Bridge project. By comparing the results from the study and the literature, the investigation demonstrated that the LPS implementation on the Minnevika Bridge project had multiple similarities to the best practice process map mentioned by Ballard et al. (2007a) and Perez and Ghosh (2018). Furthermore, by contrasting this case study with other case studies from Norway, the study revealed that the companies in Norway tend to fully implement almost all LPS components similar to what described in theory.

Following the best practice for LPS implementation is a requirement for gaining significant results, but to reach the highest possible potential of LPS, the behavioural aspects of the participants should be considered and analysed .

Table 6. 1 – The implementation process of the LPS on the Minnevika Bridge project

Phase	Content	Description of the meeting /day
Training Phase	Training Session	• The Trainers explained the meaning of the LPS and Lean construction process by carrying out a theoretical explanation and by using "Villego Simulation" game. • Collaborative planning was described.
	Workshop 1	• Introduction to the five Lean principles, namely, value, optimisation, flow, pull and continuous improvement. • Introduction to **process mapping** using the pull principle to visually describe the workflow. • Roles and responsibilities for each member have been defined, and team rules have been established.
	Workshop 2	• The project team defined the project gates and important milestones. • They used the collaborative planning process and the reverse **phase scheduling** for developing those plans.
	Workshop 3	• **Six weeks lookahead plan** was executed based on the steps specified by Ballard et al. (2007a), namely, explosion, screening and Make-ready.
	6 PEP (production evaluation and production planning) Meetings	• The project team established **the Weekly Work Plan (WWP)** and modified the six-week lookahead plan (under the supervision by the Trainers) – lasted for six consecutive weeks. • The Trainers used an action plan and a risk matrix as a way to make tasks ready. • The team evaluated the weekly performance using Key Performance Indicators (KPIs), including PPC, milestone completion, and Variance analysis (by going through the commitments of each party searching for reasons of failure to learn from mistakes).
The Transition Point (handing over the LPS)		
Execution Phase	LPS practical Implementation	• The Trainers handed over the Last Planner® System to the project team and specifically to the LPS Facilitator and the process expert (a person that supports the Facilitator). • The Trainers agreed with the project team to carry out **follow-up sessions** to make sure that the implementation process is on the right track.
	PEP Meetings	• The LPS Facilitator controls the system with the help of the process expert by using the same steps learned in the 6 PEP meetings. • As a way of continuous improvement, the Facilitator incorporated a new indicator for measuring the order and safety on-site. • The Facilitator included a talk about the logistics on-site in the PEP meetings.

6.2 LPS implementation challenges and the suggested measures

Table 6. 2 – The critical challenges recorded on the project and the suggest measures

Challenges	Phase Occurred	Measures utilised to overcome the Challenge by the project team
1) Doubt (doubt about the overall performance and the benefits behind the LPS)	TPhase	• Sufficient training to the practitioners by showing the benefits of the system during the training, ask them to give their feedback to the Trainers for resolving their doubts and learn by doing to increase the trust towards the LPS.
2) Language barriers	TPhase	• Presentation of the commitments by the last planner at the end of the PEP meeting to assure understanding of what they have committed to. • Definition of simple team rules
3) The non-participation of the JV partner in the training sessions and workshops.	TPhase	• The Trainers escalated the issue, and changed the person that should attend the meetings, and explained in detail the LPS to the newcomer.
4) Partial implementation of the lookahead planning and the WWP (during the outbreak of Covid-19).	EPhase	• No measures were taken
5) Maintaining participants' commitment to be part of the process and to take the system seriously.	EPhase	• Building up the real trust towards the LPS and between all of the participants (by building a positive environment) by consistently elaborating the benefits behind the LPS to the different parties.
6) Newcomers to the PEP meetings	TPhase +EPhase	• The Trainers and the Facilitator demonstrated the LPS to the newcomers into detail to reach an equivalent level of knowledge with other participants.
7) Difficulty in understanding the KPIs by participants	TPhase +EPhase	• No measures were taken. • The Trainers just relied on the experience that can be obtained when implementing the LPS.
8) Fear of responsibility when making the commitments (mainly from lower-level management)	TPhase +EPhase	• Internal agreement/discussion within different companies about the minimum experience needed to be in the PEP meetings in order to make reliable weekly plans.
9) The non-participation of critical participants due to circumstances beyond their control	TPhase +EPhase	• Request him/her to inform the other participants about the executed work and the planned work for the next week (by email for example), or by sending a delegate who has the responsibility to make the commitments in the PEP meeting.
10) The non-participation of the supervisors and foremen.	TPhase +PPhase	• The supervisors and foremen were kindly invited to the meetings (some have responded and some not)

* *TPhase represents the Training Phase*
* *EPhase represents the Execution Phase*

Table 6.2 illustrates the critical challenges that occurred through two phases of the implementation of the LPS; namely the Training Phase (TPhase) and the Execution Phase (EPhase) and the measures used by the project team to overcome these challenges.

Based on the literature study conducted, infrastructure projects and other construction projects tend to meet similar challenges in the Training Phase when adopting the LPS for the first time, despite their different characteristics. These challenges were associated with behavioural aspects of participants, namely the resistance to change and participants' commitment towards the new system.

On the Minnevika Bridge project, the results were in agreement with the literature review; there were two challenges which had the greatest influence on the LPS implementation during both phases. These challenges were the resistance to change during the Training Phase and the fear that the participants' commitment towards the LPS and other participants may reduce after the Transition Point.

On the Minnevika Bridge project, most of the presented measures in Table 6.2 have proved a success, while just the last measure associated with the non-participation of the supervisors and foremen has proved a failure. The author has suggested some measures as a replacement for the ineffective measure.

Based on the lessons learned from the case study and the suggested measures by the author, some measures were obtained for eliminating the following challenges:

1- Resistance to change
2- Maintaining the participants' commitment towards the LPS
3- The non-participation of supervisors and foremen

1- Resistance to change

In order to reach the highest possible potential of LPS, it is recommended that the resistance to change should be controlled before the end of the Training Phase. In order to have control over "the resistance to change" challenge, the doubts towards the LPS should be diminished. And, in order to diminish the doubts, the following measures should be followed:

1- The Trainers should give sufficient training to all the participants by using two different mechanisms for training, namely, learning by doing and classroom training. It is the responsibility of the Trainers to start building up the trust of the people towards the system and towards each other.
2- During the training sessions, the Trainers should expect some disruption from some of the participants and be prepared for it by discussing the levels of escalation (e.g. maintaining a hierarchy of top-level managers to whom issues can be escalated)
3- Participation from all the critical members, especially those who had troublesome experience with the LPS from a previous project; to give the Trainers a chance to diminish their doubts. It is the responsibility of the top-level managers to get the refusers into the PEP meetings. And, it is the responsibility of the Trainers to listen to his/her doubts, remove these doubts in a proper way, and make him/her see the benefits of the system.

4- Good internal team communication should be established between the top-level management and lower-level management
5- Train “the newcomers” to reach the same level of knowledge with other participants
6- The Transition Point should be specified by the Trainers. They should make sure that the project team members and specifically the LPS Facilitator and the process expert have acquired sufficient training and knowledge towards the LPS before entering the Execution Phase.
7- Use the Trust-Doubt indicator in order to measure the doubts towards the LPS and to help the Trainers to define the Transition point more precisely.

Additionally, the following points should also be fulfilled:

1- Well-experienced Trainers
2- Openness from all the participants towards the new system
3- Participants should be aware that it may take a considerable amount of time and effort to reduce doubts.
4- A strong leadership from the top-level managers

2- Maintaining the participants’ commitment towards the LPS

For the sake of maintaining the participants’ commitment during the Execution Phase, the trust towards the system and other participants should remain stable or even increase.

