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Production planning with the Last Planner system on construction projects in Sweden

An exploratory case study of challenges and improvement measures

Maria Dag and Apoorv Garg

ROYAL INSTITUTE OF TECHNOLOGY

DEPARTMENT OF REAL ESTATE AND CONSTRUCTION MANAGEMENT

Master of Science thesis

Title	Production planning with the Last Planner system on construction site in Sweden An exploratory case study of challenges and improvement measures
Author(s)	Maria Dag and Apoorv Garg
Department	Real Estate and Construction Management
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Supervisor	Andreas Ekeskär
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Abstract

One of the main assumptions in conventional production process is that each component or part of the production process can be controlled separately as if they are not dependent on anything. This assumption gives rise to problems such as need of effective collaboration with different actors and constraints in budgets. Conventional planning process also causes delay as well as cost overruns which ultimately leads to reduction in productivity.

The Last Planner system, LPS, is a tool used in the construction sector with the goal of streamlining production. The tool has several advantages, for example, to make collaboration between different actors more efficient, achieve a better workflow and increase production efficiency. The purpose of this masters' thesis is to explore how two construction projects in Stockholm work with LPS. Apart from the fact that LPS provides many advantages in the production planning of the projects, this study aims to explore the challenges that they face while working with LPS. The goal of this study is to be able to suggest improvement measures for the challenges that the projects are facing.

Semi-structured interviews were conducted on both projects to understand how they work with LPS and what challenges they face. The results section contains the information from the interviews. That is then discussed against the theory on which the Last Planner system is built.

The conclusion of this study is that the production planning in the projects differs from how the tool should be used according to the framework of LPS. Learning, which emphasizes what has been done during the project, is a phase in LPS's framework. According to one of the founders of the LPS system, 'learning' is the most important phase. However, due to the lack of time, the studied projects were not able to involve the learning phase into their production planning. The projects faced several challenges, including repeated changes from the design teams, which entailed new actions during the project. Also, the involvement of the construction workers in the planning phases came out as a big challenge for the managers. Furthermore, communication problems and lack of cooperation with subcontractors is also present. Some of the improvement measures suggested to meet the challenges are that managers should increase commitment to involve especially construction workers in the planning phases, create nucleus teams, create a standard protocol for how production planning should be implemented, and improve visual planning to enhance communication.

Acknowledgement

Firstly, we would like to thank our supervisor Andreas Ekeskär and our examiner Tina Karrbom Gustavsson as well as Inga-Lill Söderberg and Anna Kadefors for providing their guidance.

This master thesis was conducted in collaboration with a large Swedish construction company and we would like to thank our supervisor at the construction company for providing us the opportunity to extend our horizon of knowledge and experience.

We would like to extend our gratitude towards all the involved participants and experts in our interview study. Without their time and knowledge this research could not have been completed. Also, a special thanks to Dr. Glenn Ballard (Faculty, Civil and Environmental Engineering, University of California Berkeley) and one of the academic founders of the Last Planner system for providing his time for a video interview.

Examensarbete

Titel	Produktionsplanering med Last Planner systemet på byggrojekt i Sverige En explorativ fallstudie av utmaningar och förbättringsåtgärder
Författare	Maria Dag and Apoorv Garg
Institution	Real Estate and Construction Management
Examensarbete Master nivå	TRITA-ABE-MBT-19158
Handledare	Andreas Ekeskär
Nyckelord	Lean Construction, Production Control, Last Planner system

Sammanfattning

I de traditionella produktionsprocesserna har det antagits att olika komponenter kan styras separat d.v.s. att de är oberoende. Detta antagandet har gett upphov till problem som till exempel försämrat samarbete mellan olika aktörer. Den traditionella produktionsprocessen har också lett till förseningar och kostnadsöverskridanden i projekt.

Last Planner-systemet, LPS, är ett verktyg som används inom byggsektorn med målet att effektivisera produktionen. Förutom att effektivisera produktionen är syftet att involvera byggarbetare i planeringsfaserna. Verktyget har flera fördelar, till exempel att effektivisera samarbeten mellan olika aktörer, uppnå ett konstant arbetsflöde och ökad effektivitet i produktionen. Syftet med denna uppsats är att utforska hur två byggprojekt i Stockholm arbetar med LPS. Bortsett från att LPS tillför många fördelar i projektens produktionsplanering har denna uppsats som mål att utforska vilka utmaningar projekten står inför kring arbetet med LPS. Målet är att kunna föreslå eventuella förbättringar för att möta utmaningarna som projekten står inför.

Semistrukturerade intervjuer genomfördes på båda projekten för att förstå hur de arbetar med LPS och vilka utmaningar de står inför. Resultatavsnittet redovisar informationen från intervjuerna, som sedan diskuteras i relation till teorin som LPS bygger på.

Slutsatsen av denna uppsats är att det skiljer sig mellan hur verktyget används i praktiken jämfört med vad ramverket för LPS står för. Att ta lärdom av vad som gjorts under projektet är en fas i LPS ramverk. Enligt en av grundarna av LPS-systemet är ’lärande’ den viktigaste fasen. Men på grund av tidsbrist har inte projekten som denna studie undersökte kunnat genomföra den fasen. Projekten stod inför flera utmaningar, bland annat upprepade ändringar från designteamen, som ledde till nya åtgärder under projektet, att involvera byggarbetare i planeringsfaserna, kommunikationsproblem mellan aktörer och bristande samarbete med underentreprenörer. Några förbättringsåtgärder är att chefer borde engagera sig mer för att involvera byggarbetare i planeringsfaserna, skapa ett standardprotokoll för hur produktionsplanering bör genomföras och förbättra den visuella planeringen för att uppnå bättre kommunikation.

Förord

För det första vill vi tacka vår handledare Andreas Ekeskär och vår examinator Tina Karrbom Gustavsson samt Inga-Lill Söderberg och Anna Kadefors för vägledning och visdom under arbetet av denna masteruppsats.

Denna masteruppsats genomfördes i samarbete med ett stort svenskt byggföretag och vi vill tacka vår handledare på byggföretaget som gav oss möjlighet att utvidga vår kunskaps- och erfarenhetshorisont.

Vi vill gärna tacka alla inblandade deltagare och experter i företaget för vår intervjustudie. Utan deras tid och kunskap skulle denna forskning inte ha kunnat utföras. Också ett stort tack till Dr Glenn Ballard (Faculty, Civil and Environmental Engineering, University of California Berkeley), en av Last Planner systemets akademiske ”grundare”, som ställde upp på en videointervju.

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1. INTRODUCTION

1.1 Background

The conventional production process in the construction industry has been perceived as the transformation of input to output (Koskela 2000). One of the main assumptions in conventional production process is that each component or part of the production process can be controlled separately as if they are not dependent on anything. This assumption gives rise to problems such as need of effective collaboration with different actors and constraints in budgets (Ballard 2000). Traditional planning process also causes delay as well as cost overruns which ultimately leads to reduction in productivity (Abdalla and Battaineh 2002). Also, conventional construction method contributes toward generation of various type of waste in form of failure in meeting client's requirements, overproduction, defective production, idle inventory, movement of material, processing, waiting and transportation (Howell 1999; Horman and Kenley 2005; Mossman 2009). According to Shenhar and Laufer (1995), construction projects are complex, uncertain and quick. Complexity mainly occurs due to number of interdependencies in activities, uncertainty of goals, change in demand of clients, market economy and technology (Baccarini 1996; Williams 1999). Since the construction environment has several variables, it is hard to link activities in a simple sequence with conventional management. Due to the uncertainty, complexity and pace in the project, its coordination with the most detailed construction management schedules is even harder as these schedules focus on the activities of the process and neglect the work flow between them (Koskela et al. 2002).

To mitigate the conditions mentioned before, production control is necessary. It can be described as a sequence of various tasks such as aggregate production planning, material coordination and workload management, work order release and production unit control (Ballard and Howell 1998). Construction industry in general uses different methods and techniques to achieve this goal. Planning involves creation of schedules, budgets and other detailed specifications which has to be followed for project execution (Ballard and Howell 1998).

To mitigate these problems the Last Planner system (LPS) was first introduced by Ballard (2000). Ballard, who is one of the founders of the Last Planner system was working as a craftsman when he got inspired to make a system that makes the production more efficient and to include the downstream actors (interview with Ballard 2019). The LPS is a Lean Construction tool (Ballard 2000; Kalsaas 2012) based on the production control theory and Lean principles that includes three goals: (1) creating the product, (2) focusing on product characteristics such as reduction in process costs; and (3) finally meeting the needs related to customers such as quality, dependency and flexibility (Koskela 2000; Koskela et al. 2002). Kalsaas (2012) explains that the LPS provides collaboration between the managers, team leaders and subcontractors to be able to get a task ready, which in turn can be achievable with high degree of reliability whilst improving the work stability and predictability. LPS consist of Lean principles and with the implementation of Lean thinking in a project, the aim is to minimize activities that do not add any value (Forbes and Ahmed 2011). "Lean is the way to design production systems to minimize waste of materials, time and effort in order to generate maximum possible amount of value" (Koskela et al. 2002 p.211). The basic outline of Lean approach focuses on instant custom product delivery with no existing intermediate inventory. The concept includes identifying and delivering value for the customers and eliminating waste, to organize continuous flow in the production, perfecting the product, creating reliable flow

and delivering the product to customers on time without creating inventories (Howell 1999). Contractor and subcontractors are integrated with each other to be able to collaborate in more details with an aim to achieve the practical implementations that are needed (Kalsaas 2012). The most important role of LPS is to provide realistic planning instead of optimistic planning by the evaluation of the worker's ability to complete the tasks. With proper team efforts and resource optimization, several non-value adding activities can be pulled out of the production process (Ballard 2000).

To implement production control the companies have influenced their production planning from the Last Planner system, LPS. As mentioned above research shows that the LPS provides various benefits including effective collaboration, smooth workflow, increased efficiency and productivity but, from previous studies (Daniel et al. 2015; Dave et al. 2015; Perez and Ghosh 2018) it is evident that there are number of challenges that come up with the practice of the LPS and Lean principles. One of these challenges also include the partial practice of the LPS (Porwal et al. 2010). Friblick et al. (2009) conducted research within the Swedish construction industry in a company that practices LPS and found that the involvement of downstream actors and especially of the construction workers is a huge issue for the implementation of LPS as it is described by theory. Furthermore, research by Koskenvesa and Koskela (2012) conducted in a Finnish construction company highlights that efficient collaboration between actors and subcontractors was a problematic issue while practicing LPS. However, not enough knowledge is provided by these earlier on the specific problems and challenges for construction practice to implement a tool that is meant to streamline production. There is also a gap, highlighted in the literature on ways these challenges can be mitigated by different improvement measures.

1.2 Aim of the study and Research questions

The aim of this study is to explore how an organisation is working with the Last planner system in their production planning and to investigate the challenges that they face while working with their production planning process. The study focuses the downstream actors' use of the Last Planner system as this type of study has not been found in earlier research. Also, one of the main purposes is to provide improvement measures to these challenges according to suggested framework from previous research.

The specific research questions asked are:

- Do the studied Swedish construction projects follow every element of the theoretically grounded LPS framework? If not, why?
- What are the practical challenges to work with the Last Planner system in large construction projects?
- How can the identified challenges be mitigated according to improvement measures developed by earlier research on LPS?

1.3 A Swedish Case

This is a case study that has been conducted in collaboration with a Swedish construction company. The company developed their new production planning in the year 2010 influenced by the Last Planner system. The main purpose of this change to the production planning was

to get a more efficient process and a better collaboration “on the floor” involving visualisation, joint planning and follow ups. This was done with a deliberate perspective of Lean theory and the Last Planner system. In the present study two different constructions projects have been analysed in relation to their relation to LPS. The two projects were chosen together with the company based on an assumption that they would display possible problems and challenges in the implementation of LPS. The main purpose of this was to possibly detect a wider range of problems in implementing the LPS. The specific projects were chosen by the company based on the possibility to get access to the site in time and space. More information on the investigation will be given in the methods section.

1.4 Delimitations

The Lean concept and tools are very broad. This study has focused on examining the Last Planner system in one construction company in Stockholm, Sweden. In order to obtain a confined scope two projects have been investigated, which of course is limiting the study. However, the time scope of the project made it necessary to choose a case study design. This study includes interviews with respondents that are working within the production line and excludes possible insightful comments by management that does not work on the construction site.

1.5 Structure of this thesis

This introduction has described the master thesis background, aim and the research questions. The next chapter, the method chapter, describes the type of research that has been done, the case study approach and methods used for data collection and data analysis. This chapter also includes a discussion on validity and reliability. The third chapter describes the chosen theoretical framework and relevant literature: the theory of Lean production and the theoretically based tool Last Planner system which provides the basis to validate the findings and through the connection of the results to earlier literature make them more reliable. It also gives a literature review over earlier research on these two concepts and on the implementation of LPS in the construction sector. The contents in the result chapter is a presentation of the collected interview and document data. In the analysis section we discuss the scientific literature, that is found in the theory section, in relation to the practice, where empirics is taken from interview respondents. We also present our own reflections and arguments in a discussion based on this analysis. This will then form the foundation for the master thesis conclusions that are given in the last chapter. In this last chapter we describe the answers to the master thesis research questions and make a conclusion in accordance with the aim of the study. We also discuss limitations and possible problems with our study and make recommendations for future studies.

2. METHOD AND DATA

2.1 Research approach

To be able to answer the research questions on challenges and possible improvement measures for constructions projects working according to the Lean inspired Last Planner system a case study approach has been used. This approach is both described as a methodology and a method and focuses on finding the specifics in one or just a few cases studied (Yin 2009). This approach is well suited here as we, in collaboration with the construction company, decided to focus on two specific projects. The case study approach has been criticized for being too myopic and not giving grounds for generalizing from the research findings (Tellis 1997). But as others point out (Yin 2009) deep investigation in specific cases gives important new knowledge of great use within social science.

For this study a case study approach was therefore chosen and, to get a better understanding of Lean and the implementation in practice of the tool, the Last Planner system, a qualitative method was chosen to study the two projects within the company. To combine the collected information from literature review, interviews has been conducted in construction projects in Sweden to have a practical point of view. Firstly, the theory was studied, and later interviews were conducted in order to see how the process actually works in the reality.

