


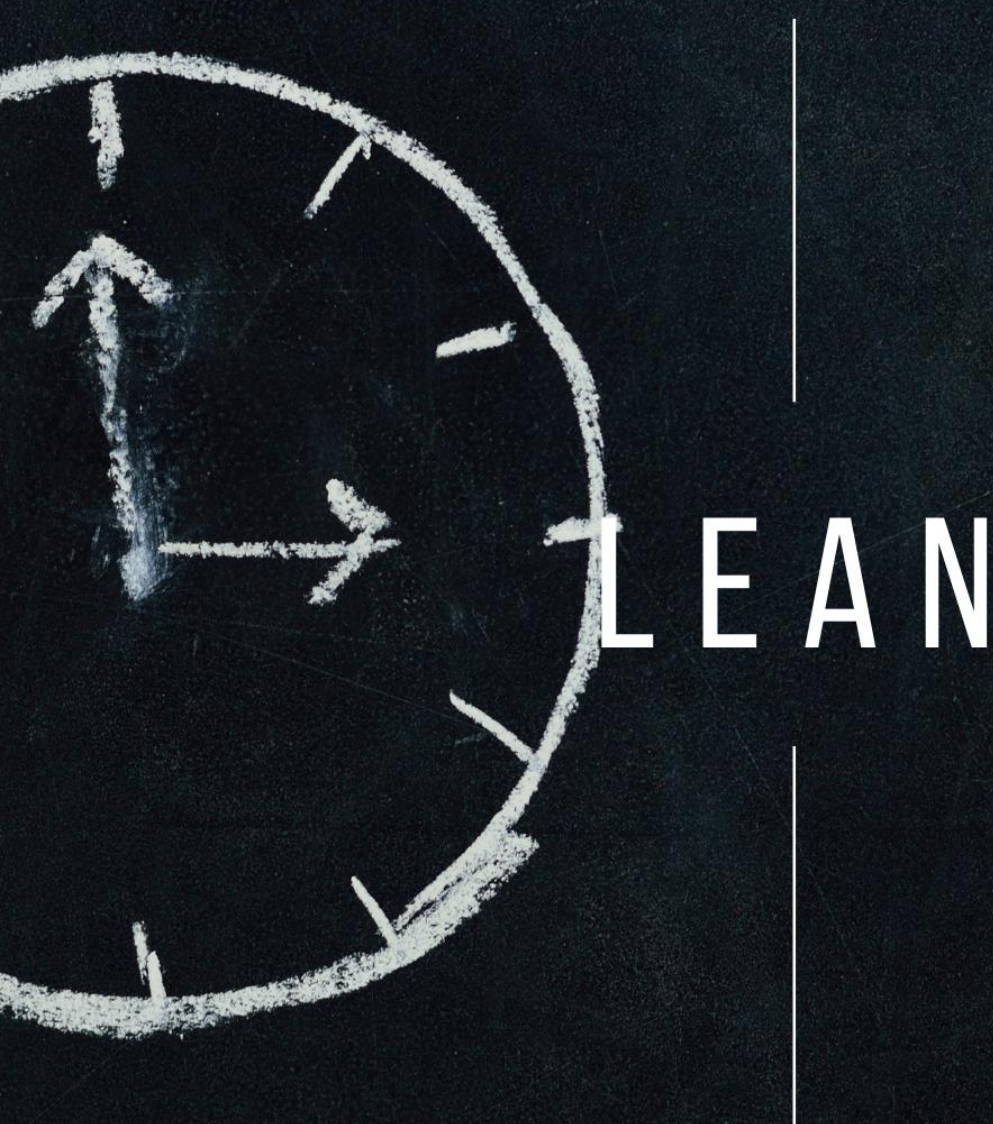


Universitetet
i Stavanger

FACULTY OF SCIENCE AND TECHNOLOGY

MASTER'S THESIS

Study program/specialization: Master of Science in Engineering Structures and Materials Specialization in Offshore Structures and Structural Engineering	Spring 2021 Open/ Confidential
Author: Amirhossein Karimzadeh Esfahani	 (signature of author)
Program Coordinator: Sudath Sirwardane Supervisor: Sindre Lorentzen	
Title of master's thesis: A comprehensive review on Lean Project Management , transformation & Implementation methods, and its utilization in the construction industry (Lean Construction)	
Credits: 30	
Keywords: Lean Thinking Lean Management Lean Construction Project Management	Number of Pages: Stavanger, Norway 06.2021



A comprehensive review on Lean Project Management,
transformation & Implementation methods,
and its utilization in the construction industry (Lean Construction)

AMIRHOSSEIN KARIMZADEH ESFAHANI

Abstract

The construction industry, as the most conservative industries, has faced multiple problems. Many of its projects are delivered with poor performances, unacceptable quality, ridiculous budgeting, and wasted time. In addition, many organizations are operating with disorganized project delivery processes, generate a tremendous amount of waste, and low-grade return (policy) to clients. Lean construction has been introduced as a strategy for a more efficient management method to overcome the problems linked to project delivery and organizational processes in this industry. Regardless of the multitude of frameworks for executing lean strategies, a suitable framework for promoting lean management in this industry is lacking. In addition to the lack of an appropriate framework for executing lean strategies, there is a scarcity of knowledge and researches about the issues linked to the implementations, barriers, and CSFs or critical success factors. Consequently, the importance of implementing these strategies is still left unknown, and this was one of the main reasons behind carrying out this study. The primary contention of this paper is to equip the reader with the necessary knowledge to implement lean principles.

Since the early nineties, the interest in utilizing lean production principles in construction projects increased. This matter was studied for decades in order to find approaches to better implement such production philosophies in the construction industry, which is a different industry than the one this system was originally designed for. Conservatism in the construction business, together with the mentioned issue, brought many challenges, which resulted in various adjustments to the initial philosophy for the sake of translating it to a set of principles as Lean Construction. These changes kept the soul of lean philosophy intact while adjustment adapts the principles with the specifications of the construction industry.

Therefore, A thorough study is carried out to showcase Lean techniques, means to implement them, and its philosophy which could be executed in order to obtain the desired results and improve the performances as it had happened in the manufactory industry. These techniques are introduced with their components, objectives, and the area of influence. The implementation and execution of new processes are presented, and various stages to follow are evaluated. The influence of each implementation phase is thoroughly discussed as well as the potential barriers in implementation.

In the end, conclusions are drawn based on the results that are obtained from implementing Lean techniques in Construction Project Management.

Acknowledgments

I would like to thank Dr. Sindre Lorentzen for his support, guidance, advice, and patience. This thesis would not have been possible without his mentorship and assistance. I would also like to sincerely thank the University of Stavanger for allowing me to pursue my education, which is an opportunity beyond my wildest dreams. I will forever be indebted to the professors, staff, and students for one of the most incredible years of my life.

To all,

Thank you.

Table of Contents

Background	
Abstract	
Acknowledgments	1
List of Figures	4
List of Abbreviations	5
Chapter 1 Introduction	7
1.1. Background	7
1.2. Objectives and Research Questions.....	8
1.3. Thesis Structure	8
1.4. Novelty and Utility	9
Chapter 2 Method	10
Chapter 3 Literature Review	12
3.1. Introduction	12
3.2. History	13
3.3. Lean Manufacturing	16
3.4. The Manufacturing Process versus the Construction Process	17
3.5. The Philosophy of Lean Enterprise	18
3.6. Moving from Lean Manufacturing to Lean Construction	19
Chapter 4 Technique	22
4.1. Plan-Do-Check-Act Cycle	22
4.2. Muda – Lean Waste	25
4.3. Five Whys	31
4.4. Gemba Walk (Real Work Happens Here)	35
4.5. The A3 problem-solving technique- A3 sheet	38
4.6. The Last Planner System (LPS)	42
4.7. The Five S	47
4.8. Push Planning	48
4.9. Kanban	49
4.10. Pull Planning	51

4.11. Poka Yoke	52
4.12. Just in Time	52
4.13. Takt Time	52
4.14. Hoshin Kanri	54
Chapter 5 Lean Transformation.....	55
5.1. Introduction	55
5.2. Lean Transformation Model	55
5.3. Roadmap (to Implementation)	55
5.4. Lean Transformation Model in detail.....	56
5.5. Answering the questions of Lean Transf. Model	58
Chapter 6 Implementation of Lean Construction Principles.....	62
6.1. Implementing new Processes	62
6.2. Implementation of Lean Construction	65
6.3. Implementation Barriers	67
6.4. Strategies to Implement	68
6.5. Tips for a better Implementation	70
Chapter 7 Lean Project Management	72
7.1. Applying Lean Project Management	72
7.2. Lean Management Tools	75
7.2.1. PDCA in the Lean Project Management	75
7.2.2. Kaizen and Kairyo	76
7.3. To cut it short; Lean Project Management is...	77
Chapter 8 Conclusion	78
Chapter 9 References	79

List of Figures

Figure 1 | Chain Reaction [9] – page 14

Figure 2 | Continuous Improvement [9] – page 15

Figure 3 | Plan-Do-Check-Act cycle – page 23

Figure 4 | A3 report page – page 40

Figure 5 | The LP system procedures - page 43

Figure 6 | The Last Planner System – page 43

Figure 7 | The Five S's Principles – page 48

Figure 8 | Lean Transformation Model (Framework House), adopted from LEI – page 57

Figure 9 | PDCA Cycle – page 59

Figure 10 | Macleamy curve – page 66

Figure 11 | Lean Project Management Principles – page 72

Figure 12 | PDCA Cycle – page 75

List of Abbreviations

AEC - Architecture, Engineering and Construction
ERP - Enterprise Resource Planning
FBI - Federal Bureau of Investigations
HR - Human Resources
IT - Information Technology
LC - Lean Construction
LP - Lean Production
LPS - Last Planner System
LT - Lean Thinking
LT – Lean Transformation
BIM Building Information Modelling
CAD Computer Aided Design
CSFs Critical Success Factors
EFA Exploratory Factor Analysis
ISM Interpretative Structural Modelling
JIT Just-In-Time
LC Lean Construction
LPDS Lean Project Delivery System
LPS Last Planner System
IGLC International Group for Lean Construction
MICMAC Matrix of cross-impact multiplications applied to classification analysis
PDCA Plan-Do-Check-Act cycle
PM Project Management
SSIM Structural Self-Interaction Matrix
SCM Supply Chain Management
SC Sustainable Construction
TPS Toyota Production System
TQM Total Quality Management
VM Value Management
VSM Value Stream Mapping
NGO - Non-governmental Organizations

PPC - Percentage of Plan Completed

RPS - Reverse Phase Schedule

SWLA - Six Weeks Look Ahead

TPS - Toyota Production System

UN-HABITAT - United Nations Habitat Division

USA - United States of America

WWP - Weekly Work Program

1. Introduction

1.1. Background

Lean Philosophy

manufacturing plants established the foundation for TPS or Toyota Production System, that is known by the name of Lean from 1990. Henry Ford, the famous American car manufacturer, revolutionized the production process, and it had many outcomes which one of them is the production speed rate increased. He then later mentioned this in his book that is called Today and Tomorrow, which is mostly concerning the importance of making continual material flow all around the standardizing process, manufacturing processes, and eliminating waste. But he did not fully utilize what he suggested. He gave priority to batch production methods that generated batches of products and parts rather than continual material flow. The Toyota Foundation, which was inspired by Ford's plant, utilized Ford's idea on the continual material flow and later on developed it with the help of making their own flow. Toyota desired to master customer-demand fluctuations and deliver goods immediately. They gave life to Ford's ideas and changed the concentration from individual (exclusive) machines and their use to the product flow throughout the entire process.