So, in order to sustain the trust of participants towards each other and the LPS, the following measures can be taken:

1- Use the incremental strategy when dealing with the KPIs at the beginning of the Execution Phase. However, do not be so slow when applying this strategy. The use of KPIs should increase dramatically once the Facilitator notices the improvement of trust towards the LPS and other participants. Furthermore, the Facilitator can monitor the trust level between the participants and towards the LPS by the use of the Trust-Doubt indicator.
2- Train “the newcomers” to reach the same level of knowledge with other participants.
3- Use the follow-up sessions; During the Execution Phase, the process could deviate, the LPS implementation may lose momentum, or people could start making wrong use of the system, as a consequence they may lose the trust towards the system.

Additionally, based on the lessons learned, key factors to make a successful Facilitator should also be fulfilled, and they are as follows:

1- The Facilitator should receive sufficient training in the LPS and Lean thinking
2- The Facilitator should have a good understanding of his/her duties and responsibilities
3- The Facilitator should have support from other participants
4- The Facilitator should assure that the project team fully implement the LPS components in order to maintain and ensure the intent and the success of the system. In other words, the Facilitator, in most cases, is the champion of the implementation process during the Execution Phase, and he/she should secure this process.

3- The non-participation of supervisors and foremen

The only measure used by the Trainers and Facilitator to eliminate this challenge has proved a failure. The non-participation of supervisors and foremen on the Minnevika Bridge project was recorded as a form for **resistance to change**. So, all the seven measures mentioned before should also be taken into consideration, and all the four points should be fulfilled. However, the author suggested the following additional measures:

1- The supervisors and foremen can attend the PEP meeting just during the last part of the meeting in order to support the project team with the planning process and talk about safety and the logistics on-site.
2- One of the supervisors or the foremen can be the Facilitator. However, in this case, key factors to make a successful Facilitator should also be fulfilled in order for this measure to be applicable.

Concerning the Transition Point, the literature study did not reveal any researchers that mentioned the importance of the Transition point. The Transition Point is very vital and should be chosen carefully by the Trainers. At this point, the team members should have received enough training by the Trainers ; otherwise, they may easily deviate from the drawn path.

Regarding the uniqueness of the project, the author managed to find two new challenges from Minnevika Bridge project that seem not to have been identified in the literature, namely, **fear of responsibility when making the commitments**, **newcomers to the PEP meetings**.

Finally, the author recommended the use of Trust-Doubt indicator. This indicator was created and suggested by the author for the new adopters of the LPS in construction projects in order to track the development of two attitudes: 1. The trust of the project team in the PEP meetings towards the LPS and other participants 2. The doubt towards the LPS.

The indicator is a graph that represents the relationship between “trust over time”, and “doubt over time”. In this graph, the doubt attitude values are plotted using the results from a simple survey that encompasses straightforward questions based on an 11-point Likert scale method. While the trust attitude values are not measured, the Trainers and the Facilitator can sketch the curve of trust based on their perception to give a general description of the trust inside the PEP meetings. To monitor the trust, the Trainers and the Facilitator can observe the transparency of the participants when dealing with each other, the willingness to cooperate, and their engagement during the PEP meetings.
There are several benefits for the Trust-Doubt indicator. However, the most important benefits are:

1- Warning sign if there is an increase in doubt.
2- With the help of the graph, the Transition Point can be easier defined.
3- Can be used as a way for continuous improvement in the system.
4- Help with building the Lean culture inside the organisation.

This indicator is built on the transparency of the participants, which may be considered a flaw of this indicator. However, the importance of the indicator should be transferred to the participants by repeating it every meeting.

The main objective behind introducing this new indicator was an initiative from the author to encourage the LPS researchers and practitioners to focus more on the negative behaviours and attitudes that can influence the implementation process, such as the resistance to change and lack of trust towards the system and other participants. The need is to find some measures for eliminating these negative behaviours and attitudes, and the Trust-Doubt indicator can be the beginning.

7 FURTHER WORK

The best departure point for further work is to build upon and enhance this case study by addressing the previously mentioned limitations. During the study, it became clear how PNC implemented the LPS on the Minnevika Bridge project by addressing all the steps undertaken by the project team. However, due to the time limitations and some unexpected situations such as the outbreak of Covid-19, the follow-up sessions and its possible impact on the project member's attitudes and the process, in general, was not fully addressed in this study.

The literature review conducted did not reveal evidence of any research being done on the application of follow-up sessions by Trainers during the implementation of the LPS and how these sessions can influence the process. It is, therefore recommended by the author as a topic to be further studied.

In this study, the trust and doubt formed a great challenge during the LPS implementation on the Minnevika Bridge project. Furthermore, the results from the literature study revealed that many construction projects face similar challenges concerning the behavioural aspects of participants. The author, therefore, suggested the Trust-Doubt indicator as a possible tool for tracking the doubt and trust during the LPS implementation in projects. However, this indicator was just built upon hypotheses that require to be further improved and examined. Firstly, there might be some more flaw backs in the indicator which requires to be identified. Secondly, a possible enhancement in the indicator can be to review the literature for better ways for measuring the trust and doubt inside an organisation or between employees, which in turn can give more reliable results. Then, the indicator can later be tested on different projects before and after the application of the indicator. Finally, the results can be compared and contrasted to examine the possible improvements in attitudes and behaviours and the possible impacts on the implementation process in general.

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PART 2 – A PUBLISHED RESEARCH PAPER

IMPLEMENTATION OF LAST PLANNER® SYSTEM IN AN INFRASTRUCTURE PROJECT

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ABSTRACT

Since the establishment of the Last Planner® system (LPS) by Ballard and Howell, multiple studies have been conducted to evaluate the implementation of LPS in many construction projects. However, few studies have recorded the implementation process in infrastructure projects. This study investigates the implementation of LPS in an infrastructure project (Minnevika Bridge project), detect the challenges that arise during the implementation, and suggest measures to overcome these challenges. Several data collection methods were used in an action research approach; namely, a single case study, a literature study, non-participant/participant observations, six semi-structured interviews and two surveys.

The study revealed that the project followed the best practice process map for LPS implementation mentioned in the literature. Moreover, the project experienced challenges described in the literature that tend to arise when adopting LPS, similar to those reported from other construction projects (e.g. participants' resistance to the system). The study concludes with suggested measures to overcome these challenges (e.g. sufficient training and openness towards the LPS). Finally, the researchers represent challenges that are not clearly described in the literature (e.g. fear of responsibility when making the commitments).

KEYWORDS: Lean construction, Last Planner System, Action research, Challenges, Infrastructure.

INTRODUCTION

According to the research report conducted by Barbosa et al. (2017), the construction industry lags behind other industries in terms of productivity. This is demonstrated by an annual 1.0 % increase in productivity in the construction industry, compared to 3.6 % for the manufacturing industry over the past 20 years. One of those factors causing productivity increase is the use of Lean manufacturing in the production process. Koskela (1992) aspired to apply Lean manufacturing to the construction industry. Later, Howell and Ballard (1998) claimed that Lean is suitable for dynamic projects, as it is the case in construction projects. Multiple Lean construction tools have been developed since then (Ansah et al. 2016). The Last Planner®

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System, which has been developed and invented by Ballard and Howell, is classified as the most advanced tool in Lean construction (Cerveró-Romero et al. 2013). Howell and Ballard (1998) developed LPS to enhance the workflow reliability in projects. Increased workflow reliability leads to a reduction in overall waste (Ballard and Tommelein 2016). As a part of the construction industry in Norway, PNC Norge AS (the company under-study) experienced a need for increased workflow reliability. To improve their internal work practices, they have chosen to introduce the Last Planner® System on one of their projects as a pilot. The project referred to as Minnevika Bridge. LPS can help them in turn to improve their productivity, focus on increasing the customer's value, reduce the non-value adding activities, and as a way to distribute ownership of the project to all levels of the project organisation.