2.2 Literature review

At the beginning of constructing the study, but also during the work with this report, previous research has been studied on the wide area of Lean theory and practice to further examine Lean construction and then further investigate deeper into a tool of Lean – the Last Planner system for production control. Articles and reports have been searched on the internet through KTH library, Scopus and Google Scholar. Mainly literature in English was searched for but some Swedish articles were also studied in order to get a better understanding of how the situation has been in Sweden. However, as one of the authors is non-Swedish, a main focus has been on reviewing international peer-reviewed research literature.

The material that has been critically reviewed has been used for structuring the study in defining research questions and methods chosen; for analysing the results from the empirical study and for writing up the thesis and formulation the conclusions. The literature review is an important part of this study because it gives, for example, credibility in a sense that we have read the existing earlier research and that the chosen material is from trustworthy sources. The literature review is the starting point for this research.

2.3 Method for data collection: Qualitative interviews

Interviews were held with a purpose to obtain an understanding of how the production planning and control of the company is working in practise, how the actors who are working with the tool understand it, if there are any challenges applying the tool and how they perceive them. By having interviews, information about how the situation in practise was obtained which has then be compared to the Last planner system framework by the authors to see if there is any difference between them.

The approach that has been used is semi-structured interviews. This approach gave both the interviewer and the participants advantage because the interviewer could ask open questions with follow up questions and the participants were able to formulate their own answer (Ejvegård 2009). Since this report is written in English, most of the interviews were held in English, however some respondents did not feel comfortable or felt they could give better answer in Swedish. In both cases, when interviews were held in English and in Swedish a risk that the respondents exactly meaning, and words were not presented corrected in the report. Since English is not the respondent's native language, they might have chosen another word in English then they were thinking of in Swedish. For the interviews that were held in Swedish, the author may be biased when choosing the English words. All interviews were recorded, with approval from the respondents. By having them recorded the interviewer could in peace write down what had been said (Ejvegård 2009). The Swedish interviews were first translated to English and then all the interviews were transcribed in English and summarized in the result chapter. The respondent's names are anonymous but their title and years of experience in construction industry is presented.

2.4 About the company and the chosen projects for data collection

The contractor is a large construction company in Sweden and they have many projects running all over Sweden. The company has a production planning that is influenced by the LPS since 2010. There has not been any investigation about how the LPS works in the projects since they applied it into their projects. To be able to understand and find out how the projects works with the production planning according to the LPS framework two projects has been studied through several interviews that are represented in Table 1 and 2 below.

One project will be called project A and the other will be called project B. Project A has a client and is remodelling a building from the 1960s. Since it is an old building and a client included it was an interesting choice as there are other actors involved except for the contractor. The contractor is building offices, apartments, restaurants and bars of a size of 6,000 square meters in space with a budget of 500 million SEK. The contractor is building it in a sustainable way with LEED Platinum certification. It is a design and build contract.

Project B is a new construction project without a client i.e. the contractor is building for themselves. They are working with production planning influenced by LPS and are building offices and restaurants of a total size of 44,000 square meters with a budget of 1,2 billion SEK. The contractor is building it in a sustainable way with BREEAM EXCELLENT certification. Both projects are ongoing when this case study was conducted.

The projects were interesting to investigate because they are both said to be following the LPS framework in their production planning. They are also a bit different as one is a remodelling with a client and the other project is a new construction project without a client so different aspects of problems in the process might be found. They were both in the same time phase when the interviews were conducted and both the projects are building similar things in the same city, even though they have some difference as mentioned above. But mainly the projects were chosen to generate more data on the challenges with the LPS framework in building practise.

The interviews were performed with Project manager, Design manager, Site manager, Installation leader, Logistic manager, Site supervisor, Construction workers in two different projects with a total number of 15 interviews, see Table 1 and 2 below. These actors are chosen

because they are involved in the planning for the project, they either works close to the production planning or on the site. The interview questions are presented in Appendix 1.

Table 1: Information about respondents from Interviews, project A

Project A			
Respondent	Role	Work experience	Time
1	Project manager	12 years	60 minutes
2	Site manager	30 years	50 minutes
3	Design manager	20 years	50 minutes
4	Installation leader	24 years	60 minutes
5	Logistic manager	18 years	50 minutes
6	Site supervisor	4 years	60 minutes
7	Construction worker	33 years	30 minutes
8	Construction worker	30 years	20 minutes

Table 2: Information about respondents from Interviews, project B

Project B			
Respondent	Role	Work experience	Time
9	Project manager	11 years	50 minutes
10	Site manager	23 years	60 minutes
11	Design manager	8 years	50 minutes
12	Visual manager	13 years	40 minutes
13	Site supervisor	18 years	20 minutes
14	Construction worker	23 years	30 minutes
15	Construction worker	23 years	20 minutes

Except for the respondents in Table 1 and 2, an interview was conducted with Dr. Glenn Ballard, Faculty, Civil and Environmental Engineering, University of California Berkeley, who is one of the founders of the Last planner system. The reason for this interview was to get a wider understanding of the Last planner system and of any more recent findings about problems in implementation or ideas on how to correct the theory out of empirical findings done since the tool was first invented and communicated by the founders.

2.5 Research Ethics

All the respondents were aware of the purpose of this master thesis and how the data was to be used. Project members were asked by the authors to participate in the interview and it was voluntary to participant and anonymous. Before the interviews started, all the participants were asked if recording was allowed. Participants were told that they had the option to cancel the interview if they so pleased. Furthermore, the identity of the respondents is classified and even the company can't identify who took part in our study and who provided which answer As all respondents accepted to be recorded, they also did not want to see the transcribed protocols but gave permission to the authors to use the material for the purpose of identifying problems within the planning of the project. The transcription of the interview with Ballard has been sent to him for checking and has been approved. The supervisor from the company has read and

approved the text in this thesis. Also, following requirements in GDPR, the respondents have been informed about how their personal data are handled and stored.

2.6 Data Analysis

A thematic content analysis was done in order to gather the relevant information required for an analysis of problems in relations to the theoretical idea of the LPS tool. Out of the transcribed interviews the material was categorised in to different sections so that the pattern in the responses could be figured out. Also, during the interviews some information was also gathered which was not relevant for the analysis in this this specific study and was therefore removed from the presentation of the results. As some of the interviews were held in Swedish they were therefore translated and transcribed by the one person speaking Swedish in the research team. However, the analysis of the full material was done jointly by both authors discussing the themes and analyzing the results in relation to the theoretical framework.

2.7 Reliability and Validity

As it is described by (Sreejesh et al. 2014) and (Saunders et al. 2016) to ensure the quality of qualitative research it is necessary to check the validity and the reliability for it. Reliability can be defined as the consistency with which the results are formed under a similar situation and on the other hand validity refers to the suitability of the measures used to collect the data. Validity defines the ability of the research survey to produce results relevant to the researcher. The structure of the whole thesis is built upon conceptual and qualitative studies, therefore, the validity is of higher degree (Sreejesh et al. 2014). The overall reliability, on the other hand, is on the lower side especially the generalizability regarding another market context (Sreejesh et al. 2014). It is mentioned by Sreejesh et al. (2014) that the quality of the research is affected by various factors including sampling methods, questionnaire design, interviewer qualification and training. Quality also depends on the selected survey method's acquired pros and cons.

To increase the reliability of this master thesis unreliable sources such as Wikipedia and blogs have not been used. Instead almost all articles that has been used in the literature review and theory are peer-reviewed research articles. The conference papers that are used has high credibility since the conference is reputed, researchers from around the world are involved and the people who present the paper has been well established in their research area. Since articles are generally specific to one area, books have been used to get a deeper understanding of the topic.

We have increased the reliability by having semi-structured interviews and trying to do the best to not influence the participants when asking questions. We did have the possibility to ask follow up questions if anything was unclear. By doing that it has both advantages and disadvantages. Advantages includes less misunderstanding between interviewee and interviewers, but it could also influence the participants to answer in a certain way. Another researcher should be able to do the same research and come up with the same conclusion. This thesis also has reliability since data is collected from different projects and the interviews were recorded to not miss out important information. If the right method has been chosen to collect data and if the data is relevant to the study validity has been achieved (Saunders et al. 2016). Saunders et al. (2016) also describes external and internal validity. Since Lean is a broad subject, focus towards the Last Planner system was made to be clear on the particular subject. Since the interviews were held in projects within a construction company the interview questions were shown in advance to the supervisor at the company. This was done to confirm

that those questions were understandable for the workers and relevant to ask in order to achieve the required answers for this master thesis.

3.THEORETICAL FRAMEWORK AND LITERATURE REVIEW

3.1 Theory of Production

The primary characteristic of theory of production is that it should be authoritarian which means that it should depict how actions by involved actors contribute to the goals of production (Koskela 1999). The theory of production can serve different functions (Koskela 2000). Firstly, theory of production serves as a theory, where it accounts for processes such as-

- **Explanations** A theory provides answers for the behaviour and incidents in the process and adds up towards process understanding.
- **Prediction** It provides tool to predict future trends and behaviour.
- **Direction** a theory highlights the sources of further improvement.
- **Testing** it is possible to test a theory to assure its validity.

A theory also provides a basis for developing tools for analysis, design and control. It provides a communication framework through which effective employee participation or assistance can be facilitated. Furthermore, it provides a basis of identifying sources of further progress and also serves an instrument of learning. The theory of production is based on three basic ideas which are Design of Production System, Control of Production system and Improvement of Production system (Koskela 2000).

Production involves three goals that are creating the product, focusing on product characteristics such as reduction in process costs and finally meeting the needs related to customers such as quality, dependency and flexibility (Koskela 2000; Koskela et al. 2002). Koskela (2000) pointed out that the construction process lacks the theory of production in general and argued that the theory would include the elements of transformation, process and value. Koskela concluded that in traditional process focus is towards the transformation perspective and less towards process and value generation aspects (Jørgensen and Emmitt 2008). The theories in general are not scientifically tested but if construction industry is considered as a large laboratory, it can be implied that the theories has been tested from the industrial point of view. It is like a paradox where the theories which have been scientifically validated has been used for a long time in the construction industry (Ballard 2000). The existing theories are further discussed .

The theory of transformation was one of the first theories of production which was dominant in the twentieth century (Winch 2006). The transformation theory has evolved from both economic and scientific management approach. One of its main functions is in detailed planning where the work is divided in to a series of tasks (Winch 2006). The idea behind the transformation theory was simple as it just involved converting input to output. The transformation theory has provided various economic approaches which are used till date but with passage of time this theory started showing problems as the projects started getting complex. One of the major deficiencies in the transformation theory of production is that it does not acquire customer requirements in the process. Even though the transformation theory is beneficial in discovering the tasks required for the production process, it proves inefficient in estimating waste reduction potential from the construction flow. Therefore, conventional project management with time became feeble or ineffective (Koskela 1999; Koskela 2000).

The second view towards the theory of production is the production of flow. This theory emerged in the dawn of automobile industry in 1940s in Japan, firstly for the production of war machinery and then in Toyota Production System. From the analysis of workflow in the transformation concept it is observed that the materials take little time in actually being transformed and most of the time goes in waiting for its transformation, movement, inspection and controlling. The theory was developed in a view of reducing the manufacturing time as a whole by focusing and optimising flow. The basic principle in production of flow focuses on waste elimination in the process and promote reduction in variability, construction lead time and process complications (Koskela 1999; Koskela 2000).

The third theory of production was developed during 1930s and is known as the theory of value generation. This theory mainly focuses on the value generation for the customers. The framework for this theory was continuously refined by involving continuous improvement in the process. The continuous improvement requirements are obtained by research viewpoint or learning from practical application (Koskela 2000; Koskela et al. 2002).

The theory of production mentioned above do not represent any alternate theory rather than it provides a complementary view on project management. The theory of production and its tools are the ways to integrate the theories of transformation, flow and value together to optimize process and unify concepts. The unification of transformation, flow and value theories is called TFV theory. The unification can be achieved by modelling, structuring, controlling and improving production with the TFV theory combined (Koskela 2000).

3.2 Lean Production

The Japanese manufacturing techniques have been used for more than three decades and are considered as part of the new production system, known as Lean production. Lean has both production and service systems thus the construction industry has adopted it for improving its own performance. The Lean concept comprises of several principles of production systems which were derived from the Toyota Production System such as an effective relationship between the value chain, continuous improvement, waste minimization, acceptance to change, just in time and quality from the beginning (Salem et al. 2006). Lean production is either described from a philosophical perspective related to principles and goals (Womack and Jones 1997) or from the practical perspective which involves management practices, tools and techniques (Shah and Ward 2007). In the Lean approach, waste is considered as something which does not contribute to value generation. Waste is defined in terms of performance criteria of a production system for example failure in meeting client's requirements, overproduction, defective production, idle inventory, movement of material, processing, waiting and transportation (Howell 1999). Shah and Ward (2007) mentions that one of the primary causes of waste generation is holding inventories to mitigate the effects of variation in supply, processing time and demand. It is further mentioned that to cut down inventories, the firms have to manage the variability in processing time, supply and demand. To capture many faces of Lean production Shah and Ward (2007) proposed the following definition:

"Lean production is an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability." pp 719

The lean strategy defines multidimensional criteria that focus on constant improvement of processes and demotes sub-optimization for it. The main reason for implementing lean

production is to increase productivity, enhance quality, shorten lead times, reduce cost and achieve efficient production control. The described factors indicate the performance of a lean production system. The determinants of lean production are actions taken, principles implemented and changes made to the organization (Howell 1999). Since the Lean applicability is not defined Pettersen (2009) argues that there are existing concepts that cover Lean principles such as Just in Time concept, resource reduction, standardization, scientific management techniques and defect control.

3.2.1 Lean Principles

The Lean production incorporates the Lean principles to provide a framework for understanding the implementation in the production. It is highlighted in the study by Mossman (2009) that waste elimination is a subset of the Lean approach. The basic outline of the Lean approach focuses on instant custom product delivery with no existing intermediate inventory. In the research of Womack and Jones (1997) and Pettersen (2009), they mention five distinct principles referred to as Lean principles.