Lean production could be summed up into four main points:

- recognize and add value: eradicate non-value-adding activities or anything that will not deliver/add value to customers
- Organize the production process as a continual flow
- Refine products and make a dependable flow
- Aim Perfection: Delivering a product as it was promised, which satisfies the customer demands with less or nothing stockpiled in the inventory

Lean and Construction Industry

The construction industry is considered as a complex and conservative industry, where every project has specific peculiarities as well as many uncertainties that are involved. The success in almost any construction project depends on the accuracy of the cost and time of the contracts as well as customer satisfaction. That is why researchers are examining the factors and causes which result in project delays.

The construction industry accounts for about ten percent of global GDP, which for developed countries it is said to be around six to nine percent. It employs about seven percent of the worldwide workforce that would be around 273m people. The output of the construction industry, based on what is estimated recently, is worth approximately eleven trillion USD.

Enhancing project management in this industry will reduce the waste occurring during the process. One of the best ways of enhancing project management and eliminating waste is to implement lean principles. In other words, the implementation of lean principles and techniques in the construction industry is known as Lean Construction.

Implementation of Lean Construction is made up of plans, techniques, tools, cultures, and concepts to add value while reducing all kinds of waste. The given method is not only bounded to processes, but it is also involved in product development, strategic management, HR management, and the relationship between suppliers. It was made to satisfy the customer's demand with the help of better performance, lower costs and quality products.

1.2. Objectives and Research Questions

As it was mentioned earlier, the construction industry is a conservative industry which means it takes a considerable amount of time and resources to make a change in it. On the other hand, it needs a better way of management to reduce the wastes, improve the quality, etc. Besides all these, the current method of construction and management has left this planet in a crisis that is threatening everyone's life. Many species are in danger, global warming is at its peak, deforestation is becoming a severe problem, and pollution is now widespread in many forms.

Therefore, it was my responsibility to promote Lean Construction so that maybe in the future, at least in my area of expertise, there would be fewer wastes produced, and great importance would be given to environmental matters. Consequently, a thorough literature study was carried out to increase awareness.

The primary research questions that were answered throughout this thesis are:

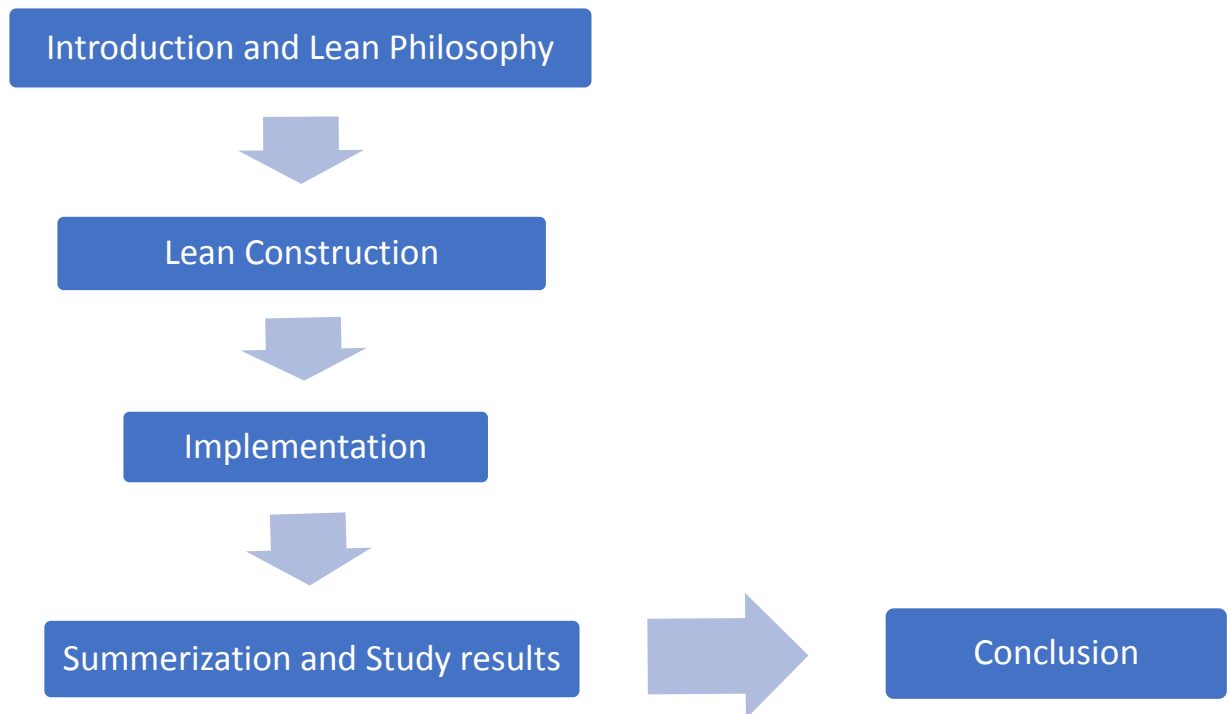
- 1- How could Lean be applied to the current method of project management?
- 2- How to increase the efficiency of Lean Transformation in an organization?
- 3- How to better implement Lean Construction Principles in Construction Projects?

After a complete introduction to the lean philosophy and its techniques, three chapters are devoted entirely to provide the reader with enough knowledge about these questions.

1.3. Thesis Structure

Implementation of Lean principles to almost any field of practice is considered as the most significant achievement that was achieved in the project administration. In this thesis study, the main focus was on a thorough literature study to once more introduce this treasure to construction managers and people involved in this business. In fact, for the sake of providing relevant and practical information, some of the unrelated content was removed to bring coherence and practicality to this article.

First, an introduction to the philosophy of lean thinking is given as an entrance to the unknown world. It is worth mentioning that for the purpose of allowing the readers to get a better image of this concept, a chapter dedicated to the chronological history of lean is followed afterward. Then the relevant techniques and principles are provided with the implementation methods to showcase the practicality of the given ideology. In the end, a conclusion is drawn based on the instructed content.



1.4. Novelty and Utility

Bringing new ideologies into existence was the principal objective of choosing this topic. Lean itself is a novel philosophy that nowadays is being utilized in many businesses all around the globe. As said before, the construction industry is one of the most conservative industries that almost rarely a new advancement could be put to use in it. Connecting lean philosophy with construction project management has been helping many organizations to increase productivity, eliminate wastes, boost clients' satisfaction, etc. For this purpose, a considerable amount of time was invested in linking various fields of study to each other with the hope of providing a comprehensive review.

Secondly, this article was arranged to not only focus on the theoretical aspects, but it also walks you through the entire procedure and familiarizes you with the necessary steps to implement lean with high chances of success. In fact, there are many articles that are dedicated to this matter, but only a few of them could be this helpful to the people in practice. Implementation methods, procedures, common mistakes, and some recommendations are given for each approach to increase the utility of this study.

Besides promoting Lean Thinking and its new vision for management, United Nations Sustainable Development goals are also discussed and linked to the topic.

In addition to what is mentioned, although the thesis itself was an ultimate goal, it also provides a stepping stone for future researches. Throughout this article, many uncertainties and novel questions were found, which is prove this claim.

2. Method

From the definition of a literature review or a critical review essay, a proper evaluation and summarization of specific articles on this topic were carried out. The primary focus was on two main elements that are essential for a practical review; firstly, summarizing earlier researches and findings on the given subject. Secondly, drawing to an end with a conclusion where the accuracy and fulfillment of the topic are acknowledged. This presents the author's judgment and what is inconclusive or missing in the literature. Serious attempts were made to focus and demonstrate the matter as a whole instead of combining individual work. In other words, the utilized method was simply to synthesize several elements into a whole, rather than mentioning separate findings as a form of an article. [70]

In the end, a conclusion was made primarily to assist the reader with the following:

- 1- Giving the reader a general overview
- 2- Clarifying what has already been carried out on that subject
- 3- Offering new insights for future researches
- 4- Demonstrating flaws of the existing research

Generally, one of the contexts below is what a literature review is made out of:

- 1- A preliminary stage in a considerably larger research project

Such reviews are only carried out for a dissertation proposal, proposal for research fund, and thesis. The very reason behind all of them is to ensure that the proposed research questions have not been addressed before. If so, it is better to be aware of this fact before starting the study.

When there is no prior study on the proposed research topic, it could be considered as a contribution to knowledge. The objective here is to provide the readers with new pieces of information on that topic.

To summarize, in a research proposal, a review provides an overview of the existing study and shows how the given research will revise or add to the current body of knowledge. [70]

- 2- A component of a finished report

By bringing a new revision, the main objective here is to demonstrate how the final conclusion is linked to the earlier knowledge on that topic. [70]

- 3- It can be the ultimate goal itself

Literature reviews are also used to evaluate and identify the practicality of the existing knowledge in terms of tackling a particular issue, such as the lessons learned from the previous efforts on one specific subject. Critically evaluating available research in a literature review can make a considerable difference in that context. Those critical analyses are not only

entitled to the opposing side; in fact, it is of great importance to point out the positive results of an existing job. [70]

Throughout this thesis, the main concern was to help readers gain more information about the theory of lean as well as its practical side. However, by criticizing the common mistakes and lessons learned through the implementation of lean techniques, a new vision of lean philosophy is offered.

It is worth noting that this literature review is capable of addressing both practical and theoretical questions. Usually, a literature review focuses primarily on the theories that other scholars and researchers proposed to investigate and clarify a phenomenon. However, in this article, the reader is introduced to both aspects. You could learn more about a specific lean technique while its procedure and common mistakes are also embedded there. [70]

Literature reviews are also used to evaluate and identify the practicality of the existing knowledge in terms of tackling a particular issue, such as the lessons learned from the previous efforts on one specific subject.

Critically evaluating available research in a literature review can make a considerable difference in that context. Those critical analyses are not only entitled to the opposing side; in fact, it is of great importance to point out the positive results of an existing work.

All and all, collecting all the necessary documents, summarizing them, and organizing all the information in a way that could answer the proposed research questions is what has been considered for this article. Many efforts were made to find the areas of debate or uncertainty with the hope of finding what is missing. This could raise many questions that someday might be considered as research questions themselves.

Therefore, a literature study has been conducted on multiple publications from various reference books to scientific journals and other materials on the internet with the hope of reaching an accurate judgment. Paper traced by applying some keywords, for example, "lean Management," "Lean Construction," "project management," in portals such as Emerald Insight, ScienceDirect, ResearchGate, Lean Construction Institute, and any other publishers.

3. Literature Review

In this chapter, the reader will be introduced to the lean philosophy and its utilization in the construction industry.