Multiple studies have been conducted to evaluate the implementation of LPS in construction projects around the world, but few studies have recorded the implementation process in infrastructure projects. Therefore, this study fills this gap by examining the following research questions:

1. How is PNC going to implement the LPS on the Minnevika Bridge project?
2. What are the challenges that arise during the implementation of the LPS?

RESEARCH METHOD

PNC Norge AS forms part of the Joint Venture (JV), AFHP, which is the main contractor for the construction of the Eidsvoll Nord-Langset project. As part of this joint venture, PNC is responsible for the Minnevika Railway Bridge. The bridge is 836 metres long, which will become Norway's longest railway bridge. It is a Design-bid-build contract. The LPS was not used during the design phase, nor was there any interest from the client to participate in the process. PNC is the only user of LPS. However, the JV partner and all the subcontractors were invited to participate in the implementation process.

In action research, the researchers work with the studied organisation to answer practical issues that show up (Järvinen 2007). The presence of two of the authors as employees on the Minnevika Bridge project facilitated the data collection. Multiple methods for data collection were used, namely a literature study, non-participant/participant observations, semi-structured interviews and two surveys.

A comprehensive literature review – according to the steps mentioned by Wee and Banister (2016) – was done to find the best possible practice for LPS implementation in construction projects. In special, the literature review investigated challenges faced by eleven case studies of LPS implementation. The researchers attempted to focus more on the challenges that occurred in infrastructure projects, but also considered other construction projects. The challenges faced by these eleven cases were compared to the challenges detected on the Minnevika Bridge project.

The first author carried out – non-participant – observations in an initial training session to record participants' attitudes towards the system. Then the first author carried out – participant – observations in three workshops and in the weekly Production Evaluation and Planning (PEP)-meetings to identify planning practices and detect challenges arising.

Two semi-structured interviews with the LPS Trainers were conducted to examine the LPS implementation on the project, the challenges expected, and measures to tackle these challenges. Four semi-structured interviews were conducted with the LPS Facilitator (the Lean manager), a Site Manager, a Site Engineer, and the Project Planner. The two first interviews

were carried out before the implementation, and the four next interviews were implemented during the implementation.

A first survey – comprised of 15 closed-ended questions and one open-ended question – was answered by 13 respondents from the training session to examine openness towards the LPS, and to record the challenges from the participants' perspective. A second survey – comprised of 22 closed-ended questions and one open-ended question – was answered by eight respondents during Execution Phase (the phase after the Training Phase as will be indicated later in the Results chapter) to examine openness towards the LPS. Moreover, the second survey encompassed a dedicated section, using Likert scale method, to determine critical challenges from the participants' point of view that arose during the Execution Phase.

LITERATURE REVIEW

Last Planner® System

Glenn Ballard and Greg Howell were the ones that invented the Last Planner® System in 1992 and took the lead for improving the LPS over the last three decades. Several papers have previously been published by Ballard related to this system, the first of them was published in 1993 and was called Improving EPC Performance (Ballard 1993) at the conference of the International Group for Lean Construction (IGLC) www.iglc.net, in its first year, where he mentioned the term Last Planner® system. The Last Planner® System is primarily based on all the principles of Lean Construction which always seek for perfection, and excellent performance concerning productivity and this can be realised by the improvement of reliability of planning, which in turn can be done by "*taking action in several levels in the planning system*" (Ballard and Hamzeh et al. 2007). The main focus of LPS is to reduce the uncertainty and variability in a project's workflow, which has been neglected by the traditional project management and appears to be the primary factor for the low performance of construction projects (Ballard and Howell 2003; Howell and Ballard 1998). The LPS also seeks to improve the predictability of the planned activities on construction sites (Mossman 2014).

The Last Planner® System planning cycle (implementation process) is made up of four different levels; namely, the master schedule level, the phase schedule level, lookahead planning level, and finally the Weekly Work Plan (WWP) level (Ballard et al. 2007a). The master and phase schedules are part of a planning phase called front-end planning, whereas the lookahead planning and the WWP are part of another planning phase called production planning. The process starts with front-end planning. In this phase, **the master schedule** is carried out, which means setting up the milestones and conducting the Critical Path Method (CPM) in order to recognise the overall project duration and budget. After carrying out the master schedules, comes the more detailed scheduling, **the phase schedule**, which improves during the lifetime of the project. The participants can modify the Critical Path Method by using collaborative planning, and the reverse phase scheduling (pull technique) (Ballard et al. 2007a). Once the phase schedule ends, the second phase, the production planning phase, begins. In this phase, we start by magnifying the activities from the phase schedule to the more detailed **lookahead plan** (a process called **explosion**). The participants plan what they are going to do in the upcoming six weeks (the typical number of planning weeks to have a reliable plan). Any constraints that threaten the workflow should be studied to be removed (referred to as **constraints analysis**). The constraints analysis should be carried out every week, followed by an update to the Lookahead plan. Every participant of the team should identify their responsibilities, make assignments ready (this is called **make-ready**), and finally analyse the resource management information (Ballard et al. 2007a). Subsequently, **the Weekly Work Plan (WWP)** can be carried out; this plan is considered as the most detailed plan compared to

all the previous plans. Ballard et al. (2007a) mentioned the (WWP) in their research and said that "*It directly drives the production process*". The quality assignments and reliable promises are then conducted so as to have more reliable plans; as a result, the production unit now is shielded by those quality assignments form the uncertainty in the upstream. Finally, The participants have to analyse **Reasons for Non-Completion (RNC)** and learn from that for future work; this can be obtained by performing **a root cause analysis** to identify "*the source of the action or event chain in order to learn how repeated failures can be prevented* ". Additionally, The participants can utilise some key performance indicators such as **the Percent Plan Complete (PPC)** to measure the system performance. The PPC is defined according to Ballard et al. (2007a) as "*the number of actual completions divided by the number of assignments for a given week.*"

Futhermore, Ballard (1994) presented the team workshop in order to develop the LPS process (Lim et al. 2006). Additionally, Ballard et al. (2007b) mentioned that companies utilise two different mechanisms for training their personnel in LPS; some of them learn by doing, while other firms require a certain amount of training (classroom training). The workshops and the training sessions have been applied in many projects, according to the following research papers (Alsehaimi et al. 2014; Lim et al. 2006). Finally, in their publication, Perez and Ghosh (2018) presented the recommended best practice process map for LPS implementation (based on an extensive literature review). This best practice process map was identical to the planning cycle mentioned by Ballard et al. (2007a).

Last Planner® System implementation challenges

Last Planner® System has multiple advantages, but still, many organisations confront sufficiently significant obstacles when implementing this new system (Hamzeh 2009).

A wide range of literature has already examined and evaluated the Last planner® System's performance in different countries over the last years. Some of them highlighted the success stories of the implementation of the Last Planner® System in several projects, while the other part of the literature indicated the challenges that arose during the execution through complete or partially failed stories of the application of LPS. The researchers have recorded two types of challenges that tended to appear during the implementation. One of them is related to the LPS components and practical use of LPS, called "the practical challenges", while the other type is associated with the transformation process or to the Participants' attitudes and behaviours, referred to as "soft (intangible) challenges" as described by Hamzeh and Bergstrom (2010). In this literature review, the researchers concentrate on both types of challenges, as this research is mainly based on the challenges in general and not limited to a specific type. There are several challenges that appear during the implementation process related to organisational change, and there are many publications from the researchers in the field of change management and Lean construction that included a trial of various organisations to conduct Lean practices. Some of these organisations failed, while the other organisations did not manage to reach the correct form of Lean production, or achieved it to a certain degree (Ballard et al. 2007b; Hamzeh and Bergstrom 2010; Kotter 2012; Liker 2004). Teamwork and continuous improvement are the major components of Lean production. Sadly, many organisations fail to work with them, especially in the construction industry, which includes several "self-interested parties" that are not motivated to develop. They do not know each other and do not have the trust between each other (Liker 2004).

