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Lean Construction Tools for a Construction Project

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I would like to thank the management and colleagues of the case company for all the assistance in my Master´s Thesis project. There have been many good and interesting discussions about the subject, and it has been my pleasure to work with such skilful professionals. In particular, my special thanks go to Jarkko Lahti for all the help and support during this process.

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It sure was challenging, interesting, and rewarding project.

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Abstract

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Lean construction is now a famous term in the construction business. There has been discussion about the lack of productivity growth in the construction business for several years and many actions has been provided to tackle it. The lean construction project delivery method clearly has many practical improvement ideas to the problem. The objective of this study was to provide a proposal of lean construction tools for the commercial department of the case company, to improve the production in a construction project.

This research includes four phases. The first phase is the current state analysis in which current production tools are reviewed. The second phase is the literature research of the lean construction knowledge and best practices existing. The third phase of this study includes building the proposal of the lean construction tools for the commercial department according to the previous phases and the feedback. The final phase is the validation of the proposal and selecting the lean construction tools for the implementation.

Several strengths and weaknesses were found in currently used production management tools in the company. The pilot projects provided some very good information about the use and experiences of these production tools. The outcome of this study is the final proposal of the lean tools which will be implemented, and which are suitable for the case company´s commercial department. The objective was to present a practical solution how to apply lean tools for a construction project and present how to utilize the tools to improve the production.

Keywords: Lean, construction production, waste reducing, process improvement.

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List of Abbreviations

CSA	Current State Analysis
HVAC	Heating Ventilation Air Conditioning
JIT	Just In Time Delivery
IPD	Integrated Project Delivery
PDCA	Plan Do Check Act
TTP	Takt Time Planning
5S	Sort, Organize, Clean, Standardize, Sustain (Japan words are Seiri, Seiton, Seiso Saiketsu, Shitsuke)
3D	Three-Dimensional Modelling of the Design
CBA	Choosing By Advantages
TVD	Target Value Delivery
TP	Total Productivity
TPS	The Toyota Production System
SCM	Supply Chain Management
TFV	Transformation-Flow-Value
LPS	Last Planner System

1 Introduction

The construction business has traditionally been one of the largest industries in Finland. The industry employed approximately 190 000 people in 2021. The productivity has been an issue for the construction industry for a long period of time. The low productivity growth compared to the other industries has risen a question why it is happening. In recent years, there has been an increasing interest to provide better productivity in the construction business.

The lean construction philosophy is changing the construction industry and management of construction in many ways. It emerged in 1993 by Lauri Koskela in his thesis and research. After that several other construction industry experts such as Greg Howell and Glen Ballard began to research the lean approach. By continuous improvement and due to good results, such as lower building cost, shorter building schedules, improved quality and site safety, the lean construction has acquired more positive reputation (Forbes et al. 2020:2).

Productivity is the measure of how well resources are brought together in organizations and utilized for accomplishing a set of goals. It is measured as the ratio of outputs to inputs, so productivity is greater when the highest level of performance is achieved with the least expenditure of resources. Productivity in the construction environment may be represented as the constant-in-place value divided by inputs such as euro value of material and labour. Productivity measurements may be used to evaluate the effectiveness of using supervision, labour, equipment, materials, and so on to produce a building or structure at the lowest feasible cost. In the manufacturing industry productivity is usually described in quantitative terms, but in the construction industry it is usually understood in qualitative terms. The work situation in construction is project-oriented and much more dynamic than is the manufacturing industry, introducing many complex factors affecting productivity in construction. These factors involve: managerial, technological, regulatory, labour related, engineering and craft-related items (Forbes et al. 2020:6).

Total productivity (TP) ratio

$$\mathrm{TP} = \frac{\mathrm{T(total\ sales\ or\ value)}}{labor\ cost + materials\ cost + machinery\ cost + money\ cost + management\ cost + technology\ cost\ a}$$

(Forbes et al. 2016:13)

Measurements of productivity are made to investigate how well resources are working in a building project. The productivity is measured by equation of inputs and outputs. The productivity is highest when the highest level of performance is made with the lowest level of resources. Productivity in construction business can be measured and evaluated based on effectiveness of man work, equipment, materials, and so on to provide a building at the lowest possible cost (Forbes et al. 2020:6).

1.1 Business Context of the Commercial Building Department of the Case Company

The case company is a building company which is operating in Finland as well as in other Nordic Countries. It has four business areas such as construction, civil engineering, industry, and project development. It has approximately 15 000 employees. The case company´s key values are to be reliable, personalized, practical and to develop functions of the company continuously within the construction business.

The case company wants to build a reliable relationship to the customer and wants to use good building practise in all aspects of its actions. To be able to build a personalized collaboration with the customer, it requires long term collaboration with all stakeholders and with the company personnel as well. The company wants to work near the customer to provide successful building projects for the client. This way the company can understand the client needs better and can provide practical solutions when needed. By innovative and flexible way of operating the company aims to develop continuously its

functions. All these values support the lean philosophy in the construction business and are good background to implement lean thinking to the organization.

The top-level executives of the company have provided a decision to implement several steps to improve the productivity and reliability in all building projects. This decision was made some years ago and it is a great improvement project in the company. There are several different development areas which are focused on, such as to decrease the overall costs in the projects, shorten the project lead time and to improve quality by diminishing the number of defects in the hand over for the customers.

One part of the development plan are the lean construction delivery methods. The company has already experienced that different kinds of construction site audits, such as internal audits concerning quality and safety, correlate directly with the profitability. And by providing the audits the company has been able to clearly increase safety, quality, and the profitability. Accordingly, the company aims to increase the productivity even more with the lean project delivery methods. The top-level management provided a schedule for the change plan which was published in 2019. Unfortunately, there has been some delays due to the covid pandemic, but the plan has been implemented according to the decision as soon as it has been possible (Company documents in intranet. 2022).

It was estimated in early stages of the implementation, that there might occur some obstacles for the implementation of lean project delivery, such as, the staff participation, the right tools, the flow of information, some unclear processes in the company and lack of standardization. On the other hand, it was estimated that there are some existing strengths in the company, such as a positive company culture which encourages to the continuous improvements, existing overall production procedures and clear company processes.

The way to approach the lean construction methods for the company, has been gradually, step by step. According to the plan to apply the lean construction methods, the company has had an education program for the staff, which includes, for example, seminars in the Teams by lean construction consultants, to be able to educate the staff the lean construction philosophy and the different kind of lean methods. This education program has been voluntary for the staff. There is also one nominated project director for the lean construction project who coordinates and helps during the change process. Moreover, there have been some pilot projects using the different lean production delivery tools to gain experience and to be able to share information and best practices between the different departments of the company (Company documents in intranet. 2022).

The commercial building department will implement lean approach and tools gradually step by step according to the top-level executive´s decision. There was no set schedule for the implementation of the lean project delivery and this study was part of the process. It was agreed with the director of the commercial building department, that this thesis would propose which lean construction tools will be implemented for the commercial department, according to the best practices and the knowledge that was gained from the different stakeholders and from the relevant literature and findings of this thesis.

1.2 To Propose Lean Construction Tools for the Case Company

The case company has made the decision to implement the lean construction project delivery method. The decision was made in 2021 by the top-level management to improve the building process. The commercial department of the case company is providing different kind of building projects, such as public schools, parking facilities and office buildings. To support the overall building process, the case company has developed good process maps about the needed actions within a building process. The process maps are supporting the whole organization and this way the company has well-organized way of doing the construction business generally.

The commercial department of the company uses different kinds of production management tools which are rather traditional in the construction business. For example, the company uses Tocoman program for scheduling, Solibri for 3D modelling, Congrid for quality management and so on. The company provides education for all the staff for production management tools, and this will ensure that everyone can use the management tools properly. The object of this thesis is to improve the productivity of the building processes by implementing the different kind of lean construction tools for the commercial department of the case company. In the beginning of this thesis project, it was agreed with the director of the commercial department director, that the lean construction tools will be implemented step by step gradually. This thesis includes the proposal of the lean construction tools which will be implemented to the department. Furthermore, these lean construction tools will be implemented in a pilot project in the commercial department.

1.3 Outline of the Study

In this study there are four different phases. First phase includes current state analysis in which the case company´s current lean tools in pilot projects and other production tools used for the management is covered. To gain information about the process, the interviews were made, and the existing production processes and tools were studied from the company documents. At this phase knowledge is drawn from the existing company documents and interviewing stakeholders of the case company and by own observations.

The second phase was the literature research of the lean tools. At this phase analysis of the existing literature and research was made to provide a wider perspective and knowledge of what lean construction is, and what is the origin of lean philosophy. Good literature sources exist on the subject and some of the books deal specifically with the construction industry. The object was to find good practices, example projects, especially building projects and generally examine how the lean management is provided in different contexts.

The third phase of this study is to build the proposal of the lean tools which will be taken into the use and what is the background for the decision. There are several lean construction tools and methods existing in the literature. The decision was made with the director of the department, that in the beginning of the process approximately 4 to 6 lean construction tools will be implemented.

The fourth and last phase is the validation of the proposal. It is based on the feedback form the stakeholders, the department director and the production manager of the commercial department. The proposal of the lean construction tools is provided according to the information given from the stakeholders. These lean construction tools will be implemented to a pilot project in the commercial department of the company.

2 Project Plan

The lean construction tools for the commercial building department challenge, objective and outcome were provided in the previous section. This section concentrates on the project plan for this thesis, and it describes how the research has been done.

2.1 Research Framework

Finding a business problem or distributing business knowledge or determining a managerial issue, the purpose and the objective in research can vary greatly. Sometimes the research can include an explanation for policy of a case company. In some cases, the research can study how a company or organization provide production or services differently. Although approaches can differ, these management and business research can be separated into two main categories. So called the pure or basic research provides a universal frameworks or guidelines which are not based on practical value and are more for an academic discussion. The applied research, on the other hand, is based more on the practical approach and tries to solve a business or a managerial problem for different organizations (Sounders 2016).

In a case study thematic interviews are used often to be able to understand the phenomenon. The thematic phenomenon interview is not easy technique to apply because it requires several data collection and analysis techniques. In traditional qualitative research it is possible to focus on one data collection and analysis technique. Case research method requires diverse methodological expertise (Kananen 2013:58).

The case study almost always uses a thematic interview method to gain an understanding of the phenomenon. The researcher must be able to formulate the themes in the research and proceed within the themes according to what the researcher produces with his or her reports, and description of the phenomenon. The researcher must be flexible and be able to communicate

while providing the research. Analysing and interpreting the data is also challenging because the researcher needs to see inside the data (Kananen 2013:58).

The case is a unit that forms the phenomenon under the study. For example, when an organization is the object of the research, information is available from the members of a particular organization. Information for the research is also obtained from the company documents, reports and business plans. One of the most important questions in the research is the subject of the research, what is being researched, from whom the information is obtained to solve the research problem (Kananen 2013:75-76).

According to Kananen (2013) the subject of the case study is a current phenomenon, and the research is implemented in a natural environment utilising many information sources. The subject of the research is one or more cases, from which a profound information is needed (Kananen 2013:54).

2.2 Research Design

This study has four main phases. The initial business challenge was to find the suitable lean tools to improve the production of a building project. The next figure presents the research design and its different phases. As it is shown in the Figure 1, the current state analysis is the first phase of the research design after the objective was provided. To ensure the starting point it is important to research the current state, it was in this case production management tools of the commercial department. The current state analysis was provided by reading the existing documents of the company and by interviews with the stakeholders. It was gathered twelve so-called traditionally used production management tools and four lean tools which were used in the pilot project in the company. The strengths and weaknesses were analysed concerning the production tools of the commercial department.

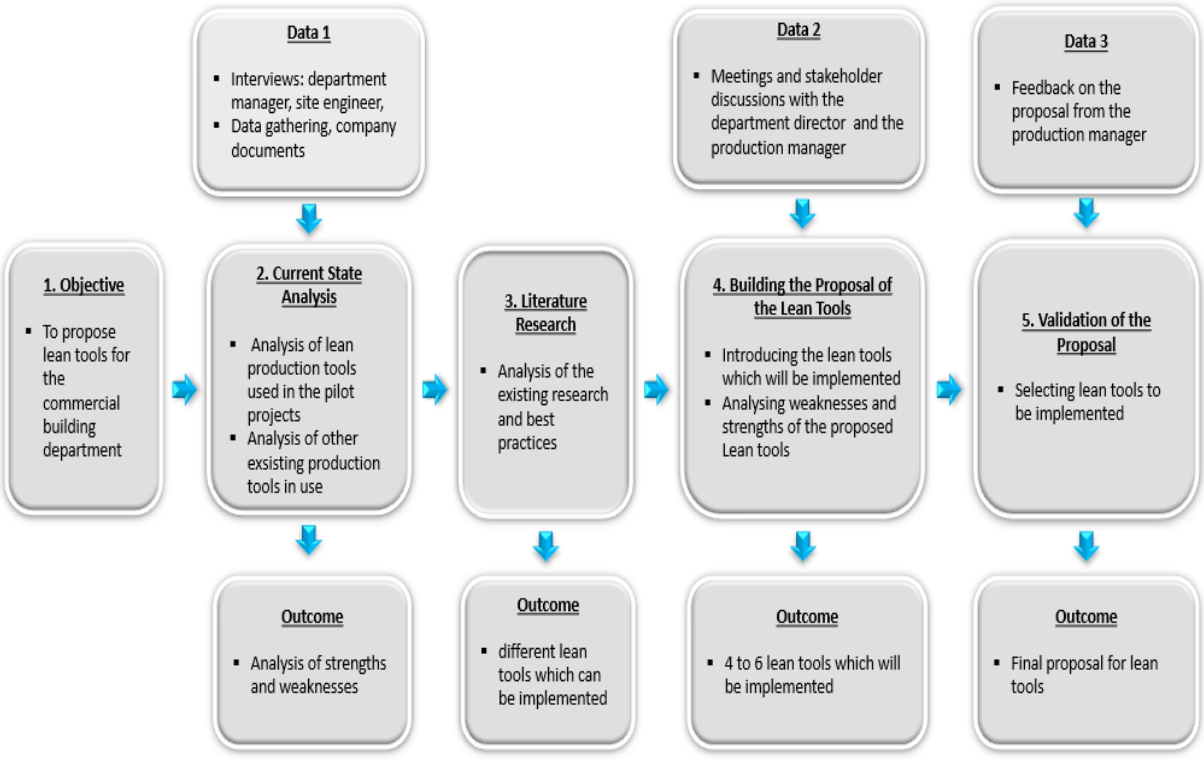


Figure 1. The Research Design

The second phase is the literature research. The existing academic literature was searched concerning the lean construction project delivery and what kind of lean tools would be best to implement for the commercial department of the case company. There are many kinds of lean tools which are available for the construction business and the focus were on which ones would be suitable in this case for the commercial department. First it was chosen fourteen different lean construction tools

The third phase in Figure 1 is building the proposal of the lean tools. At this phase it was selected first 14 different kinds of lean tools which would be suitable for to be implemented. Then the amount of the lean tools was reduced to 7 different lean tools for the validation. According to the discussions with the department director it was originally intended to choose approximately 3 to 4 lean tools for the implementation for the commercial department. Due to the discussions with the stakeholders, it was later selected 6 different lean tools which were chosen for the implementation for the commercial department.

The fourth phase was the validation of the proposal in which the selection was provided which lean production tools were selected for the implementation. The decision was performed according to the feedback given from the stakeholders. At this stage it was decided that it will be implemented six different lean tools and that the different tools will be shown in a master schedule of a pilot project. This was decided due to the practical application for the selected lean tools, the stakeholders wanted to have a visual and easy to read presentation of the implementation.

2.3 Data Collection

There are several resources of data in this study. The data 1 was collected from existing related company documentations and organized stakeholder interviews. The current company documents were studied from the company´s intranet and by interviewing the production manager and the production engineer. The interviews were provided in the teams with the participants.

Table 1. Data 1 Collection

DATA 1 CURRENT STATE ANALYSIS				
	Source	Data Type	Topic	Time
1	Company documents in intranet	Power point	Process information	27.2.2022
2	Company documents in intranet	Power point	Process information	14.3.2022
3	Production manager interview	Workshop in Teams	Lean tools used in a pilot project	3.3.2022
4	Site engineer interview	Workshop in Teams	Lean tools used in a pilot project	25.3.2022
5	Lean material in intranet	Videos in intranet	Lean construction project method	5 hours during the January
6	Company´s lean management seminar	Video in intranet	The management decisions to implement lean construction method	2 hours during the January
7	Takt schedule	Teams	Takt time planning seminar	31.3.2022
8	Company documents in intranet	Power point	Company instructions about the master schedule	12.4.2022
9	Education seminar	Teams	The company´s management education	24.2.2022

The Data 1 collection was made to gain needed information about the current state in the company. The study was provided to analyse which production tools were used to manage the production currently. The required material was found from several sources in the company. The information about the current production management procedure was found mainly in the company´s intranet. To gain more information about the current production management tools and

the pilot project results, the interviews were provided. The goal was to investigate the current production management tools, how they are used and what kind of experience the interviewees has had using them. A series of questions were provided during the interview to which the interviewees answered. These questions can be found as appendix 1 in this thesis. The answers were provided by the production manager and the site engineer in two separate meetings in the Teams. Most of the production management tools are quite commonly used in the construction industry, so the answers and the experiences may be thought of as representing the construction production quite generally in the company, although the participants were not working in the same department.

The data 2 was collected by interviewing the production director and the production manager of the commercial department. The objective was to gain their opinions about the chosen lean construction tools. A series of questions were provided in the interview to which the participants answered during the meeting. The department director participated via the Teams to the meeting, and the production manager was present. The questions which were used in this meeting are as appendix 2 in this thesis.

Table 2. Data 2 Collection.

DATA 2 CREATING THE PROPOSAL OF THE LEAN TOOLS				
	Source	Data Type	Topic	Time
1	Department director and production manager	Teams and meeting room	Which lean tools will be implemented	9.5.2022

The data 3 were collected by interviewing the production manager of the commercial department. According to the feedback and discussions that was given, the proposal of the lean tools was provided. The questions and comments provided in this meeting are as appendix 3 in this thesis.

Table 3. Data 3 Collection.

DATA 3 CREATING THE PROPOSAL OF THE LEAN TOOLS				
	Source	Data Type	Topic	Time
1	Production manager	Meeting room	Which lean tools will be implemented	17.5.2022

2.4 Data Analysis

The data which was collected for this thesis was collected from various resources. First part was the current state analysis. This was provided to gain the information about the current management processes and tools. There are well organized production processes in the case company. There are all the different obligations for the different phases of the production, such as the preproduction phases, production phase and the maintenance phase available for the staff. Moreover, there are guidelines what kind of actions must be made to follow the given tasks in different phases of the production.

The data how the actual production management is made in the company was searched from the company´s different kind of production programs, such as schedule program, 3D modelling program, and different kind of other production management programs that are used in the company. There are several programs that are quite common in the building industry, and this kind of data was collected mainly from the company documents. There has been a couple of pilot lean projects in the company, and it was interviewed two participants, a production manager, and a site engineer, who participated in these projects. These interviews were provided to gain the information and to have the best practices which kind of production tools are suitable for the production. The company provides different kind of education for the personnel, such as how to manage the workforce at the site. There has been also education for the lean construction management production. The top-level management has made the decision to implement the lean construction project delivery method in the

company. The data was collected from these company education seminars and documents as well.

3 Current State Analysis

The current state analysis (CSA) describes how the production is managed currently and analyse the strengths and weaknesses in the process. In this section there are list of used production management tools, these tools are either so called traditional production management tools or lean tools used in pilot projects.

According to Kananen (2013) observation can be used to gather information about the object under study. Especially if the research is about the processes involved personnel, the observation is recommended. The different functions of a process are usually described and documented in an organization, but it does not necessarily mean that the organization would act as planned. It is good for an external researcher to become familiar with the subject for example by observing. In this kind of work tools are needed to record how the observations have been made, for example by a research diary. Observation is recommended to be provided if the information is not available or reliable by other means, such as interviews or inquiry. The process of work tasks can be a long-term learning process, and it may be difficult for the operator to describe the process. In many cases it is difficult for the interviewee to describe the activity and then the researcher must observe the process (Kananen 2013: 88).

3.1 Overview of Current State Analysis of Existing Production Tools and Lean Production Tools Used in Pilot Projects

The current state analysis and data collection was provided by interviewing stakeholders and studying the company documents. The process maps of existing production management procedure and the tools used currently in the building projects were examined. The company has well organized production process maps existing, and the main processes were established including the production and the procurement.

The company had pilot projects in another department and interviews were provided what kind of best practises and observations was made with the

stakeholders. According to the information given from the pilot projects, it was focused on how the lean production tools were used. There has been some education on the lean tools, so it was not totally new subject for the participants but despite the education, the lean philosophy and production tools were quite new approach for the participants and for the case company generally.

3.2 Analysis of the Existing Production Management Tools in Use

In this section, the existing production management tools used in the company is analysed. There are several so-called traditional production tools which are used currently, and some lean construction production tools or methods, which were used in the pilot projects in the company. There are also comments about the different management tools concerning the lean production approach.