3.1. Introduction

Lean is known as a concept of an efficient and productive management system which has been used in multiple disciplines, including manufacturing, operations, constructions, governments, and many other fields to which this way of thinking could contribute. Lean grew out of the Toyota's Production System in the midst of the 20th century, which is based on the definition of values from the customer's point of view, and constant improvement and development of the way in which value is delivered, that could be achieved by eliminating every single use of resources which is wasteful or would not contribute to the goal value. [2]

Lean is focused on keeping value with the help of less work; with the goal of providing an excellent value to all the customers through a ideal value creation process which has zero waste; it is done by empowering all personnel to achieve their full potential so that they could make a great contribution both to the team and the final value.[2]

The goal of this encouragement and empowerment is based on the fact of showing respect to the people. Respect for people could even extend beyond the end customer; which means it could include all the personnel, suppliers, and mankind. For the end customer, Lean tries to boost the value delivery while reducing waste through the process. Lean plans to increase human potential by energizing workers to regularly advance their work. Lean leaders facilitate and expedite achieving this goal through a system called problem-solving training. They help workers develop and flourish both professionally and personally, allowing them to be proud of their work. [2]

At the core of the Lean philosophy, there is a concept named "kaizen" or continual improvement. The goal of this improvement is to get rid of all waste in through the whole process of value delivery. To obtain this, Lean leaders must find where value is created – which is known as the Gemba. At this place, Gemba, they often spend their time training ,oomunicating, and developing their staff. They encourage and empower their workers to identify problems and look for opportunities that could improve the process. [2]

Soon after the world war II, there was a general focused on rebuilding and renewing societies that translated to a primary focus on economy. In the 1950, Taiichi Ohno, from Toyota Motors, studied some of the americans industrials such as Ford to understand where room for enhancement could be obtained from their production system. The americans had their focus primarily on mass production with comparably larger batch sizes to the ones they had in japan [1], which were functioning. The leap to take for them

was substantial, and a better way to attain productivity leading to gain and more profit was required. Ohno changed his perspective, and he tried to look at the situation different from the Americans. Rather than increasing the production, he put his primary focus on reducing the wastes through the process by constantly trying for improvement. [1]

Toyota production system spread around the globe, in 1970, among the manufacturing companies with their supply base system, and in 1980, with their distribution and sales operations. [3] The performance gap between the Americans and Japanese was described as a consequence of some key elements gathering under the philosophy of lean production. Lean was used as a primary reference to the resources used between various departments of an organization with respect to the invested capital, time, human resources or inventory. The Lean manufacturing strives to associate from craft production and mass production: improvement in quality and cost reduction while expanding the range of products. [2]

As mentioned previously, the primary reason of having high performances are because of the waste hunt which is carried out continually, leading to substantial reductions of consumption of capital, human resources, and time. Wastes are described as any sort of activity which would not make value to final product. Value is generally defined as the financial worth of an item that is gained through the defined processes which are improving its condition including making raw minerals into jewelry. In manufacturing industry, according to some estimates, only five percent of the activities are adding value to the end product. The rest, other ninety five percent, are called non value-added activities which are divided between non-avoidable and avoidable activities. Avoidable activities are treated as waste. [3]

3.2. History

Frederick Winslow Taylor, a brilliant American mechanical engineer, carried out many researches on the duration of steps in a production line in 1881, which led him into dividing tasks into measurable and quantifiable elements. [6] These small adjustments helped to ease the workflow and made the work to be more structuralized, manageable and efficient. [7] He then proceeded with developing a theory in which the objective is to utilize the human resources efficiently while they're working with the minimal effort, scientific management; which could be a steppingstone to the genesis of Lean management. [1] [5]

Simultaneously, Henry Ford was working on standardization in 1906; a method to increase the quality of products with the lowest costs possible. The assembly time was cut down, thanks to the standardization methods he initiated; using similarities in products. This means, when a technician was working on a same assignment over and over again, the period at which the job was done was reduced substantially. [5] [4] He also figured out that having a moving assembly line is better efficient since having

people changing their station through the line could bring out confusion and extension to the overall duration. By just moving the products and fixing personnel's spot, an efficient flow was made to the production process. Consequently, a considerable increase was observed in value and wastes were reduced, that is why he then named this production system "mass production". [8]

The management systems Ford and Taylor devised were problematic. For instance, human development was not considered as an element of scientific management that Frederick Winslow Taylor initiated. This element could have granted the people involved in the process with a feeling of progress and development as well as satisfying their need for change. By not considering this vital element, tasks were regarded dull and monotonous by the workers. Psychologically, the human being loathes tedious events. Now imagine that event continues for a long period of time, each day, each month until the person retires or fails to deliver the purpose. People are not generally in favor of being regarded as machines. They could not suggest for a change since those management styles were restricted and controlled, and mostly workers were not even allowed to propose a slight change to the system. In addition, Ford's management system was unable to address customers' need and demands. It was all because of the production style he developed to be entirely plain and simplified. The products he made had the same color and features while customers demand was more focused on more stylish and colorful options, and his company could not offer those variations since it was costly to them to change their production system. Later, they faced a major problem, causing a dramatic loss in resources. It was due to the lack of requests and demands which lead the company to OverProduction. As it's defined in the following, Overproduction is one of the major flaws that Lean tries to solve. [1][2][5]

In a short trip to Japan, William Edwards Deming was debating over a management style that could reduce the costs while there is an increase in quality. [9] At that time, Japanese managers could not get on a same page with him since staying in business and improving the quality was not synonym to them. Lacking quality products was not only destroying the company's reputation, but also caused many human resources to deal with those imposed problems. Some to correct the defects and others to figure out what caused those issues and what needs to be done to stop the reoccurrence of those matters. With the help of this new method, the quality of products enhanced along with observing less defects in the production line. Implementing this new mean of production brought many other benefits such as saving more capital and resources because of cutting down on the number of employees. Deming was always in the belief that working smart is of importance than hard working.

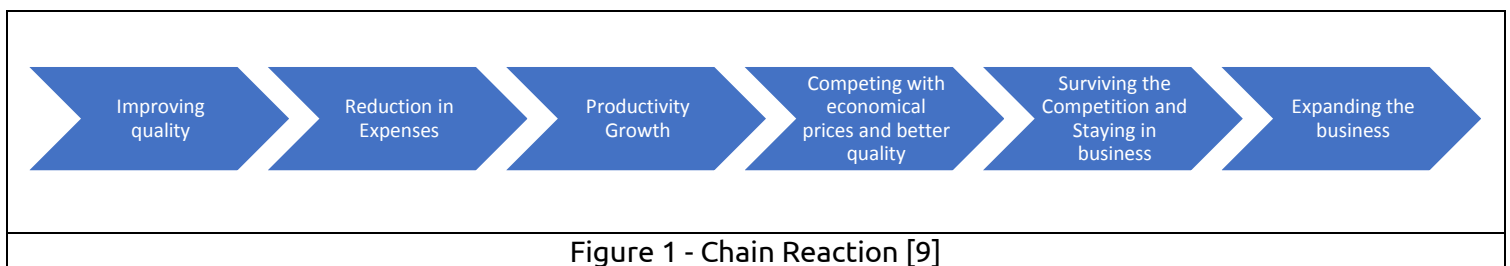
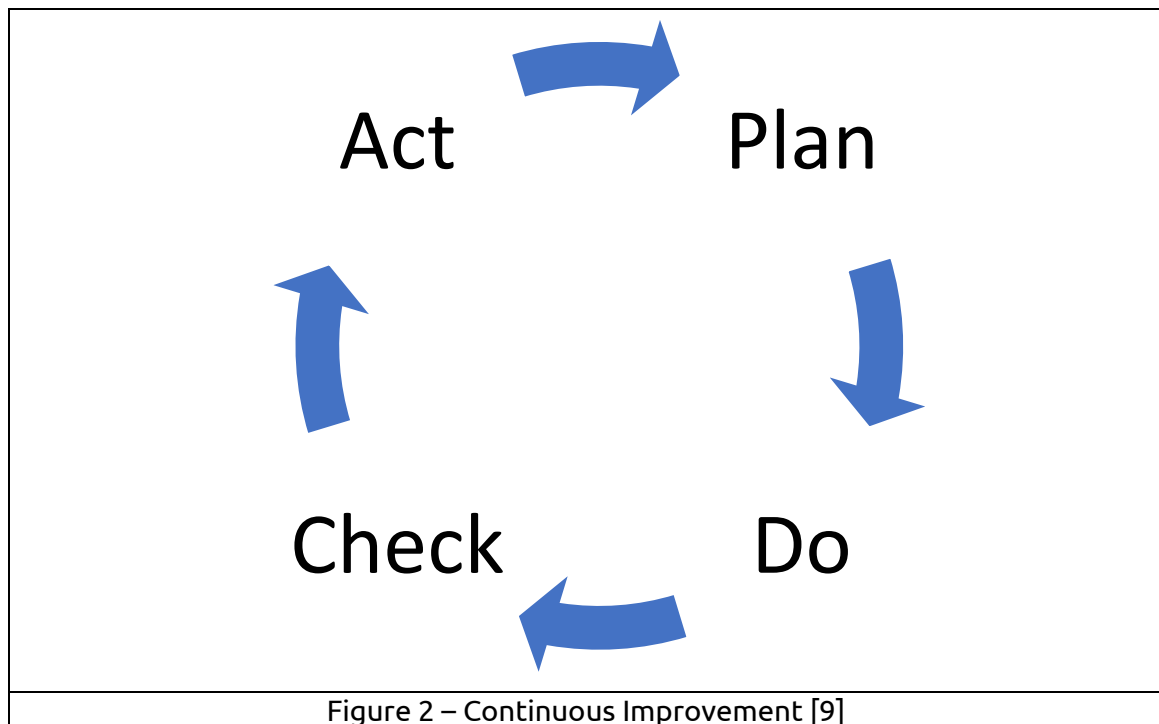


Figure 1 - Chain Reaction [9]

Plan-Do-Check-Act cycle was then initiated from Deming's thoughts, management system, and continuous improvement theory. This cycle was based on the notion that planning and designing the products precedes developing it. Then, the statistics about the purchase rate and customer's feedback should be checked. This would help the engineering team to figure out what should be altered and what needs to be improved. The following cycle is to be repeated until the perfection is reached.



Over the course of time, production styles and systems have changed, and this also has brought a new vision to the management theory which is more concerned with mass production along with quality improvement; which have resulted in the development of novel perceptions on the processes and procedures of a production line. Toyota, the famous Japanese car manufacturer, sent an engineer, Eiji Toyota, to visit Ford Motor Company to see their production line and management style they implemented. Eiji witnessed that Toyota does not have the capacity and resources to mass-produce like how Ford was manufacturing. Little by little, Taiichi Ohno realized in order for them to compete in the market, they need a distinctly different production system since they were only capable to produce in small numbers. [2]

Toyota almost reached the same perception as what Deming had achieved by improving the quality while defects were reduced. Toyota started finding the cause of flaws in their

products, production line, and their management system so that they could make sure flaws will not happen again as well as recovering resources, saving time, and reducing the wastes. Consequently, they manufactured products with no defects, which was a result of improved quality. Because products were primarily made in accordance to the customer's demand, storage space was freed. This was the starting point to Lean Production.

"Just in Time" was the theory that Taiichi Ohno improvised. Following explained are Seven Wastes and Five whys that are essential parts of Lean Thinking.