These principles depict the physical aspects of the production process where the first principle is to identify and deliver value for the customers and eliminate waste. In the Lean approach, the first principle says that the value is defined from the client or customer's point of view. Moving on, the second principle of Lean thinking includes organization of continuous flow in the production, information and components in the value stream. The aim is to eliminate batches in the production and perfecting the product by creating a reliable flow. In Lean production it is necessary to establish a value stream (Pettersen 2009). The third principle emphasizes on the generation of value stream which depicts the activities that generate value to the production system. The aim is to reach maximum productivity by maintaining the flow of information, products, and components. To deliver product to customers on time without creating inventories. The fourth principle involves production with pull planning. Lean production follows a pull system rather than push. It means that production only takes place when there is customer demand. Also, the quantity produced is equivalent to the quantity demanded by the customer to reduce the inventories. In the push system, the plan is pushed towards a realization of a goal. But in reality, Sacks et al. (2010) mentions that the production system follows both a push and pull system and a correct method has to be chosen according to the situation. The final principle in lean production is achieving constant improvement and to focus on perfection. With the aim of perfection, the waste can be eliminated whilst value-adding activities can be added to value stream.

3.2.2 Waste Reduction

One of the basic principles of Lean production philosophy is based on the first principle of the Toyota Production System (TPS), which is cost reduction. The cost reduction is mainly achieved through the elimination of waste. Waste is described as something that does not add value to the product and something for which the client and customer not willing to pay for (Karlsson and Åhlström 1996). One of the most common sources of waste, as mentioned by Karlsson and Åhlström (1996), is creating and sustaining inventory. Creation of inventory creates additional work and activities which proves wasteful thus decrease productivity. However, elimination of inventory is not advisable rather the sources that create inventories are encouraged to be removed. The inventory sizes can be reduced by taking measures like reduction in lot sizes by increasing flexibility and decreasing set-up times. Reduction in lot sizes will cause deliveries in smaller quantities and increase the importance of set-up times

during the deliveries (Karlsson and Åhlström 1996; Koskela et al. 2002). Through previous planning, the set-up times can be reduced from several hours to minutes. Thus, a reduction in set-up time makes it possible to maintain smaller lots thus pushes waste minimization (Koskela et al. 2002). Furthermore, reduction in transportation in the manufacturing process. This means that the production process should only be focused on the transportation of components from the factory to the site and avoid any form of movement of the component in the factory. Also, the reduction in defects and reworks is yet another factor that can contribute to waste elimination (Koskela et al. 2002).

3.2.3 Continuous Improvement

Continuous improvement of the process is one of the fundamental principles for Lean production. Earlier the Toyota production introduced Kaizen which means continuous strive for perfection. This terminology has gained popularity around the world. Later on, the English translation for Kaizen came out to be an improvement of the process including everyone. The involvement of everyone in the value stream of process pushed the management to improve quality circles. Quality circles is a process where different actors gather and discuss the suggestions for possible improvements. The suggestions from employees are encouraged and are processed yearly. The implementation of suggestions depends on the organizational structure of the company. Along with the implementation of suggestions, employee rewards and feedback are yet other techniques to achieve improvement (Karlsson and Åhlström 1996; Salem et al. 2006).

3.2.4 Zero Defects

To achieve higher productivity, quality is a key element in the production system as all parts of the system should be fault free. In order to achieve higher quality, it is necessary for an organization to achieve better process control. This process control can be achieved through better knowledge management of the process. Thus, instead of emphasizing on defect control on singular units, the process is kept under control by discovering the errors that can lead to defects. For defect identification, it is required to have dedicated personnel in the quality control department (Karlsson and Åhlström 1996).

3.2.5 Lean manufacturing

Lean manufacturing is a process of combining the capabilities of the workforce with organizational techniques to achieve better results with fewer resources. The goals of Lean manufacturing are determined by Lean principles. Lean approach intents to develop the performance of the production system to meet the unique customer requirements (Salem et al. 2006). The manufacturing processes follow the lean principles defined above. With time several other principles came into the existence which is also applicable to lean construction. One of the most important elements of Lean manufacturing is reduction in variability. The foundational principle to reduce variability is derived from industrial engineering and quality engineering. The focus is given towards reducing variability or liability in the product characteristics according to the quality theory. Also, according to the queuing theory of production coined by Wallace Hopp and Mark Spearman in 1996, the aim is to minimize the temporal variability of flows. The variabilities from both these theories interact in a complex way (Sacks et al. 2010). Variability in supply occurs when the suppliers are unable to deliver the right quantity at the right time or the right place. This variability is reduced by implementing involved supplier base and obtaining regular feedback on quality (Shah and Ward 2007).

Furthermore, reduction in cycle times can be achieved in the process. Cycle time is the time between the start and finish of the work. Reduction in cycle time is directly related to variability reduction. With the consideration of Little's law, (Little and Gravies 2008) which states that the average number of items in queuing is equal to the average waiting time in a system multiplied by the average number of items arriving per unit time makes this principle equivalent to inventory reduction. The reduction of cycle time in the production could be achieved by several levels of analysis on total construction duration, stage of construction, the flow of materials from the factory and tasks (Sacks et al. 2010). Moreover, Lean manufacturing provides an option of workforce flexibility and standardisation. Flexibility in the context here refers to the workstation capability and capacity. With flexibility, the cycle time is reduced and production system activities are simplified (Sacks et al. 2010). Another salient feature towards work organization and improving flexibility in the process is extensive use of multifunctional teams. A multifunctional team consists of a group of individuals who are able to perform multiple tasks. The team's tasks are integrated with the production flow so that the team performs all the task in parallel to product flow. The aim of the multifunctional team is to have the employees in the production system more than one task in the team. The tasks are also rotated in cycles so that the flexibility is increased. This increased flexibility puts less pressure on the production system. Along with flexibility skills, training and competence of employees can be improved (Karlsson and Åhlström 1996). With the standardization of work both temporal and product, feature variability can be minimized and continuous improvements can be made in the process (Sacks et al. 2010). Visual Management is another technique which is related to standardization where visual methods are used to define production, offers access to standards and supports conformity with them. The visual management is closely related to continuous improvement as visualization helps during the design phase and eliminates design changes which constitute waste (Sacks et al. 2010). Focus on concept selection can done during design phase as the process of designing is divided into conceptual and detailed design. As much emphasis is given to detailed design it is also necessary to evaluate and address conceptual design and come up with different concepts (Parrish et al. 2007; Sacks et al. 2010). Finally, Lean manufacturing focuses to cultivate an extended network of partners. This principle is based on the concept that extended partnership should be built, challenged, and helped to improve. In construction projects, the long-term partnerships can be maintained with long term agreements (Sacks et al. 2010).

3.2.6 Effects of Lean on Sustainability

Through the implementation of lean approach in construction process its effectiveness was observed with overall profits, Waste minimization (Womack and Jones 1996; Ballard et al. 2007), and employee safety and welfare (Koskela et al. 2002). Lean strategies have been proven effective in improving the overall sustainability in terms of social, economic, and environmental aspects (Nahmens and Ikuma 2011).

The Social aspect of sustainability aims to improve the human wellbeing throughout the product lifetime. The goal is to enhance worker's performance while minimizing risk towards their health and safety. Safety and Lean go hand in hand when sustainability is considered. Safety regulations in Lean process administer the safety hazard present in each task. Thus, the means of tools and techniques with careful planning leads to risk minimization through the reduction in activities, motion, and required materials. In turn, the probability of occurrence of accidents and hazards gets reduced (Nahmens and Ikuma 2011).

The environmental aspect of lean for sustainability pushes the issue of environmental protection and the elimination of waste. The waste is described as various types such as overproduction, waiting time, transportation and material handling, excessive inventories and storage requirements, unnecessary movement of workers, quality defects and overproduction of items. These lean wastes directly or indirectly contribute to the production of solid waste. Along with the Lean wastes, there are environmental wastes that hinder with productivity. These wastes are consumption of extra energy, consumption of extra water, material waste created from design defects, cost spent on garbage handling, waste constituted through unnecessary transportation of material, emission of pollutants into atmosphere and cost incurred through the destruction of flora and fauna. Lean tools help to reduce all types of waste described above (Nahmens and Ikuma 2011).

The economic aspect of Lean towards sustainability incorporates all the cost incurred in the process. In the traditional construction process, Lean and sustainability had different concepts a lean focused towards improving economic constraints on the other hand sustainability aimed towards improving environmental goals. But with improved construction methods, the two aspects can be joined together (Nahmens and Ikuma 2011). The study by Bae and Kim (2007) showed that the implementation of lean construction tools provides improved economic sustainability by reducing operational cost, upfront costs, resource costs and improving performance capability. Furthermore, Lean implementation leads to reduced number of reworks operation as well as provides a basis of applying continuous improvements.

3.3 Lean Construction

A significant contribution has been made by the International Group for Lean Construction (IGLC) towards the establishment of a theoretical foundation for lean construction by using the core principles of lean production and applying them in construction project management (Salem et al. 2005). In the year 1993, IGLC coined the term Lean Construction and since then it has gained popularity within architecture, engineering and construction industry (Perez and Ghosh 2018). The application of Lean Construction was first discussed by Koskela (1992), which he first referred to as the ‘new production philosophy’. The philosophies of Koskela paved foundation of Lean Construction. In the seventh conference proceedings of IGLC, it was mentioned by Howell (1999) that Lean production approach can be implemented in the construction process. Lean construction originates from the application of the Lean manufacturing approach in the construction process. Lean construction techniques help to minimize non-value adding work to improve the efficiency and effectiveness of the construction process. The research on the applicability of lean production principles in the construction process has been studied since the early 1990s (Salem et al. 2005). To complement Lean construction, Lean principles are followed to achieve the desired goals. In lean construction, the main aim is to optimize all the activities and to identify customer’s value in the design phase. The project is divided into pieces to estimate cost, time and resource requirements and then these pieces are put into the logical sequence to complete each process (Howell 1999). The fundamental difference between lean and traditional approach is presented in Table 3.

To make construction Leaner the work structure of the production control is integrated with the product (infrastructure) design which extends up to the operations performed on materials and information shared within the system. This Lean work structuring differs from the work breakdown structure which is a practice in the traditional project management of the construction (Ballard et al. 2007). Implementation of better design and construction involves

planning and control, by set of people involved in the process. These measures are done at different levels and different times within the project life cycle. The goals and objectives are set at higher levels in organisation and they flow downwards to lower levels in the process as a mean to achieve desired goals (Ballard and Howell 1994).

Table 3: Comparison of lean vs traditional (Koskela et al. 2007)

Lean	**Traditional**
Focus is on the production system	Focus is on transaction and contract
Transformation, Flow and Value goals	Transformation goals
Downstream actors are involved in upstream decisions	Decisions are made sequentially by specialists without the involvement of others
Product and process are designed together	Product design is completed then the production design begins
All product lifecycle stages are considered in design	Not all project life cycle stages are considered in the design phase
All activities take place at last responsible moment	Activities are completed as soon as possible
Efforts are made to reduce lead time in supply chain	Separate organizations link together through the market and take what the market offers
Process of learning is accepted by a firm it its project management	Learning is rarely incorporated in the production process
The interests of stakeholders are aligned	Stakeholders interest are not aligned
Sufficient buffers are provided to reduce variability	Participants create large inventories to protect their own interest

3.4 Production Control

Production control can be described as a sequence of various tasks such as aggregate production planning, material coordination and workload management, work order release and production unit control. Construction industry in general uses different methods and techniques to achieve this goal. Planning involves creation of schedules, budgets and other detailed specifications which has to be followed for project execution. As the production starts the control i.e. monitoring the performance, the corrective measurements become a necessity (Ballard and Howell 1998).

In the production control three processes for planning are involved:
1) Initial planning which provides the detailed plan and budget.
2) Lookahead planning where details, plans and budgets are restructured through pulling resources into play.
3) Commitment planning depicts what actually can be done through the resources available. Through commitment planning the aim is to achieve most detailed plan which shows interdependence between various works in the construction process. The detailed plan is the driving tool of production process. The reliability of the plan is assured through quality assignments and protecting the workflow from any uncertainties rising from upstream actors. After completion, the assignments are reviewed to measure the production performance to improve the process for future references (Ballard and Howell 1998; Ballard 2000). The criteria for project control systems were presented in the work of (Ballard and Howell 1998; Ballard 2000; Thomas et al. 2002). The main criteria are summarised below:

- Creation of sound assignments.
- Measurement and monitoring of the control process
- Investigation and removal of causes that leads to failure.
- Making resources available before the start of activities.
- Maintaining buffer of sound assignments for the production crew.
- Pull techniques are supplemented in the production process.
- Achieving reliable work flow and value through production control
- Decision making is divided in production control system because traditionally the responsibility had a central position where a single mind takes all the decisions.
- Management of variability within the project- In the traditional project management the variability is generally disregarded but construction industry shows different variabilities in the process and ignoring them leads to further problems. Variability often gets created due to buffer in flows and lower resource utilisation

3.5 Last Planner system (LPS)

The Last Planner system, LPS, was developed by Glenn Ballard and Gregory Howell in early 1990s as a system for production control. Production control is a subset of project management which also consist of project controls. Project controls provide a framework to align project scope with targets and monitor progress. It is done by setting cost and schedules. Production control provides the basis to move towards those targets. Both project and production control go hand in hand. With time LPS got improved as more research and validated theories came up with time (Ballard and Tommelein 2016).

A person or group of individuals decide on the physical task that will be done in future and these tasks are called Assignments. The person or group of individuals are called the Last Planner (Ballard and Howell 1994). The goal of assignments in a production unit is to shape physical work. In case of uncertainties like inadequate design information, missing materials or incomplete prerequisite work leads to additional costs. The assignment does not meet the quality requirement and improvement in quality becomes crucial for production control and performance. The term “assignments” pushes the Last Planner to communicate with the designers and construction crew in the most efficient way possible. The information is passed through the words Will, Should, Can and Did (Ballard 2000).

LPS, provides a framework to unify the theory of transformation, flow and value generation in the production process. As discussed before the unification of TFV theory leads to better production control so that the targets can be aligned with the project goals. The Last Planner system incorporates the principles of Lean production control and is a tool that facilitates to look upon variability in the process and shapes the construction workflow. LPS can be considered as a group of individuals who provide operation planning and works towards the stabilization of the process by deciding what Will be done, what Should be done, up to what extent it Can be done and learning from what they Did (Ballard and Howell 1994; Ballard 2000; Ballard and Howell 2003). "Will" depicts the commitment necessary to complete the work with all constraint present in the process. "Should" indicates the work which is required to be done to meet the schedule. "Can" depicts what work can be accomplished with the existing constraints. "Did" depicts the situation of the completed work where the improvements and defects are noted. These techniques are useful for developing methods for work execution, improving communications between trade, matching workflow capacity, shaping work sequence, flow, and rate (Ballard and Howell 1994; Salem et al. 2005).