In the following tables 1 and 2, the researchers have summarised the most critical challenges faced by the construction industry professionals when implementing LPS in construction projects (using eleven case studies). It is noteworthy of mentioning that this table is presented following the format utilised by Fernandez-Solis et al. (2013).

Table 1 - List of case studies

Case	Reference	Projects	Project type
C1	Ballard et al. (2007b)	Air Products: Large chemical plant	Industry
C2	Ballard et al. (2007b)	Heathrow Terminal 5 building: civil phase	Commercial
C3	Hamzeh (2009)	Cathedral Hill Hospital project	Health care
C4	Alsehaimi et al. (2014)	Faculty of business and administration building	Institutional
C5	Alsehaimi et al. (2014)	General classrooms and laboratories	Institutional
C6	Kim et al. (2007)	Seoul subway project	Infrastructure
C7	Kim et al. (2007)	Busan subway project	Infrastructure
C8	Ansell et al. (2007)	3 miles of carriageway renewal	Infrastructure
C9	Jang et al. (2007)	Seoul Ring Road project	Infrastructure
C10	Cerveró-Romero et al. (2013)	GDL project	Infrastructure
C11	Cerveró-Romero et al. (2013)	Los Cabos project	Infrastructure

Table 2 - Reported challenges and the corresponding case studies

TY	Challenges	In which case?
Soft (intangible) challenges	Lack of commitment from the top-management level or from participants themselves	C1, C3, **C6**, **C7**, **C9**, **C11**
	Participants resisted the change "this is how I'have done it" attitude	C1, C3, **C6**, **C7**, **C8**, **C11**
	Organisational inertia	C3, **C6**, **C7**, **C8**
	Lack of Leadership	C1, C2, C3, **C9**
	Bad team chemistry	C3, **C9**
	Cultural issues (e.g. "Commitment and attitude to time")	C4, C5
Practical challenges	Novelty of LPS to the participants and lack of understanding of the new system and Lean thinking	C3, **C6**, **C7**, **C8**, **C9**
	Short term vision	C4, C5
	Human capital (lack of skills and training)	C3, **C8**
	Lengthy approval procedure by the client	C4, C5
	The language barriers	**C10**

RESULTS

Last Planner® System Implementation

Table 3 is a summary of what has been recorded during the observations and from the first two interviews.

Table 3 - The implementation process of the LPS in Minnevika Bridge

Phase	Content	Description of the meeting /day
Training Phase	Training Session	• The Trainers explained the meaning of the LPS and Lean construction process by carrying out a theoretical explanation and by using "Villego Simulation" game. • Collaborative planning was described.
	Workshop 1	• Introduction to the five Lean principles, namely, value, optimisation, flow, pull and continuous improvement. • Introduction to process mapping using the pull principle to visually describe the workflow. • Roles and responsibilities for each member have been defined, and team rules have been established.
	Workshop 2	• The project team defined the project gates and important milestones. • They used the collaborative planning process and the reverse phase scheduling for developing those plans.
	Workshop 3	• Six-week lookahead plan was executed based on the steps specified by Ballard et al. (2007a), namely, explosion, screening and Make-ready.
	6 PEP (production evaluation and production planning) Meetings	• The project team established the Weekly Work Plan (WWP) and modified the six-week lookahead plan (under the supervision by the Trainers) – lasted for six consecutive weeks. • The Trainers used an action plan and a risk matrix as a way to make tasks ready. • The team evaluated the weekly performance using Key Performance Indicators (KPIs), including PPC, milestone completion, and Variance analysis (by going through the commitments of each party searching for reasons of failure to learn from mistakes).
Execution Phase	LPS practical Implementation	• The Trainers handed over the Last Planner® System to the project team and specifically to the LPS Facilitator and the process expert (another Facilitator for the meeting). • The Trainers agreed with the project team to carry out follow-up sessions to make sure that the implementation process is on the right track.
	PEP Meetings	• The LPS Facilitator controls the system with the help of the process expert by using the same steps learned in the 6 PEP meetings.

LPS implementation challenges and the suggested measures

Doubt towards LPS formed a significant challenge in the Training Phase. In contrast, **doubts** decreased dramatically after entering the Execution Phase. Many of the participants have reaffirmed their support to the LPS thanks to the benefits gained.

During the training sessions, the **language** formed a great barrier against the implementation process. Gathering almost seven different nationalities, speaking five different languages in the same room could result in some challenges. It was mentioned by one of the site managers that " *you cannot take it for granted that everyone understands the same thing when something is said* ". Additionally, **newcomers started to show up in the PEP meetings**, which resulted in some challenges associated with the level of knowledge they had compared to the other participants.

According to results from the interviews and surveys, **maintaining participants' commitment to the LPS** was considered as the most critical challenge in the Execution Phase due to its huge ramifications on the implementation process. It was clear-cut when the site manager said that "*Without the commitment of the participants, it would be very hard to take any benefit from the system, it is based on the commitment from all the parties*."

The interviews revealed one more critical challenge which emerged during the Execution Phase, namely, Difficulty in understanding the KPIs by some of the participants.

Fear of responsibility when making the commitments (mainly from lower-level management) was observed multiple times during the Training Phase, and it was declared by the participants (through interviews) that it is still a challenge during the Execution Phase.

Table 4 illustrates the critical challenges that occurred through two phases of the implementation of LPS; namely the Training Phase (TPhase) and the Execution Phase (EPhase) and the measures used to overcome these challenges. Those challenges have been recorded with the help of eight months of observations (the researchers observed the training sessions, the three workshops, and all the PEP meetings), six semi-structured interviews, and two surveys.

Table 4 - The critical challenges recorded in Minnevika Bridge

Challenges	Phase occurred	Measures utilised to overcome the Challenge by the project team
1) Doubt (doubt about the overall performance and the benefits behind the LPS)	TPhase	• Sufficient training to the practitioners by showing the benefits of the system during the training, ask them to give their feedback to the Trainers for resolving their doubts and learn by doing.
2) Language barriers	TPhase	• Presentation of the commitments by the Last planner at the end of the PEP meeting to assure understanding of what they have committed to. • Definition of the team rules
3) The non-participation of the JV partner in the training sessions and workshops.	TPhase	• They escalated the issue, and changed the person that should attend the meetings, and explained in detail the LPS to the newcomer.
4) Newcomers to the PEP meetings	TPhase	• The Trainers demonstrated the LPS to the newcomers into detail to reach an equivalent level of knowledge with other participants.
5) Maintaining participants' commitment to be part of the process and to take the system seriously.	EPhase	• Building up the real trust to the LPS and between all of the participants (building a positive environment) by consistently elaborating the benefits behind the LPS to the different parties.
6) Difficulty in understanding the KPIs by participants	TPhase +EPhase	• No measures were taken.
7) Fear of responsibility when making the commitments (mainly from lower-level management)	TPhase +EPhase	• Internal agreement/discussion within different companies about the minimum experience needed to be in the PEP meetings in order to make reliable weekly plans.
8) The non-participation of critical participants due to circumstances beyond their control	TPhase +EPhase	• Request him/her to inform the other participants about the executed work and the planned work for the next week (by email for example), or by sending a delegate who has the responsibility to make the commitments in the PEP meeting.

In Table 4, the researchers sorted out the challenge connected to the non-participation of the different participants into two different categories due to the fact that the company used different measures to cope up with each case, but in general, the impact of the non-participation of

any of the key persons in the meeting had a substantial influence on the meeting. The site manager said " *if we are missing one party during the meeting, sometimes we can assume their plan, but we will not do it with the required precision. We cannot do it on behalf of them every time.*"

Openness and attitudes towards LPS

The two surveys examined openness and attitudes towards LPS during the implementation. The results from the first survey indicated that 8 out of 13 respondents had never heard about LPS before, while 11 out of 13 had not worked with it. Ten of the respondents from the first survey were ready to be part of LPS and learn more about it. In the second survey, the responses were even more positive. 8 out of 8 were motivated to be part of the LPS after understanding its benefits.