3.3. Lean Manufacturing

As Katayama mentioned, lean manufacturing connects and combines the workforce capabilities with organizational techniques in order to obtain desired results with few and limited resources. The goal of lean manufacturing is determined by lean principles. Flow, pull, value stream, continuous pursuit of perfection, and value specification are known to be lean principles. The activities that the system focuses on, are defined by The lean organization, referring to supply, manufacturing, and design as the main activities of lean organization. Toyota have developed the required techniques which support lean production principles. Ohno and Monden presented the Toyota production system, TPS, which was a combination of approaches and methods with consistent objectives to ensure sustainable development and growth. [18] Respect for humanity, quality assurance, and cost reduction were inherent in the given system. Also, four key elements of Toyota production system as Monden identified, were Creative thinking, workforce flexibility, automation, and just-in-time JIT. [16]

J.I.T. or just-in-time depends on the notion that units should always be available when required, and inventories are to be regarded as waste in fact, not valuable. Mentioned below are three common methods which are associated with J.I.T :

1. The Kanban, which means sign or card in Japanese. This system is generally used to decrease inventories according to backward requests which flow through digital signals, cards, and baskets, as it is stated in Chaoiya et al. 2000
2. Production Leveling, as stated by Miltenburg 2002, ensures that demanded fluctuation could be met by the appropriate sequence of products in minimal batches.
3. To have changeovers not interfering with the minimal batches, a reasonable approach would be to cut down on the number and quantity of setup activities so that there would be a reduction to the number of activities which are performed all through the downtime.

Autonomation is the prevention of flaws and defects, a substitute to the traditional quality control. A functional management system supports autonomation; which promotes and publicize quality and cost management throughout the company. [11] Quality is translated into supply, design, and production which are the main activities of an organization. Autonomous control, as the second method, prevents defective parts from flowing throughout the process. Poka-yoke or visual inspection devices provide a support to control, that is different from the traditional autonomation which does not permit a direct intervention in the given process, as mentioned in Shingo 1985. [3]

The only approach to match a company's labor requirements with the varying level of need for its products, is to maintain a flexible and open workforce. Two methods that help flexible labor, including standard operations and multifunctional layout design. With a flexible arrangement of machine, it is more than likely to rotate and shift positions throughout the production line and change the crew size to the intended or required pace. Only with well-defined and clarified operations could the crew members attend various machines reliably. Also, there is a need for the machine operation to be planned through maintenance activities for prevention. All of these techniques depend on workforce abilities and potentials which have been overlooked by the Western manufacturers. Firstly, creative thinking provides continual enhancement through feedbacks. [18] It'd also support the continuous betterment of daily tasks in a production line. Secondly, problem-solving techniques avert defects from recurring. The third one is about the teamwork which permits the task rotation and empowers all personnel with control over operation. The human component is comprised of the three mentioned qualities; that makes the lean manufacturing being regarded as a dynamic system which constantly seeks to enhance the performance. [12] To assure a balance between employee satisfaction and the value added, Toyota is now working with Toyota Verification of Assembly Line which is an ergonomic evaluation of each position's workload. [18][19][1][3]

3.4. The Manufacturing Process versus the Construction Process

Both manufacturing and construction processes seek to add more value to their final products with the help of high returns from investment in the long run, but they utilize different methods to accomplish this goal. [34] Considering the manufacturing processes, a product' lifecycle in market is generally lengthy, therefore, many training capabilities and related research being developed. However, in construction, the lifecycle of a product is comparatively short, known as projects of limited duration, consequently, it would be challenging to justify training and research. [34] As it is mentioned in Banik 1999, the scarcity of investment is posing a considerable risk and weakening the technological and innovation capacity of the construction industry. It also endangers this industry's competitiveness both in global and local markets. Moreover, through the manufacturing planning process, decision making is crucial because it is concerned with the capacity optimization to fight against trade-off between machine depreciation and future growth. Yet, based on the proper time-value analysis, equipment used in construction processes could be either rented or purchased.

Ensuring the availability of equipment, Reducing the operation costs, and having minimal ownership throughout the project was something contractors have always been seeking. [20] [29]

In manufacturing processes, the extent of operations is appropriately defined from the day one, and only in the case of a drastic and sudden change in costs, there will be a change to the components to be purchased or produced. On the other hand, the supply chain In construction is more flexible. Depending on the costs of a project and the required resources, the main contractor or subcontractors could perform the operations. Correspondingly, in manufacturing, the workforce commonly appreciates more stable income policies and maximum employment security. [34] Positions are appropriately defined and personnel get experience through performing the tasks they have been assigned to. Differently, wages could vary based on expertise, experience, skills, and employers, in the construction industry. In addition, the Job security is usually low, and workers carry out a variety of tasks until the project is fully developed. In the manufacturing industry, specialized skills and experience are considered to be highly valuable, and well compensated. [20] [29]

In manufacturing industries, quality is more related to process control in comparison to product conformance. General tasks are monitoring, defect prevention and intervention. It is apparent that commonly, rework is avoided, and for some cases, manufacturers tend to discard the parts instead of reprocessing them. [23] On the contrary, in construction industry, quality is fundamentally associated with product conformance, and quality standards is determined by drawings and Specifications. To achieve quality assurance, Both the owner and the construction company mutually strive to meet environmental considerations, safety requirements, and conformance with codes and regulations. [29]

Finally, In manufacturing, supply is regarded as an order-driven activity which is synchronized through the material handling system. During the phase of product design, determining the operations sequence is one of the key elements, which any sudden changes are bounded by the layout. [34] Contrarily, in construction, supply is schedule driven since the processing time length is usually longer, and it's possible to modify the sequence of tasks, if needed. In addition, Supply chain in this industry is also based on both contractor and client. Subcontracting could also make up for a major part of the project's total value. The general contractor and subcontractors have a strong cooperative and transparent relationship so that project activities could run smoothly since those activities are closely interrelated. [22] [29]

3.5. The Philosophy of Lean Enterprise

Western manufacturers, mostly the American companies, have benchmarked techniques that Japanese manufacturers have developed. As it is stated in a report by the International Motor Vehicle Program or I.M.P.V., lean production is known to be a

new production system which is comprised of techniques that Japanese had developed. The scope of those techniques is not only limited to the manufacturing industry, but it also applied to the process-based services which utilize production practices of lean. [24][25]

The construction industry applied the concept of lean production; which had both the service and production systems' characteristics. On the other hand, challenges had been introduced by the lean construction since it concerns project-based production. The concept of lean enterprise is made up of different production systems which share principles such as effective relationships in value stream, waste minimization, constant improvement, responsiveness to change, and quality from the beginning. [18] [26]

A novel project management foundation had been sought by Lean construction. The IGLC had done many researches on the application of lean principles and techniques; which had given us a bright vision and tools to a better operational planning, continual improvement, control, and supply. There're also some other techniques which are in their early state of development that constructors use to manage their operation. [27]

Some manufacturing techniques' connection in terms of extension and development to lean construction is yet to be discovered. Apparently, they conform to a concept of sociotechnological ideology that is based on the fact that the relation between technical elements and human could contribute to higher performance outcome. Yet, in practice, determining the skillset and tools required that could be applied to obtain better performance results is crucial for the projects in the construction industry. [28]

3.6. Moving from Lean Manufacturing to Lean Construction

Lean Project Delivery System is divided into four main inter-connected phases which are:

1. Project Definition
2. Lean Design
3. Lean Supply
4. lean assembly

These divisions are made by a scholar named Ballard which his studies were mostly about Lean Assembly. Lean Assembly is a phase which begins with the delivery of earliest resource to the site and get finished by the project turnover. This phase, lean assembly, is more associated with the general contractors, and they think of it as a particularly important phase. General contractors are the ones developing the technical and human structure for the given activity. [27] [30] [31]

Techniques are inherently heuristic based approaches, and in lean principles, they are connected through a theoretical framework. Following is a discussion regarding the transfer of techniques in lean manufacturing to lean construction:

-Flow Variability

The effects of flow variability is addressed by production leveling in lean manufacturing. Production leveling checks and controls, the effect of fluctuating require levels that are controlled by improving the products sequence with minimal batch sizes.

At the time that batches are deducted, making small changes to the allocated resources and the volume of production could manage the demand fluctuations. Multi-functional layout design, flexible standard operation, preventive maintenance, and scheduling of product sequence are among the techniques that are related to production leveling.

Flow variability heavily affects lean construction practices since one trade's late completion could influence project's completion time. "Last planner" is defined as a specific technique which supports the plans to be realized in a timely basis and manners. Last planners are also referred to as the people responsible for the completion of the operational-level assignments. This process initiates with a sort of scheduling which is called the reverse phase schedule or R.P.S. Reverse phase schedule is a comprehensive work plan which specifies the handoffs between each trade for all the phases. According to the reverse phase schedule, lookahead schedule could be defined as a schedule which provides activities to get finished during the backlog and subsequent weeks. Every planner make weekly work plans ready to control and monitor the workflow. In case of not completing the assignments at the planned time, planners certainly should find the source of the variance, and then prepare an action plan in order to avoid the recurrence of future problems. [15]

-Process Variability

Taking immediate action to prevent defects at the source in order to not allow them flow though the whole process is a notion which is called Autonomation. In the lean manufacturing, personnel and workers could use the help of visual inspection to monitor their machine and results so that at the time of spotting defects in their end result and putting a stop to the process, they could find the root cause. There's also an alternative to this scenario which instead of visual inspection, defects are automatically detected and blocked from proceeding to the next process, and in fact, the following steps. [14]

After all, in the lean construction, since finding defects is quite demanding before installation, traditionally quality has been concentrated on conformance. Lean construction primarily concentrates attempts and efforts to prevent defects. On a job site, ensuring quality compliance for the first time, could only be obtain through implementing fail-safe actions on all the assignments. [13]

-Transparency

The resource which does not contribute to a more desirable performance is viewed as a waste is to be removed from the given system in lean manufacturing. In order to recognize housekeeping in plants, utilizing the famous five S is of the essence. The five S's are

1. sort
2. straighten
3. standardize
4. shine
5. sustain

Having the job site transparent in lean construction, is plausible with the help of the five S. This would allow for materials to have an efficient flow in the field between the specific jobs and the warehouse. Owing to the mobile workstations in the construction industry, increased visualization could facilitate recognizing the work flow, and it could also develop awareness of action plans in the job site.

-Continuous Improvement

Continuous improvement could not be associated with a particular technique. In reality, each technique is set to facilitate continuous improvement with the help of creative thinking and problem solving. In lean manufacturing, on the other hand, workers could actively participate in process improvement; which is only possible via the opportunity that quality circles provide. Periodically, there would be a meeting for these groups to express their ideas and opinions on the issues in the workplace; including cost reduction, safety issues, maintenance, and quality. These topics could be worked out by them in order to provide practical solutions for the activities in future. The quality circles has many advantages that among which implementation of ideas and the ability it would provide to the personnel to learn throughout the process, could be regarded.

Based on the set of objectives, for sake of developing the assignments, during each daily meeting, workers express their input on their everyday progress. New targets would be set up monthly. Usually they are established at the end of each month, and in order to revise important assignments, first-run studies have been utilized. A detail examination of operations could present suggestions and ideas to explore and investigate other

means of getting the work done. A plan-do-check-act plan or in short PDCA is primarily being used to advance first-run studies. Listed below are a short description of a PDCA plan:

1. Plan: used to examine the process steps, and figure out ways to get rid of redundant steps
2. Do: Testing novel ideas and opinions about the first-run studies.
3. Check: Inspecting and monitoring the concrete description of what had happened
4. Act: In the reconvention, enhanced methods are discussed with all the team members in order to consider them as new standards

All the capabilities of a team should be properly utilized to make a great contribution to ensure the continuous improvement.