The main goals in LPS according to (Ballard and Howell 1998; Ballard 2000) are:

- Moving the schedule task for lookahead planning and constraints screening. Advancement to the next stage is only done when all the constraints are highlighted.
- Focusing towards quality task and reject defective task.
- Tracking the percentage of work completed in the process in form of Percent Plan Complete.

LPS operational planning includes improvement of workflow through the structuring of product design. The most important role of LPS is to provide realistic planning in place of optimistic planning by the evaluation of the worker's ability to complete the tasks. With proper team efforts and resource optimization, several non-value adding activities can be pulled through the production process (Ballard 2000). In addition to the benefits it promotes building collaboration and trust between the involved participants or actors in the project which leads to longer employee relationships in the construction industry. Furthermore, the production flow can be made smoother as LPS provides a basis where it makes waste visible as well as ensures the task and material availability. LPS is basically divided in three levels which are long term planning or master plan and phase plan, medium term planning or lookahead plan and short-term planning or weekly work plan. In LPS the commitment is given towards the near term (weekly) tasks usually by the team leader (Ballard et al. 2007).

On the basis of available theories, the tools and methods are invented and can be implemented to various circumstances for example, Plan-Do-check-Act which is implemented to redesign critical tasks. Furthermore, through collaboration pull planning was adopted to establish control in production process. Similarly, the subsets of LPS which are defined below provides a standard language to understand efficient schedule planning techniques and framework. The levels and framework of last planner system is shown in figure 1. The levels are divided as project, phase, process and operation. The master schedule expresses the peculiarities of project and provides a vision to all the people involved in the project. The phase schedule consists of the process which is to be done. The lookahead schedule initially represents the process but as tasks are broken down the lookahead schedule becomes the operation design. Operation design depicts how tasks should be performed and which individual or team should conduct it. The commitment planning involves operations to be done by the management and the workers on the site and finally learning through which the process of continuous improvement can be followed (Ballard and Tommelein 2016).

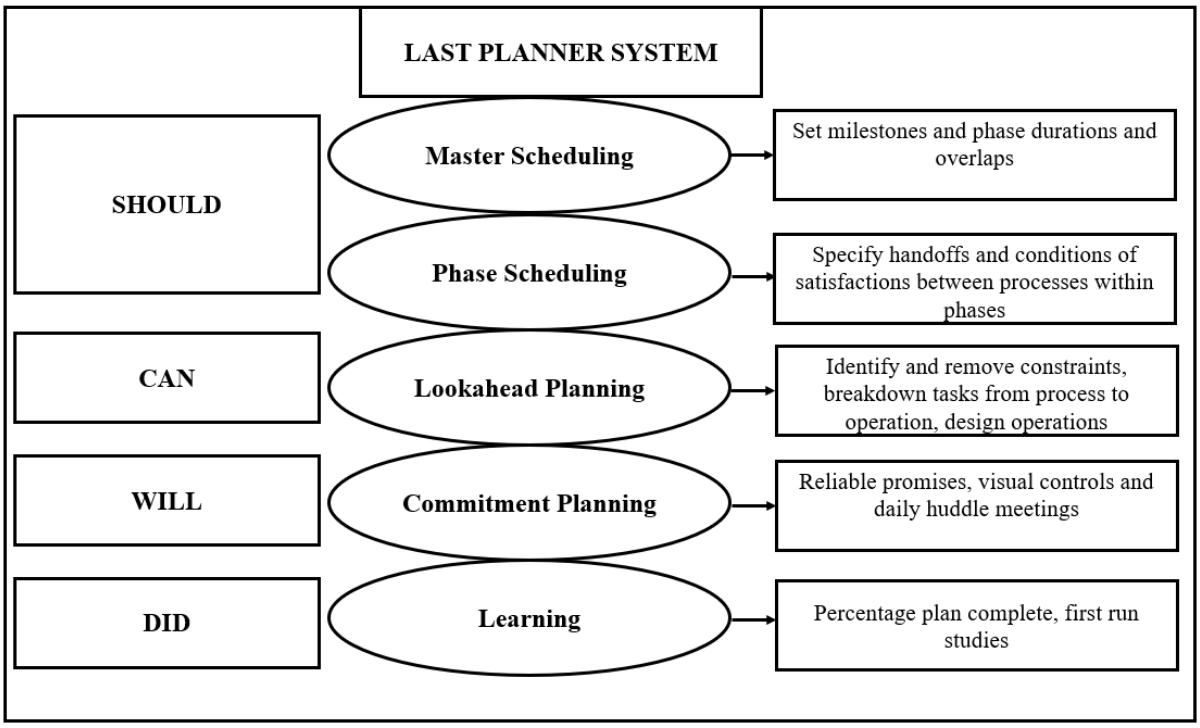

Figure 1: LPS Framework (adapted from Ballard and Tommelein 2016)

The process of LPS which is shown in figure 1 are further described below.

3.5.1 Initial Planning

The process starts with the initial planning where it is decided what should be done in order to complete the project. The two subsets of initial planning are master schedule and phase schedule. The master schedule describes the framework of activities to be carried over entire project duration. Its function mainly involves the identification of overall project activities mostly in relation to contract documents and consideration of all possible milestones and their date of completion. The schedule depicts what tasks have to be completed (Ballard 2000; Salem et al. 2005; Hamzeh et al. 2008). As the milestones are obtained the project is further divided into different phases through phase scheduling. Phase scheduling is a process of collaborative planning which covers each phase of the project for example foundation, structural frame and finish. It is a technique in which a schedule is developed that works backward from the completion date of the project. The team management uses a pull technique and reverse phase scheduling for the development of the schedule. Pull planning is a technique in the Last Planner system to produce coordinated plans for different phases of the project with Lean principles. The sessions of pull planning generally involve all the actors with decision making power as well as those who can provide important information for example safety, logistics, quality etc. Through pull planning key milestones are identified and defined. The primary question which is asked here is how the decided goals for the milestones can be met. Also, the conditions to fully satisfy these milestones are identified as well by creating a description of what to include or exclude from value chain (Ballard and Howell 2003; Ballard and Tommelein 2016). Through reverse phase scheduling (RPS) it is possible to identify and fix the link between work structuring and production control so that a plan can be produced for the integration and coordination of special operations to meet milestones mentioned in the master schedule (Ballard and Howell 2003; Salem et al. 2005).

3.5.2 Lookahead Planning

Furthermore, the lookahead planning provides the estimate of what can be done with the available resources. It is one of the most common method for planning workflow is lookahead schedule (Salem et al. 2005). Lookahead planning gives a detailed estimate for the work that is supposed to be done in the future. Also, lookahead planning provides a link between the master plan or long-term commitment plans and weekly plans or short-term commitment plans (Ballard 1997). The number of weeks for lookahead depends on the activities to be completed. For the design phase, it can vary from three to twelve weeks. All the six-week lookaheads are estimated through reverse phase scheduling to solve the problems before the actual product comes into existence. Lookahead planning is a tool to minimize the uncertainty to achieve constraint-free workflow. Also, after achieving smooth workflow it is necessary to maintain worklog of ready work (Ballard 1997; Ballard and Howell 2003; Salem et al. 2005). To achieve efficient lookahead it is necessary to ensure that the work which should be done by a particular date must be available prior to be performed without any interruptions (Ballard and Tommelein 2016). To ensure this several activities are followed describes following steps-

Constraint Removal - Constraints are physical or informational barriers that hinders with the production process. The responsibility to remove constraints is divided throughout the team instead on a person or a certain group of individuals. However, the timing to identify constraint is a crucial factor. If the constraints are identified in advance (for example early material deliveries), it may prevent the effective execution of work (Ballard 1997; Ballard and Tommelein 2016).

Task Breakdown - This procedure considers breakdown of master schedules into various processes for example phases, process of operations and operations of steps. Usually, the lookahead window in a project is of six weeks in which constraints are identified. These constraints may be applicable for whole process or be applicable in a specific process depending on the level of constraint. In theory the operation of process should start not later than 3 weeks ahead of the scheduled time so that the identified constraints can be removed (Ballard and Tommelein 2016).

Collaborative design - It is a method that describes what steps should be performed in what sequence by which candidate using which tool. This is decided by the last planner who drives the project execution. The last planner designs the operation which involves both upstream and downstream actors (Ballard and Tommelein 2016).

3.5.3 Commitment Planning

Moreover, the commitment planning is done to increase workflow reliability in the project. As mentioned before “Should”, “Can”, and “Will” are key terms in the planning process. Weekly work plan is a product of Lookahead planning which includes safety issues, quality issues, material needs, manpower requirement, report for completed work, construction methods, weekly schedule, and the relationship among team members. Weekly work plan aims to emphasize on the learning process by investigating the uncertainties. These uncertainties are studied through the analysis of variance in the process based on previous Weekly plans (Salem et al. 2005; Ballard and Tommelein 2016). Weekly Work Plans proves to be effective when they follow five quality requirements i.e. definition, soundness, sequence, size and learning (Ballard and Howell 1998). These quality requirements protect production from work flow uncertainties. Failure to meet the quality requirements exposes non-productive delays in the

production unit. Some examples of these non-productive delays are waiting for resources, multiple stops and starts in the project, inefficient construction sequences and reworks. More risk to productivity occurs when there is failure to match labour capacity (Ballard and Howell 1998). According to the workflow reliability is ensured through:
Reliable promises-It is a disciplinary approach towards commitment planning where both the management and foreman interact and ensure that the decided goals are clear to everyone (Ballard and Tommelein 2016).

Visual controls-these controls are required as visual indicators that tells the condition of production process at any period of time and provides an understanding of the necessary actions. The visual cues that are provided are-appropriate measurements, colour coded post it notes, recent information, graphs and charts of the information created through production and software (Ballard and Tommelein 2016).

Daily Huddle Meeting-These are the meetings conducted on a daily basis where the employees describe the progress in the work, the occurring issues, and prevention measures. Daily huddle meetings are efforts towards employee involvement through two-way communication process. This process is also beneficial for employee's job satisfaction as they contribute towards problem-solving and process improvement (Salem et al. 2005; Ballard and Tommelein 2016).

3.5.4 Learning

The methods presented below are methods of process improvement and knowledge gaining (Ballard and Tommelein 2016; Salem et al. 2005). Percent plan complete is a part of metrics to get estimates of the completed activities in the project. Percent plan complete is calculated as the number of planned activities completed divided by the total number of planned activities (Ballard et al. 2007). Increase in PPC leans to increment in productivity. The main causes of project failure are identified and attacked so that future issues can be avoided. The positive slope in the calculation of PPC says that production planning is reliable. The PPC values generally vary between 30 to 70 percent and to achieve more than 70 percent additional lean construction tools like first run studies has to be used (Salem et al. 2005). The second method to implement learning and improve process is through conducting first run studies for the involved activities. First run studies are the mechanism of redesigning critical tasks. This is done to improve productivity and the working methods of the overall process with different functions involved. The critical task selected is thoroughly inspected in detail for which different ideas are analyzed to progress them in alternative ways. PDCA cycle is a technique used to carry first run studies. PDCA stands for Plan, Do, Check, and Act where the process of the plan includes the selection of critical task, assembly of the required workforce, analysis of the process, discussion to eliminate steps, analysis for safety, quality, and productivity. Do implies trying out ideas discussed in the plan. Check refers to the data collection of the ongoing process and act implies setting up communication regarding the performance of the designed process (Salem et al. 2005).

3.6 Challenges with implementation and use of the Last Planner system

The Last Planner system has been the most commonly used lean tool around the world to tackle the problems with the production management. This tool has been used in construction industry for more than twenty years and with time certain challenges were reported in its implementation (Dave et al. 2015; Perez and Ghosh 2018).

Porwal et al. (2010) conducted literature survey on the implementation of LPS and highlighted that challenges can be categorised as implementation challenges and user challenges. The implementation challenges include the absence of training, failure of commitment from management, resistance towards adopting change, missing support from stakeholders, partial implementation of LPS and problems in contractual structure. On the other hand, the user challenges involved issues such as lack of understanding of new system, lack of motivation towards accepting LPS as a method, lack of efficient collaboration, additional administrative or paper work and long-time duration in approval of procedures. In the research conducted by Friblick et al. (2009), in the Swedish construction industry it was found that involvement of downstream actors like site workers in planning process is an issue and effectiveness of collaborative planning is not up to a sufficient standard. Furthermore, Koskenvesa and Koskela (2012) conducted case study in Finnish construction industry where they found that there is a similar challenge of collaborative planning with the implementation of LPS. According to a literature survey of Brady et al. (2011), unsteady communication, lack of involvement of construction foreman, lack of time for continuous improvements, lack of training and lack of collaboration are most highlighted challenges towards the full implementation of LPS. The survey study by Fernandez-Solis et al. (2012) also suggested that lack of training among workers is one of the main issues of ineffective implementation of LPS. Along with that absence of effective leadership, resistance towards change from organization, issues with contracts were some of the most occurring challenges. Their study specified challenges for senior and mid-level managers in the organisation which mostly focused on better implementation of the process. Furthermore, the study by Daniel et al. (2015) showed that even though the industries have adopted many aspects of the last planner system, still the practice of learning and improvements are not implemented in full potential. The study by Dave et al. (2015), highlighted several challenges which are failure in implementing collaboration, reduction in the importance of master schedule and phase plan, non-implementation of continuous improvements and missing connection between master plans and weekly plans. Also, they define that keeping updated with changing technology is not implied in organisations. They further mention that even though the weekly planning is the most widely implemented process in production planning, the implementation of continuous improvement, constraint analysis and collaboration with actors still remains a challenge while working with LPS. Perez and Ghosh (2018) in their case study about a firm transitioning from traditional planning to the last planner system highlighted the challenges faced by them. The most common challenges were incomplete root cause analysis for non-completion of tasks, difficulty in creating lookahead plans, lack of standard framework to update the master schedule after introducing design changes and missing structured approach to introduce LPS on site.

3.7 Improvement Measurements for LPS

As the production planning and control of the company is based on the Last Planner system, the suggested framework for that should be tailored in all forms. It is discussed before that there are various challenges while implementing and practicing LPS but several studies were conducted by (Goh and Richards 1997; Ballard et al. 2007; Hamzeh 2009; Hamzeh 2011; Ballard and Tommelein 2016) which provided framework for overcoming the barriers faced during the practice and implementation of LPS.