PPC results

The researchers managed to record the PPC results over a period of eight weeks. The results showed high Percent Plan Complete (PPC), which ranged from 80% and 100% (100% PPC was observed two times over the eight weeks).

DISCUSSION

Last Planner® System Implementation process

In the beginning, PNC chose to carry out both of the training mechanisms recorded by Ballard et al. (2007b), namely, "classroom" training (the training sessions) and "learning by doing" training (the three workshops and the 6 PEP meetings). The project team implemented the Master phase schedule at the beginning of the project, and overall project duration and important milestones were defined. During the first workshop, they applied "**the process mapping method**", which has been highlighted by Hamzeh and Bergstrom (2010) as vital for LPS implementation. During the second and third workshops, the Trainers presented **the phase schedule** and **the lookahead plan,** as suggested by Ballard et al. (2007b). Subsequently, the company executed Weekly Work Plan-meetings, but they gave it the name PEP meetings. The PEP meetings were comprised of all the components of the WWP meetings; including, assessment of PPC, applying the variance analysis, using the root cause analysis method, modification of lookahead plan, and learning from mistakes. The only difference is that they used Pareto charts, instead of "The Five Whys technique" mentioned by Ballard et al. (2007b) for identifying root causes for failure.

Moreover, as a way of continuous improvement, the Facilitators incorporated new tools, for instance, an indicator for measuring the order and safety on-site and an indicator for completed milestones. The Facilitators even incorporated a talk about the logistics on-site in the PEP meetings. Finally, the Trainers suggested follow-up sessions in order to ensure that the participants had understood the process and did not deviate from the drawn path. The high PPC results on the Minnevika Bridge project proves a very good beginning.

LPS implementation challenges and the suggested measures

The Training Phase

According to the literature review, participants' resistance to the system and lack of commitment towards LPS have been challenging for many construction projects, irrespective of the type of the project (e.g. infrastructure projects or other construction projects). Whenever there is a change in the management system that involves participants (such as adopting the Last Planner system for the first time in a pilot project), it would be vital that participants accept it. Participants often resist changes. In this case study, resistance to change materialised during the Training Phase. **The JV partner did not participate in the training sessions, nor in the workshops**. This may be a result of **doubt** towards LPS. According to the interviews and the two surveys, there are three root causes for the doubt: 1. The novelty of the system for most of the participants 2. Troublesome experiences with LPS for some of them from before 3. Broad experience with other systems makes it unnecessary to change. Diminishing those doubts will take some time (depending on the participants). Every participant should be open towards the new system. This happened in the case study, as according to the first survey, more than 80% of respondents have shown openness towards the system. Once the team was ready to know about the system, sufficient training, building trust towards the system, and building trust towards each other was the responsibility of the Trainers. The trust towards the system can gradually increase by continuously working with it and elaborating the benefits. The trust towards each other, especially when the participants are from different companies like in this case study, will be built with the help of long term efforts.

Ballard et al. (2007b) mentioned that the training sessions help to create a better understanding of the system. The lack of training in C3 and C8 identified in the literature review impacted negatively on the participants' understanding. On the Minnevika Bridge project, many participants gave positive feedback about how they benefitted from the training sessions. Finally, regarding "Learning by doing" training, the three workshops and the 6 PEP meetings represented the final step to reduce the doubts before handing the system over to the project. Before that, it was vital to get all the critical participants involved, so the initial representative from the JV partner was substituted by a new representative, who was introduced to the system in detail.

As mentioned in Table 4, the participants started to learn by operating the system under the supervision of the Trainers who trained them, guided them, and showed them the benefits of the system and how to utilise its tools. Subsequently, many of them started to change their minds towards the LPS; and that was quite clear when **many newcomers started to show up** during the last PEP meeting in the Training Phase. On the other hand, this formed a new challenge as the newcomers were not on the same level of training with other participants. The introduction of new participants, if not handled correctly, could change the atmosphere of the sessions and lead to some members forming a bad image of the system. It is a requirement to elaborate the system into greater detail for them in the beginning until they get up to speed with the others. This is how it was handled on the Minnevika Bridge project.

In addition to the previously stated challenges, **language** formed a significant challenge during the Training Phase, similar to that which occurred in C10. Moreover, Fauchier and Alves (2013) declared that when using LPS, clear commitments (understood by all) should be made, but if the language is a challenge that could be unfeasible. To address this, at the end of the meeting, the Facilitators should make sure that everybody understood what they committed to

by presenting those commitments to the other participants in the room. Additionally, the presence of various languages in the same room could lead to a mess. It is therefore advisable to form team rules, such as the one carried out by the project team in this case study, to create a more stable environment, for example by using the rule "*all discussions in English. The use of other languages only permitted if it is really necessary to explain a difficult topic*". This rule seems simple but can have a positive impact on the working environment during the meeting.

The Execution Phase

After diminishing the doubts and acquiring participants' commitment towards the LPS, the next area of focus is to maintain this commitment. It was mentioned in the findings that "**maintaining participants' commitments**" was considered as the most critical challenge between all the other challenges during the project phase. The transition from the Training Phase to the new Execution Phase, with the handing over the system to the project team, is termed the transition point by the researchers. After this point, the Execution Phase begins, where the Facilitator and the process expert were held responsible for the implementation process of LPS on the Minnevika Bridge project. In order to maintain the participants' commitment towards the LPS in this phase, trust towards the system and between the participants should remain stable, or even be improved. Fauchier and Alves (2013) detected that the system contributes to building trust between participants by making them more transparent, but this occurs over the long term. The researchers support this point of view, but it is also vital to consider the short time and maintain the level of trust established. This is where the responsibility of the Facilitators arise. The Facilitators should be cautious when using the KPIs, at least in the beginning of the Execution Phase, regardless of the value KPIs add to the system. On the other hand, KPIs can act as a reason for shaming and blaming inside the meeting, and that can result in destroying the established trust between participants, and by extension, towards the LPS. The Facilitators should show the results to the participants as usual, but he/she can be a bit "soft" when dealing with those results. On the Minnevika Bridge project, although they got high PPC, they thought in the same manner. The point was to build trust, and the results were expected to come with time.

The challenges emerged in both phases

It was **confusing for many of the participants to analyse and understand the KPIs**, and that was in the same line with what was mentioned in C3, C6, C7, C8, C9. "Learning by doing" is the solution for this challenge. The point here is that they had not experienced so much of the process yet, and that needs time.

"Fear of responsibility when making the commitments (mainly from lower-level management)" was also recorded as a critical challenge during the implementation. This seems to be conventional due to lack of experience. The point here is to have a minimum level of experience inside the room in order to make reliable promises; the attendance of critical participants (e.g. site managers, supervisors and especially foremen) is always a requirement to have the most reliable commitments. Otherwise, should a critical member not be available, preparation in advance with a representative (e.g. site engineers) should be executed to ensure as many reliable plans as possible are committed to in the PEP meetings.

CONCLUSIONS AND FUTURE WORK

By the use of action research, this paper studies implementation of the LPS on the Minnevika Bridge project, which will result in Norway's longest railway bridge. In addition, the challenges

from implementation and the measures suggested to overcome the challenges, were studied. The study contributes to filling the knowledge gap connected with the lack of research papers examining the implementation of LPS in infrastructure projects.