To better ensure the process of continuous improvement, team's competencies and capabilities have to be ultimately utilized to advance further both individually and collectively. [1]

4. Techniques

As it was mentioned earlier, Toyota was always looking for an approach to satisfy the customer needs, enhance the quality, and facilitate and ease the process. Lean thinking was the answer to all the questions Toyota production factory always had. It was a theory that was formulated by Toyota to help them mass-produce vehicles faster and easier. Simply by concentrating on flow, sources of waste, and product improvement, all the probable errors and defects were detected early in the system so that the production line ran smoothly and there was neither a single failure found in the system nor any imperfection in the products. That is why many companies and businesses have been utilizing lean techniques. [5]

Lean production is the term used for the application of lean thinking in production. Likewise, in the construction industry, the practice of lean is referred to as lean construction.

In the construction industry, lean thinking helped to uncover the sources of wasted resources, such as material waste, human potential, and time. Daily coordination meetings, just-in-time principles, and pull planning are just some of the lean methods and techniques that are commonly used to detect the mentioned sources. Besides, in order to prevent any misunderstandings and issues in the workplace, holding frequent meetings is greatly advised. [5]

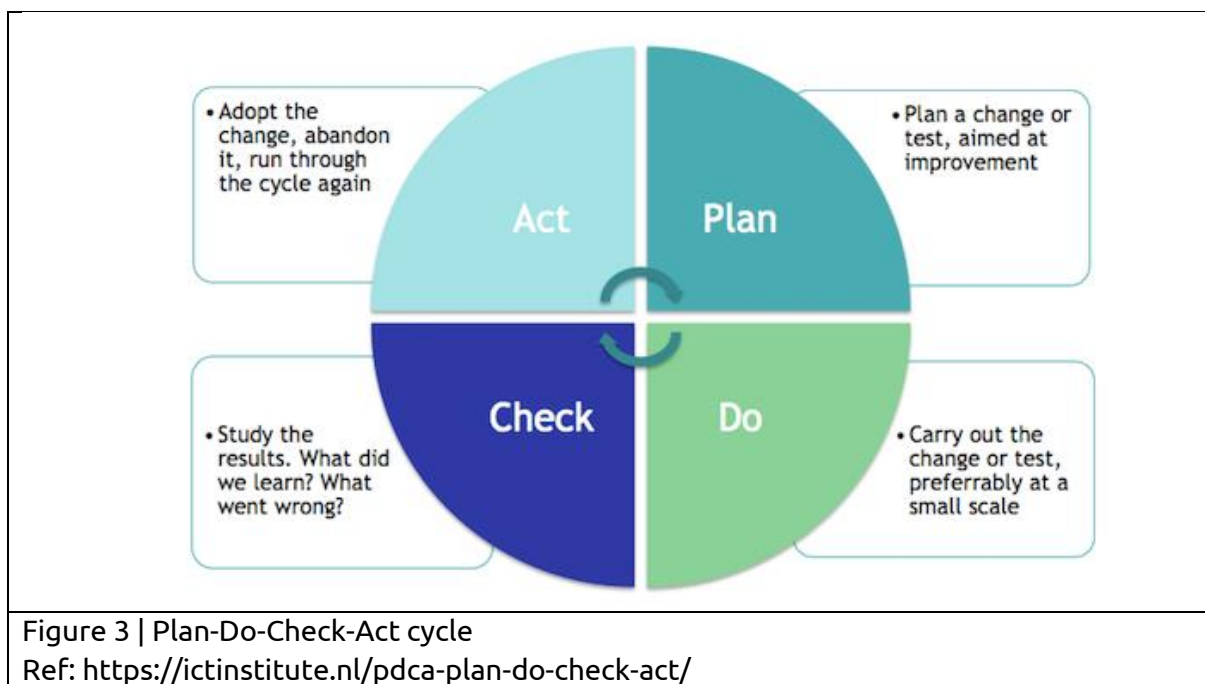
4.1. Plan-Do-Check-Act Cycle

PDCA is a cyclical model which is primarily used for implementing change. It is considered as the one of the principal techniques of lean manufacturing, and a requirement for continuous improvement. It became a common framework for continuous improvement in various fields, including management, manufacturing, and other related fields. Walter

Shewhart first proposed this concept, then William Deming developed it to what is known today. It is a four-step method which provides this opportunity for businesses to improve processes and prevent recurring mistakes. [37] [36]

PDCA Cycle History

Walter Shewhart, the American physicist and statistician, who was working on quality improvement and statistical analysis, initiated the foundation of PDCA concept. Later on, William Deming who was inspired by the fundamental establishment of this concept, developed it further into a learning and enhancement cycle that later was introduced as PDCA cycle. That is why this concept is also known as the cycle of Deming or the Deming cycle. [37] [36] [35] [34]



PDCA Cycle in more Detail

Plan-Do-Check-Act cycle is a cyclic and iterative process for the purpose of continuous improvement, and it consist of improving the process, analyzing results, and solutions testing.

For instance, imagine that an organization have many clients' complaints regarding the delayed response rate of the help desk. Therefore, their managers are required to enhance the way their team operates for the sake of keeping the customers satisfied. This is where PDCA cycle enters the game. [35][5][36]

Below, four stages of PDCA cycle is explained in detail

PLAN

In this step of practice, based on the size of a project, planning process will be done which sometimes could take up a tremendous effort. It is usually made up of small steps that prevent failure and errors throughout the process, so that the final plan could be properly arranged.

Before moving on to the next step, the following questions are to be answered:

- What is the main issue that we are required to solve?
- What kind of resources and in what amount do we have/need?
- How to solve the given problem with the resources?
- What are the success criteria of this plan? Its objectives?

The planning team is required to review the plan multiple times before proceeding. It is advised to make open feedback cycles like Kanri Catchball which would help you to gather more information. [5][34][35]

DO

After the plan was accepted, then it is the time for carrying it out. In this step, anything that was previously planned, should be considered. It's probable that unpredicted problems would appear at this stage, which explains why its important to first incorporate the plan in a controlled environment and small scales. With the help of Standardization, the designated team could smoothly apply the plan. It is paramount to clarify everyone's responsibility. [37]

CHECK

Many consider this step as the most important part of the cycle, and it is all because of the fact that by paying enough attention to this phase, the plan will be clarified, recurring mistakes will be avoided, and continuous improvement will be successfully applied.

In this step, constantly checking and monitoring the plan's execution as well as making sure that the primary plan was actually working, are what is supposed to be done here. Moreover, the designated team should spot the problematic parts of the process and take them out right after. In case of having an unexpected problem through the process, the given issue should be properly analyzed and studied with the purpose of finding its root cause. [37]

ACT

Eventually it's the time to introduce the last step as you are already introduced to the development, application, and monitoring stage of carrying out your plan.

If the original objectives were achieved, then it's the time to proceed and apply the initial plan. It is well-suited to adopt the entire plan if goals are met. In the same order, the PDCA model will then become a novel standard baseline. But, each time a standardized plan is repeated, it is required to examine all the stages again with the purpose of improvement. [37]

The Plan-Do-Check-Act cycle is effective framework for solving the problems in any levels of an organization. It can also be a part of a planning process like Hoshin Kanri. The method of repetition provides a great opportunity in terms of finding a solution and testing it as well as improving them in a waste-reducing cycle. The process of Plan-Do-Check-Act, have a solid commitment to the continuous improvement, and it could have a great impact on efficiency and productivity. Also, it is proven as a fact that the PDCA model takes some time , therefore it is not a perfect choice for resolving urgent matters. [37] [5]

4.2. Muda – Lean Waste

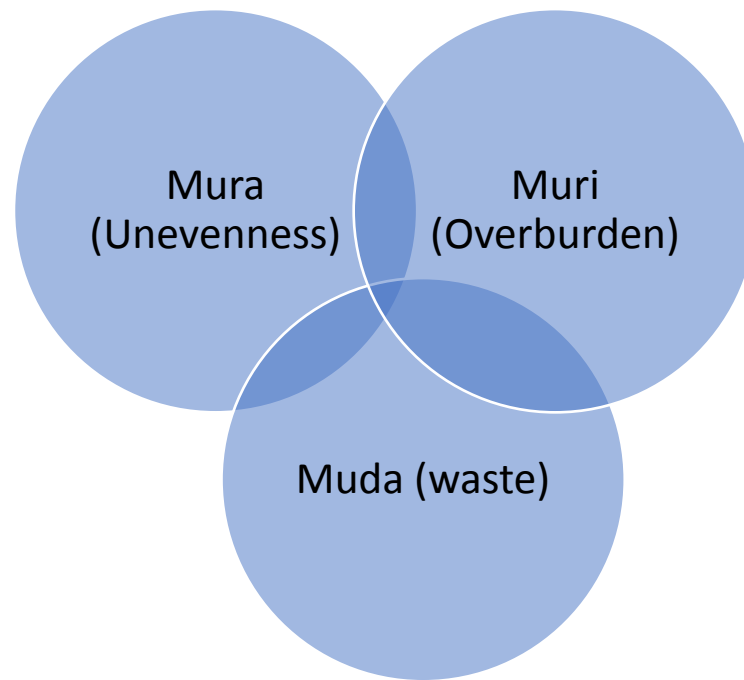
Eliminating wastes and wasteful activities is almost the most important aspect for thriving a business and forming a successful/profitable company. This concept is indeed an essential part of the Lean Thinking; which helps you maximize profitability and satisfaction. [3]

The idea of waste elimination originates from TPS or Toyota Production System. A Japanese engineer, Taiichi Ohno, who has been regarded as one of the founding fathers and pioneers of lean manufacturing, had dedicated his life to form an efficient and capable work process.

During his journey, Ohno introduced three main roadblocks that could make a great negative impact to a company's work processes:

1. Muda (wasteful activities)
2. Muri (overburden)
3. Mura (unevenness)

According to his observations, thoughts, and in-depth analysis, seven types of wastes or seven Mudas had been categorized, which then became a well-known practice to reduce the costs and optimize resources.



4.2.1. Muda – What is Lean Waste?

In Lean Thinking, waste is any activity or whatever effort that uses energy and resources but would not add value to the customer (End Customer).

In fact, activities which create/add value for customers consist of a small percentage/portion of the entire work process. That being the case, businesses should only focus on cutting down on wasteful activities as much as they possibly can; so that they could identify opportunities to enhance their performance.[3]

Do NOT make a mistake. **Not all the wasteful activities/Wastes could be removed from work process.** In actual fact, a certain amount of them are indeed inevitable and necessary.

For Instance, testing/quality checking a product is not considered as an activity that essentially neither add value to the product nor customers would be inclined to pay for. But, without a proper quality check, you may hand over a poor-quality product which will not only harm your reputation, but also economic performance of the company would be put at stake. [39]

There are two main categories of waste:

1. **Necessary waste** – such as Planning, Reporting, Testing, and etc.
They are considered as necessary and non-value-adding activities, which are done for the sake of quality assurance or preventing errors.