The existing production process maps were provided well in the company, and it has been used several years. The information is well organized, and these process maps are presented first time to all staff during the introduction when a person starts working for the company. This mean that it is well known for everyone, and the company makes sure that the needed information is provided at the early stage for the staff. The existing production tools which are used in the company are, for example, for providing schedules, and other management tools for the production. The supervisors use these tools on daily basis at a construction site. To be able to use these production management tools effectively, the case company provides a wide range of education for the use of these programs. This is well organized in the company and the support for these programs is available for everyone if needed.

3.2.1 The Main Production Process

The core values of the company are the five fundamental principles that lead all activities in the company. These values are called in the case company the company spirit, reliability, a personal approach, to be practical, and to develop. The company code of conduct presents the guideline that leads the production

and all the functions. They are the main principles that applies all personnel and activities in the company.

The main business process model is available at the company´s intranet pages and the company policy is that everyone will be acquainted with the document. The company has well organized business processes for the production and other process which are included. There is a business process chart in which it is presented, depending on the department, which different steps needs to be taken within the building process from start to the end.

The business process for the commercial building department includes all the needed steps within the whole process of production. I will concentrate in this study to the production phase, so it means that the other phases of the procedure are excluded from consideration. The process map starts from the very beginning of a building project. In the process maps it is clearly shown all the different phases of the process and duration guidelines. There are presented the activities which are included in the process from the start to the completion and the maintenance phase depending on the form of the building process. These steps include the different tasks which are needed to provide during the building process, the tasks are presented clearly for all the stakeholders.

The three main phases considering the production process are the production preparation and implementation planning phase, the construction phase, and the warranty period and customer aftercare phase. The documentation includes the tasks which are obligatory for all the participants from the top-level management to the site staff. For example, the tasks for the department director, for the procurement, for the cost estimation, and for the project manager and as well as for the site staff. This list of tasks is supported by a more detailed list of tasks, where anyone participating the project can check out what kind of tasks he or she is obligated.

The first phase, production preparation and implementation phase, consists of getting the building permit, implementation planning and preparing the construction stage. There are slightly different kinds of tasks depending on the contract form but in this guideline, it is provided in a more general perspective. The next phase is the construction phase, and it includes the construction phase and the hand over phase. The third phase is the warranty period and customer aftercare phase which includes final financial statement and warranty repair within the warranty period.

There are also check points where the management is monitoring the procedure from the beginning to the completion of a project, and during the maintenance phase. For example, the project manager must present the risks and potentialities that may occur in a project, and the lawyer´s risk assessment is made before the procedure of a project will go on. Moreover, during the construction phase, there are certain check points in which the management of the company will follow the project in terms of financial, quality and site safety issues. The case company has a comprehensive education for all the managers. Every manager is obligated to participate this education as part of the company´s education program. This program includes different methods (TO GROW method) how to manage the site functions and the people working in different parts of the building process. There are practical tools how to manage different kind of situations such as, providing the feedback to the staff (it can be positive or corrective feedback), and how to deal with different kind of personality types (Disc method). During the education program there are lots of different kinds of exercises how to apply the good management with these different personal types in different situations. The building schedule planning is a process which starts in the very beginning of a building project. The general contractor provides a preliminary building schedule during the project planning phase, and the schedule will develop to a more detailed version as the project progresses. The master schedule is usually the more general schedule in a project. The progress of the building schedule includes more details about different work packages and detailed durations. In building schedule planning

the rough level targets define the more specific and detailed level goals (Koskenvesa et al. 2007:8).

3.2.2 The Master Schedule

There is a guideline about the master building schedule in the company`s intranet. The document is so called room board which shows the different steps how to create a master schedule. According to the company document, the firsts phase is the planning. This phase includes five different steps:

1. The different schedule tasks are scaled based on quantities, work accomplishments and resources.
2. The progress of the work is shown according to the work order and the HVAC works are also included. The main work packages are planned with the different stakeholders.
3. The schedule is provided as a location-based schedule.
4. It is important to ensure the concrete drying times and other risks. The different milestones are shown with separate vertical lines and other important key tasks such as waterproof roof, heating is on, and technical facilities are ready. The hand over stage schedule is show separately in the master schedule.
5. To ensure the master schedule is approved by different contractors and stakeholders.

The second phase is managing and monitoring the master schedule. This phase includes five different steps:

1. To ensure that the different tasks are possible to start as planned in the schedule.
2. To monitor and control the different tasks based on the quantities and resources, including the HVAC works. The master schedule should be seen on the wall of the site office.
3. To monitor weekly the master schedule and the more detailed schedules.

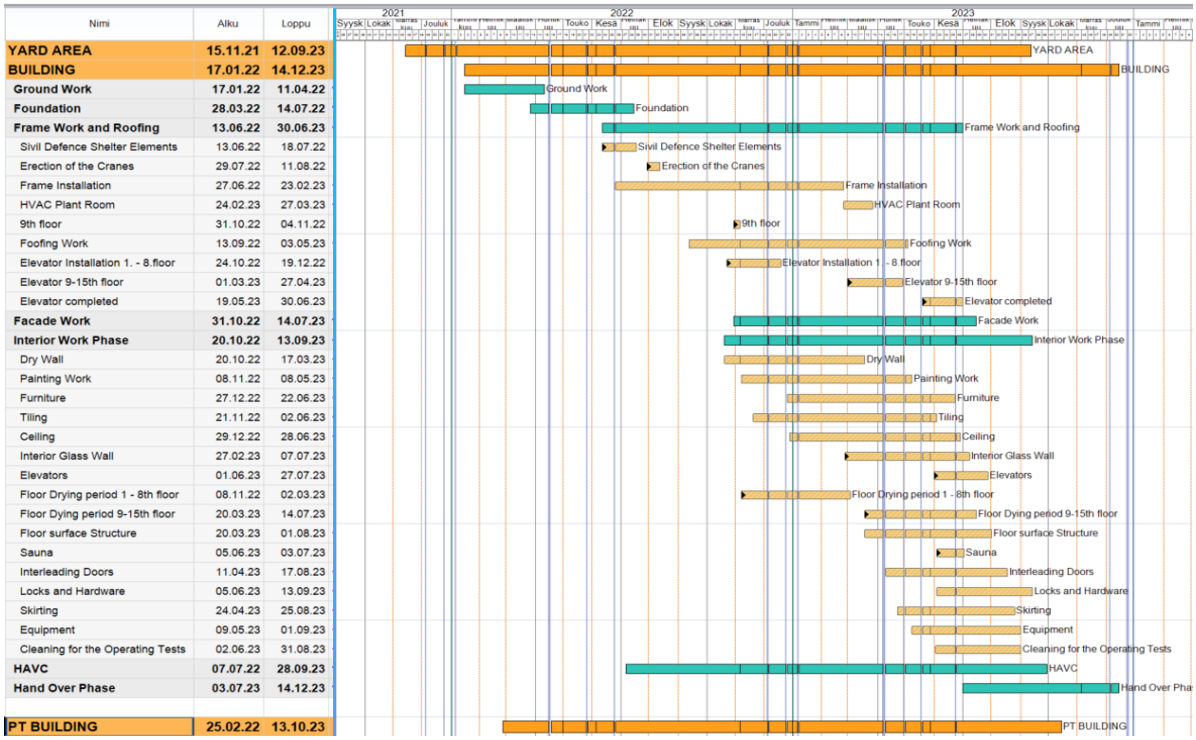
4. To prepare well to the schedule meetings and to report the up-to-date situation at the jobsite. To plan and provide the needed work if any corrections should be made.
5. Provide the situation in the meetings according to the work progression at the site. Write down the corrections which are made. If it is needed provide the accelerations schedule.

The construction phase building schedule will be specified with the work task planning and with the weekly work planning. The purpose of the work task planning is to plan and manage the construction production so, that the production will achieve the given goals, that is the lead time, economical and qualitative goals. The focus is on the building time and critical tasks. The purpose of the weekly work planning is to complete and review the designs according to the current state. It is important to develop the right circumstances to be able to start the work and to tackle the possible obstacles (Koskenvesa et al. 2007:8).

The purpose of the building schedule is to plan the duration of the building project. This information is crucial for all the different parties of a project. The initial building schedule is usually required in the building contract and the general contractor is obligated to provide it according to the signed contract with the client. In many cases the general contractor will provide a more detailed building schedule as the construction phase will progress. This means that it is a continuous process to maintain the building schedule during the completion of the construction phase. At the end of a building project, before the project is fully completed, a final phase schedule is provided. The company uses Tocoman scheduling program for the scheduling of the building projects. This program is a flexible to use and here are all the needed functions, such as durations for the tasks and location-time based functions. According to one participant of the CSA interviewee, it is very important to provide the building schedule as accurately as possible from the very beginning of the process.

> “The better the schedule has been provided early on, the better is the result” (Site Manager).

The interviewee points out that they started to work very early on with the main building schedule. He said that the different items which include into the work were examined, and all the quantities of different work packages were carefully studied. To be able to estimate the duration of the work, it is crucial to know the amount of material and work included. In order to estimate the duration of a particular work package, the amount of the workmen must be estimated as well. It is a demanding and complicate task to go through all the different items included in the main schedule. The more detailed building schedule is usually provided separately. The most important reason for the master building schedule is to describe the whole building project from the start to the completion. The master schedule is a useable tool to manage a building project, but it is not quite detailed enough considering the lean construction project delivery method. It has been used as a management tool for many years in the construction business. But the information is provided in too general level considering managing waste time between the different trades at the site carefully. It is difficult to manage and plan the production in a very detailed way and it does not consider the value added to the customer enough



Nimi	Alku	Loppu
YARD AREA	**15.11.21**	**12.09.23**
BUILDING	**17.01.22**	**14.12.23**
Ground Work	**17.01.22**	**11.04.22**
Foundation	**28.03.22**	**14.07.22**
Frame Work and Roofing	**13.06.22**	**30.06.23**
Sivil Defence Shelter Elements	13.06.22	18.07.22
Erection of the Cranes	29.07.22	11.08.22
Frame Installation	27.06.22	23.02.23
HVAC Plant Room	24.02.23	27.03.23
9th floor	31.10.22	04.11.22
Foofing Work	13.09.22	03.05.23
Elevator Installation 1. - 8.floor	24.10.22	19.12.22
Elevator 9-15th floor	01.03.23	27.04.23
Elevator completed	19.05.23	30.06.23
Facade Work	**31.10.22**	**14.07.23**
Interior Work Phase	**20.10.22**	**13.09.23**
Dry Wall	20.10.22	17.03.23
Painting Work	08.11.22	08.05.23
Furniture	27.12.22	22.06.23
Tiling	21.11.22	02.06.23
Ceiling	29.12.22	28.06.23
Interior Glass Wall	27.02.23	07.07.23
Elevators	01.06.23	27.07.23
Floor Drying period 1 - 8th floor	08.11.22	02.03.23
Floor Dying period 9-15th floor	20.03.23	14.07.23
Floor surface Structure	20.03.23	01.08.23
Sauna	05.06.23	03.07.23
Interleading Doors	11.04.23	17.08.23
Locks and Hardware	05.06.23	13.09.23
Skirting	24.04.23	25.08.23
Equipment	09.05.23	01.09.23
Cleaning for the Operating Tests	02.06.23	31.08.23
HAVC	**07.07.22**	**28.09.23**
Hand Over Phase	**03.07.23**	**14.12.23**
PT BUILDING	**25.02.22**	**13.10.23**

Figure 2. An example of a Master Schedule

A location-based building schedule is one form of a more detailed master schedule. This approach breaks each work packages down to physical locations in a project, and it enables to monitor the workflow a bit more precisely. By doing this it is easier to ensure that the previous trade has been completed before the next trade begins. This is important concerning continuous workflow, and it is important for the site supervisors to be able to have a general view of the production.

Location-based schedule shows better if there are any overlaps with the work packages compared with traditional schedule. As the term location-based suggests, the different trades at the jobsite are shown in different sections. With more detailed building schedule it is possible to manage the work more specifically.

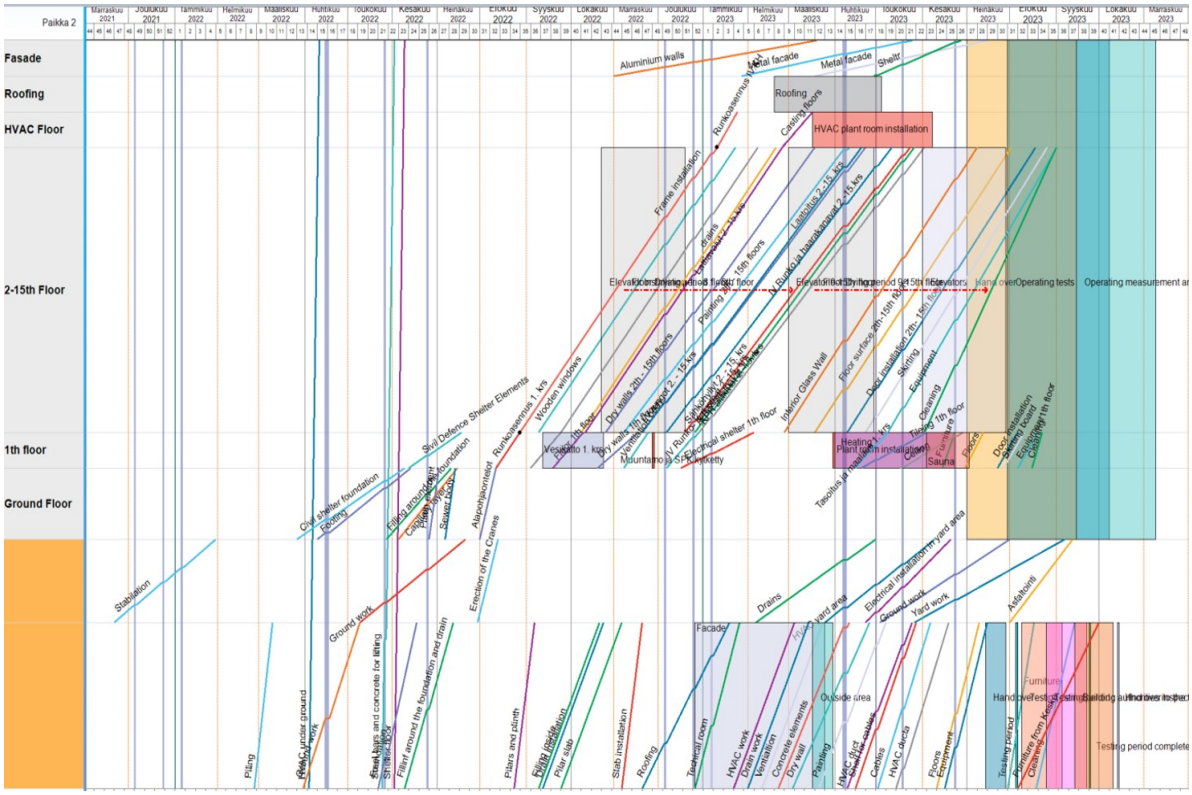


Figure 3. An example of a Location-Based Schedule.

The downside of the location-based master schedule is that it does not provide enough detailed schedule concerning the lean construction production method.

There is more information, such as different locations of a building project, compared to the traditional master schedule, but it does not provide opportunity to manage the waste enough.

3.2.3 Site Plan

The site plan is an important plan to be able to manage the use of the site area. The superintendent and the site engineer will provide the plan to be able to organize the different functions and location at the jobsite. For example, the different stakeholders like workers and all the staff the uses the jobsite need to have the information about the location of the site office, the crane, the waste area, and the actual building and for example the position of the site fence.

The transportation to the site is also planned in the site plan, it is shown, for example, where it is permitted to drive in and out to the site. All the subcontractors and other stakeholders, who are using the site, need to follow the plan. This plan can change according to the progress of the project, and it is important to review it on weekly basis. This plan is made usually by computer using the pdf program to draw the needed information to the plan.

Considering lean construction method, the site plan is supporting the method well enough. The site plan can be compared with the 5 S tool because its purpose is to organize and keep the site area clean although it covers the whole site area.

3.2.4 Construction Project Team Meeting

The weekly construction team meeting is a regular meeting with the general contractor´s site personnel. It is typically held at the same time and on the same day each week at the site office. In this meeting the superintendent is the chairman, and the site engineer will keep the minutes. The purpose of this meeting is to monitor the building budget, schedule, communicate about the overall situation in the site and other issues with the team. It is one of the

regular weekly meetings, which is not a so-called formal meeting, but important to the members of the general contractor´s team, in order to coordinate the different functions at the site. This meeting includes monitoring the look ahead and up-coming schedule.

The different work packages and tasks are divided between different supervisors and the progress of these different tasks is monitored and needed corrections planned to be able to stay on the schedule. This management tool is supporting the lean project delivery method well enough due to it is possible to go through needed information with the project team on weekly basis.

3.2.5 Weekly Construction Contractor Progress Meeting

The weekly construction progress meeting is an important meeting for all the contractors, in which the contractors and other participants meet regularly on weekly basis. In this meeting the super intendent of the general contractor will be the chairman and usually the site engineer will keep the minutes. The agenda of this meeting includes the follow up of the building schedule. This means that all the subcontractors report their status of the work and the building schedule. Several important topics such as the quality, the site safety and the mechanical and electrical inspector’s issues are on the agenda. In the weekly progress meeting it is supposed to solve the issues that have occurred at the site and identify possible problems. The participants are usually the different subcontractors project managers and foremen. Each party will go through their situation at the site and report the progress. The general contractor takes notes and follow the building master schedule.

The interview revealed that the superintendent and the site engineer thought that the weekly construction contractor progress meeting was pointless and took too much time on weekly basis. This was due to the tasks and schedule monitoring was organized so well that the meeting was considered useless. They both thought that the different contractors were monitoring and managing so well their own work, that only in some rare cases it was considered important

to organized. In generally the weekly contractor progress meeting is supporting lean project delivery method well due to it enables all the different participants to meet and go through the needed information concerning the common objective in the building project. This improves the ability to reduce the waste and increase the value for the customer.

3.2.6 Site Meeting

The monthly meeting is a one of the so-called formal meetings with the participants of a building project. In this meeting all the stakeholders of the project are participating and report the status of their work for the client, including the designers, inspectors and other stakeholders. Usually, the chairman of the monthly meeting is either a consultant representing the client or one of the clients' own personnel.

The agenda of this meeting is to go through the building schedule, the current situation at the site, to inform the client about the possible change orders, to inform any kinds of issues concerning the project. The purpose of the site meeting is to inform the client and other stakeholders about the progress of the jobs and what are the next steps in the project. To communicate face to face is also important for all the stakeholders to be able to get the needed information.

The monthly site meeting is supporting the lean construction project delivery method due to all the stockholders are participating the meeting and it is possible to share the needed information within the project and this way add the value for the customer.

3.2.7 Kick off Meeting for the Work Tasks

The kick off meeting is a meeting in which the general contractor meets the subcontractor and goes through the work task which has been contracted. It usually takes place just before that the actual work is supposed to start. The agenda of this meeting includes all the designs, specifications, and other issues

which the subcontractor must complete according to the signed contract. It is crucial to have a common consensus about when the work will start, what is the building schedule, what are the quality standards, and when the work needs to be completed.

The meaning of the kick off meeting is to bring into focus the more detailed production plans and building schedule, so that the general contractor´s supervisors can manage the work and the sub-contractor´s staff have the sufficient information about the given tasks. For example, the starting time, needed material, material delivery, number of craftsmen and milestones for the job.

The kick-off meeting is supporting the lean construction project delivery method due to it is possible to inform the subcontractor how the project is planned to deliver.

3.2.8 3D Modelling

The 3D modelling is a design tool which is easy to use, and it gives a wider perspective to the designs of a building project. It enables to check out the needed details of any designs included the project. There are different layers or parts of the designs that can be either taken off or on, for example, technical, electrical or construction designs can be switched off if needed.

The 3D program is useful when different parties are coordinating the work together, for instance, electrical or mechanical contractors need their penetration holes to be able to assembly their cables and ducts according to the building schedule. By using 3D model it is easy to mark the needed positions exactly (height and width) for the holes for the driller. In many cases this saves time and effort in a building project. The company uses a commonly used 3D program, and the education of the program is provided for the staff, it is well organized, and the needed support concerning the program is available.

The 3D modelling is supporting the lean construction project delivery method due to the model provides a modern and more easy way to monitor the plans, so it saves time, and it is easy to use.

3.2.9 The Daily Management at the Site

The daily management at site includes the supervisors' daily instructions and monitoring of the different work packages and tasks. It is crucial to follow the progression of the work visually and collaborate with the different sub-contractors and teams. The subcontractors need to have continuously instruction to various questions that occur sometimes daily. It is crucial to react quickly to the problems to be able to manage the workflow effectively.

The daily work management at the jobsite includes the walk through the construction site several times in a day and encourage teamwork and cooperation. This kind of management is performed through the whole project to ensure all the participants contribute to the project. This is good and practical way to receive the needed information about the progress of the work. The supervisors can monitor and manage according to the information from the building schedule, the designs, and the specifications they have received. The daily management at the site is supporting the lean construction project delivery method due to it is important to go to the source of the problem and this way to solve the possible problem with the staff who actually do the work. In the lean construction production, there is actually a term for this, the Gemba Walk. Therefore, this a good example of a method which is commonly used in the traditional construction project delivery, but it is not emphasised enough, or it is not detailed enough as a method.

3.2.10 Quality Management by Congrid

The observations of the safety issues and other construction issues are collected to this program and shared to all the parties of the project. This is important tool to be able to manage the cleaning work, and overall order of the

jobsite. By this tool it is easy to point out the different issues, for example safety or cleaning issues, which needs to be corrected by one of the contractors at the site, usually the general contractor provides this information for the subcontractors.