The study indicated that the implementation had many similarities to the best practice process map mentioned by Ballard et al. (2007a) and Perez and Ghosh (2018). Infrastructure projects and other construction projects tend to meet similar challenges in the Training Phase when adopting the LPS for the first time, despite their different characteristics. These challenges were associated with behavioural aspects of participants, namely the resistance to change and participants' commitments towards the new system. Doubts were essential root causes for these aspects. Following best practice for LPS implementation is a requirement for gaining significant results, but diminishing these doubts is also necessary. Building trust towards the LPS and towards each other is a measure for overcoming these doubts. This can be achieved with three steps; sufficient training (Trainers' responsibility), openness towards the system (participants' responsibility), building trust to maintain participants' commitment towards the system (Facilitators' responsibility).

Finally, regarding the uniqueness of the project, the researchers managed to find two new challenges from Minnevika Bridge project that seem not to have been identified in the literature, namely, **fear of responsibility when making the commitments**, **newcomers to the PEP meetings**.

The literature review conducted did not reveal evidence of any research being done on the application of follow-up sessions by Trainers during the implementation of LPS and how these sessions can influence the process. It is, therefore recommended by the researchers as a topic to be further studied.

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PART 3 – APPENDICES

APPENDIX A – FIRST INTERVIEW GUIDE

Introduction of interviewer

- Introduce myself to the interviewee (s)
- Introduce the purpose of the interview and the research questions

Introduction of interviewees

Ask permission to record the interview

Names, ages, position/role, Their previous (if applicable) work experience in construction projects and with PNC, Their previous experience with LPS and their impression about it.

Discussion

Introductory question

- Why will PNC implement the LPS on the Minnevika Bridge project?

Implementation process of LPS on the Minnevika Bridge project

1- Training session

- How are you going to implement the training session?
- What will be your responsibilities in the training session?
- What are the challenges expected to arise during the training session?
- Could you mention some measures to overcome these challenges?

2- Workshops

- How are you going to implement the Workshops?
- What will be your responsibilities in the workshops?
- What are the challenges expected to arise during the workshops?
- Could you mention some measures to overcome these challenges?

3- Production evaluation and production planning meetings (PEP)

- How are you going to implement the PEP meetings?
- What will be your responsibilities in the PEP meetings?
- What are the challenges expected to arise during the PEP meetings?
- Could you mention some measures to overcome these challenges?

4- Follow-up sessions after the training (if applicable)

- How are you going to implement the follow ups?
- What are the challenges expected to arise during the follow ups?
- Could you mention Some measures to overcome these challenges?

Practical work with LPS

1- Meetings

- What sort of meetings are you going to have on the Minnevika Bridge project concerning the LPS?
- What are the challenges expected to each of them?
- Could you mention some measures to overcome these challenges?

2- Tracking the weekly performance

- How are you going to track the weekly performance?
- What are the challenges expected to arise during the tracking process?
- Could you mention some measures to overcome these challenges?

Closing up

- Ask the interviewee about supplementation of interview/call in case something is inexplicit or forgotten to be discussed during the interview.
- Thank the interviewee for attending the interview.

APPENDIX B – SECOND INTERVIEW GUIDE

Introduction of interviewer

- Introduce myself to the interviewee (s)
- Introduce the purpose of the interview and the research questions

Introduction of interviewees

Ask permission to record the interview

Names, ages, position/role, Their previous (if applicable) work experience in construction projects and with PNC or other companies, Their previous experience with LPS and their impression about it.

Discussion

Introductory question

- Why did PNC implement the LPS on the Minnevika Bridge project?

Implementation process of the LPS on the Minnevika Bridge project

1- Training session (refresh their memory of what the training session was)
- What are the challenges that arose during the training session?
- Could you mention some measures to overcome these challenges?

2- Workshops (refresh their memory of what the workshops were)
- What are the challenges that arose during the workshops?
- Could you mention some measures to overcome these challenges?

3- Production evaluation and production planning meetings (PEP)
- What are the challenges that arose during the PEP meetings?
- Could you mention some measures to overcome these challenges?

4- Follow-up sessions (Applies to the Trainer and the Facilitator)
- How are you going to implement the follow ups?
- What are the challenges expected to arise during the follow ups?
- Could you mention some measures to overcome these challenges?

Practical work with the LPS

Key Performance Indicators (KPIs)
- What are the challenges that arise during the use of KPIs?
- Could you mention some measures to overcome these challenges?

Results from the second survey (See Table 4.4)

Based on the results from the survey, the following challenges were considered as the most critical challenges that emerged during the Execution Phase.

I have arranged them from the highest to the lowest based on the average scale value (According to the respondents' point of view).

List of the critical challenges:

1- Maintaining people's commitment to be part of the process and to take the system seriously (**Average scale 3.50**)
2- The decisions and input are primarily provided by top management (**Average scale 3.00**)
3- Fear of responsibility (mainly from lower-level management) (**Average scale 3.00**)
4- Non-participation of critical team members or lack of engagement (**Average scale 2.85**)

For each of these challenges

- Why do you think (this challenge) was considered as a critical challenge?
- How would that influence the implementation process of the LPS?
- What are possible measures for overcoming this challenge?

List of other challenges from the survey *(With less influence on the LPS implementation process on the Minnevika Bridge project during the Execution Phase)*

1- Lack of Transparency in the interfaces between project team members
2- Resistance to the system
3- The language barriers
4- Short-term vision
5- Misunderstanding of the basic concepts of the LPS
6- The time commitment required to participate in the weekly meeting
7- Doubt (doubt about the overall performance and the benefits behind the LPS)

For each of these challenges (the less influence challenges)

- Was it a challenge during the Training Phase?

If applicable!

- How could the team members overcome these challenges?

Do you have any more challenges you want to add (from your point of view) that have not been discussed in the survey?

Closing up

- Ask the interviewee about supplementation of interview/call in case something is inexplicit or forgotten to be discussed during the interview.
- Thank the interviewee for attending the interview.

APPENDIX C – THE FIRST SURVEY

Survey question	Survey answers				
1- Have you heard about Lean Construction before?	Yes			NO	
2- Have you heard about the Last Planner® System (LPS) before?	Yes			NO	
3- Have you worked with the LPS before?	Yes			NO	
4- What is your impression of the LPS?	Positive		Negative		Undecided
5- Would you say that in general, you are open to new ideas?	1	2	3	4	5
6- Would you say that you are ready to be part of the LPS?	1	2	3	4	5
7- Are you curious to know more about the LPS?	1	2	3	4	5
8- Are you satisfied with this transformation/change in the project's system? (Applies to PNC employees)	1	2	3	4	5
10- Would you say that it will be challenging to change to the LPS?	1	2	3	4	5
11- Do you think that the LPS is a waste of time and effort?	1	2	3	4	5
12- Do you think that the LPS will improve the way by which the project will be planned?	1	2	3	4	5
13- Would you say that traditional project management is enough for the success of infrastructure projects?	1	2	3	4	5
14- Would you say that the LPS can lead to a successful project in comparison to traditional project management?	1	2	3	4	5
15- What are the challenges you are expecting to arise during the implementation of the LPS on the Minnevika Bridge project? (Please talk about the challenges from your point of view).					