- 2. Pure waste** – e.g. generally Waiting could be taken as an example here which is commonly considered as a pure waste. They are unnecessary and non-value-adding activities, which would not bring/ add value. In fact, they should be immediately eliminated from the process. [3]

4.2.2. The Seven Waste:

By definition, waste is anything that clients are not willing to pay for. Optimizing processes to reduce waste is indeed vital for the company's success. Wasteful activities could reduce profitability, maximize customer costs, lower quality, and most importantly it could cause employee dissatisfaction. Accordingly, identifying the non-value adding activities and improving the process is essential. [39]

In Lean thinking, seven major areas are described; where it is possible to detect Muda Activities, which are referred to as the seven wastes of the Lean Theory.

1. Transportation

This type of waste is regarded to as when resources (materials) are moved, and the movement does not necessarily add value to products. Unnecessary movement of materials not only could impose extra expenses to the business, but it could also reduce the quality and cause damages. Transportation often inflict additional costs for machinery, space, and time. [39]

2. Inventory

Just-in-case inventory (Excessive inventory) are referred to inventories in which the company piled up a considerable amount of products with the purpose of meeting the unexpected demand, low quality, reduce the effects of production delay, etc. On the other hand, such inventories will not add value nor meet the customer's needs. [3] Instead, costs depreciation and increase storage is the most probable outcome.

3. Motion

Motion is referred to as wastes which are caused by complicated and nonessential movements of machinery or personnel. Among many disadvantages they cause, extended production time and injuries are the most common ones. It is advised that a detailed and early process arrangement, this would clear the air for all the personnel, and consequently responsibilities are clarified and workers could do as little as required to finish the job. [39]

4. Waiting

The easiest waste to recognize is Waiting. Generally, whenever products are not moving, and tasks are not yet finished, Waiting occurs. It is identifiable since the time lost could be easily recognized. For instance, waiting for the products to be

delivered, the issues to be solved, or paperwork to be dealt with before another task could begin could be among good examples of this type of waste. [39]

5. Over Production

Literally, Over Production means producing more, which implies on exceeding the clients' need, therefore more costs would be imposed. Also, other wastes would be triggered if overproduction appears; it is all because of the fact that excessive products need more resources and support from the company. Transportation, additional movements, prolonged waiting time are just some of the losses that would be emerged. Besides, in case of any probable defects during over production, the production team would need to invest more time and effort to rework more units. [39]

6. Over Processing

Usually, it is referred to the processes which would not bring or add any value. Sometimes, the processes that bring more value than what is required would also be enlisted among Over Processing Wastes. This means, by over-processing, features that no one would utilize are added to the project. As a result, the consumption rate of the resources would be skyrocketed while the business costs are increasing. In addition, the end price of the product would go high enough that people find no interest in it. Contrarily, customer satisfaction drops. [39] For instance, imagine that a car manufacturer embeds a mega computer in the trunk of their vehicles to process its data. When a small chip could process and do all the analysis of a car, imputing a mega computer would not only be a waste of time and resources, but it would also be a feature that nobody could use or find value in it.

7. Defects

Defects are a major part of the wastes, not only because they are a waste of time, effort, and resources, but they would also bring about rework, or they could be thrown away and discarded. Generally, a defective work would again go back to production. This is considered costly. In some cases, an area dedicated to reworking might be needed, which would require more capital and fund, as well as more tools and human resources to be utilized in that area. [39]

As you can see, these seven wastes have highly detrimental effects on your business. But you could consider them as an opportunity to grow, improve the work processes, and optimize resources. For each business and industry, the aspects of these seven wastes may be varied. [39]

Sometimes another waste would be applied to this list, which is more concerned with the utilization of talents. Not using the full potential of employees and their abilities would result in major failures. If your personnel are not satisfied with the tasks they had been given, the loss of motivation, resignation, or a career change would be their next move. In fact, losing experienced employees is detrimental for a business since not only newcomers would need guidelines, time, and experimentation, but also dismissing qualified and experienced employees would decrease the efficiency of the outcome. [39]

4.2.3. Seven Wastes in Different Industries:

Usually, a change is offered and implemented first from the top levels of a hierarchical system. A broad view of all processes of a company, which is crucial for identifying Wastes/Wasteful activities is only available to the high-ranked managers at the top levels of a company.

They manage projects, functional areas, a portfolio of various activities, and it is indeed their responsibility to enhance processes and propagate the culture of continuous enhancement/improvement. [2] [39]

Wasteful activities/wastes might be different in each industry:

Lean Manufacturing:

- **Transportation** – (production) it means transporting materials/parts from a location to another.
- **Inventory** – Overstocking equipment which might be needed in future or undelivered products/parts
- **Motion** – unneeded movements of machinery/employees
- **Waiting** – waiting for the delivery of goods
- **Overproduction** – producing too much (just in case), more than the market demand
- **Over-processing** – Splurging funds, time, and effort on a single task which would not add/bring value.
- **Defects** – broken/defective parts in need of getting reworked

Project Management:

- **Transportation** – needless long marketing funnel, interruptions, task switching
- **Inventory** – rarely-used tools that are purchased and stockpiled, office supplies that exceed needs.
- **Motion** – poorly structured/organized workspaces, redundant meetings, organizational paths scarcity, desperate strives to find information
- **Waiting** – waiting for an approval (e.g. higher management)
- **Overproduction** - filling unrequired heap of documents
- **Over-processing** – too many levels of approval for minor tasks
- **Defects** – an incorrect data collection

Construction:

1. **Overproduction:** Overproduction is when the quantity of production is more than expected and required, which would cause some problems in regards to waste of resources; this sort of waste would naturally be led to the following waste.
2. **Inventory:** This item would result in spendings in storage and items handling with a database, and therefore, resources which can be used on other value-adding processes.
3. **Waiting:** Spending time without having any production is considered a waste, usually, a better-organized entity would try to have no interruption through the production line.
4. **Administrative Steps** (Extra Processing): This would refer to steps which are essentially counter-productive or non-value adding.
5. **Defects:** Defects diminish the entire performance as the item should go back through the system to get corrected and then pass the assigned quality tests or in the worst case, being thrown away, which is a total waste.
6. **Motion:** The useless and unnecessary movement of goods through the process. For instance, double handling.
7. **Transportation:** The time and resources that are spent on transporting the goods would not improve its value, therefore, it would be advised to cut down on such activities.

Each business would have its own seven wastes, and sometimes there might be more kinds of Muda added to these mentioned wastes. Therefore, this is indeed a never-ending list. In a company, all the processes should be explored to find as many wastes/wasteful activities as we possibly can, then elimination of these wastes would be a priority. Anything that could slow down the cycle of time, impair the quality, lower profitability, should be removed. [2]
[39]

4.2.4. Effective tools to tackle wastes:

Lean has different tools to identify and eliminate activities that are recognized to be a waste to the system. These tools will walk you through the entire process of reconnaissance to better understand, examine, and spot the weak aspects of a system. Gemba Walk, for instance, is capable to identify Muda activities; with Gemba Walk you could observe where

the (real) work happens; it helps you to see all the processes in action in order to locate the wasteful activities. [2] [39]

A3 report and five whys are mostly used for the purpose of problem solving, root cause analysis, and identifying waste/wasteful activities. The five why method has series of question. A3 Report, on the other hand, needs more expertise since it demands cross-organizational knowledge sharing. What is common between these two methods is they both provide a great assistance to identify and eliminate wasteful activities/wastes. [3]

4.3. Five Whys

4.3.1. Introduction:

In order to discover real cause of the problem, Taiichi Ohno did a experimentation which resulted in the notion that tackling this problem could only by done with asking five whys, which essentially means to ask why five times. Psychologically, by asking a question, you would want to know the answer, which is the key to practically any other problems we might ever face in our lives. This is how Toyota spotted the primary cause of their problems, and consequently, they devise a method to tackle them. Long before the invention of this method, only noticeable problems were detected while the initial problems were left concealed. When a system breaks apart, there is usually a reason/cause, but the most important of all is what initiated the problem and why it occurred. This would lead the team to the first cause of the issue and underlying problem. It is also advised to continue asking “why” questions until the systems is back on its feet and enhanced. [3] [40]

Likewise the symptoms of a disease, problems are caused by deeper issues. That is why fixing the symptoms does not solve the main issue which is caused at the depth of a system. A company’s work process is only saved from the reoccurrence of a problem by focusing on an issue’s root cause instead of the superficial symptoms.

The Five why technique is among the efficient methods for the root cause analysis in Lean Thinking.

4.3.2. Origin of the Five Why Method:

Toyota Production System has developed multiple technique along the way, among which the five why method was developed by a Japanese industrialist and inventor, Sakichi Toyota, that then became an important part of lean thinking. As Taiichi Ohno once mentioned, repeating why five times will clarify the solution by shedding light on the nature of the given problem.

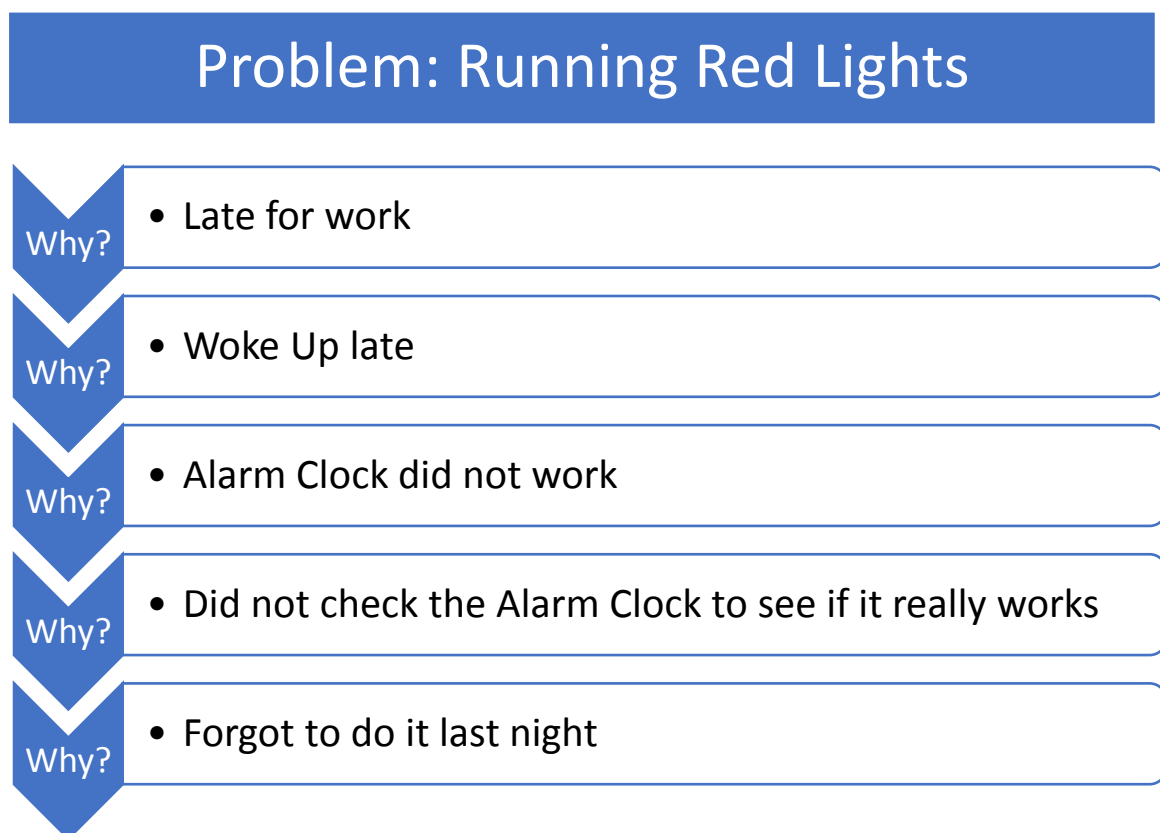
Making a conscious decision is one the important factors of an effective implementation of a technique. The process of decision making is supposed to be based on a clear

understanding of the processes, environment, and conditions. It means, those with practical experience should be counted in the root cause analysis; which is reasonable, since they are the only ones with the enough experience and knowledge to introduce us to any problem that could ever happen in the work place. [40]

4.3.3. Analysis of the five why method in action:

With the help of five why technique, we could get to the core of a problem and start fixing it. Sometimes, the source of a problem might be shown unexpected.