This program provides direct information about the situation in the site. Usually, it is one of the supervisors that will use the program at the site. It is a good way to organize and send the information forward to the different stakeholders and manage the issues. If the particular contractor, for example, has not provide the needed cleaning after the work has been completed, the general contractor is able to give orders to complete the cleaning. If the contractor is not reacting to the information, the work will be completed and charged later. The needed education is well organized in the company and the support for the use.

The Congrid supports the lean construction project method due to it enables to mark, for example, the safety and cleaning issues in a visual way for the information of everyone.

3.2.11 The Humidity Management (Kuivaketju10)

By monitoring and managing humidity during building production, it is possible to prevent the moisture damages. There are several techniques to prevent and avoid moisture damages during a building project. The case company has an education program (Kuivaketju10) in which the staff gets up dated information about the humidity issues in different location at the site. Within the Kuivaketju10 operating model it is focused in ten the most usual moisture damages. By preventing these issues, approximately 80% of the moisture damages can be avoided. This program is provided through the whole construction process to be able to prevent the moisture risks.

The different steps (Kuivaketju10) according to the program are:

1. The exterior of the building
2. Rainwater management
3. Roofing
4. Avoiding the risks coating too wet concrete
5. Avoiding the moisture coming inside the building through the openings
6. Air condition adjustment
7. Managing the water pipe damages
8. Wet space area sealing
9. Avoiding the material moisture damages
10. Maintenance management

This humidity management model supports the lean construction project delivery method due to it is possible to add value to the customer by managing the process of the construction in a way that the humidity issues are reduced. This method reduces the possible extra costs avoiding the wet damaged construction.

3.2.12 Cost Controlling

There is a guideline about the cost controlling in the company`s intranet. It is so called room board and it includes the different phases of the cost controlling. According to the guideline there are some principles that are important in the company, such as that atmosphere of the organization supports transparent, honest and timely cost management at every stage of the project. This means that it is encouraged and required to manage the cost controlling. Furthermore, all the cost controlling documents are available to everyone working in the project.

Cost controlling is clearly a responsibility for the site management as well as the project manager. The obligations are available in the responsibility matrix, and the different tasks concerning the cost controlling are given for every participant for the team meetings. Everyone attends the cost forecast meetings. The cost

information is supposed to go on through every set of the procedure and requires regular documentation. This includes that all the information about the cost controlling will be discussed at every meeting during the project. The cost controlling tools are available in the intranet of the company. There are different kinds of cost controlling tools such as JD Plus, Basen BBA, QPR and Excel. Depending on the rights for the use of the programs they are available for the personnel. The managers are supposed to give feedback and support to their subordinates to ensure the cost controlling is provided correctly.

There are two main categories in the company`s cost controlling procedure, first is to plan the cost controlling, and second is to the monitor and manage the cost controlling. The planning the cost controlling includes identifying the different risks. This means that to be able to monitor the main risks in the project, it is important to monitor such work packages that create the biggest risks (risk managing). This phase includes such things as to plan the cash flow according to the instalment table, to ensure the realism of the budget, general conditions estimate is accurate, and to ensure the budget meets the procurement packages, the different tasks in the master schedule and the way the production is carried out. Moreover, it is important to estimate the different work packages separately to be able to monitor these according the progress.

The second part of the cost controlling includes the managing and monitoring the costs. This phase contains things such as forecasting continuously, proactively, and according to the facts the construction costs. This means to prepare properly the monthly cost meeting with needed documents. Therefore, it is important to react actively to the deviation to be able to minimize the effects. Also managing the change order by agreed procedure, which includes to bid the change work and to start the work after each additional or modification work which has been accepted by the client. Accordingly, the change work must be forecasted to the budget correctly on time. The cost controlling supports the lean construction project delivery method and provides value to the customer. By monitoring the building costs and delivering the cost reports it adds value for the customer. In some contract forms the information is for the general

contractor´s stakeholders and this is important concerning to make sure the project is in budget.

3.3 Lean Tool used in the Pilot Project

The following construction management tools are lean tools which were used in the pilot project. These tools are separately presented here and analysed which kind of experiences they provided. The lean tools are new management tools and it was important to gain good practices for the later decision making.

3.3.1 Takt Time Planning

The most important reason for the building schedule is to describe the whole building project from the start to the completion. When the building project is in its early stages usually a master schedule is provided to be able to define building duration. The more the building work progresses, the more detailed schedule is needed traditionally. The site engineer pointed out in his interview that the takt planning was carefully planned in early stages of the building project. Actually, it was difficult to get bids from the subcontractors when the information was given about the takt planning schedule, many of the subcontractors declined the negotiations when they heard about the use of production method. Due to this it was agreed not to use the term takt time planning. The kick-off meeting was arranged with the subcontractors and participants beforehand. In this meeting the plans and schedule were agreed by everyone. Moreover, it was agreed that the same staff at the jobsite will continue through the whole project to be able to tackle the waste of new staff learning the production process. Additionally, subcontractors used the most qualified staff they had, to ensure the good quality of work and the requirements of takt planning schedule. To motivate the subcontractors, it was agreed about the bonuses if the work is done on the schedule.

The takt planning schedule was visually clear, and it was shown on the site office wall, and at the jobsite on the wall of the corridors for everyone. It

included all the different work packages and tasks with different colours. Every evening after the workday, the main contractor checked out that the production was able to continue next day work without delay. This check out procedure was considered very important to be able to smooth the workflow. After the subcontractors got used to the way of production, they even helped each other to be able to meet the common milestones. After the project was completed, the contractors have been contacting and asking more the same kind of projects. This was considered as very positive feedback from the subcontractors about the way the production was carried out and managed.

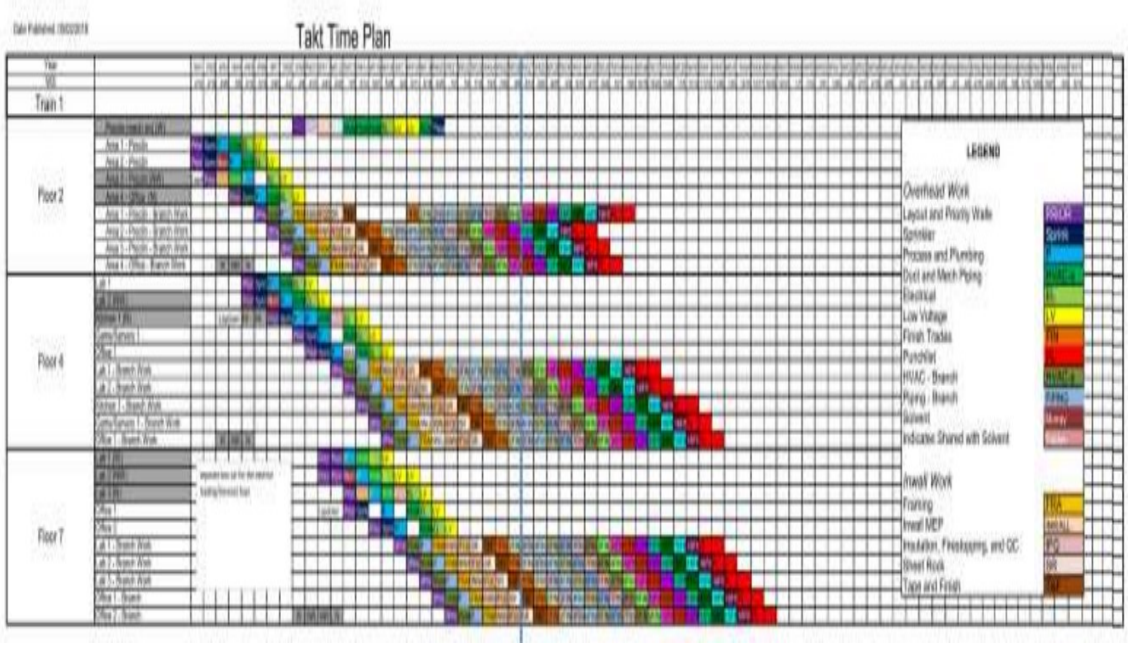


Figure 4. An Example of a Takt Time Planning
(https://www.lcicongress.org/pdfs/2018/THC3-B-Clark.pdf)

3.3.2 Lean tool used in the pilot project; Just in Time Material Delivery (JIT)

According to the site engineer the material delivery to the pilot project jobsite was planned and carried out as just in time delivery (JIT). The only exception was the delivery for the tiles, this was due to the covid situation. The production team planned to minimize the delivery risk by ordering all the tiles for the project

at one time delivery. This was due to no one knew how the covid situation was affecting to the supply chain and manufacturing, when the procurement was provided.

All the other material deliveries were just in time deliveries to be able to minimize the inventory area at the site and to be minimize the possible damages to the material while wating to be installed. The JIT deliveries worked out well according to the site engineer and was considered to be important part of the takt time planning.

3.3.3 Lean tools used in the pilot project; the 5S

According to the site engineer the 5S (sort, organize, clean, standardize, sustain) was not used as a separate management tool at the jobsite, but it was considered that they provided same kind of work otherwise. They had a separate cleaning worker, who`s obligation was to clean up and organize the work site for the next subcontractor. This way it was assured that the next task was able to continue as planned without any delays. It was noticed soon after the way of production approach was applied, that the subcontractors were willing to share the needed information with each other. The different contractors provided help to each other to be able to continue the work according to the takt time schedule.

Due to the takt time schedule was very tight and did not have much buffer time in between the different tasks, it was organized that every morning at 6.15 o’clock one supervisor checked out the jobsite and ensured that everything was ready for the next tasks. If there was anything to be corrected, it was brought up immediately and the information was reported for the superintendent. The detailed schedule for each day was agreed with the site team and different contractors, and the cleaning work was provided after each work package to ensure continuous workflow. This list of tasks was made to ensure also that all the inspections of work and quality, were provided as planned.

3.3.4 Lean tools used in the pilot project: Last Planner

The Last Planner was in use in the beginning of the project, but it was later left out of use due to the takt schedule was working so well. It was considered that different work packages and tasks were on takt time schedule so well that it was considered to be useless.

3.4 Summary of the Findings

Findings which production tools are used in the company currently are shown in the Table 4. There are strengths and weaknesses considering the production tool on the right-side column, weaknesses are highlighted in red colour. As shown in the table there are 12 production tools found used in the company. All these production management tools are used quite commonly within the production of the construction industry.

There is a separate table for the lean tools used in the pilot projects. These lean tools are shown in the Table 5. There are strengths and weaknesses considering the production tool on the right-side column, weaknesses are highlighted in red colour.

It was found that the majority of the currently used production management tools are not detailed enough to add value to the customer and to reduce the waste time between the different trades. In the next table there are the observations about the different building project management tools. There are the found strengths and weaknesses (weaknesses are in red colour), written for each tool in the right column.

Table 4. Strengths and Weaknesses of the Currently Used Production Tools.

#	**Current Production Management Tool**	**Strengths and Weaknesses of the Tool**
1	The Main Production Process	The main process is well organized and provided in the company´s intranet. The process map is little bit too complex and unclear.
2	The Master Schedule	The master is supporting the lean construction project delivery. The information is provided in too general level considering managing the waste.
3	Site Plan	Supports the lean construction, it provides a plan of the site and how to organize different trades. It is important to update the plan according to the progress of the project.
4	The Construction Project Team Meeting	Supports the lean construction and it provides a common meeting to manage the production and it is important to have a weekly meeting with the project team. It is important to use the lean tools to support the lean method during the weekly meeting.
5	Weekly Construction Contractor Progress Meeting	Supports the lean construction, it provides a common meeting with the different contractors to manage the production at the site. It is important to use the lean tools to support the lean method during the weekly meeting.
6	Site Meeting	Supports the lean construction, it provides a common meeting with the different stakeholders to manage the production at the site. It is important to use the lean tools to support the lean method during the weekly meeting.
7	Kick off Meeting for the Work Package	Supports the lean construction and enables to manage the subcontractors how to apply the lean tools and the production method at the site. It is important to use the lean tools to support the lean method during the kick-off meeting.
8	3 D Modelling	Supports the lean construction and enables to manage different designs in a visual way.
9	The Daily Managing at the Site	Supports the lean construction by continuous improvement and monitoring the progress at the site, similar to the lean tool Gemba Walk.
10	Quality Management Congrid	Supports the lean construction and enables to manage the quality of the work and building schedule.
11	Humidity Managing (Kuivaketju10)	Supports the lean construction and enables to manage the moisture damages at the site.
12	Cost controlling	Supports the lean construction and adds value to the customer by providing the cost reports according to the progress of the project.

There is a separate Table 5 for the lean tools used in the pilot projects, the strengths and weaknesses are written on the right side of the table. There are three lean tools Just In Time, The 5S and the Last Planner which were used or partly used in the pilot projects.

Table 5. Strengths and Weaknesses of the Lean production Tools Used in the Pilot Projects.

#	Current Production Management Tool Used in the Company	Strengths and Weaknesses of the Lean Tool
1	The Takt Time Planning	The takt time worked well and helped to organize the different work packages to improve the workflow. At first it was difficult to implement the takt time planning with the subcontractors before all the participants were familiar with the procedure.
2	Just in Time Delivery	Just in time delivery worked well and supported the production.
3	The 5 S	The 5S was not implemented as a separate lean tool.
4	Last Planner	The Last Planner was left out of use due to the takt time planning schedule was working so well.

At the general level it was observed that the majority of the currently used production management tools are working well as management tools. But many of the traditionally used production management tools are not supporting the lean construction project delivery method sufficiently. The found weaknesses are marked with red colour in the table. Many of the traditional production management tools are not concentrating sufficiently to decrease the waste and increasing the value for the customer. The different tools are not detailed enough to manage the site as a whole but are too general in nature. On the other hand, they are not against the lean construction method and can be used simultaneously with more detailed lean construction tools. It is reasonable to use many traditional production tools at the same time with lean tools.

Considering the different categories of the framework of this thesis which are overall optimization, value creation, reducing waste, continuous improvement, respect and grow your staff, and workflow, there are not such work tools which are supporting the production detailed enough within the traditional production tools. Furthermore, there are no real defects or flaws in the currently used production management tools, but to be able to focus more closely to the production issues, such as overall optimization and value creation, there must be production management tools which are supporting more this kind of approach. In the next section the more detailed work management tools are researched to improve the construction production and how to reduce the different forms of waste, such as waste of time and waste of materials.

4 Literature Research

This chapter presents existing lean construction context. Literature was searched to obtain how lean concepts apply to the construction environment and to obtain a good overview of lean methods to improve production . According to H. Forbes there are several ways to define lean construction and the definition continues to progress. Actually, the term “lean construction” includes both the design and construction, as these are interdepend activities. Therefore, the design phase determines greatly what will happen during the construction phase. The lean construction provides a solid framework for a construction project, unlike many other management approaches. Its roots come from The Toyota Production System (TPS), and it is a new way to provide design and construction projects in a complex and demanding environment for the building industry. The lean construction approach provides improvements to be able to tackle many inefficiencies in the building industry (Forbes et al. 2020:25).

According to Liker (2006) the Toyota way can be defined shortly by two supporting pillars: continuous improvements and respecting people. The continuous improvement defines the basic approach for the way to do business in Toyota: to challenge everyone. More important than the improvements provided by a single person, is that by the continuous improvement it will be created a learning atmosphere and environment, which will not only approve the changes but also adopt them. This kind of environment can only become if the people will be respected. This is the other supporting pillar (Liker 2006:9).

4.1 Overview of Lean Theory

Modig (2013) describes that the traditional form of productivity is resource efficiency, and it means to utilize the resources as well as possible. The productivity of the industry has based on the improvement of resources efficiency last 200 hundred years. The basic principles of development of the industry have been to divide the tasks into smaller parts, and then the parts

have be given to an organization, to a group of people or to a function to provide (Modig et al. 2013:9).

The other principle has been the advantage of scaling in production. The utilization of resources when individuals, parts of organizations or whole organizations has been providing smalls tasks repeating continuously the same task. Making work more efficient with this kind of improvements, it has had a huge influence on the unit costs of products (Modig et al. 2013:9).

The most natural perspective to review the productivity has been, and still is, the use of the resources. It is the basic principle of forming different kind of organizations and managing them. When emphasising the productivity of resources, the main focus is on the needed resources such as personnel, facilities, machinery, work tools and production process models. The productivity measures how much is a one unit of resources utilized in one period of time and opportunity costs is the loss if the resources is not used. It is possible to use the resources, at least partly, into something else. For example, to make loan payments, borrow the money or invest it, and due to this, it is important to use all the resources in efficiently (Modig et al. 2013:10-11).

According to Modig (2013), the new definition of the productivity is the flow efficiency. In this perspective the focus is not any more on the traditional resources efficiency but on the flow of activities. This is not a totally new approach; it was utilized in ship manufacturing in a shipyard called Arsenale in Venice in the 16th century. They were able to produce a ship in less than one day, compared to other parts of Europe it took several months (Modig et al. 2013:10-11).

The efficiency of flow is measuring how many units is provided in one period of time. The value of the flow efficiency is determined by the time when the flow unit is creating value. In the organization level the efficiency is determined whether the unit is gaining value or waste (Modig et al. 2013:14). To be able to understand the flow efficiency, it is important to have knowledge of the

processes and how the processes are working, due to the flow is created in processes. The value can be defined as value adding activities or as value not adding activities. When the emphasis is on the flow efficiency, all the not value adding activities are removed and the value adding activities are connected. What is being created in a process, it is called units, and during the flow of a process, units are processed from input to output. These different units can be basically material, information, and humans. It is the most important to define the different kind of processes from the perspective of units. Many organizations make the mistake of defining the process according to the operation itself and its functions (Modig et al. 2013:18-19).

When it comes to efficiency of resources, the emphasis is on the resource utilization. The efficiency of the flow, on the other hand, concentrates on how the flow of the unit progresses through the whole process. This means that to be able to ensure the efficiency of the resources, it is more important to utilize the resources, in other words, to make sure the resources have units to process. And respectively, to ensure the flow efficiency, it is important to provide the flow running and to ensure that there are some resources available which are processing the units (Modig et al. 2013:21).

Jeffery K. Liker points out, that essence of the lean production delivery method is the philosophy behind all its functions. He writes that thinking Toyota and its functions, it reminds him about the popular order which Deming provided: “the permanence of the purpose”. The permanence of the purpose explains why it is possible to win, if you bet, that the Toyota will provide profit in any given year. This is due to there are no huge growth numbers or major strategy change. Most likely there are not changes in the board of executives, in which a new management would take over the management and change the company. Instead, you will observe slow growth and solid movement forward. This is so called permanence of the purpose, as Deming probably meant. This approach will last longer than just for a couple of executive’s good options and short terms profits. It is about the Toyota´s way of providing the value for the customer, the workers and the society (Liker 2006:82).

To understand how lean techniques works in design and construction processes, it is important to understand how lean improves the process of performance in the manufacturing industry, as well as in the service industry (Forbes et al. 2020:2).

According to Forbes the term lean is considered among the researchers as a new and improved type of production system for automobiles (Womack et al. 1990). The performance measures were observed by the researchers between Japanese, America, and European firms, and the results were convincing. The results showed that due to Toyota´s performance with the Toyota Product Development System (TPS), it was an exceptional example of a new and better way of producing many kinds of goods and services (Forbes et al. 2020:2).

There can be found influences from many management theories in lean philosophy of production. Current theory of lean construction can be seen as a combination of modern management theories. In this perspective, it is easy to understand why lean management theory has been so successful around the world. In some ways lean theory integrates many of the classical management theories together and goes even further (Salminen 2021:17).

Many business functions that are reengineered are cross-functional. This means that it includes functions from many departments of a company, such as production and accounting. But many companies have reduced labour force at the same time loosing important resources and it has not been strategically profitable (Grover et al. 1997:205, 209).

By comparing craft production and mass production, it is possible to characterize the lean production. During the preindustrial era, the craft production was used, and it required highly skilled workforce to manufacture products for customers, one by one. For example, art works and hand-build vehicles. Such products were usually too expensive for the majority of consumers. On the other hand, so called mass production can be manufactured by unskilled or semiskilled workers, who can produce products in large

quantities. Products were provided by machines and the processes were designed by professional engineers (Forbes et al. 2020:28).

The characteristics of mass production are large quantities and only few products. Moreover, there is a tendency for errors in the process and it is considered acceptable for certain level. For lean production it is quite the opposite way of thinking. In lean production, the producers try to minimise the errors, minimise the inventory, decrease costs, wide variety of products, and seek the ideal perfection. The main focus is on the flow of process, is to add value for the client, producing products or services. And at the same time minimize interruptions and all the possible not value adding practises. For example, activities which are not value adding, such as wasted time and material or waiting time is being minimized during the process. The root causes of waste, such as poor decisions by management or not working processes will be addressed and improved. Lean is not just a set of different kind of tools of processes, as it was first considered when it became more know and popular. Lean can be described as a fundamental business philosophy (Forbes et al. 2020:28).

Niklas Modig et al. 2021 points out that in many companies there is more focus on resource efficiency rather than on flow efficiency. Due to that the utilisation of workforce has been observed as the main objective. This can be a positive situation for the organization as far as only the utilization of the workforce is concerned but can result problems from the customer´s point of view. This is so-called efficiency paradox (Modig et al. 2013:47).