***** *Note that 1= strongly disagree, 2= disagree, 3= Undecided , 4= agree and 5= strongly agree.*

APPENDIX D – THE SECOND SURVEY

Survey question	Survey answers				
Section 1: General questions					
1- What is your impression of Last Planner® System (LPS)??	Positive		Negative		Undecided
2- Are you still motivated to be part of the LPS?	1	2	3	4	5
3- Are you still curious to know more about the LPS?	1	2	3	4	5
4- Are you satisfied with this transformation/change in the project's system? (Applies to PNC employees)	1	2	3	4	5
5- Would you say that it was challenging to adopt the LPS?	1	2	3	4	5
6- Do you think that the LPS is a waste of time and effort?	1	2	3	4	5
8- Do you think that the LPS is improving the way by which the project is planned?	1	2	3	4	5
9- Would you say that traditional project management is enough for the success of infrastructure projects?	1	2	3	4	5
10- Would you say that the LPS can lead to a successful project in comparison to traditional project management?	1	2	3	4	5
Sections 2: The challenges arise during the Execution Phase					
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?					
11- Maintaining people's commitment to be part of the process and to take the system seriously	1	2	3	4	5
12- Lack of Transparency in the interfaces between project team members	1	2	3	4	5
13- Resistance to the system	1	2	3	4	5
14- The language barriers	1	2	3	4	5
15- Non-participation of critical team members.	1	2	3	4	5
16- The decisions and input are primarily provided by top-level management, such as site managers	1	2	3	4	5
17- Fear of responsibility (mainly from lower-level management)	1	2	3	4	5
18- Doubt (doubt about the overall performance and the benefits behind the LPS)	1	2	3	4	5
19- Misunderstanding of the basic concepts of the LPS	1	2	3	4	5
20- The time commitment required to participate in the weekly meeting	1	2	3	4	5
21- The lack of engagement	1	2	3	4	5
22- Disruption	1	2	3	4	5
23- 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? (Please talk about the challenges from your point of view).					

***** *Note that in section 1: General questions (1= strongly disagree, 2= disagree, 3= Undecided , 4= agree and 5= strongly agree)*

***** *Note that in section 2: The challenges emerge during the Execution Phase (1= very low, 2= low, 3= Undecided , 4=high and 5= Very high)*

APPENDIX E – CRITICAL EVALUATION OF LITERATURE

Method of evaluation

Based on the publications found from the databases, a critical evaluation was undertaken to ensure that each piece of literature included in this study was credible, reliable, relevant objective and recent.

The author divided the evaluation method into six important criteria: namely, authority, credibility, relevance, purpose/objectivity, accuracy, and timeliness. Furthermore, the author started to critically ask some questions for each point to make sure that it fits with the expectations of the suitable publication which can be used later during his research.

Authority

- Is the author an expert in that field?
- What work or educational experiences does the author have?
- With which institution, organisation, or company is the author affiliated?
- How many total citations does the author have?
- Has the author written other publications?
- Who is the publisher, and is he well-known?
- Does the publisher have any benefits from the research presented in the article?

Credibility

- Was the article peer-reviewed, i.e. from a refereed journal?
- How many citations does the article/the book have?

Relevance

- Is the article/the book relevant to the research?
- What audience is the article directed towards?
- Is it proper to be used in this research?
- Does the article answer the research questions?
- Does the article address a topic from a certain geographic area/region or timeframe?

Purpose/Objectivity

- What is the purpose of writing the article/the book? Is it for research purpose of entertainment/making money?
- Is the information presented objectively?
- Is the researcher biased to his opinion?

Accuracy

- Does the title demonstrate that the article is too specific or not specific enough? Is there a subtitle with more details?
- Is all the information supported by evidence(referenced)?
- Is there any obvious writing errors or typos (for books)?

Timeliness

- Is the information current and up-to-date? Does it need to be?
- What about the sources used by the author? Is it up-to-date/recent?

Evaluation of literature

- **Literature related to Last Planner® System**

1- Ballard, G., and Tommelein, I. (2016). Current process benchmark for the Last Planner® System. Lean Construction Journal.

The type of publication: Journal article

Authority

There are two authors for this journal articles; one of these authors is GLENN BALLARD which is a well-known author and needs no introduction when it comes to Lean construction and the LPS. Ballard is considered as one of the essential developers and inventors of the LPS. The other author is called Iris D. Tommelein which is also a well-known author with many publications related to Lean construction and the LPS and has a total amount of citations of 6586 which is a very high number and indicates a credible person.

The publisher is Lean Construction Journal which has been published by the Lean Construction Institute since 2003, the Lean Construction Journal (LCJ) is an international refereed journal devoted to Lean Construction practice and research. At least three people rigorously review all papers, at least one of whom is likely to be an industry practitioner which means that the article is totally credible for getting information from.

Credibility

The journal article has been cited 39 times and that makes the article seems credible regardless of the author's name. Furthermore, the journal article is peer-reviewed and that proves the credibility of the article.

Relevance

The goal was to build up the knowledge with the LPS and this article is a very good start to know more about LPS to help me later when evaluating the implementation of Last Planner System on the Minnevika Bridge project.

Questions answered:

1- The audience of the article are the researchers who want to have enough understanding of WHAT IS and WHY the Last Planner® System.
2- This article is proper to be used as it is going to give me a good understanding of LPS and why and how it is used in construction projects.
3- This article is not directly answering the research questions, but it puts the foundation for solving the required questions afterwards.

Purpose/objectivity

The article has a clear purpose which was declared by the author in both the introduction and the title. The purpose is to have a benchmark for the LPS for project production planning and control. And this forms a great start when studying the LPS.

Accuracy

All the information provided can be verified using references. There are not any obvious writing errors, or spelling mistakes noticed in the text. The title of the journal article is so specific, and that demonstrates an accurate article.

Timeliness

The article was published in 2016 which means that it is up-to-date, and the references used by the author is a combination of up-to-date sources and some other sources that are not up-to-date, but these out of date sources are mostly representing the definitions of the LPS and the original basics of LPS, so it seems reasonable to use old sources.

2- Ballard, H. G. (2000). The last planner system of production control.

The type of publication: PhD dissertation

Authority

The author of this PhD dissertation is GLENN BALLARD.

The dissertation was submitted to the Faculty of Engineering of The University of Birmingham for the degree of DOCTOR OF PHILOSOPHY.

Credibility

The PhD dissertation has been cited 1435 times, and it is considered as one of the primary sources of the development of LPS, so it is totally credible as a source of knowledge.

Relevance

This PhD dissertation is always a relevant source when it comes to talking about LPS.

The goal was to build up the knowledge more with the LPS system and this dissertation according to Ballard added some improvements to the Last Planner® System of production control which was developed and tested in a series of case studies.

Questions answered:

1- This dissertation is proper to be used as it is going to give a good understanding of LPS and to describe what was done to improve workflow reliability, measured by PPC, and the results achieved (Ballard 2000).
2- This dissertation is not directly answering the research questions, but it can be considered as a basis for knowing more about LPS.

Purpose/objectivity

The dissertation has a clear purpose which declared by the author in both the abstract and the title.

This dissertation extends system application to those coordinating specialists, both in design and construction, through a series of case studies, one of which also explores the limits on unilateral implementation by specialists (Ballard 2000).

Accuracy

All the information provided can be verified using references. There are not any obvious writing errors, or spelling mistakes noticed in the text. The title of the dissertation is specific, and the language is easy to understand and of an adequate academic level. It was also noticed that the text has unity and a clear line of argument. Finally, by skimming through the thesis, the author also found out that the text does not contain any unnecessary duplications or repetition and the reference list is complete and accurate.

Timeliness

The dissertation was published in 2000 but can always be considered as a primary source for the knowledge concerning LPS.

3- Ballard, G., and Howell, G. (2003). An update on last planner. Paper presented at the Proc., 11th Annual Conf., International Group for Lean Construction.

The type of publication: Conference paper

Authority

Two authors wrote this paper. One of the authors is GLENN BALLARD, and the other is Gregory A. Howell; a well-known author and has multiple publications related to Lean construction with a total citation number of 7340, which is very high.

The paper has been published in the 11th annual conference, International Group for Lean Construction (IGLC), which is an international conference that started in 1993. The IGLC brings together an international community of researchers and industry practitioners each summer to develop the research and practical applications of Lean Design and Construction.

Credibility

The conference paper has been cited 248 times which is also considered as a very high number of citations.