In the recommended framework it is suggested to develop a strategic planning from the start of the projects in order to increase the effectiveness of production planning and control. Moreover, the commitment from the top management and stakeholders is required at all levels of production planning, as it is necessary to implement changes. Moving on, it is mentioned in

the study by Hamzeh (2009) that establishment of cross functional teams are an essential component in order to achieve improvement in the production planning which are practicing or are influenced by LPS. These teams should be responsible in identifying hurdles, training needs, goals, and necessary requirements in both planning and production. Also, these teams should directly be involved with the front-line managers to apply changes in faster way. Furthermore, it is suggested to map the ongoing planning process to visualise the failures as well as opportunities in the planning process. As the map is developed the nucleus teams should set both short- and long-term goals for production planning so that the involved actors have clear plan of their jobs, get the idea of work performed by them. Moreover, the development of a standard procedure of collaborative schedule should be devised. This standard should contain process of master schedule to weekly plans, contents of schedule, update of schedules as well as learning measures. As the standard is developed the next step involves identification of barriers and opportunities in implementing the production planning and control. The nucleus teams are also responsible for the training programs for the individuals involved in both planning and control of production process. The main idea behind the training program is to make people realise the usefulness and necessities of the way of production planning in order to meet the desired goals. Also, the trainees should be provided with actual experience by involving them in pilot projects where the full implementation of LPS is practiced. Finally, the improvement framework suggests initiation of the culture of continuous learning in the organisation which aids and encourages experimentation, acknowledgement of failure, innovation and willingness to take risks.

The study by Brady et al. (2011) also suggests some improvement measurements to mitigate the challenges which come up with practice and implementation of LPS. The previous case studies (Alarcón et al. 2005; Friblick et al 2009) revealed that involvement of construction workers in planning process and communication barriers has been an issue for a long time. Brady et al. (2011) suggested for involvement of construction workers visualisation of work at site is a useful technique. Through this method the small intricacies about project site can be collected by the site workers so that their involvement can be increased and the communication can be improved. Furthermore, practice of visual management is suggested as much as possible. With display of process available on site all the involved actors can get a clear picture of progress and planned work. Also, the information gathered through the visual management can be used to measure the performance and identifying reasons for hindrances in workflow. With visual management a learning effect can be instigated by showing corrective actions on processes which showed problems. A suggestion for adequate preparation of planning and control process is suggested where the roles and responsibilities should be cleared to all the involved actors. The important question asked in this process are Who is associated in successful implementation of production planning? Who should be present in the meetings? and What process should be followed in particular project? As required members are involved in necessary meetings, an integration of whole production chain (i.e. clients, suppliers and subcontractors) is suggested. Visual management is an important aspect to convey necessary information to clients and subcontractors who are not involved in the detailed process planning (Brady et al. 2011). The study by Macomber et al. (2005) suggests that breakdown in production process due to noncompliance of reliable promises is inevitable. They mention that one can only think how to make the best out of the situation when promises are not met. Their study suggested three steps in order to act upon failing commitment and promises. Firstly, they suggest conducting practice of continuously updating the commitment and promises made and declaring them complete when they are fulfilled. The second practice involves putting attention on special and outstanding commitments and promises and act on providing prerequisites to

complete them. Finally, in case of breakdown of commitment, compensating measures should be suggested so that something beneficial can be adopted from that situation.

Based on this exploration of the theoretical grounds for Lean and for the tool Last Planner system as well as the existing literature, we have identified a clear gap in existing knowledge on the implementation of LPS. There is a lack of research that includes the downstream actors while using LPS and the literature also lacks studies that highlights challenges and possible improvements of implemented LPS. The present study is an attempt to overcome this lack of knowledge by exploring two cases: two constructions projects in Stockholm, Sweden.

4. RESULTS

In this section results from a video call with Glenn Ballard, one of the founders of the Last Planner system will be presented in the beginning. This is done in order to present the first hand information from the creator of LPS. The interview with Ballard gives an insight of how the concept of LPS came into existence and what are the various issues still present in the construction industry. Ballard also mentioned various process to improve the workability with LPS. Furthermore, in this section the results from respondents, that is presented in section 2.4.4 in Table 1 and Table 2, from project A and B will be presented separately. The results involve the answers of the respondents on the production planning for the two projects and the challenges they face during the overall process. From these findings the analysis of the study will be conducted and the interview with Ballard will be used to increase the reliability of the answers in discussion and conclusion.

4.1 Interview with Glenn Ballard

Ballard started to work as a craft worker in construction industry and got experience of failure of production planning. He got inspired to develop a system that can make the production planning more efficient. Ballard mentioned that when he was working as a craftworker, there was failure to engage people who is actually doing the work. The upstream actors did not know how to involve more actors. The projects were missing out possibilities to make the planning better. The basic problem was that managers were just making assumptions. They assumed that what *should* be done, *can* be done, which proved to be wrong. Work tasks needed to be prepared in advance and it needed to have a plan. The lookahead planning, an element in the LPS framework, should be done to be able to realise what actually can be done. However, a project can have perfect Percent plan complete, PPC, and yet there is a possibility that the project not complete in time. The production is then protected but the project is not done in time. The contractor has a desire to achieve both. That is how Ballard came up with lookahead planning. To involve more actors in the planning will make more actors motivated and the final check in the production system will be improved. If the project plan in advance how a certain task *should* be done, it will not be a problem to actually *do* it:

"If people are committed, they will do what they promised, give them that opportunity" – Ballard.

The project need have to have a design plan i.e. a plan from the projects end to the beginning and have reliable promises which will increase the customers reliability towards the contractor. Collaboration is important between the different actors that is involved in the project, for example contractor and sub-contractor etc. Ballard expressed that people within projects are not aware of what they are able to do according to what they have committed to do in a week. Furthermore, he explained that it is important to know this because it is only then they would be able to make a better plan about what they can do, and this is how Ballard came up with the concept of commitment planning. Also, according to him the learning process is the most crucial element in the LPS framework through which continuous improvement can be implemented in the organisation and overall process can be made better. The production planning and control can be made better if organisation incorporates learning in the process. By using methods like first run studies or root cause analysis for the defects, effective increase in the percentage plan complete can be observed. With involvement of learning process organisations could achieve PPC between 30% to 70%, but with more organised learning process PPC up to 80% to 90% can be achieved.

4.2 Background of LPS in the construction company

According to the managers, project planning and financial control have been handled as two separate processes. They further mention that integrating these processes is an important key to actively managing the projects and creating a predictable production where the company can identify problems and opportunities early on and create a space for action. One of the main aims of the adoption of production planning from LPS is to simplify and improve governance in projects. Moreover, to capture all the phases in the process, from an overview of the whole project to daily planning at the workplace. The master schedule was created at the beginning of the projects with an aim to determine the overall structure of the projects and to ensure that the management of design, purchasing and production takes place on the basis of a clear overall picture. Furthermore, through phase planning the management creates an understanding of the activities of different actors and reach a consensus on how production should be conducted during the current period. One important aspect is to take advantage of the participant's knowledge and to allow for self-determination within given frameworks. Moreover, the managers and site supervisors mentioned that through lookahead and commitment planning the purpose was to disseminate important information, tune the production schedule, and plan and coordinate the upcoming activities. The planning of the weekly meeting can be designed in several different ways depending on the nature and size of the project. Also, according to them, the downstream actors obtained a clearer picture of their own work in the upcoming days.

4.3 Project A

4.3.1 Master schedule

According to the managers project A started with a master schedule which covers the time plan and initial plans for design, manufacturing and installations. According to them the master schedule includes the critical tasks for the project which are obtained through a Gantt chart. When establishing the master schedule, cost calculations were done for all the involved activities and the timeline as well as the main milestones were created. Milestones were set by creating a critical path through work breakdown structure. Managers, client and installation leaders were involved in the planning for the master schedule. It was also suggested by the managers that subcontractors, supervisors and workers should be involved in the master schedule.

All the respondents were aware that a master schedule was made before the production started. However, not everyone was aware of the content of the master schedule, for example, the milestones. The managers expressed a desire to involve actors that were not aware of the content of the milestones by having an introduction about the project's milestones to every new actor that entered into the project. Furthermore, the design manager expressed that it is positive to involve a few construction workers in the initial planning stage since they have practical work experience and can give inputs of the duration of time for certain tasks. But he also mentioned that it is equally important to involve people who has the power to make decisions, because that will decrease the time for making the initial plan:

"*More people should be involved in the initial stage, but it has to be the right people - the people with power to make decisions." (Respondent 3, Design manager)*

The desire to involve more actors was there but the managers did not know how to do it and how to improve the communication. The construction workers did not know what the

milestones were and according to them it would be good if they had an overview of the project. They did not feel involved in any planning stage but wished to be involved in the production planning. They wanted to feel that their voice is heard but did not perceive that this was the case.

The management try to increase motivation and participation by celebrating small victories such as completion of milestones or overcoming problems in critical tasks. According to the managers the intent of the celebration was to involve actors. The managers felt that with small celebrations all the actors, especially construction workers, can be gathered at one place and important information can be conveyed to a larger group of people. The project manager added that through this activity the information regarding the progress in the projects can also be communicated to all the involved actors:

"We try to increase the motivation of workers by giving them surprises for their efforts like last week we had ice creams for everyone." (Respondent 1, Project manager)

The project had many different phases and every phase was allotted a three-week period:

"You can't have too many weeks in a phase plan, it will be hard for everyone to understand and remember." (Respondent 1, Project manager)

4.3.2 Phase Planning

According to the managers, the project was divided into production phases, for example, roof completion and external façade. The managers further mention that, as knowledge of phases were obtained the project manager and site manager created a detailed phase schedule with reverse phase planning. This provided an estimate of start and finish dates of the phases and a basis to identify the material, resources and labour requirements. The phase plan also included logistics and storage plans. Thus, the logistics manager, safety manager and the subcontractors who were involved during specific phases were involved in the phase plan meetings. The main purpose of the phase plan was to get a realistic view of the time plan and an idea for the assignments. Pull planning was yet another technique which played a main role to remove unnecessary activities. During the phase planning the different actors who were involved put up post-it-notes on a wall to show where they were working and when, which gave everyone a clear picture of the following three weeks:

"In week three they should have started with the next phase, in a perfect world." (Respondent 1, Project manager)

According to the managers the visual tools gave knowledge of any collisions and what needed to be done from one actor so that the next actor could do their work at the same place on the construction site. By involving actors, it gives them knowledge of why something needs to be done on agreed time:

"To communicate with everyone, make them feel that they are a part of the planning, making them feel important, that their work is good for the final product is a very important part to create a good flow for the whole process, it will give better result. But in Sweden we think we are clear when we speak to each other, but I don't think we are, we are too afraid for setting demands." (Respondent 1, Project manager)

Furthermore, the site manager and site supervisor mention that each team of construction workers have a team leader, or representative who participated in the phase plan meetings and then inform the construction workers of what has to be done. It would have not been possible for all workers to participate in the phase planning since they are too many in numbers on site.

4.3.3 Lookahead Planning

According to the respondents there was no additional meeting for a lookahead meeting, it was done in the phase planning. Which means it was done every third week. When a project has a good planning, it makes the construction workers more motivated to plan ahead too. By having a good plan, the construction workers will, for example, know that every Thursday concrete will coming, and they plan after that:

"We have milestones in our head for our own work and plan ahead as much as we can. But sometimes it feels like it does not matter how much planning you have, it will not go as planned anyway. Today we are ten guys working on the same task tomorrow it might be three. That is a main reason why I sometimes just do not care about planning too much and take each day as it comes." (Respondent 7, Construction worker)

In this project, according to the managers, supervisors and the construction workers, the main emphasis was given towards making the resources available prior to the starting date of the tasks. The managers mentioned that tasks and activities were broken down to get the idea of smaller activities which were to be completed in order to complete the main task. Also, identification and removal of risk and safety measures were done so that production flow can be made better.

4.3.4 Commitment planning

To ensure the work flow, the method used was weekly planning. As the starting date approach or as the work started, weekly progress meetings were conducted. These meetings involve visual aids like charts, schedules, graphs and detailed drawings to convey information to the site supervisors, subcontractors and the workers. The site managers were responsible for conducting the weekly meetings and providing necessary updates to ensure safety and quality of the project. The site manager included the subcontractors who had to perform the task on the following week and assign the tasks and timing which was decided in phase and lookahead planning. Also, the leader of construction workers was present in weekly meetings so that he can communicate the plans and decisions to his team of construction workers. The logistic manager was involved in the weekly meetings to plan the material deliveries, transportation schedule and storage plans.

The daily meetings were conducted where supervisor and site workers were involved to discuss the work tasks of the day, workers safety issues and logistics planning. Since this project was aiming to reach LEED Platinum certification it was very important to eliminate as much waste as possible and also to sort it right. On the daily meetings the logistic manager reminds the construction workers and subcontractors of how and where to throw waste. There was a list with instructions above the bin that explains how to sort different materials and where to put them. Since there were many different construction workers from different countries on the site, there were a QR code they could scan to be able to read the instruction in their language. If any construction workers or subcontractors throw the waste in a wrong bin, they would have to sort it out before the trucks come and take the bins.

In the daily meetings site supervisors described specific project part which had to be worked on and also described the roles of individual as well as teams of construction workers:

"It is a good thought to have daily meeting every morning at 7 am. To have this every morning workers do not care in advance! By having a site supervisor telling the construction workers what to do every morning, every day will make the workers, to not think about planning. I think it is destructive. Have good planning, follow it, understand what to do this week/next week." (Respondent 2, Site manager)

Even though the LPS framework suggest numerous benefits of daily meetings, the response of the site manager contradicts with the LPS framework. The site manager thinks that the workers get dependent on the meetings and do not think about future planning on their own.

Moreover, the construction workers mentioned that they knew that a site supervisor was going to have a meeting with them every morning, to tell them what to do that day, and to motivate them to plan ahead. They further added that the construction company decided that their construction workers, i.e. not subcontractors, must have a work out session in the morning with an aim of decreasing injuries:

"We start every morning by having a workout section on site to wake up the body and it is very nice because it also makes us feel like a team." (Respondent 7, Construction worker)

4.3.5 Learning

The learning process was missing from the production planning method. All the respondents confirmed that learning process takes a lot of time and limited time is a big issue. Therefore, as the phase gets finished the next task was started without any review on the previous work:

"All the calculations are done roughly and mostly in mind and no record is made." (Respondent 1, Project manager)

According to the project manager the learning process is beneficial in the projects which were similar and repeating in nature like student accommodations. On the other hand, in a complex project like this one he mentions that the scope of implementing learning was difficult. The process of learning was not present, but improvements were done based on experience according to the respondents.