Often, technical problem is a term which is mistakenly used for the process and human problems. In other words, to avoid iteration of failure, finding and removing the root cause is of crucial importance. [40]



Problem: Delay in Publishing new Software Update

- 1- Why there was a delay in publishing new update?
Updates were not done by the designated deadline
- 2- Why were updates finished on time?
Because all the developers were busy with designing new features
- 3- Why were developers still busy with the new features?
Their team was not ready enough, besides, there were many beginners in that team which made the cooperation ultimately hard.
They were not familiar with the procedure and instructions.

- 4- Why they were not familiar with all the procedures?
The training program was not thorough, consequently, they were not trained properly.
- 5- Why were they not trained properly?
Because CFO (the chief technology officer) was insisting on having a brief training in the mistaken belief that the new employees would learn while working.

It is apparent that the root cause of a problem is completely different from what was expected to be. [40]

4.3.4. 5 Why Procedure:

As it was mentioned earlier, continuous improvement is achieved by the help of the five why technique at any level of an organization. Listed below are the steps to get started with this technique:

1- Form a Team:

Assembling people from each department that are called representatives could help you gain a unique point of view of almost all the process in the workplace. It is all because the chosen representatives are supposed to be familiar with the processes that are under investigation. Collecting enough information is indeed necessary to make the right decision. Mind that this task is not an individual assignment, and it should be executed by a knowledgeable team.

2- Define the Problem:

A clear problem statement should be made by discussing the issues with your team. It is essential to develop such statement to identify the scope of issues that are about to be examined. The investigation process is time-consuming, tiresome, and unlimited. In this context, Unlimited means boundaries of the given exercise are blurred, but staying focused would help to find the best possible solution.

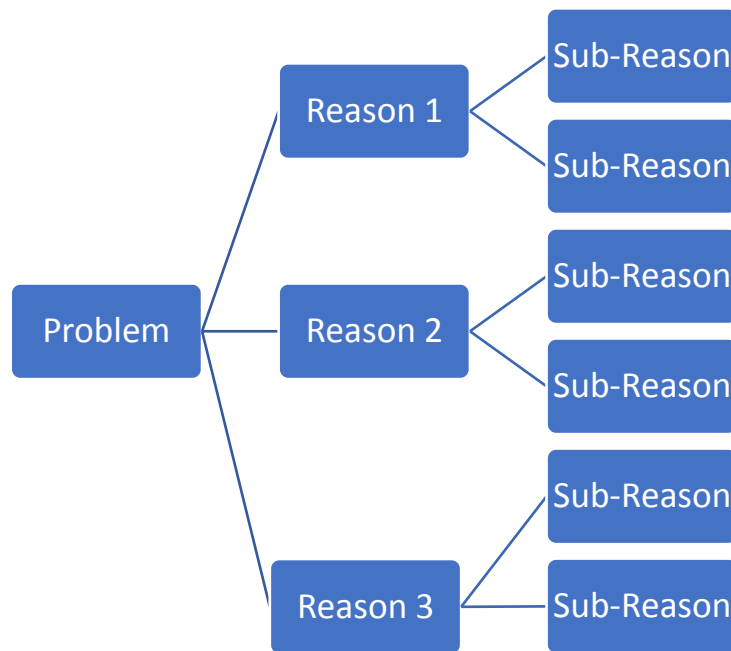
3- Ask Why:

Leaders empower people in order to facilitate the entire process. They keep their team focused. The answers must be based on facts instead of emotional opinions.

The chosen facilitator needs to question the team as much as it takes to spot the root cause of the initial problem. Also, the facilitator should take this into consideration that although asking “why” would help you to identify the issue, overdoing it would deviate you from the objective. It is all because of the reason that asking too many whys’ would give you many answers that some of which are unreasonable complaints and ridiculous suggestions, which

are not the purpose. Note that you should only be focused on uncovering and analyzing the root cause. [40]

Sometimes, the five why analysis looks more like a matrix with many parameters. This circumstance is only seen when there are many root causes (more than one). Though it seems like an impossible task, identifying and getting rid of organizational issues could help revive from their negative impact, and consequently improve the overall performance. [40]



4- TAKE ACTION!!!

After identifying the root cause, taking corrective actions would be the next step. You should involve everyone in a discussion just to come up with the best possible solution. Not only finding the solution is needed, but the discussion should cover a lot about applying these practical solutions to better avoid the recurrence of problems.

At the time the judgment and decisions are made and finalized, a team member should accept all the responsibilities to supervise the entire process and apply the right actions.

After a while, there should be another meeting for the team to check if their solutions made a difference. In the case the process was not successful enough to make a positive impact, the entire procedure should be repeated again. [40]

At last, the case has to be documented as well as being sent all across the organization. Documenting these data files and sharing them provide a broad overview of various problems that a team might ever encounter. It is advised to document how these problems could be eliminated as well.

4.3.5. 5 Why Procedure:

According to Deming's theory (plan-do-check-act), the A3 sheet was made. It is a A3 paper with multiple sections which are dedicated to identify what is exactly relevant to the project and whom will utilize it. A typical A3 sheet is organized as listed below:

- 1- Background
- 2- Statuesque
- 3- Objectives
- 4- Analysis
- 5- Suggested Countermeasures
- 6- Strategy (Plan)
- 7- Follow up

They all help us to identify the problem. It starts by asking why and how this problem occurred. Evidently, it also seeks methods, objectives, and actions that could correct the mistakes and solve the problems. Using the given technique, five why, is also highly suggested to spot the real cause, the reason why it occurred, and how to solve it. This sheet should be filled out with the hope of finding the real cause. [40]

4.4. Gemba Walk (Real Work Happens HERE)

Insanity is defined as continuously doing the same thing with the hope of a different result, which almost a majority of contemporary managers could be classified in this group. It is because of the fact that by sitting in an office and taking part in KPI meetings, one cannot hope for different results from their personnel.

Gemba walk is a crucial part of lean philosophy. Its first objective is to let leaders and managers observe the work process, acquire knowledge about the processes, engage with the personnel, and explore all the opportunities for continuous improvement. [16][41]

4.4.1. What Is Gemba Walk?

Gemba is a Japanese term, which means real place. In the Lean management, it is considered to be the most important place for a responsible team since it is where the operations and works takes place. For instance, in the music industry, Gemba is referred to as a studio. In racing, Gemba is fundamentally where the car is. In the manufacturing industry, it is the company floor. By definition, it is exactly where the work happens, which you could have the ability to observe and inspect it. The founding father of Just in Time production, Taiichi Ohno, is the man behind the development of Gemba Walk. The reason why they developed such a concept was to allow executives and managers to get out of their office, put away their mundane routine, observe the real work & its processes, and form a professional relationship based on mutual trust with the ones involved in the real work. [16][41]

Gemba's three crucial elements are:

1. **Go & see.**

The common notion of Gemba is for the leaders and managers in every level to take walks around the place where the work happens in order to be better involved in spotting wasteful activities. [41]

2. **Ask why?**

Gemba walk's primary goal is to take a detailed look into the value stream and detect its parts that are problematic through open and active communication. An experienced leader or manager craves to listen instead of talking non-stop. [41]

3. **Respect the people.**

Clearly, Gemba walk is not a technique for those who like to boss around!!! NOT in fact, a "boss walk." Blaming people and pointing fingers is not what is expected from you in this technique. In fact, one must not be doing that. Managers are not supposed to review results and judge; as a matter of fact, your only responsibility is to fully cooperate with your team and detect the problems altogether. Try to concentrate on spotting the weak points of a process, not of the workers. [41]

4.4.2. Gemba's Seven Steps to Follow:

Before managers walk into the workplace, they need to form a plan and follow its steps. The given plan has to depend on their objectives. It might be unstructured sometimes, for instance, if they are new to an organization, however in other cases, their plan will be more accurate since they will become familiar with all the details. Be prepared, in any case, for a Gemba walk, or else, it will be wasteful and inefficient. [41]

4.4.3. Listed below are the Gemba's Steps:

- **Pick a theme**

When one go on Gemba, they are required to choose a theme, which will help them focus on all their efforts and be more effective. There are various themes one might want to explore, like safety, cost efficiency, productivity, and etc. So as to be more precise, they will need to make a list of all the questions they are going to ask. [41]

- **Prepare the team**

The team that is going to be observed and analyzed should be ready for what is about to happen. Members are required to have a better understanding of the Gemba walk that it is a common process which its resting-place and aim is the continuous improvement. Therefore, the personnel will collaborate and feel in ease. [41]

- **Only Concentrate on process, not on the people**

A Gemba walk is not for assessing the team's performance. In fact, its purpose is to observe, comprehend, and enhance the process. If managers only concentrate on personal abilities of their personnel, what they will face is only resistance. [41]

- **Be at the value stream**

Tracking the value chain could help managers to spot the areas with potentiality of having wasteful activities. Removing the given activities will provide a great assistance in terms of improving the overall performance.

- **Record the observations. DO NOT make any suggestion throughout the walk.**

Managers should record whatever grabs their attention as much as they possibly can. They, sometimes, might be tempted to suggest a solution, but this might be wrong. Put the analysis for a later time. The analysis will be more accurate when having all the required facts. A comprehensive overview could allow us to use better problem-solving techniques like the PDCA cycle, which is far better than an instant suggestion without considering all the facts. [41]

- **Ask for an extra pair of eyes.**

Asking someone from another department that has been always engaged with unlike daily tasks and less familiar with your processes, someone who has a different perspective, would help considerably by asking different and uncommon questions which you might never ever think of. As Jordan B. Peterson, Canadian clinical psychologist, once said, when you ask a question, you really want to know the answer, otherwise, what else would be the point of asking? Asking the proper questions helps you to get closer to the answer, and the answer could change everything. [41]

- **Follow-up.**

Even if managers and the ones who observed the process do not spot anything critical through the Gemba walk, they still need to share what they observed and eventually learned. Other than that, the entire process will be considered as waste itself, and all the staff will think that they were being watched. They should analyze what they had recorded through the Gemba walk, take action, inform their team about the forthcoming changes and the reasons why they are needed.