Relevance

It is always important to search for new updates or innovations in the systems. In the abstract, the two researchers mentioned that the inventors of LPS provided an update for the system on theoretical foundations, proposals regarding work structuring, phase scheduling and reliable promising, so it would be very useful to be acquainted with all the updates in LPS over the years.

Questions answered:

1- The audience of the paper are the researchers.
2- This conference paper is proper to be used; it gives a good overview of the innovations related to LPS up to the year 2003.
3- This paper is not directly answering the research questions, but it puts the foundation for solving the required questions afterwards.

Purpose/objectivity

The article has a clear purpose which is declared by the author in both the introduction and the title Balled said that "*the purpose of the article is to provide an update consisting of a description*

of innovations and changes, thoughts on theoretical foundations, proposals regarding work structuring, phase scheduling and reliable promising."

Accuracy

All the information provided can be verified using references. There are not any obvious writing errors, or spelling mistakes noticed in the text. The title of the conference paper is so specific, and that demonstrates an accurate paper.

Timeliness

The paper is a bit old, since it was published in 2003, but it essential to know the history of improvements of LPS all over the years to give the author a good understanding of the LPS.

- ## Literature related to Lean construction

1- Bajjou, M. S., Chafi, A., and En-Nadi, A. (2017). A Comparative Study between Lean Construction and the Traditional Production System. International Journal of Engineering Research in Africa.

The type of publication: Journal article

Authority

The first author of this article is called MOHAMED SAAD BAJJOU and is currently working at an industrial engineering laboratory, Faculty of Sciences and Techniques, University of Sidi Mohamed Ben Abdellah-Fez. He researches Industrial Engineering and Civil Engineering. His current project is Lean construction. He also had some previous publications related to LPS. So, it seems like the researcher is an expert in the field, and the information he has in the journal article can be credible. The journal published the article is called "International Journal of Engineering Research in Africa" which is a peer-reviewed journal devoted to the publication of original scientific articles on research and development of engineering systems.

Credibility

The paper has been cited 21 times, and that increases the credibility of the article. The journal article is also a peer-reviewed journal which also increases the credibility even more.

Relevance

One of the main purposes to make the literature review was to find some articles to illustrate the differences between Lean construction and the traditional production system. So, this article was relevant.

Questions answered:

1- The audience of the article are the practitioners and researchers from the construction industry.
2- It seems like proper to be used as it is going to give the author a good overview on the differences between Lean construction and traditional production systems to facilitate understanding the changing in methods and techniques when transferring from traditional production system to Lean system.
3- This paper is not directly answering the research questions, but it puts the basis for answering the questions.

4- It does not address the topic from a certain timeframe or geographic area.

Purpose/objectivity

There is no apparent biased direction from the author in the title or the abstract, and the information is presented in an organised way. Moreover, the information has been written for the purpose of the research and not for entertainment.

Accuracy

All the information provided can be verified. There are not any obvious writing errors or spelling mistakes seen in the text. The title of the journal article is so specific, and that shows an accurate article.

Timeliness

The journal has been published in 2017 which mean that it is up-to-date, and the references used by the authors is a bit old, but that seems reasonable as the authors are giving a generic review of what is meant by Lean and how it is used to promote what the traditional construction.

- **Literature related to barriers due to the implementation of LPS**

1- Porwal, V., Fernandez-Solis, J., Lavy, S., and Rybkowski, Z. K. (2010). Last planner system implementation challenges. Paper presented at the Proceedings of the 18 Annual Conference International Group for Lean Construction, IGLC.

The type of publication: Conference paper

Authority

There are four authors for this paper, and one of these authors is called Vishal Porwal which is, the second is called Jose Fernández-Solís, the third is called Sarel Lavy and the final author is called Zofia K. Rybkowski. All the publishers are well-known publishers and have a high number of citations which indicates a credible source.

The paper was published in the 18th annual conference, International Group for Lean Construction (IGLC), which is a well-known conference.

Credibility

The conference paper has been cited 45 times which is also considered as a high number of citations.

Relevance

This conference paper is relevant as it represents findings from a literature survey about the challenges faced by construction professionals during the implementation and use of LPS. The researchers identified the challenges faced by construction professionals during the implementation and use of LPS at both organisational and project levels (Porwal et al., 2010) and that suits with my research.

Questions answered:

1- The audience of the paper are the researchers.

2- This conference paper is proper to be used as it gives a good overview of the possible challenges that arise due to the implementation of LPS.
3- This paper is directly answering the research question number 2, so it gives a good overview of the challenges in implementing LPS.
4- It does not address the topic form a certain timeframe of geographic area.

Purpose/objectivity

The article has a clear purpose which declared by the author in both the abstract and the title. Moreover, it does not seem like the author has any bias concerning the topic. In addition to that, the article seems like an informational article that made for the sake of learning. Finally, the author does not have any arguments regarding the literature, and his purpose is to represent the challenges with the implementation of LPS. The method used for this research is declared, that is a literature survey.

Accuracy

All the information provided can be verified using resources. There are not any obvious writing errors, or spelling mistakes noticed in the text. The title of the conference paper is so specific and obvious, and from the first look, it was obvious that it is relevant.

Timeliness

The paper was published in 2010, which means that it is slightly up to date source. Furthermore, the author mostly depended on up to date sources and that increase the credibility of the source.

2- Fernandez-Solis, J. L., Porwal, V., Lavy, S., Shafaat, A., Rybkowski, Z. K., Son, K., and Lagoo, N. (2013). Survey of Motivations, Benefits, and Implementation Challenges of Last Planner System Users. Journal of Construction Engineering and Management.

The type of publication: Journal article

Authority

The researchers of this article are Jose L. Fernandez-Solis, Vishal Porwal, Sarel Lavy, Ali Shafaat, Zofia K. Rybkowski, Kiyoung Son and Nishi Lagoo. Most of these authors have a high number of citations and some number of publications related to LPS and Lean construction.

The name of the journal is The Journal of Construction Engineering and Management publishes quality papers that aim to advance the science of construction engineering. Finally, the journal has an H index of 95 which is considered as a high number (based on SCIMAGO INSTITUTIONS RANKINGS)

Credibility

The journal article has been cited 67 times, and that makes the article a credible source. Moreover, the article is a peer-reviewed article which increases credibility dramatically.

Relevance

The researchers' purpose, as indicated in the title, is to make a research on the motivations, benefits, and challenges that arise during the implementation of LPS by using a structured survey of senior and mid-level managers and that seems relevant. The author planned to conduct some interviews with this management level on the Minnevika Bridge project, and that helped to define the interview guide and be aware of the challenges arose during the implementation of LPS in many other projects.

Questions answered:

1- The audience of the article are the researchers and users of LPS.
2- This article is proper to be used as it is going to give a good understanding of the motivations, benefits, and implementation challenges of Last Planner® System users based on 26 case studies that have been reviewed by the authors.
3- This article is directly answering the research question number two and three, regarding the challenges that arise during the implementation of LPS and the measures based on these 26 case studies as a basis for doing the survey.

Purpose/objectivity

The article is an informational article made for the sake of learning. The author does not have any arguments regarding the literature, and his purpose is to represent the benefits and challenges with the implementation of LPS using 26 case studies that have been published by other authors in a period of 9 years (from 2000 to 2009). The method used for this research is declared, which is a literature review, and a survey to more precisely assess the challenges faced by senior and mid-level management during the implementation of LPS.

Accuracy

All the information provided is supported by evidence and can be verified by the resources. The author skimmed through the article, and there was no glaring writing errors or spelling mistakes noticed in the text. The title of the journal article is so specific, which demonstrates an accurate and relevant article.

Timeliness

The article has been published in 2013, which indicates recent and up-to-date data. Additionally, the 26 case studies that the researchers used in the research are ranging in dates from 2000 to 2009, which also indicates a recent data. The references used by the authors are up-to-date sources that show reliable data when it comes to comparing it to the findings collected from this single case study.