4.3.6 Experience with production planning

The planning method was useful in widening the horizon of planning and provides better ways to deal with the uncertainties and risks. The involved actors felt more valuable as their opinions were heard and considered. Furthermore, through phase planning very precise planning could be done for the tasks which would take place three weeks in the future:

"Our planning process has improved the information and communication flow throughout the value stream. Also, with involvement of visual tools, all the involved actors get an idea of what they are working on, which previously was a challenge." (Respondent 3, Design manager)

The managers mentioned that the tasks can be broken down to the smallest detail and uncertainties in logistics can be controlled which was not possible with the traditional planning method.

By using the visual tools in the phase planning and weekly planning, the process become effective since everyone started visualising and understanding the process. The downstream actors such as site workers and site supervisors were clearer on the reasons for why they were performing a specific task. Actors were updated with their responsibilities prior to the task so that they can do early preparation and planning. With this method they can finish the work earlier than planned which was not possible with other planning method.

4.3.7 Challenges with LPS

According to the managers numerous changes in the design plan occurred because the client changed their mind of what they wanted many times. That made previous design planning useless and forced designers and production planners to redesign planning again, in which time, cost and efforts was wasted:

"The client often change their mind and we have to do whatever they want because they are the one who is providing money." (Respondent 1, Project manager).

It was necessary to involve all the subcontractors in planning meetings. The establishment of effective collaboration with subcontractors often fails according to the managers and site supervisor. According to the managers this is a normal case where the subcontractors were not familiar with the planning process in the company and their involvement in planning process becomes difficult:

"We are still struggling to figure out how subcontractors can be involved in planning process effectively." (Respondent 2, Site manager)

The managers mentioned that the involvement of actors in effective way was not possible. The management was not aware of the procedure of how to involve right and required number of actors at different levels into the initial production planning. Due to that there were several people who did not get the necessary information which they were supposed to have:

"Participation of construction workers is not effective in our project." (Respondent 4, Installation leader)

"We try to involve everyone on the site, for the best communication but if too many people are involved it's too many chefs for one dish and if several people are involved then important information do not reach to the people who are supposed to do the work i.e. construction workers." (Respondent 5, Logistic manager)

According to the managers striving for continuous improvement should be the aim in production planning and not applying continuous improvement in the planning process is a huge issue. While following LPS, learning or improvement measures are not considered in the process by the management and the reason for that according to the managers is due to non-availability of enough time:

"If we do proper planning, we can provide ourselves extra time where we can reflect on learning but unfortunately it's not the case." (Respondent 4, Installation leader)

According to the project manager and site manager an efficient communication is very important factor in construction industry but the language barrier on the construction site is a big problem in this project. According to him as some construction workers were from different

countries the problem of language barrier were common. Due to weak grasp on Swedish and English, misinterpretation of information happens which ultimately leads to wrong decisions on site. Also, he adds that the goals and vision cannot be conveyed effectively:

"Language barrier among the construction workers is an issue which we face on regular basis." (Respondent 6, Site supervisor)

Furthermore, the production process was heavily affected when there was unavailability of material on time according to the logistic manager. He further mentions that the uncertainties in material deliveries were very common and had to be tackled on day to day basis. This according to him reduces the efficiency on site and waste huge amount of labour time in waiting. The purpose of whole planning process was to eliminate the activities which leads to any type of waste but still this is a recurring issue according to the managers, site supervisors and construction workers:

"No matter how much preplanning you do to make smooth material deliveries, problems still occur." (Respondent 5, Logistic manager)

"We waste lot of time in waiting for material deliveries and the activities which we planned for the day is wasted." (Respondent 8, Construction worker)

The project manager and site manager states that some actors that were involved in the project did not show strong commitment and dedication towards the project goals were lacking, which contribute towards reduction in productivity. When the managers and supervisors want to implement new ideas to make the production more efficient, they felt resistance towards those changes from the construction workers. According to the construction workers, they have been working in the same way for many years and do not understand why a new method of working should be better:

"I believe for effective implementation of planning, commitment towards the project goals is necessary which is not shown by everyone in this project." (Respondent 1, Project manager)

"We have a conservative thinking and are scared to death for changes." (Respondent 7, Construction worker)

According to the managers, for this project the site workers were less involved in the decision-making process. Moreover, the construction workers felt that they were included in very later stages of the process and the information conveyed to them were through verbal communication only thus, it makes it hard for them to get the idea of the master plan:

"If we are involved in the early stage, we can get a clear picture of what we are working on." (Respondent 8, Construction worker)

4.4 Project B

4.4.1 Master schedule

In this project it is the construction company's managers who are involved in the creation of the master schedule. They did all calculations for activities and created a critical path of involved activities in order to set the milestones for the whole project. However, for detailed planning, the sub-contractors and site supervisor were involved. The important part while creating the master schedule was to get an idea of the timeline of the whole project. When creating the time plan it was important to know what tasks had to be done before the next task was going to start. This was done to be able to set milestones that can make the whole project flow. The milestones were clear to everyone in the project from the beginning but during the production process some changes were made. When changes were made which affect the whole project, i.e. the master schedule, it was important that it was updated so the production time schedule also gets updated. But updates were not made, and the production team continued to work on the old time plan:

"When I first started in this project I got introduced of the master schedule and the milestones, but it has gone up and down. We work a little and then changes are made, I don't know what it is happening in the end, I just have the old plan." (Respondent 14, Construction worker)

The construction workers were aware of the milestones since the managers and supervisors explained it to them at the beginning of the project. New actors come and go in projects, and it was important that they got introduced of the project's milestones. The managers introduced the master schedule and safety rules to all new actors that started working in the project.

The project management in this project workred toward the upliftment of worker motivation by getting the team together and celebrating the success they achieve during the project:

"We get everyone in the project together and celebrate by getting cake where the whole team from management to site workers can enjoy the occasion" (Respondent 9, Project manager)

4.4.2 Phase planning

The phase planning was based on the milestones which were created in the master planning. Meetings were held once a month and involved a representative from each of the different teams that worked on the site. During the phase planning different coloured post-it-notes were used to describe where and when someone is working, with an aim of avoiding collisions and adjust so that everyone can work without being interrupted by someone else. The different colours were used for different actors. They divide the planning week by week. The subcontractors provided their time schedule for each phase which was created, so that material deliveries can be planned. During the phase planning they did not do any planning. It is only to verify the work, to see that the teams can do their work at the decided time:

"Often phase meetings are misunderstood to be planning meetings but these are conducted to verify the planning and divide the responsibilities." (Respondent 10, Site manager)

The construction workers were not involved in the phase planning, but they have a colleague who are their representative, team leader, who informed their team on the site about what was said during the meeting:

"Involving too many actors at once creates complexity and the decision-making process becomes difficult and consumes a lot of time." (Respondent 10, Site manager)

The ones who were present during the phase planning have a responsibility to pass on the information they get during the meeting to their team on site. If that person, for any reason, does not show up to the meeting, the people on site will not get the information that was said during the meeting. The project does not have a structure to see if anyone was missing from the meeting to be able to inform the team on the site.

4.4.3 Lookahead planning

The managers and site supervisor planned for the future tasks in the phase planning and the weekly meetings, i.e. every week and every fourth week. The phase planning was done to verify what was going to happen the following month. Every meeting starts with a discussion about safety and if there is anything that needs to be highlighted to every involved actor. In the weekly meetings the involved actors started to look at the previous week's work to find out what was accomplished and what was not. When a site supervisor gives a task to the construction worker they usually do not rely that it is going to work. The construction workers usually have longer work experience than their site supervisor. The construction workers take the task and give it a thought before they do something in practice. They made their own plan of how they were going to do a specific task and always think of the third party:

"We can not just take a task and go and work as the supervisor said because if we see some risk from early stage it is better that we say it and can, hopefully, make a better plan together with our supervisor. Sometimes the supervisor is humble and does come to us and ask for advice before he does a plan for a certain task, which we really appreciate." (Respondent 14, Construction worker)

Because of their long work experience the construction workers believe that they can contribute in the planning stage for certain work task. Risk that the site supervisor might not see the construction workers might, and they have a better knowledge of how long time a certain work task takes. Sometimes, construction workers have gotten involved in the planning stage and they really appreciate it, they felt that they were involved and important actors that can affect the production.

4.4.4 Commitment Planning

The method of weekly meetings was conducted in their planning process. One day per week site manager, site supervisors, subcontractors team leader and the construction worker's team leader were gathered in the office. During this weekly plan the tasks that were made in the phase plan is discussed and all actors who were involved in the meeting specify their requirements. A drawing was shown on a screen where all actors went up and wrote where they were going to work a week ahead. All the team leaders were supposed to go out on the site and spread out the information to their team, so they also got aware of where they are, and others are working the coming week. The construction leader also receives the construction workers ideas and brings them to the weekly meeting:

"Every team leader is supposed to spread out the information that was being said on the meeting, but I know that is not the case." (Respondent 15, Construction worker)

When a team leader has missed the meeting for any reason the construction workers is missing the information. There is no one else that takes the team leaders role to spread out what was being said during the meeting to the team on site.

Daily meetings took place in an unstructured way. The site supervisor went out to the site some days per week and some days he did not. It is a large project, a daily meeting with everyone involved on the site would not be preferable. There was be too much unnecessary information, too much that does not concern everybody. The information that was necessary was given out on the weekly meeting:

"*You can't give out too heavy or too much information to the workers, you have to find a balance." (Respondent 15, Construction worker)*

Site supervisors were having a short meeting on site with the leaders of the different teams every day to make sure, that they have the material they need and if someone is sick or not present on work:

"The supervisors are too busy with having meeting and they don't have time for us who should be their priority. If I need to ask something they must be able to answer because if they can't, it will affect the whole project since I may just stand still and not know how to do something." (Respondent 14, Construction worker)

The construction workers felt that the supervisors were not on the site as much as they should, and they were not contactable even if the construction workers went into the office.

4.4.5 Learning

For the design phase the designers implement learning process by taking examples from the previous projects since that data is stored and catalogued and also has easy access at any time. The progress of project was not discussed whereas the meetings were only conducted to provide the technical details about the project:

"We do rough calculations of how much plan is completed but its just for our own idea." (Respondent 11, Design manager)

The planning method got stuck to commitment planning and learning was not involved directly. A framework of learning was missing in the project. The construction workers used verbal communication only to inform or apply any improvement in the process.

4.4.6 Experience with production planning

According to the site manager, with long experience in construction industry, it was easier to see if there were any problems at early stage. The managers and construction workers mention that to have a good team that puts a lot of effort to make planning work better gives a flow to the production. The key to get a better flow in production is to involve actors:

"All people that has a job spend a lot of time at their workplace. Some people are just here to work. You must use your heart to be involved. When you involve people, they feel more responsibility and do a better work." (Respondent 15, Construction worker)

The managers emphasised that if people receive respect, they will give it back. Moreover, they added that by looking at the long run, increasing the capacity will be beneficial. They further add that by having more workers on the site, the project will be finished earlier, and the project will save money because it can be rented out earlier.

4.4.7 Challenges with LPS

According to the managers a standard form of communication was missing. Even though the meetings were conducted, but with no standard framework of communication. The information either got lost or not conveyed to the responsible individual. The site supervisor added that, often important decisions were taken on email or phone call and failure to convey that information to rest of the involved personals creates big problems in later stages of the project:

"We are bad in communicating the small details throughout the project and we realise it later in the process when it gets too late." (Respondent 10)

According to the most respondents in this project the design changes also took place too often like in project A. Even though the clients are not present but the changes in design plans still occurs due to changes or introduction of policies by higher management. These may involve environmental, social or economic policies as mentioned by the design engineer. The design changes introduced during the project were not updated or catalogued properly in the master schedule. Thus, it became hard later on in the process to keep track of changes and to convey information to the right individuals:

"There are too many design changes in the planning process and also during production and it is okay, but these changes need to be updated." (Respondent 11, Design manager)

The site manager and design manager mention that a lot of necessary information was present in the contract between the company, the subcontractors and the employees. According to them weak and imprecise contracts often make it difficult for everyone to understand the scope of the project:

"The company fails to provide a straightforward contract where the language and goal of the project is often unclear." (Respondent 13, Site supervisor)

Another issue which often occurs according to the construction workers in this project is frequent changes in teams. According to them during the project duration there are many changes in the team of workers or supervisors. Typically, the project can take up to several years in completion and between this period the ones working in the project either leave the work for personal reason, moved to other project or just fired which create problem in maintaining a smooth workflow. Involvement of different sub-contractors in different phases is another reason:

"A lot of times the management makes big changes in the teams on site for example, brings in new people. This breaks the workflow and creates huge pressure on production. Also, the new people are unaware of the situation and find it difficult to understand what is going on." (Respondent 15, Construction worker)

According to the managers and site supervisors, too often the higher management or company bosses fail to show commitment from their side. The managers mentioned that there are many situations in which the involvement of higher management can simplify the process, but it

never happens. The managers further added that frequent complications from the municipality, unnecessary design changes, and lack of right resources are common hindrances in the production planning and that the support from the higher management can improve the situation but that support is hardly given to them:

"We usually fail to get support from our bosses in complex situations and in the end, we have to solve the problem by ourselves which sometimes does not go well." (Respondent 10, Site manager)

Furthermore, according to the construction workers the planning committee presents unrealistic or over ambitious tasks which generally takes more time in completion than mentioned in the master and phase schedule:

"Since we have long work experience in this industry, we have a good idea of how much time a certain activity takes. Often when supervisor and management makes the time schedule they put too little or sometimes too much time for a certain task. If we could be involved in the planning for the tasks, we can use out experience and make the flow for the production better." (Respondent 14, Construction worker)

As the project moves further in time, the managers mention that the importance or influence of the master schedule fades away. This is due to the fact that everyone gets involved in various tasks which are going simultaneously and gets disconnected with the main goal.

Moreover, the project manager and site managers mentioned that when the management introduces changes in the way of working, often times the behaviour of reluctance towards those changes is experienced. They further add that most of the construction workers on site has a conservative thinking. People feel more comfortable in working with the current method and introduction of any kind of changes troubles them.