If a company focus only on its resources very effectively it can create some problems for the organization. These problems can occur for both customers and employees. There are three kinds of sources of inefficiency as Modig describes. The first can be described as long throughput times, this creates lots of waste such as unhappy customer, quality issues and other sources of waste. The second source of inefficiency would be too many flow units, for example, for a manufacturing company too many ready units will create too much

inventory which creates more waste, such as managing the inventory and looking for the material, transportation the material and so on, these wastes can be described as “secondary needs” and these are increasing the more complex the process is. The third sources of inefficiency are too many restarts per flow unit. This may occur in a company which is too much focusing on resource efficiency. If there are too many work tasks for the staff, it may result many restarts due to workload. Lot of time and effort is being spent to reorganizing different tasks and it creates delays, waste, and low flow. The idea of efficiency paradox involves, that an organization or some other entity, is actually losing resources in many levels. To solve the problem, the kay factor is to focus on the flow. By providing flow, it is possible to decrease many forms of waste and every decision which decreases the flow or lead time will diminish unnecessary work. Paradoxically not focusing to resources efficiency it can release resources (Modig et al. 2013:48-65).

Niklas Modig et al. 2021 describes that there have also been some problems in developing the lean concept if the objectives and the means are mixed and not separated. It has been emphasized how in Toyota corporation the values, principles, methods, and tools are provided. These all are different ways to provide changes, in other words, a way to obtain an objective. Unfortunately, obstacles will occur, and if it is only concentrated what means or tools to utilize, but it is not understood why these tools are utilized, that is, what was the Toyota´s underlying philosophy (Modig et al. 2013:93).

4.2 Evolution of Lean

According to H. Forbes the Toyota has been a very successful vehicle manufacturer as well as a lean manufacturer and organization. When Toyota studied Ford´s manufacturing operations, they noticed several points to improve in the manufacture process in Japan. The Toyota´s chief engineer, Tacii Ohno, visited several times auto manufacture plans in Detroit. There he noticed many waste in the Ford´s processes. Cost waste was caused in through colarge inventory of parts and additional waste were later found faulty parts. Moreover,

different types of waste were found, such as waste of waiting, waste of transport, waste of manpower, and waste of facilities. The only ones who were adding any value to the process were assembly line workers. Specialists were obliged to plan the process and to conduct the workers of the production process. Ohno understood that all the different kind of waste caused financial loss and he identified the seven types of waste (TIM WOOD, look at the next list of waste). The different types of waste are listed (Forbes et al. 2020:30):

1. T - Unnecessary Transportation: The transportation of unfinished parts or product from one process to another increased energy costs

2. I - Unnecessary Inventory: Unnecessary inventory of unfinished parts or product increases inventory costs.

3. M - Unnecessary Motion: All wasted motion results such as reaching the tools and parts and walking around increase the waste.

4. W – Waiting: Waiting time between different phases, delivery, and component increases waste and costs.

5. O – Overproduction: Overproduction results unnecessary labour, inventory, and transportation costs.

6. O – Overprocessing: Overprocessing results waste due to unnecessary processing, unnecessary planning and providing defects and waste.

7. D – Defects (in production): Defective production and products results reproduction and waste such as replanning, supplement parts.

8. Other wastes such as non-use of the creativity of the staff or new improvement ides or better methods of production.

Toyota had difficulties to provide variety of customer needs with its small budget, Detroit had the opposite strategy, they had huge inventory which

customers could choose from. Moreover, the Detroit strategy was to minimize the costs per vehicle instead of minimizing wasted inventory. The mass production of Ford was able to minimize the unit costs, but it was not able to tackle the errors occurred during the process. Toyota´s improvements in the production processes and too optimistic sales forecast, generated too large inventories and large number of unsold cars in the 1960s due to this they had large financial losses. In Japan consumers desire customized cars which is difficult to provide with mass production and long set up times for the production. In Toyota they decided not to generate human and material waste as it was provided in the United States. It was decided to deliver a system which was suitable for rapid changes between different types of vehicles and the same time decrease amount of waste (Forbes et al. 2020:30).

This system developed to be an amazingly effective and successful Toyota Production System (TPS), it was invented during the period from 1960s to the 1980s. TPS has proved to be an effective production system that provides cost reduction, good quality, respect for human, and sustainable growth (Forbes et al. 2020:30).

4.3 History of Lean in Construction

According to H. Forbes, Koskela et al. (2002) wrote in the article “foundation of lean construction” about his earlier research on theory of production and system of production. Koskela defined three aspects of production in construction (TFV-theory) which has to be combined and provided simultaneously, these aspects are transformation, flow and value (Tommelein 2015) (Forbes et al. 2020:35).

Koskela find out in his research (2000) that there are three different kind of production models which all try to achieve efficiency in its own way:

1. **Transformation:** Traditional form of production process, in this type of production the inputs are transformed into outputs by different kind of

production tasks. The efficiency will be developed by improving the efficiency of production tasks.

2. **Flow:** The production goes on step by step; the process includes value adding and waste adding phases. The efficiency will be developed by decreasing the waste.

3. **Value creation:** The client defines the needs they have, and the manufacturer designs and delivers the product. The improvement of process is created by adding the value for the client. For example, measuring performance of the production.

In his TFV-theory Koskela suggests that all these aspects are important in construction process. In every phase of construction process (design, industrial production, production in construction) all aspects are crucial. This theory is linked closely to the lean philosophy, because in its essence is value added to the client and the workflow (Salminen 2021:25).

The traditional project delivery was considered to be too limited. The management is provided by using scheduling, cost management, and different kind of output measurements. Therefore it was proposed that lean is a better way of project management procedure, because it manages the value creation by the work processes. Koskela considers lean construction as a new theory of construction project delivery, as well as a new application of production. According to H. Forbes, Koskela considers that a theory of production to be a framework in which certain outcomes are expected from specific activities. In the building production framework, these activities could be the design of the building production system, the management of the building production system, and continuous improvement within the production system (Forbes et al. 2020:35).

Koskela et al. emphasize that there are limitations in the “thermostat model” of project control, particularly currently due to the complexity, quick lead times and uncertainty of building projects. It is determined by project controls whether the

building project is on schedule and on budget. Deficiencies are indicated with the thermostat approach and corrected by increasing workmen or other activities. This kind of centralized scheduling is considered to be the reason for many inefficiencies within the building production, because it doesn´t manage the workflow and add value. This kind of thermostat approach is not efficient and can even provide reduced productivity if one supervisor increases production and the same time the workflow of the entire project decreases (Forbes et al. 2020:36).

According to H. Forbes the traditional construction production is similar to the craft production methods. Due to this, it is slow and costly compared to the mass and lean production models, that are used by manufacturers both in vehicle and consumer goods production. In construction projects there are many kinds of specialists working such as ground workers, carpenters, bricklayers, electricians, plumbers, and other subcontractors (Forbes et al. 2020:38).

Despite these different subcontractor specialists being highly skilled, they are interdependent and have contracts of their own with the general contractor or with the client depending on the contract form in a project. Due to the contracts the separate contractors are in a contradictory situation, and if any delays would occur, the penalties are according to the contracts. In addition, the profit margins are at risk if, for example, material costs increase, there are shortages of workforce or difficult weather condition. The parties do not have communication enough concerning the whole project completion, and contractors just try to complete the given tasks as soon as possible (Forbes et al. 2020:39).

- By using quicker working methods and better equipment, the objective is to decrease the costs and increase the productivity.

- The schedule is adapted to the amount of workforce and other factors.

- To improve the quality and safety inspections and control are used

H. Forbes points out that this kind of production model represents the so called “thermostat model” (Hofstede 1978); the output is measured at the end of the process. The difference between a standard and measured performance is corrected to meet the standard level of performance. These kinds of activities to improve the productivity usually has a small impact as far as the whole project is concerned. Furthermore, the building schedule is managed by the general contractor and due to this it is difficult to manage the continuous workflow of tasks and building activities from the perspective of the whole project. Often contractors are in a so-called reactive mode and the management just try to adjust their actions accordingly to maintain the building schedule. The master schedule usually leads the work and defines the contract milestones, and many times limit the collaboration between the contractors and their use of best practices. (Forbes et al. 2020:39).

According to Womack the vertical integration presents bureaucracy in a big scale and that causes more problems. The term “visible hand” which was used by Chandler in his book to provide defense for the modern enterprises against Adam Smith´s “invisible hand” (Womack et al. 2007:32).

4.4 What Lean Is Not

According to Liker (2006), the Toyota company´s experienced executives told to him that the lean tools and methods are not the keys of the production system. The strength of the Toyota´s productions system is the commitment of the executives to invest in the staff and to promote continuous improvement, this took many decades to complete. The problem in many companies concerning lean is, that they think a certain set of lean tools makes their company operate as a steady lean company. The way of Toyota Production System is much wider and profound change in the company culture than many companies can realize (Liker 2006:10).

Liker points out that in many companies in USA it has been adopted lean ways of working but not realized how to operate as a real lean company. Typically, some of the lean tools has been used, but the real power of philosophy has been not realized: continuous improvement which is crucial is needed to be able to maintain the lean approach.

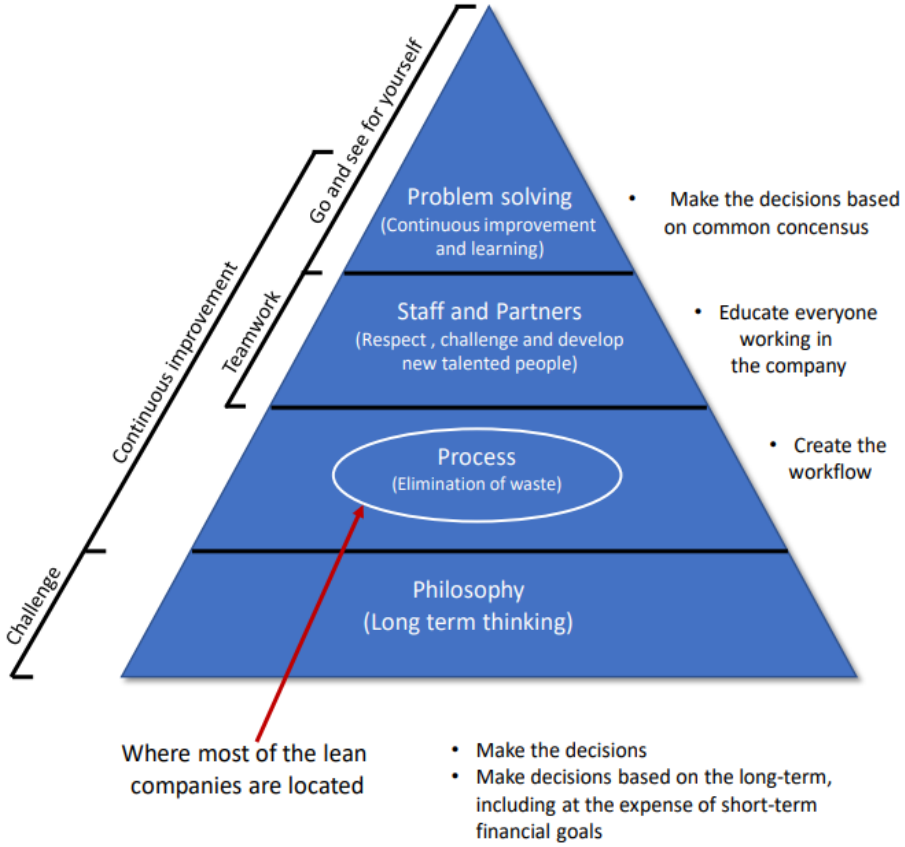


Figure 5. The Four-Level Model. (Liker 2001:13)

Liker points out that in many companies in the US they use the lean tools but do not understand how all the different lean tools work together as a whole picture. It is typical that the top-level management implement just couple of the lean tools and do not understand the continuous improvement culture which is required to maintain the Toyota way of production. Many of these companies are operating in only one level as mentioned above in the Figure 5 and that is why their performance is not as good as it could be (Liker 2001:12-13).

4.5 Description of Lean Tools Used in Construction

Due to the nature of construction production, every building project is one of a kind. This makes the construction business different from the industrial environment where the lean approach was originally invented. On the other hand, there are many phases which are repetitive, such as technical solutions and facilities within the process itself, and there are phases that are the same from one project to another. Usually, the work packages are divided into small phases and competitive procurement is produced These are the reasons why there is kind of culture of separate optimization in different parts of the project in the construction business. This includes that all the separate participants focus on their own scope of work to be able to make the project as profitable as possible (Salminen 2021:61).

This kind of approach is not the way lean works, where the focus is on adding the value for the customer and on the project as a process. This means that the main principle in lean is the optimization of the whole process instead of its separate parts. And optimization of the whole process includes aligning the separate structures of the project to be able to work together towards the common objective. These structures are the different contracts, the procurement processes, organization of the project and common information solutions. In the manufacturing industry the set up for the production in the factory has been made in the very beginning and is more stable, but in the construction business the situation is very different due to the history and special features of production (Salminen 2021:61).

4.5.1 Integrated Project Deliver Methods (IPD)

The contract form of a building project includes the scope of responsibilities and commercial terms and specifications, but also the way of how the competitive tenders, the designs and implementation of completion has been carried out. This means that the form of implementation of the building process forms the guideline for the organization, management, and collaboration. The

collaboration between the parties has been taken to the fullest in Integrated Project Delivery (IPD) model. In this model the contracts are made in the early stages of the project before the design phase (Salminen 2021:62).

According to H. Forbes (2020) the Lean Construction Institute (LCI) defines Integrated Project Delivery as a method, which unites people, organizations, company structures, and practices into a process that integrates different kind of talents and their perspective to decrease waste and to improve the performance in every stage of the project from the start to the end of the project. This project delivery method has been very successful right from the beginning (Forbes et al. 2020:228).

The IPD method has become more popular over the years in the construction industry due to the need to integrate the supply chain better in the different phases of the building process. The integrated method gives a guideline that improves the collaboration between the parties such as the client, designers, and the contractors. This method provides a new way to organize the different project parties, improve the flow of phases, including the design during the completion phase. The new kind of contracts provided with IDP admits the difference of the building industry from other project models and tries to harmonise the relations between the parties (Forbes et al. 2020:229).

4.5.2 Just In Time Delivery

According to H. Forbes it could be possible to save costs by just in time delivery in the construction business as it has been possible to save costs in other industries. It has been proven that poor supply chain management could increase the costs as much as 10 % (Forbes et al. 2020:88).

The supply chain includes all the different functions, like materials, information, and people, as a network that provides a product or service to the customer. The main parts of the supply chain management (SCM) are the information flow, product development with less waste and more effective production and

smaller inventories. A lean supply chain tries to decrease the amount of waste by improving production. Due to the physical nature of the material used in the construction business there are many sources of waste, such as waiting time for deliveries, unnecessary transportation and inventory, and overproduction. H. Forbes points out that many items in the building schedule depend on the material delivery to the site. The design process needs to support the supply chain as well. It is possible to standardize and use these elements and this will reduce waste. In the comparison between lean supply chains and traditional procurement there are differences such as, the lean approach is based on system thinking but the traditional procurement is not systems based (Forbes et al. 2020:88-89).

The just in time delivery includes the focus on arranging deliveries so that the necessary materials are delivered to production in just the right batches at just the right time. If a precise schedule is set for the delivery of materials, then the suppliers are usually used to the delivery schedule being changed in the last minute. This causes difficulties and storages are provided for this, which in turn increases costs. Just in time includes methods such as keeping all parties aware of schedules and commitments, but it is important to ensure and manage the local area circumstances on which the building project is completed. There are challenges to implement the JIT in the building industry. The trend to subcontract contracts has resulted in fragmentation, due to every subcontractor acting in their own interest. This can lead toward contractions between different parties. It is crucial to share the information between the parties and to be able to keep the commitments, for example concerning the delivery schedule. To be able to keep the commitments, allows for the just in time delivery to the site (Forbes et al. 2020:89).

Even if the contractors are committed to the JIT delivery model in a project but the supply chain is not, it will cause problems concerning the project delivery as a whole. And if the just in time is not working as the rest of the integrated project model is, this can cause problems and waste during the implementation of the

project. This applies specially if there are lots of subcontractors in the building project (Salminen 2021:68).

4.5.3 The Integrated Information Technological Equipment

In many cases the information in a building project is not shared openly in a common IT program or platform with every party of the project. Therefore, several applications are available, but they do not communicate with each other. This creates restrictions for the information flow between the parties and blocks out lot of the needed information. Of course, there is some information which is not shared with the whole organization and will be kept within the contractor´s own team (Salminen 2021:73).

4.5.4 The Big Room

Collaboration between the parties is important in lean construction and adds the value for the customer. This is acquired when people meet face to face and can work together in an encouraging atmosphere. The big room is based on Toyota's idea of getting together the different parties of a project and to improve the information flow. In the construction business the big rooms where first used in big hospital projects in California to enable the different stakeholders to work sometimes long period of time, even many years together.

There are different versions of Big Rooms depending on the building project and they can vary in the different stages of a project also (Salminen 2021: 92).

Salminen points out that there can be different kinds of big rooms, and it is possible to combine these variations according to the project.

- Full time Big Room is a room in which the participants of a project are working every day. This works in bigger building project in which the designers are working full time.

- Part time Big Room, in this version the weekly time when the participants will meet, and work together has been agreed upon.
- Project Room, this is kind of a smaller Big Room, it means that the room is a kind of workspace, in which the project team works with a smaller team of participants. The idea is to get a particular team to work intensely together, it can include both teamwork and working alone.
- Virtual Big Room means a virtual information exchange platform, which provides a way to work over the internet. This a good solution when the participants are working over big distances, but nowadays it is also a complementary way of working within a physical Big Room.

(Salminen 2021: 93).

According to H. Forbes, the Big Room is an important way to create a better project culture, and it is a project management tool for improving communication. The approach provides a visual presentation of milestones and the project schedule as well as other important information. As the name suggests it is a common space for the project participants which brings together all participants in to the same space or room for cross functional collaboration. The idea is to have all the needed information available such as notes, design details, schedule and other critical information for all participants and this is a way to improve the flow of information and commitment between the parties (Forbes et al. 2020:195).

When the Big Room has been created, the first thing to ensure is that it is big enough for the use. It can be a bigger meeting room or open space where it is possible to move the furniture around to be able to form different kinds of teams when needed. One more space is for meetings with a big screen on the wall for 3D models and other information, another space is for scheduling where the schedule is visual for all, and one space is for all the project designs and documents. The coffee room needs to be a separate space in a central location. It is important to have open wall space to be able to provide different visual material. The whole idea of the Big Room is to activate and create a collaborative and open culture of discussion and information within the project

personnel. Here are some often used principles in the use of the Big Room according to Salminen:

- everyone will participate according to the common code of conduct
- it is possible to do work for other projects as well but it is important to be available for this particular project
- to keep up the positive atmosphere
- everyone will be listened despite the status, profession of other factors
- it is possible to have discussions with everyone, but the decision is made according to the official procedure
- be critical but in a positive way
- use visual managing as much as possible

(Salminen 2021: 93-95).

Although the Big Room creates the environment for the project delivery, it is important have a solid framework and to manage the procedure at the same time. Managing the Big Room is often described as traditional project management practices. These are scheduling, clear division of tasks, and monitoring the progress. The decision making is processed. To manage the collaboration, it is crucial to create the right atmosphere and to keep up with a positive interaction. This also includes to be able to monitor the progress and to provide improvements continuously (Salminen 2021: 93-95).

4.5.5 Diminishing the Fluctuation

Diminishing the fluctuation “heijunka” is one of the fundamental parts of the lean production. It includes the idea of getting the product to the customer in a reasonable delivery time rather than only part of the product is delivered quickly but another part is delayed. Diminishing the fluctuation in the production industry is acquired by the product and volume variables. Smaller delivery sets and producing different kind of products at the same time helps to manage the production, although one would think the opposite. This same idea applies to the construction business, if for example, one company has 100 million euros

turn over and has ten building projects it is easier to manage the risk than if it would have only a couple of projects (Salminen 2021: 110).

4.5.6 Last Planner

Last Planner (Last Planner System, LPS) was once such an important lean construction tool that it was identified as a synonym for lean construction according to Lauri Koskela. It is basically designed to manage and design the building schedule and to be able to improve the flow of construction production and to reduce the waste in the production. It was invented by Glenn Ballard, and he described it more as a forecast of future activities and the most important thing was to actually forecast rather than the schedule itself (Salminen 2021:111).

Last planner helps to smooth out the variation in production and the workflow, in a way, that the resources, such as material and workforce, can be more productive. In more traditional production delivery methods, the work schedules are adapted on the staff´s ability to produce and hoped the tasks will be completed accordingly. There are research that indicates that approximately 50 % of the tasks in an any given week will be completed in the traditional construction production. Ballard and Howell (1998) studied different kinds of building projects and the average plan failure rate was 54 % (Forbes et al. 2020:94).

A delay in one task completion will have a direct effect on the next trade and so on. The last planner system is a lean method which improves the project production control. LPS tries to match workforce and material to to be able to complete tasks within the production chain. Providing a traditional work schedule, it is often concentrated more on the time frame but not so much to the possibility of completing the task. Interruptions are common and that creates waste. In LPS the focus is on the staff that are directly in contact with the task, and they will provide the schedule and, in this way, become the last planner (Forbes et al. 2020:94).