Finally, according to the site supervisors and the managers there is a tendency which is present in the organization to put blame on each other in cases where something goes wrong. They further mention that the people are scared to report about defects and mistakes which makes it difficult to find root cause of the problems.

5. ANALYSIS AND DISCUSSION

The actual working of production planning of two projects is represented in figure 2 and figure 3. Both the figures emphasize what elements have been fully implemented in production planning, which elements are partially implemented and which elements are not implemented at all. The green colour depicts full implementation, yellow depicts partial implementation and red depicts no implementation. The representation in figure 2 and figure 3 is inspired from the framework shown in figure 1 (cf section 3.5)

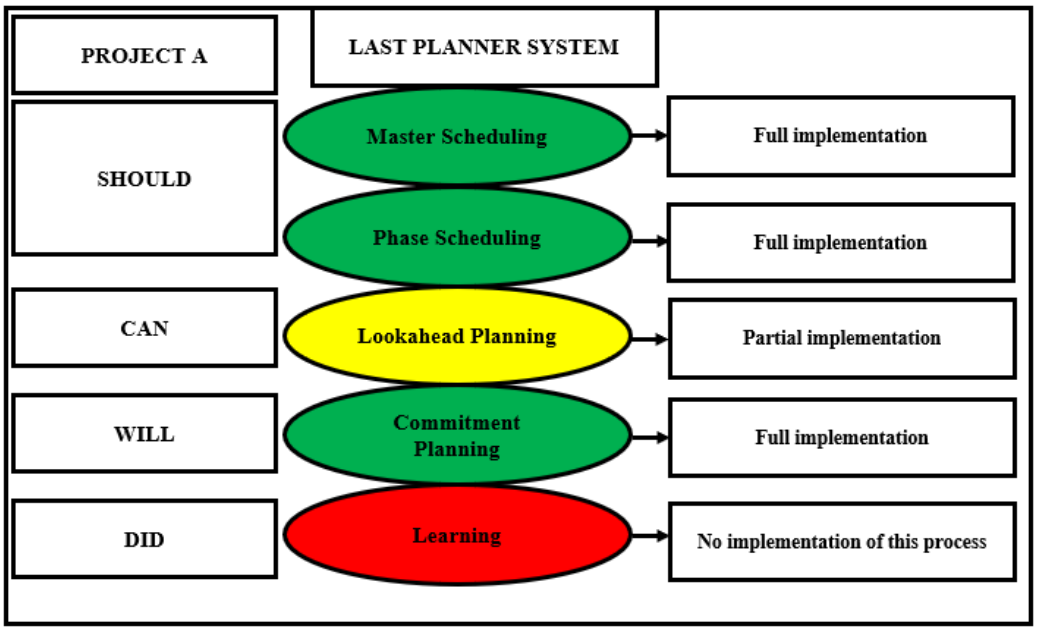

Figure 2: Production planning with LPS in Project A

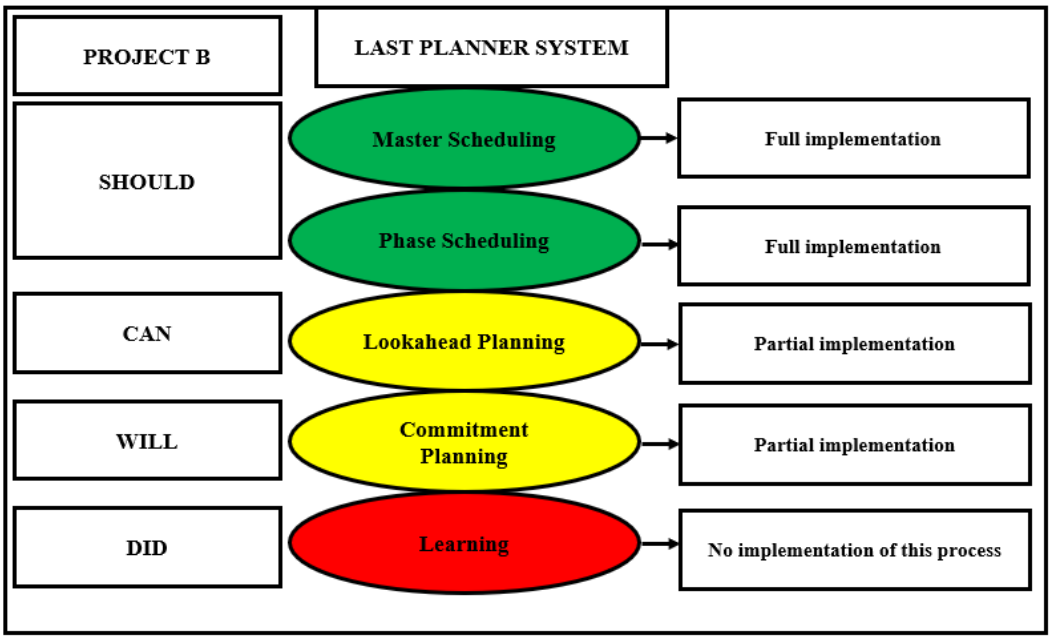

Figure 3: Production planning with LPS in Project B

5.1 Initial Planning

According to Ballard (2000), Salem et al. (2005) and Ballard and Tommelein (2016) the master schedule and phase schedule are the parts of initial planning in LPS. Their studies show that the master schedule consists of creating the project milestones as well as the time plan. In both projects studied by the authors, the planning is conducted through identifying critical milestones with the use of gantt chart. This according to Ballard and Howell (1998), is also one of the three practices of production control. From this activity, the idea of an overall time plan is also estimated. According to Ballard et al. (2007) the master schedule is created by conducting pull planning and by the creation of milestones in the master schedule. To create the master schedule the production team in the studied projects conducts, pull planning, where they involve different actors to make decisions on which milestone has to be added in the master schedule. This means that the projects create a master schedule according to the suggested theory .

In project A each respondent was aware that a master schedule, including the milestones, were created before the production started. However, not every actor was aware of the content of the master schedule and its milestones. In project B every respondent was aware of the content of the milestones since every new actor gets introduced to the project's milestones when they start working in the project. In LPS framework, it does not state specifically which actors should be involved in the master schedule, but the overall aim of the Last Planner system is to involve actors to be able to collaborate to make the flow better which was evident in the study by Ballard (2000). The managers in project A argued that they have an aim to involve more actors. They believe that it will be more efficient if everyone is aware of the project’s milestones.

According to Salem et al. (2005) and Ballard and Tommelein (2016), the phase schedule specifies the condition of satisfaction between each task. Both projects are doing phase planning according to LPS framework. The different phases are created from the milestones. The management team in both the projects uses pull planning and reverse phase scheduling to specify handoffs for each activity and obtain the time frame of each activity and this information validates the LPS framework suggested by Ballard and Tommelein (2016) where it states that the all the actors with decision-making capabilities gather together to conduct planning. Project A has a three-week period for the phase planning and project B has four weeks, and according to the managers and supervisors this setup works well for both projects. The project manager decided to have a three-week period because it will make all parties understand and visualize what is happening in the future. He argued that a longer time period might cause difficulties to understand what is happening in the future, for the involved actors. According to Sacks et al. (2010) visual management is a key component for effective Lean implementation in projects as it provides a basis to look upon variabilities, defects, collisions and improvement measures. Both the projects depend on their phase planning where they use post-it notes for planning and assigning tasks or assignments to the involved actors in the project. Every project decided how many phases they are going to have and the time period in between them, there is no theory stating what is best since every project is unique and have different sizes.

Furthermore, it was interesting that construction workers were not aware of the content of the milestones. But every actor was aware of the content of the phase planning, which is created from the milestones. In the end, they are working with an aim to reach the milestones, without knowing it. By having knowledge of the main milestones, it will give actors who are working in the project a better overview of the whole project. But if it is a big project that is going on

for many years and different actors come and go in the project, it may be enough to involve them in the phase planning. But the managers want all actors to see the bigger picture and not just a shorter time period. In project A the manager's aim is that if the actors have an idea of the main milestones in their head, they can know why they are doing phase planning in the long run.

By introducing the milestones to actors who are working in project, it makes them more aware of what further is to come in the project. When they reach a milestone, they also celebrate by having cake for the whole team at the project which also reminds them of the milestones. This continued reminder of milestones may be one variable that ensures that the project will be finished earlier than the finish date. The main reason can be that it will be finished earlier due to the increased capacity of workers, but with awareness, motivation and reward for the goal of finishing before time can be achieved.

5.2 Lookahead planning

According to Ballard (1997) and the lookahead planning is done to have detailed estimates for future tasks which reduce risks and uncertainty in the workflow. The exact number of weeks is not specified as it depends on the tasks but a six week lookahead planning is suggested in the study by Ballard and Tommelein (2016) where the emphasis is given towards controlling the workflow by ensuring that all the materials and resources are made available prior to the starting date of the tasks. The managers and supervisors understood the meaning and content of lookahead planning and argued that they have meetings where they discuss constraints removal, breakdown of milestones and collaborative design as mentioned in the theory of Lookahead planning by Ballard (1997) and Salem et al. (2005). During the interview with the construction workers, they argued that they have long work experience and they plan for the future work in their head. By doing that often, they realize if there will be a problem or not and if the time frame is realistic or not. The managers and supervisor in both project state that they are doing the lookahead planning but they do not have a separate meeting for that. They are actually doing the lookahead planning during the time that is set for phase planning. Which means that project A is doing the lookahead planning every third week and project B every fourth week.

According to the theory the lookahead planning should be conducted separately and it is recommended to be done every sixth week. However, the content of what a lookahead planning should contain is done in both projects. But since they are conducting this procedure in the phase planning it cannot be stated that it is fully implemented.

5.3 Commitment planning

According to Ballard and Tommelein (2016) the processes followed in weekly planning are visual controls, making reliable promises and ensuring daily meetings. Commitment planning ensures reliability by providing quality assignments and protecting workflow from uncertainties. It depicts what can be done with the available resources (Salem et al. 2005). In both projects, the weekly meetings are conducted where they use visual tools such as schedules, detailed drawings and software to convey information to the site supervisors, subcontractors and workers who are supposed to work in the following week. In both the projects, weekly meetings are conducted under the supervision of the site manager. In these meetings, it is ensured whether the materials and resources are present on site and the task to be carried during

the current week is understood by everyone or not. This is ensured by making commitments and promises during the meetings. Ballard (2000) mentions that building collaboration and trust between involved actors and subcontractors are one of the main benefits of the LPS framework and in both projects, the aim to achieve effective collaboration is ensured. As suggested in the theoretical framework (cf section 3.5.3), according to Ballard and Howell (1998), commitment planning provides a detailed plan which shows interdependencies between each task in the construction process by creating quality assignments. In our study, the managers aim to achieve the best quality in the tasks and assignments by discussing the needs and requirements to improve it.

To ensure the reliability of weekly plans, daily meetings are conducted between site supervisors and site workers in project A, where they discuss necessary information, safety issues and logistics plan for the day. On the other hand, in project B they conduct unstructured meetings. The meetings between supervisors and workers are not done every day. The site workers expect more supervision from the supervisors and managers. From the findings and theory, we conclude that in project A they follow the aspects of commitment planning according to the theory but in project B they practice partial implementation of commitment planning due to unstructured daily meetings.

Since project A conduct the commitment planning according to the LPS framework, that element is fulfilled. However, project B conduct the commitment planning according to the LPS framework and aims to achieve the best quality in the tasks a but they do not conduct daily meeting and therefore it cannot be stated that they are fully working according to the LPS framework. According to Ballard and Tommelein (2016) and Salem et al. (2005), the daily meetings are crucial to setup two-way communication and helps reducing the uncertainties on a daily basis. Also, with this practice the issue of lack of participation of downstream actors like construction workers can be improved up to some extent.

5.4 Learning

The production planning in our study is missing the learning process. From our study it is clear that the PPC, percentage plan complete is not calculated nor the projects conduct first run studies. The most common response for the lack of learning process in our study was the unavailability of time and this reason has also been highlighted by Brady et al. (2011). From our study it has been derived that oral calculations is conducted for their own estimates but learning process or continuous improvement as a whole is not included in the process. In the interview with Ballard (2019), he described that the learning process is a very important element of LPS framework. If construction projects include the learning process in their time plan, PPC can be increased up to 90% (Interview Ballard 2019).

Striving for continuous improvement is one of the main functions in the LPS framework as stated by Thomas et al. (2002). The construction company in this study does work according to the LPS framework in theory. But in this study the most important element learning (Ballard 2019) is not conducted in practise. That is an issue since the company has a desire to make the production more efficient and therefore started to work according to the LPS framework 9 years ago, but does not have time to reflect on what has been done and learn from experience. According to Salem et al. (2005), the learning process needs to be included in the timeline of the projects to be able to reach a higher PPC, improve the efficiency and increase the productivity. They further mention that the causes of failure can be identified and risk can be removed. Also, in the interview with Ballard (2019), he mentions that the leaning element is

the most important element of LPS framework through which continuous improvements can be implemented in the organisation practicing LPS.

5.5 Sustainability

Since both the projects have to have environmental certification, they follow all the necessary aspects of sustainability which are social, economic and environmental (Nahmens and Ikuma 2011).

The company takes several steps to improve the social aspects of sustainability in both projects. The management takes the initiative to celebrate small achievements like completion of milestones or completion of phases. Also, the employees are given additional time for training and exercise both in morning and during the time frame when they are present on site. Safety considerations are top priority in the meetings and they are discussed in details within the meetings for site workers, for the surroundings around the site and for the foreman working with tools. The purpose is to boost the overall wellbeing of the involved actors as much as possible.

In both the projects the economic aspect of sustainability is also considered as in master and phase schedule they conduct pull planning to remove the non-value adding tasks. This also leads to reduction in unnecessary costs. Also, before the start of the project or during the preparation of the master schedule cost analysis is conducted in both the projects where they get idea of upfront costs and resource costs so that they get idea of the overall budget. This process is beneficial for controlling extra expenditure.

The project A has to follow the norms of LEED certification and similarly project B has to follow the norms of BREEAM certification. The environmental aspects of sustainability are a necessary consideration. Waste minimisation is one of the top priorities in both the projects. All the involved actors in the project are encouraged to keep the site clean and organised. Also, the waste which is generated are sorted on site according to material type. Both the projects spend considerable amount of money to plan their waste management strategies.

Furthermore, it is concluded in this study that the learning process is missing from the production planning in both the projects and involving leaning will be sustainable for them in terms of increasing profits, increasing productivity, reducing waste, increasing worker motivation and applying continuous improvements. Thus, learning will be beneficial for improving overall sustainability in terms of social, economic and environmental aspect.