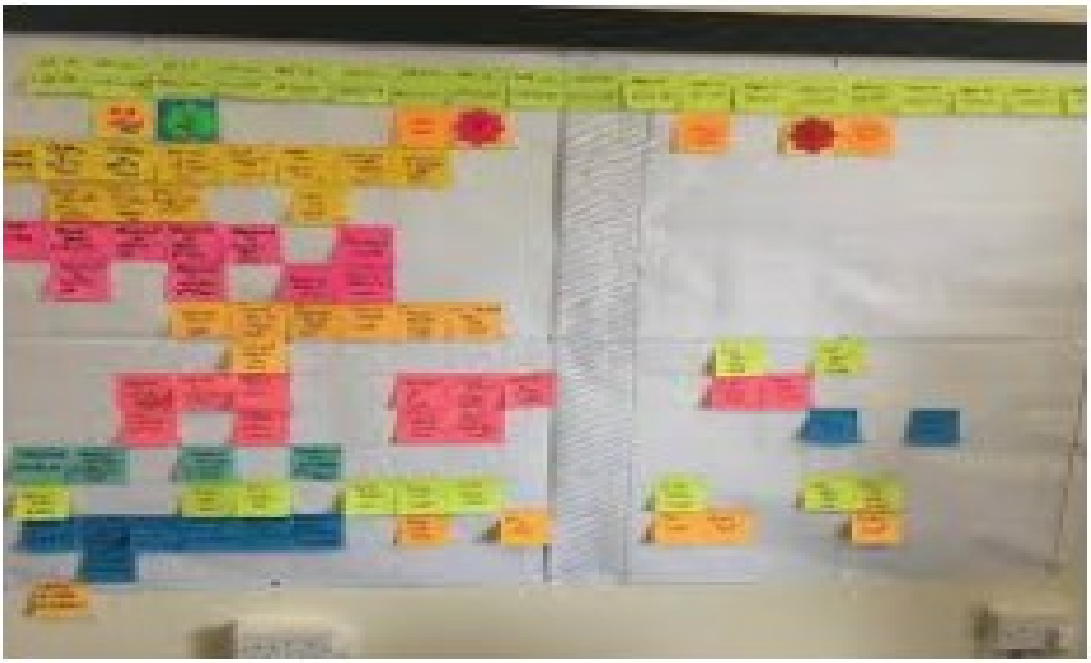


Figure 6. An Example of Last Planner Board (https://twitter.com/clancy_drangan/status/1058637832003223552?lang=zh-Hant)

According to Salminen (2021), the LPS represents the social side in schedule planning. The other schedule techniques are focused on the technical side of the schedule planning, the Last Planner is simpler, and the focus is on providing a schedule collaboratively and to commit to the result. Due to LSP there is only one perspective to provide a schedule, it is better to consider it as a complementary technique and not as an alternative technique. It is used when the work is being executed and needed information is made available as much as and as soon as possible, so it is provided during the construction phase (Salminen 2021:111-112).

The LPS is seldom used as a master schedule, but it is based on the master schedule. The intermediate and main targets come from the master schedule, so the goals and guidelines are the same. This means that the schedules are connected and should not develop separately. One person is responsible to coordinate the different schedules and update all simultaneously and provide the information for all parties involved. When the LPS is decided to be implemented, the first phase is to choose a time from the master schedule for

the construction site, which will be the time frame for planning. Due to the plan being very detailed, the time frame cannot be very long, a suitable time frame would be 2-4 months (Salminen 2021:112-113).

The schedule can be for the whole site or a part of it, due to LPS being all about the collaboration, it may not include one single isolated task which will go forward independently. However, for example, for the interior phase which include lots of tasks one after another LPS is very suitable. Furthermore, it is often used in such tasks which are a bit more specialized and require more collaboration between different contractors. That is why it is not often used in tasks which are repetitive and continuous. In such tasks the takt time schedule is better (Salminen 2021:113).

The planning event is all about collaboration therefore all the supervisors or foremen who are working in the area will participate. There has been good experiences when the foremen who really execute the work have been involved in the planning event, because they really are the so called last planners and it is crucial to be able to have their commitment for the work.

It is important that every party comes well prepared to the planning event. This includes that everyone knows their own work schedule and scope of their work. It is possible for them to prepare own schedule in advance, but it is not necessary to provide it due to it will be provided together during the planning event. Therefore, the most important thing during the planning event is to not spend time studying the designs but to focus on the content of the work (Salminen 2021:113).

If the planning event is provided the first time, it is important to review the ideas of the Last Planner, and what the requirements are for the different participants. The first task would be for every participant to provide a list of their content of the work in the order of the implementation. The level of accuracy would be approximately one day. Then these different tasks will be written, for example, to separate coloured stickers or to some other similar notes. If the accuracy of

the work is one day, then it will be written a note about every day. It is important that every contractor have different colours in their stickers, so it is easy to visually separate the different contractors. These notes are placed on the table, including approximately one month´s work (Salminen 2021:114).

The planning is supposed to be done in reverse order, that is from end to start. This principle includes the idea that the desired state is defined first, and these stickers will be fixed first onto the board. Furthermore, the idea is to allow sufficient time for the work to be completed so that the urgency would be in the beginning rather than at the end. The most important thing is to get the different parties to have a good collaboration and to be ready to solve problems together (Salminen 2021:114).

4.5.7 5S

According to Salminen, the 5S analysis procedure is a lean tool, and its goal is to create a safe, organized, clean working environment. In many building companies this is the first lean tool to be used, because it is easy to a create good lean production environment with it, such as workflow. It was originally invented for systematically organizing and standardizing working methods in the manufacturing industry in Japan. It is not about organizing the cleaning work but a deeper change of culture. The different 5S include several functions in which waste is reduced. Also, safety issues are related with accidents, the transportation of material and related searching things are few of them (Salminen 2021: 128).

H. Forbes points out that the 5s is a plan to improve operations and it provides for more organized working environment.

1. Seiri (Sort): To be more organized move away the unnecessary items from the workplace. This includes tools, documents and products.

2. Seiton (Organize): The workplace must be in order and all tools in their places so the workers can easily find their tools (it can be files too), and this way reduce the waste of time searching tools and material. This will also increase workflow.

3. Seiso (Cleaning up): Clean up the workplace daily, whether it is at the jobsite or in the office. All unnecessary items should be put away in order to maintain the good workflow. Every task tool and material should be organized and returned to the right locations. The objective is the continuous improvement of personnel to reduce waste caused by dirty and unorganized workplace.

4. Seiketsu (Standardize): To standardize the best practices with the staff to maintain and manage the first three Ss. Create a check list of the workplace or task.

5. Shitsuke (Sustain): Provide a culture which motivates the staff to maintain these objectives. The company culture includes monitoring and continuous improvement collaboratively (Forbes et al. 2020:410).

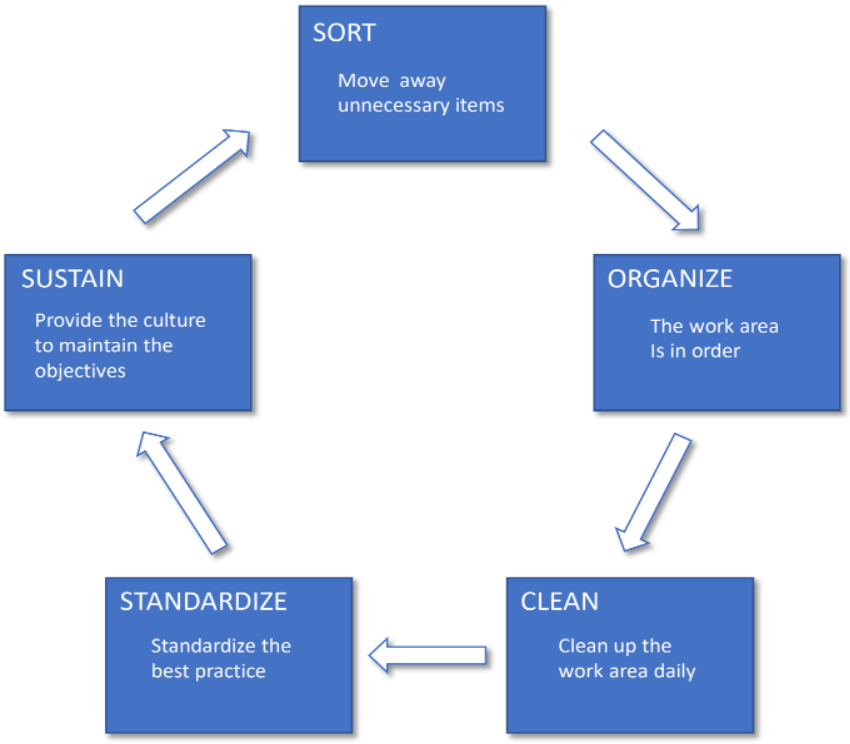


Figure 7. The 5S. (Liker 2006:151)

Although the 5S is probably one of the oldest lean tools used in the construction business it has not been used very widely. One of the reasons may be due to the constantly changing environment of building projects, and due to the fact that the benefits are obviously greater in a more static and permanent manufacturing environment. Weekly cleaning of the site is a common task but due to the 5S focus on reducing the waste of searching the tools and material, it is more effective to provide the cleaning daily (Salminen 2021:129-130).

According to Liker, the 5S is to create continuous improvement particularly for any given workplace. In many cases in mass production without the 5S a lot of waste will be hidden, for example, due to un unclean work environment and it will eventually become an accepted way of working (Liker 2006:150).

4.5.8 The PDCA Cycle

Salminen points out that continuous improvement is easy to understand and important perspective to the building industry, but at the same time it is difficult to apply. In the urgent and tight scheduled building project environment, there certainly are issues that will require improvement. It is the characteristics of building projects that makes it even more demanding to continuously improve on production, than it is in the more stable manufacturing and industrial environment (Salminen 2021:173).

Moreover, it is challenging to be able to transfer the acquired improvements in a one building project to the next project. Again, this makes it a bit harder to provide improvements within the building industry, but in the top level of the company this needs to be taken into consideration, in order to be able to provide continuous improvements in the long run (Salminen 2021:173).

The cycle of PLAN, DO, CHECK, ACT is a scientific framework of improvement in the business process, and it was originally created by W. Edwards Deming who was one of the first researchers to focus on the quality of production. There are four different steps in the cycle: Plan – first the problem has to be identified and a plan has to be created to improve upon it, Do – the plan has to be implemented, Check – monitoring the plan to see if it is working, and the Act – to fix, implement changes, depending on the case (Forbes et al. 2021:403-404).

Salminen points out that the PDCA cycle has become familiar from the quality management approaches and it is very useful in many contexts. It summarizes many fundamental principles of lean philosophy, and it can be applied extensively in lean processes and projects. Every time a new concept will be implemented, or an old concept is improved, the procedure is provided according to the PDCA-cycle principle. The fundamental idea in lean is to improve continuously and not stick to the current situation (Salminen 2021:174).

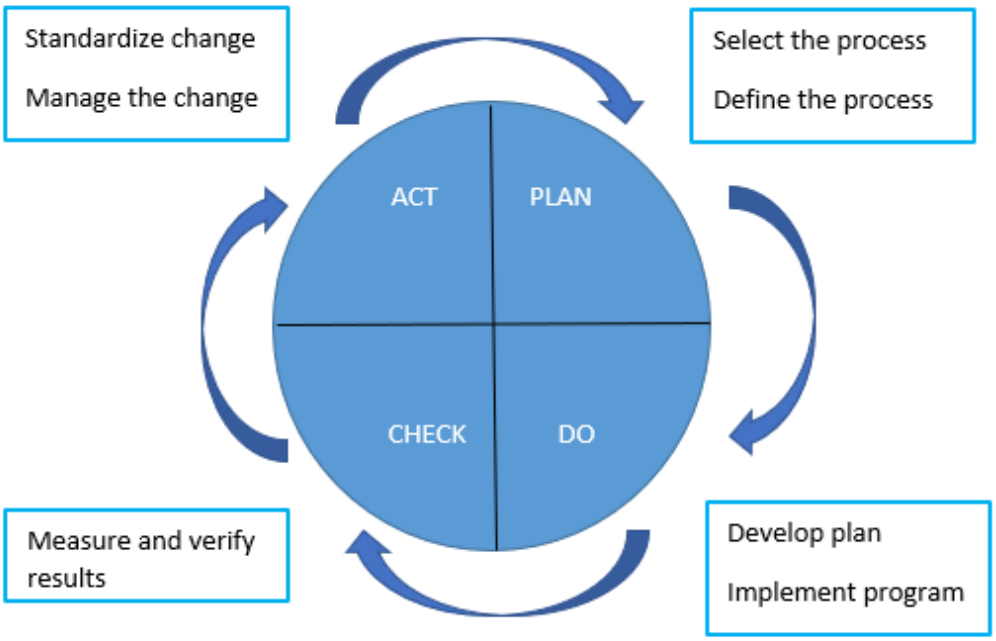


Figure 8. The PDCA Cycle. (Forbes et al. 2020:404)

4.5.9 The A3 Report

A3 report is a practical lean tool for implementing PDCA-cycle improvements. It is often related to root cause analysis and other ways to describe and analyse problematic situations. It is suitable for a limited problems or development issues which need a concrete and practical solution (Salminen 2021:191).

In a logical problem-solving process, it is recognized to solve an important problem, often used 80/20 rule (Pareto´s 80-20 rule, where 80% of the cost is included in 20% of the activities), it is supposed to recognize the consequences and costs of reinstallation (Forbes et al. 2020:421).

The name of the A3 report comes simply from the original paper sheet, where it was its own places, for each step of the process. Due to the size of the paper sheet, it was meant to eliminate waste, and forced to a simple presentation. The paper sheet was easy to fill in with a pencil and a document was ready to put to

a wall or other place to be seen for everyone. Nowadays it is more usually to provide it by computer, but the principle is still the same (Salminen 2021:191).

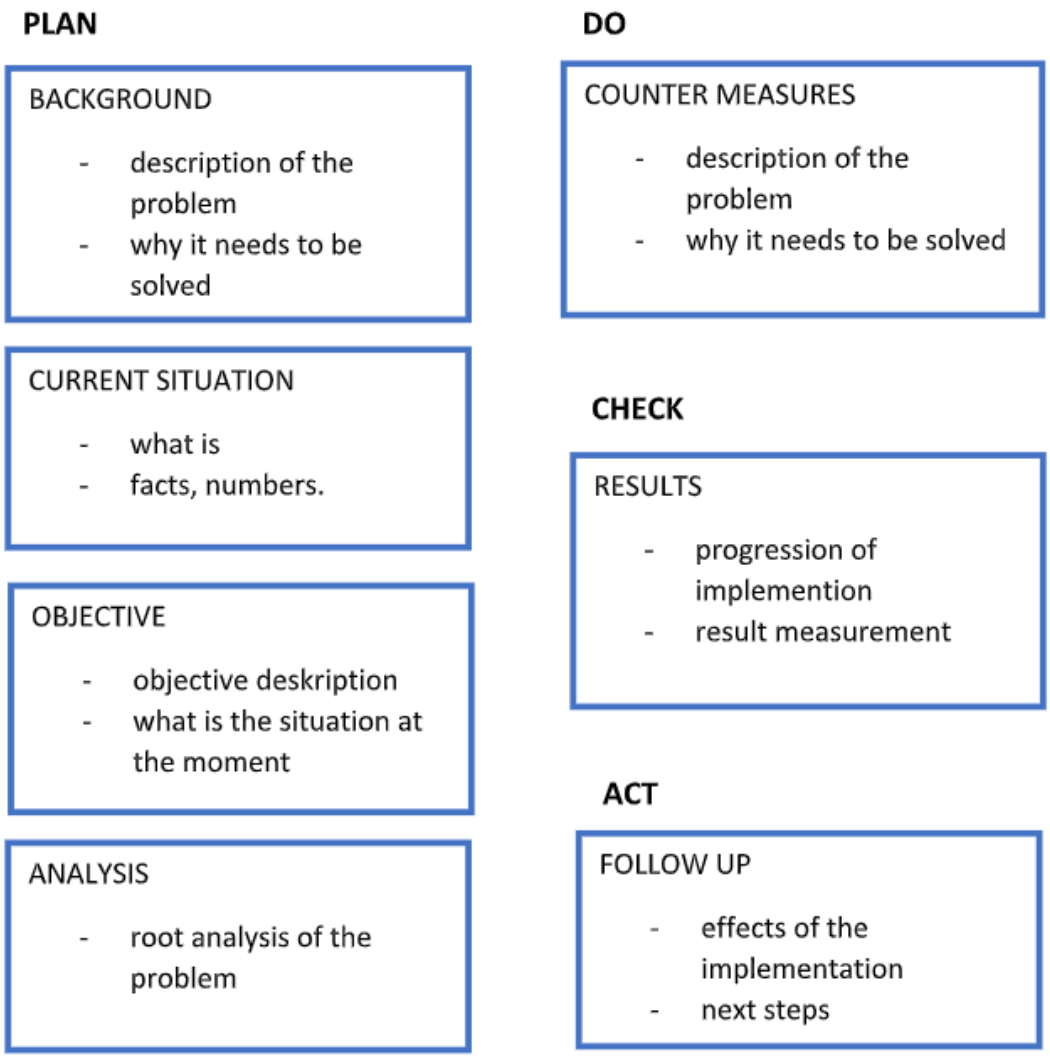


Figure 9. The A3 Report. (Salminen 2021:192).

According to the Jeffrey Liker the A3 report is based on the Deming´s circle (PDCA, plan-do-check-act). The A3 report starts with the pre-planning stage which is the background and current stage analysis. This includes to know the current situation, the practices which are used and to know the process thoroughly. After the current state analysis has been set, it is time to go forward according to the Deming´s steps – to provide the plan, to do it accordingly, to check the result and to act according the follow up (Liker 2006:246).

4.5.10 Development Event

The initiative purpose for development is to create a business culture where it is made continuously with small steps of development. These steps may be first small but in the long run they will create gradually bigger development for the company. Consequently, this way of thinking will create a positive and motivative atmosphere and it will result in more solutions from stakeholders (Salminen 2021:193).

According to Forbes development event (kaizen) is never ending change for the better. This change includes all levels of organization and members of a company. It is an active process, and everyone is participating to the improvements. It has been said that it is the most important procedure in the management and the key to success. The concept of continuous change is part of the natural improvement, and a sudden change would be unnatural. Development event is an approach to encourage the participants to improve the work performance they are involved in (Forbes et al. 2020:410).

The development event is a one-time event which has a set timetable. This means that it is tight and compact result-oriented occasion, and everyone is participating, unlike ongoing development process which is provided after all the other work is done and there is free time. Basically, all the other activities are interrupted, and the focus is on to develop new. It has a schedule and background support from the top-level management, needed resources and a set objective. Moreover, during the development event different ideas are brought to the table, different solutions and options are provided. After the proper solution or development idea is found, the testing is done in a real situation, to make sure the idea works (Salminen 2021:194-165).

4.5.11 Building and Developing a Team

The use of self-directed working teams is a popular management concept in the manufacturing industry. The fundamental idea is to allocate the different tasks

to the teams, and provide them clear goals, and give the team the freedom to decide how to do the work and divide the tasks within the team. This is the reason why teamwork has become kind of a synonym for the good collaboration, efficient work and commitment to the work (Salminen 2021: 205).

Salminen states that in the construction business there are teams also, but the environment is different from the environment in which the teamwork has been applied as a part of the lean manufacturing. It is especially challenging to apply the same kind of method to the construction business which Toyota has provided in a permanent factory environment. In the construction environment there are teams in many levels, there are different levels within the project's organization´s common functions, as well as each party has different levels within own functions. These different levels and functions create an overlapping network of teams. In lean construction it is important to get these different levels and teams to work collaboratively and to be able to form a super team, which can commit to a common goal, way of working and to trust each other (Salminen 2021: 205).

In a building project the separate teams are created in many different places, and in a way, the teams are never completely ready. In the beginning these teams work separately, for instance during the quotation phase, and when the implementation of the project starts, the actual collaboration starts between the stakeholders. The level of the collaboration between the parties varies a little bit, depending on the contract form, but in lean construction method which means that it is very important to integrate parties and to pay attention to onboarding. Certainly, there is no one universal guideline to onboarding and every project is one of kind, but it is important in every project to ensure that everyone is welcome to work within the project (Salminen 2021: 209).

4.5.12 Lean Management

According to Liker (2006), in the US in many cases corporate earnings fluctuate between very high numbers to almost a bankruptcy. To solve the problem the

corporate brings in a new executive, who takes the company to a new radical direction. This roller-coaster ride is exciting and fast, and if something goes wrong, someone new leads the way to even more radical direction. In Toyota the way to become an executive is slow and takes years, sometimes even decades. The new executive does not have to take a new direction and his success relies partly on his predecessor's hard work (Liker 2006:172).

One of the principles of the management, is to not search for so called very successful managers from outside the company. This is because the manager must understand the real situation in the factory, and to really understand how the work is provided. In Toyota the management is required to be able to instruct the staff whenever it is needed, so they must know the production philosophy and understand how it works. Moreover, only partial understanding of the production leads to insufficient decision making and management. The management tries to maintain the corporate culture, year after year in a such way, that it creates a self-learning organization. On the other hand, if the corporate culture is changed every time a new executive arrives to the company, it will be only changing the surface of the company culture, without touching deeper levels. Furthermore, this way the company cannot develop and learn continuously, and loses its ability to learn from its mistakes and create its own culture in the long run (Liker 2006:172-173).

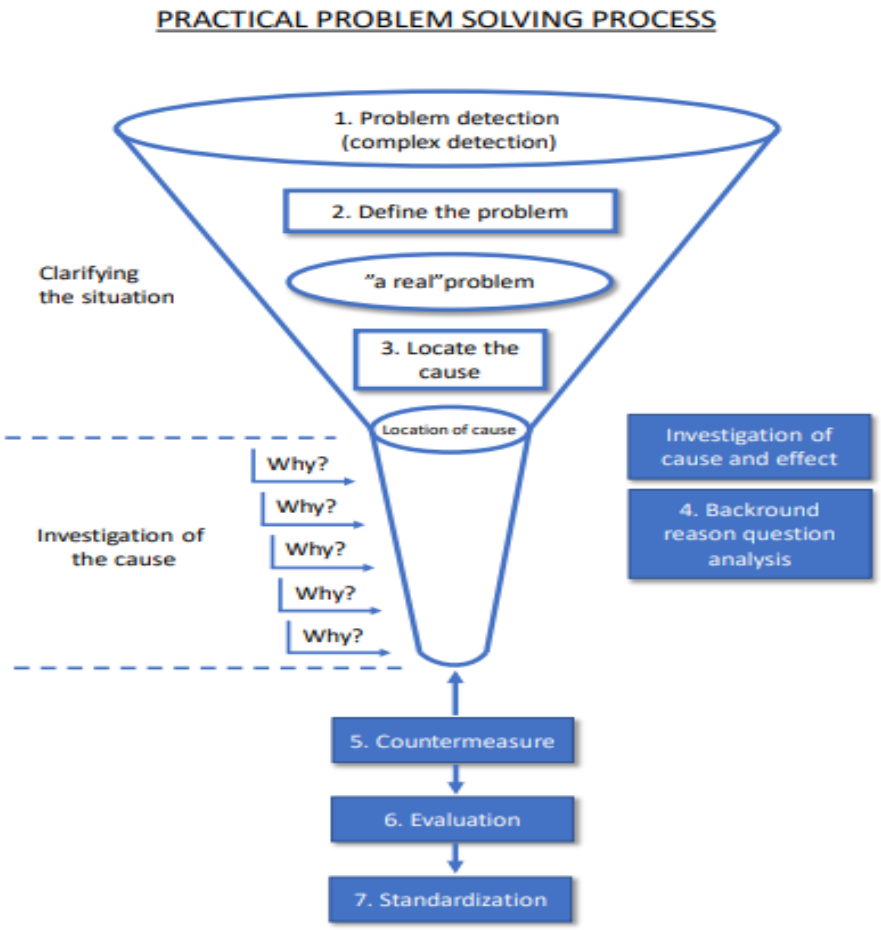


Figure 10. The Practical Problem-Solving Process (Liker 2006; 256)

According to the Jeffery Liker, Toyota managers use so called “practical problem solving” approach to find the root cause for the problem. It is seven step process and inside the process are the five questions pattern, which is often used to define the problem and the root cause. First it is important to understand the situation profoundly. To understand the problem requires often to go to the origin of the problem, which means to go to the site. This may include to use the Pareto analysis sometimes as a statistical analysis. After this is asked five times “why” to find the root cause for the problem. When the root problem is found the counter action must be made. After the counter action estimation of the results is made and finally it is important to standardize the counter action if it is an effective procedure (Liker:2006;256).

Salminen points out, that in many cases the lean method is about the different kind of tools and principles with which it is meant to reduce the waste and increase the value. On the other hand, it is often said that to focus on the methods, it is possible to gain quick results, but to be able to create a change in the long run, can be difficult to provide. If Toyota is asked, the lean philosophy creates a foundation to the management and on top of that, the methods and tools are built to solve the problems. New methods are created when needed and applied case by case according to the situation. This way the change is continuous and is being adopted into use of an organization. The technical and production-based approach becomes this way a management method, where the personnel is brought into the spotlight. The continuous popularity of lean philosophy can probably be due to its ability to connect personnel management and the technical methods. Unless the underlying philosophy is recognized, the tools are just another set of tricks and the influence is temporary. The full potential of the staff is important to have in use, and missing potential is just another type of waste. Everyone is responsible for their own quality of work and also responsible for development of oneself and the whole organization (Salminen 2021:198).

Traditionally it is considered that the top-level executives are in the top of the pyramid and in the lower level are rest of the staff. This is a way of thinking in which the whole organization is serving the top-level management. The lean approach is opposite, in the top level are the staff and in the lower level are the management. In the top-level are the workers that are creating the concrete value which the customer is willing to pay. The different levels of management are for creating the best available tools and conditions for the work (Forbes et al 2021: 98).

As Hammer points out in his article a new style of management is required nowadays. He writes that here is no room for traditional ways of management. It is not possible to just command and control, but they must negotiate and cooperate with participants. If a company wants to become a process

corporation it has to understand the changes in the leadership style (Hammer et al 1999:114).

According to Modig, the strategy of lean always emphasizes the efficiency of flow and not the efficiency of the resources. This is the most fundamental issue. If the emphasis is on the efficiency of resources, it will result in partly optimized tasks eventually. Between these different tasks, there is often a lot of extra work and waste. Focusing on the efficiency of the flow, means that these different tasks combine to be a more comprehensive process, which will create a foundation for the efficiency of the resources as well. Moreover, the efficiency of the resources will increase inside the process but not in different tasks (Modig et al. 2013:125).

Liker points out, that it is important to make decisions based on the long-term philosophy although sometimes at short-term expense. During the last decades the capitalism has become the world leader all over the world. There is a common consensus, that if a person or a company, just tries to maximize its profits, this will turn out to be good for everyone in the economy. But there is a darker side of this principle, as the different kind of company scandals shows all over the world. When Liker was visiting the Toyota factories in Japan and USA, one theme came up in discussions with various executives. They all shared a perception that they had a bigger objective and mission that just the paycheck. To do what is right thing to do for the company, staff, customers, and the society. This principle is the essence and the foundation of the Toyota way (Liker 2006:72).

4.5.13 Takt Time Planning (TTP)

Salminen (2021) points out, that the takt time planning (TTP) has become popular within the construction business although it is a new way of production. It is partly due to the construction business being considered a single, one at the time kind of production. Furthermore, it has been difficult to apply the same kind of production methods as the traditional industrial production has been

using. The ship construction industry has been one of the first industries to implement takt time planning in its production in Finland (Salminen 2021:145).

To be able to better understand what the new the takt time planning brings to the construction industry in Finland, it must be compared to the location-based schedules. It is right to say that if the buffers were removed away from the location-based schedule, it is already kind of a takt time planning schedule. Although the location is an important factor in the location-based schedule, the focus is on resources and on a single task. A single task can be any work package, for example drywalls, masonry or foundations. All these tasks have their own line in the schedule, and the angle of the line indicates the speed of the work (Salminen 2021:146).

On the other hand, in the takt time planning the focus is on the workflow in a particular place on the jobsite. Although it is supposed to organize the different work packages for a single working group, it is possible to include different kinds of work, for example HVAC work, into other work packages. With the number of resources, it is possible to adjust the length of the work package. In many cases it is not possible to avoid completely over resourcing and it must be accepted some kind of waiting and wasted time or provide some alternative work. Also, different kinds of design solutions and way of producing can be developed to smoothen the flow of work. The focus in the takt time planning is not to have empty space between the different work package but to continue immediately to the next task after the previous has been completed (Salminen 2021:146).

In traditional production planning the accuracy for the design and production is about one week, and it is monitored weekly in the contractor meeting. This is too long for the takt time planning production, due to the length of a single takt should be approximately between 1 to 2 days. This means that the focus is on a daily schedule, and it is not possible to miss even one day´s takt. The longer takt times include buffers and the production tends to go towards the so-called

normal way of production even it is well and accurately planned (Salminen 2021:147).

The accuracy of the takt time planning includes the size of the work area. To be able to provide efficient flow, the work area should be as small as possible. It can be one apartment, bathroom, hotel room or office space. The takt time planning is based on the continuous repetition, so the work area should be same size. If the size of the work area is the whole floor, it is considered as a normal way of production. The buffers in the location-based schedules are ensuring that the work package will be started as planned and these buffers are to ensure the work package can be started without delays. This kind of an arrangement extends the schedule compared to the takt time planning in which the tasks will start immediately one after another. This is according to the lean principle that the problems are forced up. Although it is possible to create buffers to the takt planning but it is emphasized that deviations are not generally accepted (Salminen 2021:148).

The most important criterion for the takt time planning production is that the work areas should be as similar as possible. This means that the work packages can be planned alike to keep the takt time similar, but it is possible to variate a little if needed. The second criterion for selection is to choose such tasks which are critical works (critical path), and to be able to diminish the lead time in these, it is possible to diminish the lead time of the whole project as well. It is important to make the decision early on which kind of tool will be implemented to make the takt schedule. It is possible simply to use excel, due to it is flexible and easy or some other suitable application. There are internet-based applications which provides the on-time information when supervisors update the completed work, and this helps to maintain un up-to-date schedule (Salminen 2021:149).

The takt time planning schedule transforms the traditional way of providing the building schedule. Traditionally the master schedule is provided in the beginning of the building project, and it is made in a quite rough level. Furthermore, the

indirect costs and the milestones of the project are based on this schedule. But when the project is making more progress, the schedule will be more detailed. In takt time planning production the more detailed building schedule is required to be provided in the early stages of the project, it is even recommended to be provided during the bid process. This way it is possible to gain competitive advantage and it will affect the master schedule. It is essential to gain the detailed information about the duration of different work packages, and then it is possible to add these work packages together to form the project time. It is possible to make the process more efficient by working simultaneously with multiple work packages (Salminen 2021:149).

When a building project is designed as a takt time planning project, it will help to commit different parties to the common objective. Collaboration with the client and with the designers is often important, due to this helps to develop and support the implementation of the project, such as to choose quickly drying concrete, to choose materials that are easy to install or diminish the installation phases by using more prefabricated parts. To be able to influence the designs and sufficient time to prepare for the production is beneficial for all parties (Salminen 2021:150).

According to Salminen there are five different stages in takt time planning production:

1. Choosing the work areas
2. Selecting which the work which is included to the work package in a work area
3. Providing the takt schedule
4. Planning the supply chain and logistics
5. Planning the resources

Usually, it is practical to define and choose the work area by its natural borders, for example a bathroom, office room etc. Choosing the different work packages includes the work which will be provided, that is the list of items in a work area. In a new residential building project, such as the framework or casting the floors

will not be included usually. And in a renovation project such as demolition, hole penetration and HVAC works will not be usually included. For each task there must be defined resources, amount of work, and material. These work packages are shown in the takt time schedule in excel or in some other application. The supply chain and material delivery must be planned and organized carefully due to the fast production phase. In the takt time planning production it is very important to make sure that the supply chain is working as planned and this cannot be emphasized too much. The whole idea is to provide collaboration with all the parties and that all parties are committed to the production and to the same goal. At the end of the day, it is intended to simplify the production process (Salminen 2021:151-153).

4.5.14 Innovation Management

The lean philosophy includes the idea that everyone who is working in the organization, would develop and use their own creative ability to improve the process. In fact, the unused creativity is one category of waste, which must be removed. Creativity and innovation are easy to remove from the organization and only provide the low-level work. In many cases where the reasons for poor performance are studied in the business, the lack of creativity and initiative are two main reasons (Salminen 2021:178).

To be able to maintain the creativity and innovation, it must have support from the top-level management and from the innovation process of the company. There are many kinds of innovation processes in use which support the process in different companies, and this is creating a positive atmosphere generally. The new idea is the first phase in the innovation process from which the actual work starts. The innovation process requires management to be able to create some valuable and practical solutions. It is crucial to encourage the staff, for example by giving bonuses or some other prizes for an innovation idea (Salminen 2021:178).

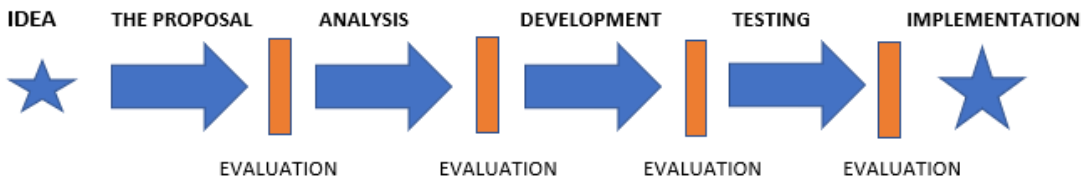


Figure 11. The Innovation Process (Salminen 2021:179)

An efficient process does not mean that every idea would be accepted, and it is obviously an impossible situation. Furthermore, every idea is not even a new nor good one. And even good ones do not lead every time to a practical solution, the reason for this is often the lack of resources. It often requires lots of development work to be able to utilize innovations. But it is important to process the different suggestions and proposals. In a systematic innovation process, there are different steps in which the idea is evaluated, and the decision is made weather the proposal is useful to go forward with. It is important to keep in mind that the development work is waste until the proposal is a solution or product. It may be better to select for the development process only a few ideas, than to concentrate on many kinds of ideas at the same time. When all the participants find the positive effects and benefits of innovations, the innovation culture will strengthen by itself (Salminen 2021:178-179).

A process is just a set of different activities, and it has been planned to generate an output for a customer (Maddern 2014:1305).

4.6 How to Implement Lean Tools and Improvement Ideas from Relevant Literature

In this section there are a few examples of lean construction projects and how to use lean tools in a real building project. There are many good examples of lean construction projects and what kind of lean tools has been implemented.

According to Salminen (2021) although everyone knows about the vehicle production in Toyota there is also Toyota construction company. Maybe it is not a traditional construction company, but they do produce so called prefabricated

buildings. They use an industrialised model of production the same way as they produce their cars. There are three different basic constructions and based on this basic structure they produce thirteen different modules. They use the “skeleton and infill” principle, which means that with the same kind of frame parts it is possible to produce many different kinds of houses. It is possible to produce houses which look different and are versatile. The frame is made of steel and the houses are very durable, moveable and can be reused. They provide a warranty for 60 years and the service life of the house is 100 years (Salminen 2021:144).

The sales transaction starts with a definition of values and wishes of the customer with the help of 3D modelling. The customer can even visit the factory to have a better look and understanding of the process. In the 3D model it is possible to compare the interior options as well to make sure that the customer is aware of the product he or she is buying. When the decision has been made by the customer to buy a house, the design and prefabrication phase takes approximately 4 days. The construction models are produced by a single part principle, a flexible modulation system and with the help of automated prefabrication. The execution of the frame takes one day and the interior work approximately two weeks. This house production method is a good example of a production process which uses more time to the design phase and preproduction phase but as little as possible to the execution phase (Salminen 2021:144).

According to the YouTube video of Toyota Housing, all houses undergo storm tests in Japan and spray testing during construction to ensure the waterproof performance and the same earthquake resistance standards are provided as on Japan mainland. The quality is ensured by inspections that covers over 80 points until construction is completed. The Toyota Super Wall System is a structure which uses structure boards inside and outside, steel pillars and heat insulation material. This is not a new construction method, and it is used quite often in Finland too (Toyota Housing Technology Movie https://www.youtube.com/watch?v=l745NYlklN4&t=39s)

Salminen points out that the more there are similar repeatable facilities the better the takt time planning can be applied to the construction. Moreover, the less there are production interrupting functions the better the takt time planning can be applied. One very good example can be a facelift project of a hotel. In this kind of project there are no plans to renovate or build the supporting structures like frame, walls, or intermediate floors. On the other hand, this does not mean that the takt time planning would not be suitable to the other kinds of building projects. Another example of a renovation project was a hotel renovation project in which the rooms and corridors were renovated. The renovation was provided one section at the time, so that there were as few as possible hotel rooms out of use. It was agreed that one takt time section was one hotel room and in this room all the different work packages were distributed among the subcontractors. The work packages were split into a standard work package, which were provided continuously throughout the whole project. It was noticed that this worked out better the smaller the work packages were (Salminen 2021:157).

The case company had couple of pilot projects in which it was used the takt time planning method in the interior phase. The bathroom was chosen to be a one takt time planning set. The work packages were agreed with the subcontractors, and it was achieved approximately 25 – 35 percent shorter interior work lead time.

In one of the major building companies in Finland the management has decided to standardize building parts, to use prefabrication, to use takt time planning, continuous learning and to use modules as much as possible in all different construction parts in a building. They consider these issues to be the key principles to increase the productivity and provide a better construction process. To be able to produce highly processed modules enables better prefabrication. The company defines the constriction process to include flow of production and takt time planning which in turn contains an accurate planned building schedule and installation sequence. If the different modules are well defined it is possible to know the exact building costs and it helps to provide better cost controlling.

This kind of building process is in its early stages at the moment in the company (Salminen 2021:177).

According to H. Forbes, one small size building company operating in USA, provides lean methods in small construction projects. This company provides simultaneous engineering and lean approach. Their main building projects are municipal projects obtained through competitive bidding and these projects cover about 80% of the firm`s business. The company provides concurrent engineering to improve the implementation phase. They form a project team which includes stakeholders needed to deliver a project. This project team recognizes the customer value and analyses the different phases of the building project to be able to reduce waste and increase the value for the customer. This includes continuous construction process designing, optimization of the workforce, focusing to the customer´s needs, developing the trust between the construction parties, continuously developing building methods, and decision making at the construction site. This approach has resulted great results in their projects, in terms of quality, no items in the punch list. Building cost reduced by 21% and 20% shorter building time (Forbes et al 2021:295-296).

How to level the building schedule when providing a complicated project such as a building project. Liker visited Toyota´s housing plant a few times and noticed that each time it was provided some improvements to the process. Some of the tasks were done by robots, such as welding together the steel parts and some tasks were provided at the building site. Continuous improvements were made in work packages, for example, how many kitchens was made at one takt to level the building schedule (Liker 2021: 99-101).

4.7 Conceptual Framework of the Study

The conceptual framework of the study was created from the relevant literature concerning the lean production concept. In Table 6 the main principles of production are shown. It was found that it is sometimes difficult to define very precise all the different terms used within the literature and other contexts. For

example, terms production method, production tool or principle can in some contexts overlap with each other, but it is more important to concentrate to the purpose rather than to the terms used.

Table 6. Conceptual Framework of the Study (Salminen, 2011)

CONCEPTUAL FRAMEWORK (Salminen, 2021)	
Production principle	Production Methods
Overall optimization	Integrated Project Delivery Method (IPD)
	Just In Time Delivery (JIT)
Value Creation	Big Room
	Target Value Delivery (TVD)
Reducing Waste	Last Planner
	Diminishing the Fluctuation
Continuous improvement	The PDCA Cycle
	Development Events
Respect and Grow Your Staff	Lean Management
	Team Building and Development
Workflow	Streamed Production and Design
	Takt Time Planning

The framework is divided into six different principles of production which all are important part of the production. In the Table 6 there are first listed the general production principles and then production methods which implement the first mentioned principles. The first principle is the overall optimization which mainly includes the project delivery contract form which defines the different obligations and relationships between the parties in a building project. The second principle is value creation for the customer. This includes all the work that the customer is willing to pay for and such work that is undesirable should be reduced. The third principle is reducing the waste. This includes all the unnecessary work

which must be minimized to improve the production at the site. The fourth principle is continuous improvement. This principle is one of the most important principles to be able to improve the processes in the company at all levels from the top-level management to the work implemented at the site. The fifth principle of the framework is respect and grow your staff. This includes such things as educating the personnel and respecting all the staff of the company. Behind this principle is the fact that the skilled and experience is the most important resource of any given company. The sixth and the final principle is the workflow. This principle includes all the actions and improvements to achieve as smooth as possible processes starting from preconstruction to the maintenance phase.

5 Building the Proposal Which Lean Tools Will Be Implemented

This phase describes how the proposal has been provided, it includes the results of the current state analysis, experiences from pilot projects and the lean philosophy, comparison between the different options of the lean tools which are suitable for the commercial department, leading to the proposed lean tools for the implementation. An overview of the process, how the proposal was provided and what kind of different steps were included.

5.1 Overview of the Proposal Creation

The proposal of the lean tools was provided according to the experiences that were gained in pilot projects. These pilot projects were part of the process that the top-level executives of the company made to implement the lean production method. The idea was to get good practices and experiences from the other departments projects and then study if these same practices could apply to our departments production.

The idea of this thesis was to determine the business problem, the objective and the outcome as a proposal which lean tools will be implemented for the commercial department. The information was gathered from the current state analysis. It included current company documents, stakeholder interviews and observations how current production management tools are applied in the company.

After analysing the current state and gathering the needed information, the relevant literature was researched to gain the information how the lean philosophy and the lean construction delivery method work in practise and how other companies have applied the method. The creation of the proposal included interviews and discussions with the different stakeholders of the company and my own initial proposal. The participants gave feedback and evaluated the initial proposal and made some improvements to the proposal, to

be able to transform the lean tools for the department. The brainstorming and discussions were recorded into the fieldnotes. Most of the interviews and the discussions were provided by the Teams to make it easier for the participants and to be able to save everyone's time in the process. In the beginning of each interview, it was introduced the business process improvement idea to the participants and what was the purpose of the interview.