5.6 Challenges with Company Production planning and Control

In both projects, the respondents described various challenges that come with time in their production planning and control. Having changes in design by the clients is a great problem according to most of the respondents in project A. According to the managers, these design changes lead to cost overruns. It disrupts the ongoing planning process and leads to the wastage of time for the involved actors in both the production and design. In project B where the project is funded by the company itself, design changes still occur. It was mentioned that these changes are not catalogued properly so that the master schedule can be updated which was also highlighted in the study by (Perez and Ghosh 2018). Even though creating better collaboration and relationships is one of the benefits of LPS (Fernandez-Solis et al. 2012), the respondents

in project A still feels that establishment of collaboration with subcontractors often fails which is also mentioned by Dave et al. (2015). The reason provided by them is that most of the time the subcontractors are not familiar with the planning process. Porwal et al. (2010) also highlighted this problem where they described that while working with LPS framework, often subcontractors lacks the understanding of the planning process and fail to deliver desired outcomes. The same issue was highlighted by Koskenvesa and Koskela (2012) in the Finnish construction industry. Moreover, implementation of learning or improvements is one of the basic principles in LPS. This process is missing from the production planning process in project A. Even though the respondents in project B did not highlight this case as a challenge but it is also a case there. No implementation of continuous improvement and learning is also discussed in the study by Daniel et al. (2015) where they argue that even though organizations incorporate all the aspects of LPS but fail to implement the Learning process to the full potential. The main reason for not involving the learning process is the lack of time which was also highlighted by Brady et al. (2011). In both of the projects the respondents feel that resistance towards change is present in the organization. This is also mentioned in the studies of Porwal et al. (2010) and Fernandez-Solis et al. (2012). The reluctance towards change is often experienced from the downstream actors like the site workers. It is observed that they want to work with the old planning system and introduction to any change makes them uncomfortable.

Moreover, in both the projects, the issue of establishing effective communication is present. These issues are in different forms and include problems such as language barrier, lack of a standard for information flow and loss of necessary information in between the process. Brady et al. (2011) mention in their study that unsteady communication is a common problem in firms that are implementing LPS as involvement and collaboration is basic framework for successful implementation of production planning and exchange of information and communication from all actors is necessary. Brady et al. (2011) also mentioned that the absence of construction foreman from the planning process is a challenge as they are unaware of the bigger picture in the project. The same issue is highlighted by the construction workers in project A where they feel that they are less involved in the planning process and they can provide useful suggestions which can be beneficial for the production process and also improves communication in the organization. Another challenge which they face in project A is the unavailability of materials on time, even though they preplan everything before. Most respondents emphasized that subcontractors fail to deliver from their part even though reliable promises were made.

Porwal et al. (2010) mentioned the failure of commitment from management is a challenge which cripples the smooth implementation of LPS. The respondents in project B also described that in many situations the higher management of the company's bosses failed to show commitment from their parts and this, in turn, led to delays in the project. The respondents especially site supervisor and construction worker mentioned that the planning presented to them sometimes is unrealistic and often takes more time to complete than mentioned in the plan. Furthermore, the issue that was highlighted in project B was a frequent change in teams. This issue is not highlighted in previous literature regarding challenges towards implementation of LPS. Respondents added that there are various reasons for which change in teams occurs but when new personas come, they are unaware of the ongoing process which often disrupts production planning.

In project B the respondents described that unclear and imprecise contracts lead to big issues as they also represent necessary information regarding the project and often there is a problem in understanding the scope of the project due to its unclear and imprecise nature. Both Porwal

et al. (2010) and Fernandez-Solis et al. (2012) mentioned that improper or weak contracts raise issues towards the implementation of LPS.

Respondents in project B added that the concern towards the master schedule gets reduced as they move further in the project. This challenge was also highlighted in the study by Dave et al. (2015) as the project gets split in further detailed process and the involved actors emphasize more on the detailed tasks. Respondents from the projects mention that people start focusing on the small tasks which were divided from the milestones and lose the importance of the original master plan with time. Moreover, the situation of the blame game is also presented as a challenge by the respondents in project B. They mention that in case of any defect or mis happening the involved actors often resort to blaming others instead of taking the responsibility themselves.

5.7 Improvement measurements for challenges with LPS

Several challenges are presented which the company has to face during their production planning and control while working with the LPS framework. These challenges have to be mitigated in order to achieve higher efficiency and productivity in overall planning and production process. The theory (cf section 3.7) suggests the framework to work upon the various challenges with LPS. In our study the respondents mentioned that changes in design plan and working team is a big issue which hinders smoother workflow during construction. Along with that it was mentioned that lack of commitment from the higher management is also present. According to the improvement framework engagement of higher management at all the levels of production is necessary as they have the decision-making power and can implement required changes. Also, the issues regarding change in design plans and working teams can be improved by their involvement in the production process. Furthermore, introduction of nucleus cross functioning teams is suggested so that they can identify the hurdles and requirements to achieve higher efficiency in the production process. Issues and challenges faced by actors can be communicated in a better way as these teams are in direct contact with front line managers in the company. The respondents mentioned that the changes in design plan is not updated in the master schedule and the importance of master schedule fades away as production moves further in time. This can also be corrected by the introduction of nucleus teams in the production planning. One of the main roles of these teams is to constantly record changes and update the information in the initial plan. Also, these teams can provide visual aid to emphasise on the importance of master schedule to the involved actors in the project. Moving on, the issue establishment of effective collaboration is presented. According to the managers even though collaborative planning is done in production process but still the subcontractors fail to deliver from their side and also fail to make reliable promises. According to the Macomber et al. (2005) this issue cannot be solved completely but improvement can be provided. They suggest a process with three steps where first step focuses on constantly updating the promises and commitments made during the process and declaring them complete when they are fulfilled. The second step involves putting attention on special commitments and finally, during failure to make reliable promises, compensation measures should be suggested, so that something beneficial can come out of that situation.

Regarding the challenge of reluctance towards change, the nucleus teams can provide solution by first providing necessary training to the involved actors and also setting up long- and short-term goals so that everyone involved get a clear picture of jobs which has to be performed by them. With the training program the information regarding necessity of new changes can be conveyed to the actors and the importance of new changes and improvements can be realised

to the actors at all levels. Furthermore, Brady et al. (2011) suggests that the challenge of communication barriers and involvement of different actors, especially the downstream actors such as construction workers can be improved by increased visualisation of work and visual management. Through visualisation of work all the actors can contribute to small details and issues which generally is not noticed by managers and supervisors. These details can be gathered by the managers and with this the communication and involvement can be increased. The issues regarding communication and information flow can also be solved by the introduction of nucleus teams as they handle information flow from top to bottom level and vice versa. As mentioned before their roles and responsibilities also includes creation of standard procedure of production planning and making it visual to all. This practice is also a form of visual communication and adds towards the better communication in the organisation.

Finally, the company is missing learning and continuous improvement in their production planning and its implementation can lead to higher efficiency and productivity which is highlighted by Ballard et al. (2007) and Ballard and Tommelein (2016). According to the improvement framework, learning measures should be incorporated in the standard procedure of production planning which is developed by nucleus teams and also the culture of continuous learning should be promoted in the whole organisation which promotes experimentation, acknowledgement of failure, innovation and willingness to take risks. According to Salem et al. (2005), practice of first run studies is a beneficial tool to incorporate learning as it provides a basis to redesign critical tasks. The selected critical tasks are redesigned using PDCA cycle which stand for plan, do, check and act. In PDCA cycle the critical tasks are planned again and after the plan is finalised it tried in the production process. As the process is going on a check is implemented to collect the information regarding the ongoing process. Finally, the data recorded is analysed and the ongoing performance is communicated with the team.

6. CONCLUSION AND FUTURE RECOMMENDATIONS

6.1 Conclusions

The conclusion made in this explorative study, based on a case study on two construction projects from a Swedish company, is here formulated as answers to the posed research questions.

Do the studied Swedish construction projects follow every element of the theoretically grounded LPS framework? If not, why?

According to our findings both the projects fully conduct the master scheduling and phase scheduling. Moreover, project A fully conducts commitment planning and on the other hand project B partially conducts commitment planning. Furthermore, the projects are partially working with the lookahead planning in both the projects because they do not conduct separate meetings for planning lookaheads and involve lookahead meetings in phase planning. The managers believe that the six week lookahead is too long of a process and time can be saved in the current process which they are following. Also, the element of learning is totally missing from the organisation's production planning which is one of the most important elements of LPS and contributes to better working of production planning. Lack of availability of time was the most common response collected from the respondents

What are the practical challenges to work with the Last Planner system in large construction projects?

In conclusion to our study, the challenges faced by the organisation includes frequent changes in design plans and lack of update of those changes in the master schedule. The study also presents the challenge regarding failure in collaboration with subcontractors as well as lack of efficient involvement of actors, especially downstream actors, in the planning process. Furthermore, frequent change of working teams is considered as a challenge. Also, lack of dedication and commitment from the involved actors including higher management is present in the organisation as well as reluctance towards change is faced according to the respondents. Moreover, communication barriers are present which also include language barriers, lack of standard form of communication and loss of information. The situation of reduction in the importance of the master schedule is also highlighted which according to site supervisors and managers is an issue on which less emphasis is given. Finally, non-implementation of learning process is a challenge which organisation faces in the production planning and control due to lack of availability of time.

How can the identified challenges be mitigated according to improvement measures developed by earlier research on LPS?

To mitigate the challenges faced by the organisation, recommendation on the improvement of production planning is suggested from the previous studies on improvement measurements of LPS. The improvement measures involve engagement of higher management in the production planning at all the levels to increase the effectiveness and efficiency of decision making. Furthermore, introduction of cross functional nucleus teams is suggested in order to improve the overall production planning. These teams are responsible to carry the numerous tasks which other actors in production process are unable to carry. Moreover, the nucleus teams are also responsible to create a standard procedure of practicing production planning which

incorporates the approaches from master schedule to the learning process and also identifying and mitigating risks and uncertainties. In regards to communication barriers and involvement of actors, increased visualisation of work and involvement of visual management is suggested. The involvement of learning is also suggested by incorporating the culture of continuous improvements where the organisation promotes experimentation, acknowledgement of failure and willingness to take risks. With regard to the challenge of failure of collaboration previous research describes the three-step process of improving and updating the promises so that efficiency from both contractors and subcontractors can be ensured.

To summarize the conclusion and answer to the aim of the thesis we can conclude that in the cases studied there seems to be a discrepancy between the theoretical ideas of the function of LPS and the way it is used in practice at the construction projects. The phase emphasized by one of the founders of LPS as very important – the learning phase – was identified as most problematic. The main challenges are lack of time for implementing learning in the production planning process, frequent changes in design plans and working teams, lack of involvement of downstream actors in production planning, lack of collaboration with subcontractors, communication barriers, lack of commitment from involved actors and higher management, weak and imprecise contracts and reduction in importance of master schedule. Furthermore, the proposed improvement measures are engagement of higher management at all levels of production planning, introduction of cross functional nucleus teams which performs numerous tasks, creation of a standard procedure of production planning, implementation of better and improved visual management, involvement of three step process for ensuring reliable promises and integrating the culture of continuous improvement.

6.2 Theoretical and Practical contribution of the study

The theoretical contribution of the explorative study is the insight that the challenges which were mentioned in previous research are also present in the Swedish construction firm studied in this case study. As our empirical material consist of interviews with the workers we can also contribute with a “from below” perspective, giving new knowledge on issues of importance for the site workers that might be overseen in studies focusing only on views of managers.

In terms of practical contribution our study investigated the real scenario of industry and presented what is missing. Our study also highlighted the challenges which were faced during the practice of LPS in the production planning. Furthermore, the improvement measures suggested in our study can be beneficial for the organisation in terms of improving their production planning with LPS.

6.3 Limitations

This research had limited time which resulted in limited projects to investigate and limited interviews to conduct. Another limitation of our study is that the results are dependent just on interviews. If there was more time to do this research, more projects could have been investigated and more interviews could have been conducted. Also, the perception of other actors such has subcontractors, suppliers and higher management could have been studied. The study should be conducted in other countries as well as with various other type of projects to know the peculiarities of the LPS framework. Also, other data collection methods, for example observations or case studies could have been added which would have contributed towards the greater reliability of the findings. The study is also limited to Stockholm and to get wider

understanding of how LPS actually works in Sweden, several organisations has to be considered for the study. Furthermore, the data collection and study were just based on qualitative data and techniques and to get deeper understanding emphasis towards quantitative data collection has to be done. Since this study did interviews in Sweden with people who has Swedish as their first language the results might be bias. The respondent who answered out questions in English might have not used the word they meant in Swedish. The interviews that were held in Swedish might also be biased when it was translated to English, as the author might have been biased when choosing the words to translate.

6.4 Recommendations for future studies

With regard to the current research further study can be conducted on the roadmap of how improvement measures can be applied by organisations to mitigate the challenges occurring during the work of LPS. Furthermore, the company is missing the element of learning from their production planning so a research can be done on the type of learning tools which can be incorporated by the company in future so that they can practice the whole LPS framework to be able to achieve higher PPC. Another area of interest for future studies may also address the issue of tracking and monitoring schedule variation and how it can be implemented in a better way in production planning. The organisations develop their own process of schedule update but a standard process is still missing.

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Interviews

Ballard, G. 3rd May 2019

APPENDIX 1-INTERVIEW QUESTIONS

How many years have you been working in the construction industry?

Initial planning

How is the schedule from the first stage developed?

- Who is involved? Do you feel someone is missing?
- How are the milestones created? Are the milestones clear to everyone?

What is the procedure for developing the phase plan?

- How is the schedule used?

What do you usually think is the reason/reasons why the work is not carried out according to planning?

Lookahead planning

Please define the procedure of planning Lookahead?

- How do you plan for uncertainties and constraints?

Commitment planning

Please define how the weekly plans are developed?

- Are the visual tools used? If yes, how are they being used
- Do you have daily meetings? If yes, who is involved how is the procedure?

Learning

How does the schedule get analysed or how do you conduct the learning process?

- Do you calculate the percentage of work that is completed? If yes what are the methods that you use?

Experience

What is your experience with the planning process? Please tell some benefits and barriers.
Is the method the same or it changes with different projects?

Does the work match with the milestones which are set before?

Does everyone understand the implementation strategy?