5.2 Summary of Strengths and Weaknesses of Production Tools Currently Used in the Pilot Project

In this section the tools used in the production in the pilot projects were reviewed. There are some production management tools which have been used for a quite long time to manage the production within the company. They are quite commonly used in the building business, and they have been used to manage different kinds of building projects. It was meant to review all the production management tools together to have a better perception about the production management in general. All these management tools should support the lean construction project delivery method to be able to add value to the customer and to reduce waste in the production.

The overall principle should be that every aspect of the management must support the production in the company. Accordingly, the lean construction project delivery method requires that every part of the management supports the common goal. There are listed twelve different traditional productions management tools in Table 4 and four lean tools in Table 5. These tools were used in the pilot projects, but the traditional production management tools are usually used in almost every project in the company. There are listed weaknesses or strengths regarding how the tools supports the lean construction philosophy and management. The perspective was whether the tool was useful for the lean construction approach (strengths) or it has some deficiencies (weaknesses).

Table 4. Strengths and Weaknesses of the Currently Used Production Tools.

#	**Current Production Management Tool**	**Strengths and Weaknesses of the Tool**
1	The Main Production Process	The main process is well organized and provided in the company´s intranet. The process map is little bit too complex and unclear.
2	The Master Schedule	The master is supporting the lean construction project delivery. The information is provided in too general level considering managing the waste.
3	Site Plan	Supports the lean construction, it provides a plan of the site and how to organize different trades. It is important to update the plan according to the progress of the project.
4	The Construction Project Team Meeting	Supports the lean construction and it provides a common meeting to manage the production and it is important to have a weekly meeting with the project team. It is important to use the lean tools to support the lean method during the weekly meeting.
5	Weekly Construction Contractor Progress Meeting	Supports the lean construction, it provides a common meeting with the different contractors to manage the production at the site. It is important to use the lean tools to support the lean method during the weekly meeting.
6	Site Meeting	Supports the lean construction, it provides a common meeting with the different stakeholders to manage the production at the site. It is important to use the lean tools to support the lean method during the meeting.
7	Kick off Meeting for the Work Package	Supports the lean construction and enables to manage the subcontractors how to apply the lean tools and the production method at the site. It is important to use the lean tools to support the lean method during the meeting.
8	3 D Modelling	Supports the lean construction and enables to manage different designs in a visual way.
9	The Daily Managing at the Site	Supports the lean construction by continuous improvement and monitoring the progress at the site, similar to the lean tool Gemba Walk.
10	Quality Management Congrid	Supports the lean construction and enables to manage the quality of the work and building schedule.
11	Humidity Managing (Kuivaketju10)	Supports the lean construction and enables to manage the moisture damages at the site.
12	Cost controlling	Supports the lean construction and adds value to the customer by providing the cost reports according to the progress of the project.

Table 5. Strengths and Weaknesses of the Lean production Tools Used in the Pilot Projects

#	Current Production Management Tool Used in the Company	Strengths and Weaknesses of the Lean Tool
1	The Takt Time Planning	The takt time worked well and helped to organize the different work packages to improve the workflow. At first it was difficult to implement the takt time planning with the subcontractors before all the participants were familiar with the procedure.
2	Just in Time Delivery	Just in time delivery worked well and supported the production.
3	The 5 S	The 5S was not implemented as a separate lean tool.
4	Last Planner	The Last Planner was left out of use due to the takt time planning schedule was working so well.

There is a separate Table 5 for the lean tools used in the pilot projects, the strengths and weaknesses are written on the right side of the table. There are three lean tools Just In Time, The 5S and the Last Planner which were used or partly used in the pilot projects.

It was found in this study that many of the existing construction management tools which are used in the company supports the lean construction philosophy, but they are not enough to achieve the wanted results, such as to improve the overall optimization and reducing the different waste. This means that these management tools need support from more detailed lean management tools which are more comprehensive and focused on the lean construction production method. Moreover, it was not found that these different kinds of

management tools would be somehow contradictory to each other, but they can support the production when used together.

5.3 Analysing the Strengths and Weaknesses of the Lean Tools

The initial plan of this study was to propose lean construction tools for the commercial department. This section examines which of the lean construction tools may be suitable for the commercial department of the company. In the Table 7 below, there are management tools in different categories according to Salminen (2021). The categories represent how the tools will affect and to which area of production they affect. There are 6 categories and 14 different lean construction tools which have been chosen for this thesis. The 6 categories represent the overall level of impact to the production. These categories are overall optimization, value creation, reducing waste, continuous improvement, respect and grow your staff, and workflow. These aspects are important parts of lean construction project delivery method. The category determines the effect of how the lean tool impacts to the production on a general level.

The 14 different lean tools are listed under the lean tool column in the chart, these are: The Integrated Project Delivery Methods, The Just In Time Delivery, The Integrated Information Technological Equipment, Big Room, Diminishing The Fluctuation, The Last Planner, The 5S, The PDCA circle, The A3 Report, The Development Event, Building and Developing a Team, The Lean Management, Innovation Management, and The Takt Time Planning. These lean tools were chosen to improve the production in the commercial department. The proposal of the lean tool which will be taken into use in the commercial department will be created within these lean tools. The suitability and usability of these lean tools were considered regarding the requirements and way of production of the commercial department. There are small differences in the way of production between the departments, as well as contract forms in some cases, although differences are not decisive, and they do not play a major role. The initial decision was made to limit the number of the lean tools which will be taken into use in the commercial department to

approximately 4 to 6. Therefore, 7 lean tools were selected from which the final decision will be made.

Table 7. Summary of the Strengths and Weaknesses of the Lean Tools

Category	#	Lean Tool	Strengths and Weaknesses Regarding to the Commercial Department
Overall Optimization	1	Integrated Project Delivery Methods (IPD)	Supports the production with common goal for all participants. It is quite rare as a contract form.
	2	Just In Time Delivery (JIT)	Improves the production by delivering the material just in time as planned to the jobsite.
	3	Integrated IT Equipment	Improves the production with better and quicker solutions. In some cases, it is not possible to integrated IT solutions with every participant in a project.
Value Creation	4	Big Room	Improves the production by common workspace and better information flow. In some cases, it is difficult to get all participants to a common workplace at the same time.
Reducing Waste	5	Diminishing the Fluctuation	Improves the production due to the workflow is smoother. In some cases, it is difficult to implement at the site due to subcontractors are not committed to the project enough.
	6	Last Planner	Improves the production and reduces the waste time. In some cases, it is difficult to get all the designers at the same meetings.
	7	The 5S	Improves the production and the work are cleaner and ready for the next trade. In some cases, it is difficult to get the sub-contractors to commit to the task.
Continuous Improvement	8	The PDCA Cycle	Improves the production by continues improvement. In some cases, it is not a familiar management tool for the supervisors.
	9	The A3 Report	Improves the production due to it is a visual and simple management tool. In some cases, it is not a familiar management tool for the supervisors.
	10	Development Event	Improves the production due to good improvement ideas from the participants. In some cases, it is difficult to use as a management tool.
Respect and Grow Your Staff	11	Building a Team and Developing	Improves the production due to the production team learns to work together. Sometimes it difficult to keep the same production team together.
	12	Lean Management	Improves the production due to better management procedure. It takes a long time to create the lean management for a company.
	13	Innovation Management	Improves the production by supporting the staff to create best practises and new ideas. It is difficult and slow procedure to apply good innovations into practise.
Workflow	14	The Takt Time Planning	Improves the production due to it is possible to reduce the lead time. It is sometimes difficult to have the subcontractor`s commitment to the procedure.

5.4 Proposal for the Lean Tools for the Commercial Department

The recommendations which one of the lean tools will be implemented for the commercial department started with the analyse of the results from current state analyse, the literature review and the results from the pilot projects. It was agreed with the department director in the beginning of this project, that there will be implemented approximately 4 to 6 lean productions tools for the commercial department. This means that it will be selected approximately 7 different lean construction tools from which final selection will be made.

The decision of which of the lean construction tools were chosen for the further processing were provided according to the experience of the pilot projects, company documents and seminars, stakeholder interviews, own experience of the construction business and literature knowledge. The pilot projects provided good first-hand information from the field and from the actual production. These results are important for the whole company and provide good practices for future development projects. The company documents and seminars about the takt time planning and lean projects provided good material for the decision making and comparing the different options. One`s own experience was provided to evaluate which of the lean tools were most suitable and best for the commercial department. It was satisfying to notice that the department director and the production manager had some experience from earlier building projects using some lean management tools, such as Big Room.

The literature review provided a board perspective on different contexts of the lean philosophy and lean production of different industries. There is much material and information about the lean production tools, and it is very valuable to gain knowledge and experiences from different kinds of production projects, to ensure a wider perspective.

Table 8. The Proposal of the Lean Tools for the Commercial Department

Category	#	Lean Tool	Strengths and Weaknesses of the Lean Tool Regarding the Commercial Department
Overall Optimization	1	The Just In Time Delivery (JIT)	Improves the production by delivering the material just in time as planned to the jobsite. Sometimes difficult to arrange for all deliveries.
Value Creation	2	Big Room	Improves the production by common workspace and better information flow. In some cases, it is difficult to get all participants to a common workplace at the same time.
Reducing Waste	3	Last Planner	Improves the production and reduces the waste time. In some cases, it is difficult to get all the participants at the same meetings.
	4	The 5S	Improves the production and the work are cleaner and ready for the next trade. In some cases, it is difficult to get the sub-contractors to commit to the task.
Continuous Improvement	5	The PDCA Cycle	Improves the production by continues improvement. In some cases, it is difficult to implement at the site.
Respect and Grow Your Staff	6	Innovation Management	Improves the production by supporting the staff to create best practises and new ideas. It is difficult and slow procedure to apply good innovations into practise.
Workflow	7	Takt Time Planning	Improves the production due to it is possible to reduce the lead time. It is sometimes difficult to have the subcontractor`s commitment to the procedure.

The decision about which lean construction tools were chosen for further proposal was provided so that there would be one lean tool from every main lean production category. This was considered as an important factor to be able to introduce as many alternatives as possible for the future decision making. It was considered as a positive and important basis for the validation phase. The most important criterion for the chosen lean tools was on the other hand, the positive impact on the production efficiency, and on the other hand, to be able to make it easy to use at the site for the production team. These categories are according to the way Salminen (2021) has provided the lean construction categories.

The first category is overall optimization, and the lean tool is the just in time delivery. There were good experiences gained from the pilot projects and the just in time delivery was working well. It is possible to optimize the material deliveries to the site and to improve the overall optimization. There were good experience concerning the just in time delivery in the pilot projects. The second category is the value creation, and the lean tool for this is the Big Room. In the building industry, there are many good experiences and examples that the Big Room is a well working method in which all the different parties of a building project, are collaborating towards a common goal. Considering the commercial departments way of working and the different contract forms this is a suitable lean tool. The third category is reducing waste and the lean tool for this is the Last Planner. The Last Planner was actually invented for the building industry by Howell et al. in the beginning of 1990. It is considered as a suitable lean tool for the commercial department. There also is a second tool in this category, which is the 5 S. It is used, for example, for organizing the working area at the site. This is a very important step to ensure the work area is ready for the next contractor. It was also considered to be beneficial for the site environment.

The fourth category is the continuous improvement, and the lean tool is the PDCA cycle. This was considered as a suitable tool for the site work due to its ability to be applied in many different contexts within the production of a building project. The fifth category is to grow and respect your staff, and the lean tool is

the innovation management. There are some very good examples in the building industry to encourage the different parties to find new and innovative ways to work and find solutions together. The sixth and final category is the workflow, and the lean tool is the takt time planning. There were rather good experiences gained when the takt time planning in the pilot projects within the company were applied. Some of the work phases were able to reduce the lead time by 25 to 35 percent.

Although different lean construction tools may overlap a little bit with each other, they can be applied slightly different in some cases. It is important to have solid frameworks which will help the building team to apply the principles of lean construction. The way of using the different tools may differ from one project to another but the core principle will stay the same. These lean tools were introduced to the department director and to the production manager for further discussions and consideration. According to the feedback, seven lean tools were selected for the final proposal, which were implemented by the commercial building department.

6 Validation of Proposed Lean Production Tools

Phase 6 describes the validation of the lean tools which will be proposed for the commercial department of the case company. First the overall validation process is described and then it presents the outcome of this study. The final recommendations for the lean tools have been provided according to the summary of the strengths and weaknesses of those lean tools. After building the proposal for the tools to be implemented, it was presented to the director of the department and to the production manager. This phase describes how the final decision was made and what kind of adjustments were needed according to the feedback that was provided.

6.1 Overview of the Validation

The validation process started by presenting the proposal for the lean tools to the department director and to the production manager of the commercial department. Feedback was requested to evaluate together how the proposed lean tools can support the production. The focus was to propose lean tools for more effective production of the commercial department and to considering its specific requirements. The validation was carried out in one meeting with the participants. The meeting was organized at the headquarters of the company in Helsinki. The structure of the meeting was arranged so that it started by introducing the topic of the study. After the introduction the current state of analysis was presented as well as the conceptual framework of the lean construction production was discussed. The initial proposal was presented in six categories of the lean tools as described in Table 8.

Then all aspects were evaluated by the participants and feedback was provided. The information from the feedback, comments, and recommendations formed Data 2 for this study. The information was recorded in the field notes during the meeting. Based on the information of Data 2, the final proposal was formed for which lean tools were implemented for the commercial department.

6.2 Feedback Received and Improvements to the Initial Production Tools

During the discussions the feedback received from the department director and the production manager were positive and encouraging. The study was introduced to the participants and the content of the study was gone through and what had been achieved at this point. Moreover, the production in general was discussed and some interesting observations were provided from previous projects:

> “Hopefully this study can be applied concretely to our future projects”. (Department Director)

After all the chosen seven lean tools were reviewed and precented, the more detailed discussion was provided with the participants regarding the purpose of the tool. It was a common consensus that it is important to plan the use of the lean tools in the early stages in a building project and which tools will be implemented. According to the department director:

> “It is important to plan which lean tools will be implemented in advance of the project”. (Department Director)

> “Big Room is a case specific production tool, and it is possible to use it if there is need for it. There have been projects in which it has been a requirement from the client”. (Department Director)

The importance of planning and careful preparation was highlighted in several comments from participants. Both interviewees had previous experience using some of the lean tools in different construction projects. Mainly the experience was gained from outside of the case company and the lean tool has been Big Room and Takt Time Planning. In some cases, it was considered that the same level of development of productivity was provided but the terms for used production tools were different than which are familiar in lean construction project delivery. According to the production manager:

> “The takt time planning is as a framework which can include many different lean tools to manage the production”.
> (Production Manager)

By this comment the production manager meant that to be able to implement takt time planning, it includes many smaller jobs, and to be able to implement takt time effectively there are many smaller jobs that must work smoothly. Moreover, it was considered that it can be possible to use only some of the lean tools in a particular building project and not them all at the same time. This is due to the projects being different in nature, and the circumstances are usually different every time. In addition, the production manager pointed out that there could be a sort of reserve of the lean tools, and depending on the project, it is possible to use these other lean production tools.

> “We could use the development event instead of Big Room in our project to kick off the building process, and we could create a common framework which we can use in other projects as well”.
> (Production Manager)

The production manager pointed out that it would be very useful to have a road map of a building project, which would include different lean tools and instructions regarding which lean tools to implement in different stages in a project. The opinion of the interviewees was asked regarding the proposed seven lean construction tools. The answers were written down in the field notes during the discussions.

6.3 Selecting the Lean Production Tools

During the meeting the opinion of the interviews regarding the selected lean construction tools was asked. There were seven different lean tools that was proposed form initial fourteen. In the next Table 9 there are comments given by the department director about the proposed seven lean construction tools.

Table 9. The Comments from the Department Director

Category	#	Lean Tool	Comments on the Proposed Lean Tool from the Department Director
Overall Optimization	1	The Just In Time Delivery (JIT)	Good principle for the production.
Value Creation	2	Big Room	Good way to organize collaboration and to seek transparency.
Reducing Waste	3	Last Planner	Good way to bring up the problems for every participant.
	4	The 5S	A new lean production tool but seems like a good tool.
Continuous Improvement	5	The PDCA Cycle	It has been used before but how it is possible to apply it in practice.
Respect and Grow Your Staff	6	Innovation Management	This is a very important issue to be able to commit the staff.
Workflow	7	The Takt Time Planning	There has been some good experience before about this tool.

The comments given by the department director were mainly very positive about the proposed seven lean construction tools. Only one of the tools was a totally new one for him, it was the 5 S`s. When it was discussed regarding the tool with the department director, he commented that it appears to be suitable for the building production management. During the meeting it was realized that the lean construction tools and lean construction management was not a totally new approach and that some of the tools were familiar to him, and that he has been using some of the tools before in previous building projects.

Because the comments were so positive and the department director thought that every one of these lean tools were suitable for the commercial department, it was considered it is possible to choose any one of the proposed.

In the next table there are the comments given by the production manager about the proposed seven lean construction tools.

Table 10. The Comments from the Production Manager.

Category	#	Lean Tool	Comments on the Proposed Lean Tool from the Department Director
Overall Optimization	1	The Just In Time Delivery (JIT)	Very important principle for the production, even more if there is no extra space at the site.
Value Creation	2	Big Room	Difficult to implement in practice. In many cases the consultant engineer uses the term wrongly and it is mixed with the workshop.
Reducing Waste	3	Last Planner	It is good way to commit the different participants, but it is important to have a clear set of tasks for example a procurement package.
	4	The 5S	The more there are repetitive tasks the better this works, need to agree what needs to be done.
Continuous Improvement	5	The PDCA Cycle	Suitable for larger entities than for example the 5S.
Respect and Grow Your Staff	6	Innovation Management	It is very challenging for the construction industry due to the information should come from the actual workers and due to the construction industry has old-fashioned management culture.
Workflow	7	The Takt Time Planning	Good production management tool but not a new one, Site Drive is probably best IT tool.

The comments given by the production manager were also very positive about the seven lean construction tools. He had some experience with working in Big Room that he considered it to be difficult to apply in practice. He felt that in some cases the construction industry consultants used the term Big Room wrongly because the real Big Room means that participants really work in a big

room during the building project. A better term would be a workshop if the participants are not working in a common room. When the Last Planner is used it is important to have a clear set of work which needs to be provided. Also, it is possible to recognize what kind of difficulties occur in the design and it helps to receive the design at the right time for the production. During the meeting it was observed that the production manager already had some experience using the lean construction tools in a building project, and that he was able to provide relevant comments and his opinions were based on his experience in real cases. The takt time planning was used in the pilot projects and it provided rather good results. It was seen that the lead time in the bathroom was able to be reduced approximately 25 to 35 percent. This is a particularly good result and due to this it is recommended to use the takt time planning whenever it is possible.

6.4 Changes Made to the Proposal of the Lean Production Tools

The department director commented during the discussions that it would be very important to have a practical approach to the lean construction tools. He pointed out that the lean project delivery method has many good and positive features for the production. Therefore, to put the focus on the practical solution is crucial to get results and to implement the tools in the right context in a building project.

According to the production manager it would be good to have a visual presentation to show how to apply the different lean tools. He suggested to create a visual map which would include the needed lean construction tools in a project, it would be very useful for the construction management. There can be multiple lean construction tools from which to select the right ones according to the situation and the project. This idea was also supported by the department director, and he thought that it is useful idea because it can be used as a guideline.

It was agreed that a guideline will be created in which lean construction tools will be recommended in a certain phase of the project or work package. This can be a useful framework for any kind of building project in our commercial department. Although the proposal is made it will be possible to apply it as necessary, depending on varying circumstances.

6.5 Summary of the Final Proposal of the Lean Production Tools

The final proposal of the lean production tools was provided according to the feedback given during the meeting with the department director and production manager of the commercial department of the case company. Both participants emphasized the practical application for the use for the construction management. This was brought up during the meeting and discussions several times.

For the above reasons the production stage was added to the table to indicate the right time for implementation of the lean tool. The lean construction tools are almost the same as they are in the table of the initial proposal in Table 8, but the Big Room has been deleted. This decision was made according to the feedback given from the stakeholders, and due to it was considered to have a need to reduce the amount of the lean tools which will be implemented.

Table 11. The Final Proposal of the Lean Production Tools.

#	Production stage	Lean Tool	Impact and Purpose of the Lean Tool	Category
1	Before or in the beginning of the production phase in a project.	The Just In Time Delivery (JIT)	Reduce the inventory space, damages, and unnecessary transfer at the site,	Overall Optimization
2	Before or in the beginning of the production phase in a project.	Last Planner	Reduce waste of not ready designs, make the production smoother.	Reducing Waste
3	Before or in the beginning of the production phase in a project.	Innovation Management	Improve the collaboration between the participants and to share information to all subcontractors.	Respect and Grow Your Staff
4	Before or in the beginning of the production phase in a project.	The Takt Time Planning	Improve the workflow, to reduce the waste time between the tasks.	Workflow
5	When a problem occurs will be implemented in every work package	The PDCA Cycle	Increase the continuous improvement in every work package.	Continuous Improvement
6	Before every work phase starts	The 5S	Improve the workflow, make ready the work area for the next subcontractor.	Reducing Waste

During the discussions with the participants, it was agreed that it would be good to add information how the lean tools affect the production of a project. Due to this there is a section for the impact and purpose of the lean tool. The categories are the same as it is in every table above, to indicate which kind of

general category the lean tool represents according to Salminen (2021). There may occur some overlapping features among the different lean tools, but it is more necessary to observe the right effect of a particular lean tool, than to categorize very strictly different tools. They also may affect in multiple ways to the production, and due to this it can be difficult to limit the effect very precisely.

Moreover, it was agreed to add these chosen lean construction tools to a real building schedule of a building project. The purpose of this is to be able to manage the implementation of the lean tools better and to put the tools into practice in a visual way. The next Figure 12 represents the master schedule of pilot project which was chosen as an example for the implementation of the lean construction tools in the commercial department.

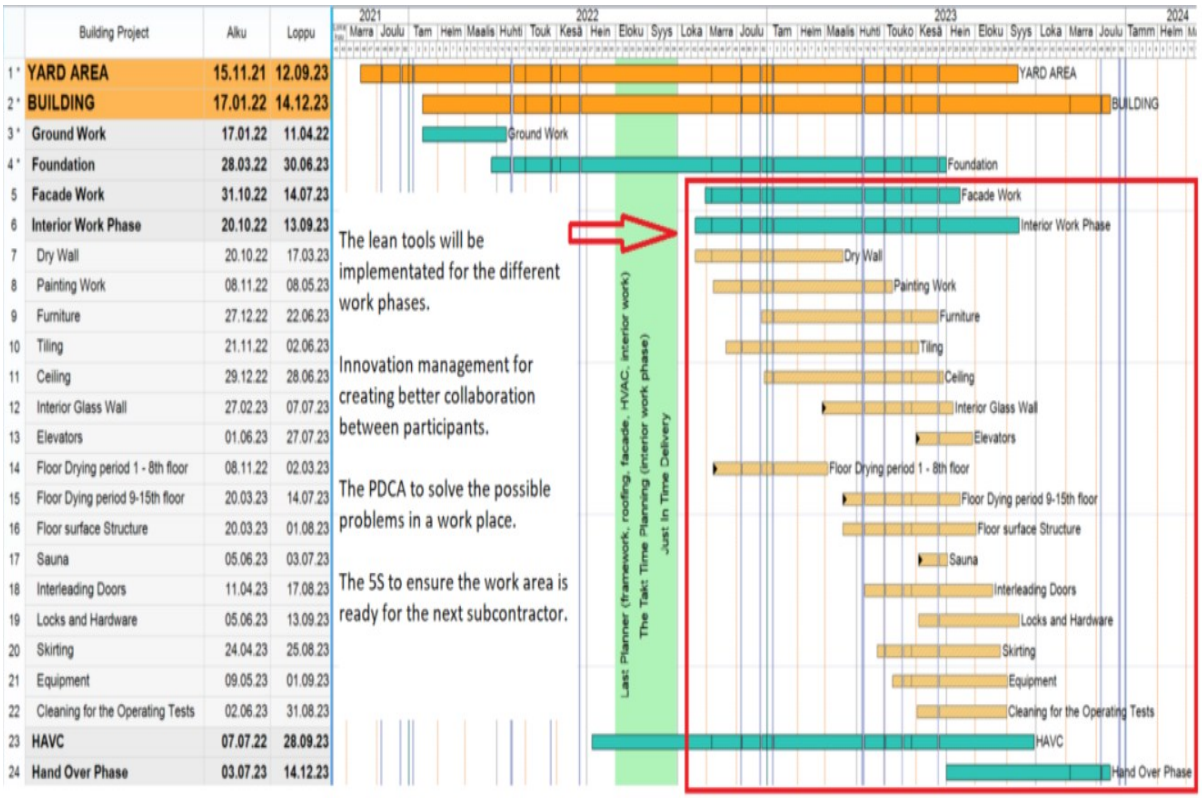


Figure 12. The Final Proposal of the Lean Tools Shown in the Master Schedule

The Last Planner, Takt Time Planning and Innovation Management lean tools should take place in the early stage of the production phase. It is recommended to ensure the designers to prepare the needed designs for the production

phases before the actual production phase starts by providing Last Planner with the participants. The Takt time Planning is recommended to start before the production phase starts and to cooperate with the subcontractors and in order to gain commitment of the participants. The just in time delivery is recommended to be ensured before the production phase starts.

7 Conclusions

The final phase of this thesis includes the summary, recommendations for the next steps for the implementation of the lean tools and a self-evaluation of the thesis.

7.1 Executive Summary

The objective of this thesis was to propose lean constriction tools for the commercial department of the case company. These lean tools allow the improvement of the productivity of a building project. The case company decided to apply the lean project delivery method in its production some years ago. This has been an important decision by the top-level executives. Many examples show around the world, that this decision is fundamental to be able to change the company culture. The transformation to become a lean construction building company is a long-term plan and requires a lot of actions and continuous improvements along the way. The business environment is constantly changing and there are internal changes within the companies as well. Therefore, to be able to adapt as a building company to these challenges it is important to improve the production methods generally. The first steps have been taken in the company already and it was very useful to receive best practices and new information from the pilot projects during the process of this thesis.

The research approach of this thesis was case study research. The case study research utilized qualitative data gathering methods. This thesis includes four phases which contain the current state analysis, the literature review, building the proposal of the lean tools, the validation of the proposal in which the final proposal is carried out. The first phase was the current state analysis. The current state analysis focused on mapping the current construction production management methods and tools of the company. The case company had pilot projects and some important experience was available regarding the use of lean construction tools. The outcome was the analysis of weaknesses and strengths

of these production management tools. It was found there are strengths in currently used production management tools, but they are not providing detailed enough perspective for the lean construction production. Traditional management tools cannot make visible the level of detail were the lean improvements need to be made.

The current state analysis was carried out through stakeholder interviews, exploring the company documents and by observing the way of production in the company. The outcome of the weaknesses and strengths are shown in the table four in a separate column. It was found that some of the currently used production management tools are not detailed enough for the lean construction production. In many cases the so-called traditional production management tools do not support the lean approach in a way that it is possible to reduce waste and add value to the customer enough. On the other hand, it is useful to provide the traditional management tools alongside with lean construction management tools.

Due to the decision made by the top-level management to apply the lean construction project delivery method in the company, the background and base for the implementation of the lean construction method is ready. The company culture is positive for the lean method, and this is one of the most important features considering the implementation phase. The company culture of the case company is already supporting the lean production method in generally, focusing, for example, on the following issues. Safety issues, staff education programs, and clear business process maps. As it is mentioned in many different written sources, top-level support and leadership is crucial in any kind of change management case.

The process maps of the production are well organized in the company, and this supports the change in the long run. The company supports the learning of the staff by providing courses for the management tools such as schedule, cost controlling and work management courses. The lean construction courses are available as well, and these lectures are voluntary for the staff.

The two participants who were working in the pilot projects were interviewed, and it was provided good information and experiences on these projects. The pilot projects implemented some of the lean construction tools, and the project was able to achieve approximately 25 to 35 percent shorter lead time in one of the interior work phases.

The second phase of the thesis was the literature review. The literature review was based on relevant literature about lean management philosophy and its applications among the production industry and as well as the construction industry. Although the lean construction project delivery method is rather new approach in Finland, there is plenty of information and experience about the topic available. The literature review was carried out based on the existing research and best practises. It was focused on improving the productivity, workflow, and other forms of building production. On the other hand, it was concentrated on noticing the weaknesses in production management and on finding them through the current state analysis. The outcome of the literature review was fourteen different kinds of lean construction tools in the T industry and the results obtained by using lean construction method are in many cases very positive.

The third phase of this thesis consisted of building the proposal for the lean tools for the commercial department in the Table 8. Building the proposal included the results of the current state analysis, experiences from pilot projects and the lean philosophy, comparison between the different options of the lean tools which are suitable for the commercial department, leading to the proposed lean tools for the implementation. According to the feedback it was agreed that lean tools will be shown in the master schedule of a real pilot project. This way it is a visual and easy way of showing when the different lean construction tools will be implemented for all the participants.

The fourth phase was the validation of the proposal. The validation was carried out by interviewing the department director and the production manager of the commercial department of the company. The whole thesis was presented and

chosen seven different lean construction tools were shown to the participants. Feedback was gathered about what the participants opinions were regarding the lean tools and which kind of experience they had using some of the lean tools.

The participants provided their comments to each lean tool separately and the comments were discussed together. The results are shown in the tables 9 and 10. In the beginning of this thesis process it was agreed with the department director, that the first steps and the implementation of the lean construction tools and project delivery method would be carried out gradually.

7.2 Proposal for the Construction Lean Tools

The final proposal of the construction lean tools is the outcome of this thesis. The proposal includes the lean tools which are selected from the initial proposal according to the feedback given by the director of the department and the production manager. The initial proposal was shown in the Table 8, analysing the strengths and weaknesses of the different lean construction tools. It was collected different kinds of lean construction tools from relevant literature and the experience gained from the pilot projects in the company. The weaknesses and the strengths were monitored to be able to consider the differences between lean construction tools. The desire was to have a practical solution so that it would be easy to implement for the pilot project of the commercial department.

These selected six lean tools and different categories have different kind of aspect to the building production. Corresponding to the category it is possible for the construction management to manage the production at the site. In some cases, it is a bit hard to separate the effect of the particular lean tool very exactly, and in some cases the effect can even overlap between the different lean tools. But the main goal is to be able to manage the production and reduce the waste and add value for the customer.

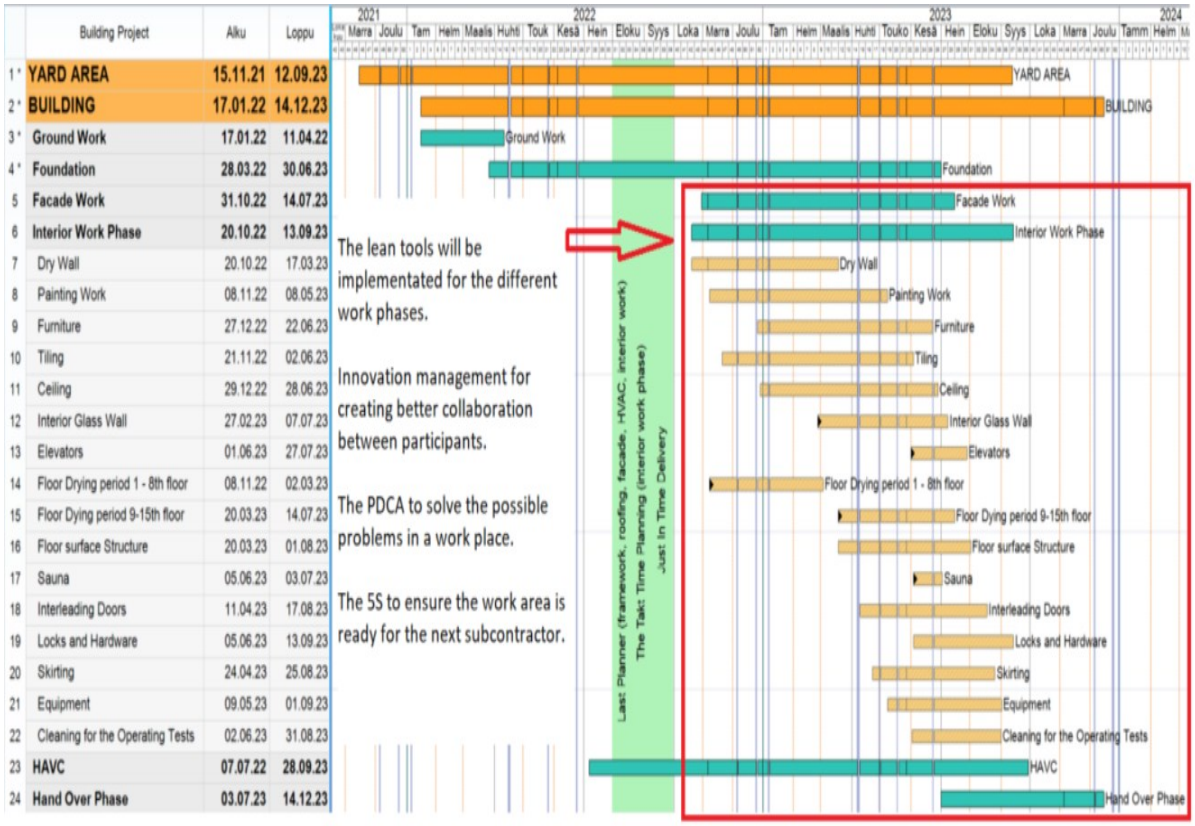
The outcome of this thesis is six lean construction management tools for the commercial department. They are shown in the Table 11 below. The table shows the production stage in which the lean tool is recommended to take in use. The name of the lean construction tool is shown on the third column. The impact and purpose of the lean tool is shown in the fourth column and the category is marked in the column on the right, showing which kind of impact the lean tool has in general on the building production.

Table 11. The Final Proposal of the Lean Tools for the Commercial Department.

Production stage	#	Lean Tool	Impact and Purpose of the Lean Tool	Category
Before or in the beginning of the production phase in a project.	1	The Just In Time Delivery	Reduce the inventory space, damages, and unnecessary transfer at the site,	Overall Optimization
Before or in the beginning of the production phase in a project.	2	Last Planner	Reduce waste of not ready designs, makes the production smoother.	Reducing Waste
During the production phase in a project.	3	Innovation Management	Improve the collaboration between the participants and to share information to all subcontractors.	Respect and Grow Your Staff
Before or in the beginning of the production phase in a project.	4	The Takt Time Planning	Improve the workflow, to reduce the waste time between the tasks.	Workflow
When a problem occurs will be implemented in every work package.	5	The PDCA Cycle	Increase the continuous improvement in every work package.	Continuous Improvement
Before every work phase starts	6	The 5S	Improve the workflow, make ready the work area for the next subcontractor.	Reducing Waste

It was also agreed that the different lean construction tools will be shown in the master schedule of a pilot project of the commercial department. By showing the lean tools in the master schedule, it is visually and easy to follow when the lean construction tools will be implemented.

Figure 13. The Proposed Lean Tools Shown in the Master Schedule.



7.3 Recommendation for the Implementation plan

The first steps of implementing the lean tools are the Last Planner, the just in time delivery and the takt time planning, these are coloured in green in the schedule. The Last Planner procedure with the designers and other participants is to ensure that the different designs are available for the production phases. This cannot be emphasized too much concerning the smooth production delivery. Due to the missing or unfinished designs they will create lots of time waste for the whole project and to be able to optimize the building time it is important to make sure the designs are ready for the production.

The just in time delivery must be agreed as soon as it is possible to ensure the flow of material to the construction site. This will ensure that the production will progress according to the building schedule. This is implemented with the

procurement department and material supplier contractors. It is recommended to set a delivery schedule and different intermediate targets in the contracts.

The innovation management is important to be able to improve the collaboration between the participants and to create new ideas to reduce the waste in the project. Although the innovation management is usually implemented to create new ideas it can be applied as a tool to improve the production in many ways. One application could be to improve the overall project management by meeting with project stakeholders (client, designers, inspectors, and contractors) and to focus on project development on regular basis.

As the work will progress in the project the 5S and the PDCA will be implemented for all work packages. The 5S is to ensure that the different work packages are able to start their work without delays. With this tool it is possible to manage the different contractors to clean and organize the work area so that continuous workflow will be carried out. The PDCA is a tool which allows the site management to solve a possible problem at the site by using the same framework of plan, do, check, act. This helps the site management to have a common systematic tool for problem solving.

7.4 Self-evaluation of the Study

The initial challenge was to improve the productivity of a building project in the commercial department of the case company. The objective was to propose lean construction tools to improve the building process. The outcome of this thesis provided six different lean construction tools for the commercial department and the schedule regarding when the tools will be implemented in a pilot project in the department. These lean construction tools were validated by the director of the commercial department and production manager. Accordingly, the objective was achieved in this thesis.

The results of this thesis are targeted for the practical use of the lean construction management tools at the jobsite. Although, there are multiple ways

of interpreting the solutions for improving the production. The objective of the thesis is achieved by providing a practical set of tools to improve the production, reduce the waste and add the value for the customer.

The author of this thesis is construction manager in the commercial department. Involvement in this improvement process has been a major advantage and it has been a very interesting journey. Furthermore, it has been a pleasure to work with such professionals as the participants in this process.

7.5 Validity

According to Kananen (2013) in the beginning of a study an objective has been set which needs to be solved. Accordingly, there must be a clear process map for solving the problem and to answer to the research problem at the end of the study. The result and the conclusions must be clearly stated for the reader. The definition of objectives is essential, for example, in development and case research where practical problems are solved (Kananen, 2013:130-131).

In this thesis validity was ensured by four different phases of the research. After the objective was defined, Data 1 was collected in the current state analysis by studying the company documents and interviewing the personnel of the company. The results of the currently used production management tools and the lean tools used in the pilot project were the outcome. These strengths and weaknesses were gathered to gain a clear picture of the current state of the production management tools.

The second phase was to analyse the relevant literature to find solutions for the objective which was to propose lean tools for the commercial department. From the literature it was found different kinds of lean construction tools to improve the production, reduce the waste and add value for the customer.

The third phase was to build the proposal of the lean tools for the department. It was selected seven lean tools in six categories and feedback was received from

the director of the department and the production manager about which tools will be implemented. The strengths and weaknesses were evaluated concerning the commercial department´s production. Data 2 was collected according to the feedback given and the outcome was a proposal of which lean tools are suitable for the department.

The fourth phase was the validation of the lean tools which will be implemented for the commercial department. A clear table of six lean tools was provided. The table included the production stage, lean tools, impact and purpose, and finally category for the lean tool. As the participants of the department desired, the lean tools are shown in a schedule of a pilot project to have a visual guideline for the site management.

7.6 Reliability

Kananen points out that reliability plus evaluation equals quality. The reliability of the study is considered already in the design phase of the study and action is taken during the research process. If something is deemed wrong it must be substantiated by research material (Kananen, 2013:135-136).

In this thesis the research design is shown in the section 2.2. The different steps of the research process are shown clearly in the process map. In this way it ensures the progress of research. All the data observed by the author was gathered from the interviews. This information is recorded into the field notes and the provided questions are recorded as an appendix of this thesis.

7.7 Logic

According to Kananen research must have a purpose. The purpose itself is evident from the research problem and the structure is linked to the table of contents. Some of the diagram of the process map illustrates the structure of the study. Providing the objectives of the study gives the reader an overview of the thesis (Kananen, 2013:129).

Case study was a logical approach for this applied study. As the director of the department desired, this study presents a clear guideline for implementing the lean tools for the commercial department. Findings from the relevant literature were examined to be able to combine different lean tools and to select suitable lean tools for the commercial department. The selected lean tools are presented in a visual and logical way for the site management and other participants in a table and in a schedule.

7.8 Relevance

There are different kinds of relevance, and they may vary depending on the purpose. Some studies are research that solve a particular business problem, or it may be the basis for a solution implemented by a company. A study may change operation of a company and become a commercial application. In science there is a competition about who manages to present a solution or innovation to a problem (Kananen, 2013:137).

Relevance of this thesis is shown from the beginning. Due to the decision had been made in the company that the lean construction production method will be implemented. The idea of this thesis was accepted by the director of the department, and he considered that it is useful for the commercial department. Improvement of productivity is a common issue in the construction industry as well as in other industries all over the world. The continuous change of the business environment encourages companies to find ways to improve productivity. To be able to reduce waste and add value for the customer is the essence of productivity.

7.9 Closing Words

Lean philosophy of production has been growing and improving for many years, and it is getting more and more attention worldwide. Within the construction industry it is a relatively new approach to management, but it is not a totally new way of production. The improvement of production is a continuous procedure,

and it will probably go forward step by step for years to come. The companies must change as the environment will change and the change will take place within the organization as well.

The possibility to improve the production is appealing and lean construction provides an interesting method for it.

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Interview questions about the pilot projects regarding the management tools

- Interviewer name and day:

- Interviewee name and day:

- Background information on the project:

    - Contract type:
    - Building type:
    - Number of the site workers:

1. What tools have been used to manage the production?

- Master Schedule
- More detailed schedule
- Handover schedule
- Site plan
- Contractor progress meeting
- Team meeting
- Site meeting
- Kick-off meeting
- 3D model
- Quality management Congrid
- Humidity management (kuivaketju10)
- Any other comments?

2. What are the good features of the management tools?

3. What are the bad features of the management tools?

- What is an issue that you would like to develop related to management tools?

- Any other comments?

Interview questions for the selected lean tools

- Interviewer and day:

- Interviewee and day:

- The presentation of the lean tools

- Presentation why these lean tools were selected

Answers to the selected lean tools of the department director:

1. The Integrated Supply Chain
2. Big Room
3. Last Planner
4. The 5S
5. The PDCA Cycle
6. Innovation Management
7. The Takt Time Planning

Answers to the selected lean tools of the production manager:

1. The Integrated Supply Chain
2. Big Room
3. Last Planner
4. The 5S
5. The PDCA Cycle
6. Innovation Management
7. The Takt Time Planning

- General comments and opinions on lean tools:

Interview questions which of the lean tools will be implemented in the pilot project

- interviewer name and day

- interviewee name

- 1. What lean tools will be implemented?

1. Takt Time Planning
2. The PDCA
3. Last Planner
4. Just In Time Delivery (JIT)
5. The 5S
6. Innovation Management

- 2. What kind of experiences there are about different lean construction tools?

1. Takt Time Planning
2. The PDCA
3. The Last Planner
4. Just In Time Delivery (JIT)
5. The 5S
6. Innovation Management

- General comments