4.4.4. Gemba Walk Checklist

Every time a Gemba walk is performed, a checklist should had been prepared in advance. The given list will help them to better focus and target their efforts. The questions which will help them understand the process they will observe, should be included in that checklist. Questions might differ based on the Gemba walk's theme. [41]

Listed below are some questions that a basic checklist for Gemba Walk would have:

- What are you working on currently?
- Is there an established process for this type of work?
- Do you have any problems with the established process?
- Why is there a problem?
- How could you solve the problem?
- What do you do to spot the problem's root cause?
- Who will you contact if there is a specific problem?

The mentioned questions will vary when inspecting various areas like innovation, problem-solving, tools, resources and etc. For this reason, before managers start performing Gemba, they prepare their checklist depending on the area they want to probe. [41]

4.4.5. Post-Gemba Walk

Prior to taking any further actions, based on the inspections of the Gemba walk, managers should take some time to arrange their documents and notes, organize their thoughts, and think of a proper feedback. In fact, their feedback is important, and they should always consider that an early feedback could devastate everything. That is why analyzing the situation with the leadership team is necessary for a proper and careful analysis. It would not be a terrible idea to ask some of the personnel whom you observed to join the meetings. All the collected data should be utilized as a part of the continuous improvement process, which is commonly known as the Gemba Kaizen circle.

Usually, a meeting would be held after every Gemba walk which might consist of participants from multiple departments. Having many unlike points of views is the primary purpose of gathering everyone who could contribute to this process. It is crucial to walk around the Gemba zone and collect information about everything that could be improved. [41] However, what matters the most here is to return back to where they started.

Post-Gemba walks ends the loop and values the ones who have been observed, which would pave the way for leading a future, rewarding Gemba Walk.

4.5. The A3 problem-solving technique- A3 sheet:

4.5.1. Introduction

Problem solving has been always part of life, in business, management, etc. Almost anything that faces even unprecedented issues is in need of a thorough inspection. However, acting fact to eliminate an issue would not only solve the problem but also prone the system for chronic challenges. Besides, you may also face those issues repeatedly. [22]

As it was mentioned earlier, fighting symptoms will not cure and preserve the root cause of the given problem. You need to dig deep into the system to discover the root cause. Consequently, the work process will be protected from reoccurring problems. A3 technique is what exactly come handy at this scenario. [22]

A3 technique is a problem-solving tool that by its implementation, problems could be treated efficiently. With only some simple steps, techniques, and ideas, you would be able to tackle the problems through good collaboration, simple structuring, and active communication. [42]

4.5.2. What is A3 thinking?

A3 thinking tries to develop a mindset that develops certain elements: [42]

1. Logical Thinking – A3 portrays a thinking process (step-based process)
2. Results & Processes – To share the results and ways to achieve them
3. Objectively presenting and exchanging information – with no hidden agendas
4. Sharing vital information & putting them in visual formats
5. All the taken actions have to be aligned with the strategy of company and its objectives.
6. Developing a organized and structured means for problem-solving
7. The concentration is on forming a consistent attitude and perspective which could be adapted all across the organization.

4.5.3. The origin of A3 technique:

It is a lean management technique which is developed as a part of Toyota Production System (TPS). No one has been reported for claiming the rights of inventing this way of thinking, however, a senior manager in Toyota, Isao Kato is on the belief that this techniques is a mixture of Toyota philosophy and PDCA cycle, with the hope of providing more clarification. [42]

The reason why this method is so summarized that it is only a one-page report is because Taiichi Ohno was not in favor of reading more than the first page of a report, as was his custom.

Besides, its name is originated from A3 paper size which corresponds to 11 inches by 17 inches. [42]

Commercial Success of Toyota was mostly because of A3 thinking. It has become a universal technique which is now used in different businesses and industries.

4.5.4. Foundation of A3 Technique:

A3 method is not regarded as a tool to fight problems, in fact, it is just a single-page report. The three key roles/elements in the process of developing an A3 sheet: [42]

1. Owner is in charge of the process management and document maintenance. Owner, on the other hand, needs to be supervised/advised by the experienced mentor in problem solving.

2. Stakeholders/Responders are only interested in the end result of the given A3 project. They are regarded as the third party.

3. Mentor/Coach has the responsibility of mentoring, giving direction, and provoking a problem owner to look for the solution instead of giving them the propositions and answers.

Sometimes, there is a broad range of stakeholders that are involved in the process, and the owner is required to have access to them.

However, it is apparent that attaining higher management with a policy of strict hierarchy is almost impossible.

This proves why an organization have to be thoroughly familiar with the lean thinking and always be prepared to cooperate. It is challenging, however it could demonstrate the flexibility of an organization.

Eventually, the active and open communication among all the involved parties could play an important role in the A3 project's success. [42]

4.5.5. The A3 Report:

The A3 report is a document with only one page that demonstrate the end results of the entire process. It, usually, consists of seven steps, however some variations might also apply to this rule. Below you could see an example of an A3 report:

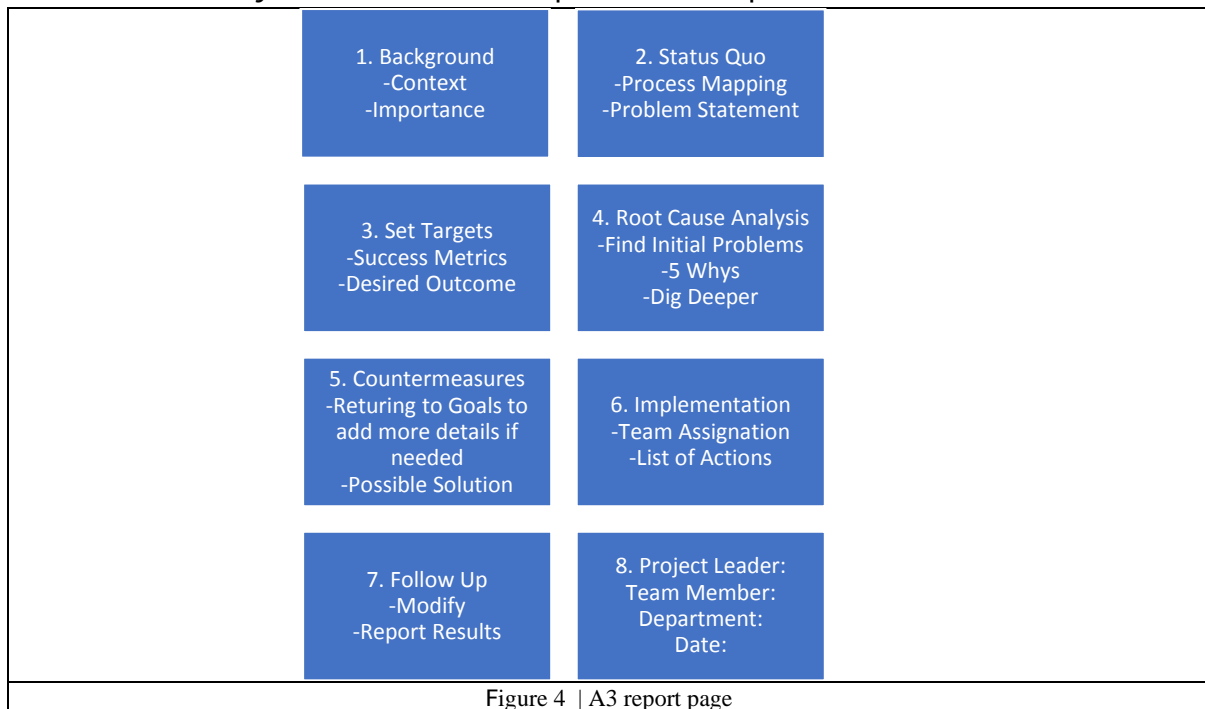


Figure 4 | A3 report page

4.5.6. The A3 Process

The A3 idea is a process of lean thinking that the owner of the problem has to go through the various steps of a model until a solution is found for implementation. The problem owner needs to openly and actively communicate with the project's mentor, all his colleagues and personnel. [42]

- 1- **Background:** The first move is to spot, clarify, and describe the problems. At this stage, the owner could add the contexts and provide a support to the following steps.
- 2- **Current situation:** Before addressing any problem, the owner needs to provide a thorough and precise description to the status quo. Here, the processes could be mapped, which could help in terms of spotting the root cause and seeing the bigger picture.
- 3- **Set the targets:** At this stage, goals are to be set. Here, we still do not have access to the full picture. After finishing the entire procedures, a need to return back to this step to add details to the initially-defined goals, would be sensed.
- 4- **Root cause analysis:** This is the pivotal step toward the success of an A3 project. Immediately fighting the detected problems would not solve the issue, unless the root cause is dealt with. It means, fighting symptoms will not cure the disease, and if it takes a long time to find the initial cause of the problem, it might become a chronic one. This way, the given problem would appear in considerable bigger proportion each time on a regular basis. Hence, having a good understanding of the processes, how they work, and the defined objectives, are the prerequisites of finding the root cause. For this purpose, usually, the five why technique is used.
- 5- **Countermeasures:** after getting familiar with the detected root cause, now it's the time to offer solutions. From this step, you can always return back to the set goals in order to add details to them. The countermeasures, in all cases, must lead to a better understanding of how the objectives will be accomplished.
- 6- **Implementation:** when the countermeasures are set, an implementation plan needs to be presented which is consist of a list of actions that should be applied to have the countermeasure in place. It is advised to define due dates and assign individuals for every task.
- 7- **Follow-up:** The final step is important in terms of establishing a custom of continuous improvement. It is crucial to assess the end results and confirm the countermeasures' effect. No matter if the results are negative or positive, actions must be taken. In the case of having different results than the ones that were predicted, the plan should get modified, re-implemented, and

followed-up. In case of having a positive effect, improvements should be communicated to the entire organization and be made as standards. [42] [22]

4.6. Last Planner System (LPS)

4.6.1.Introduction

Last Planner System or in short LPS is based on Lean Ideology which is primarily used for planning and controlling systems. It is a workflow method that is developed by Lean Construction Institution in order to enhance worker's accountability and productivity through detailed group planning and tight scheduling. [43][15]

Last Planner is considered as a managerial method to run a project efficiently. All the principles of LPS are aiming to ensure that both the subcontractors and contractors could manage their workload, and in the meantime, hold them responsible for what they had promised to finish. [15]

When employing pull planning in last planner system, there should be someone responsible for when the subsequent phase commences. This person is recognized as the last planner. They are in charge of the work done in just a section of the production. Generally, on large scale or infrastructural construction projects, all the phases of the project will have their own last planners. [15]

In 1993, the founding father of IGLC or International Group of Lean Construction who was working on pioneering research on the last planner system, Glenn Ballard, introduced the last planner system. International Group of Lean Construction is an international organization aiming to alter the concepts of production management in the construction industry.

The four elements of the last planner system are should, could, will, and did. Simply, one can ask what should be/could be/will be/ had been done, to find a way through the process. These steps brighten the path for managers to better observe the project's flow. [31]

Should implies that planning is vital for the project's success

Can is ensuring the feasibility of the project

Will is what exactly will be accomplished, and what last planners should do to fulfill the commitments made in the planning phase.

Did is what had be done for the project's success, lessons learned, and what could be improved for the execution of the next project. [45]

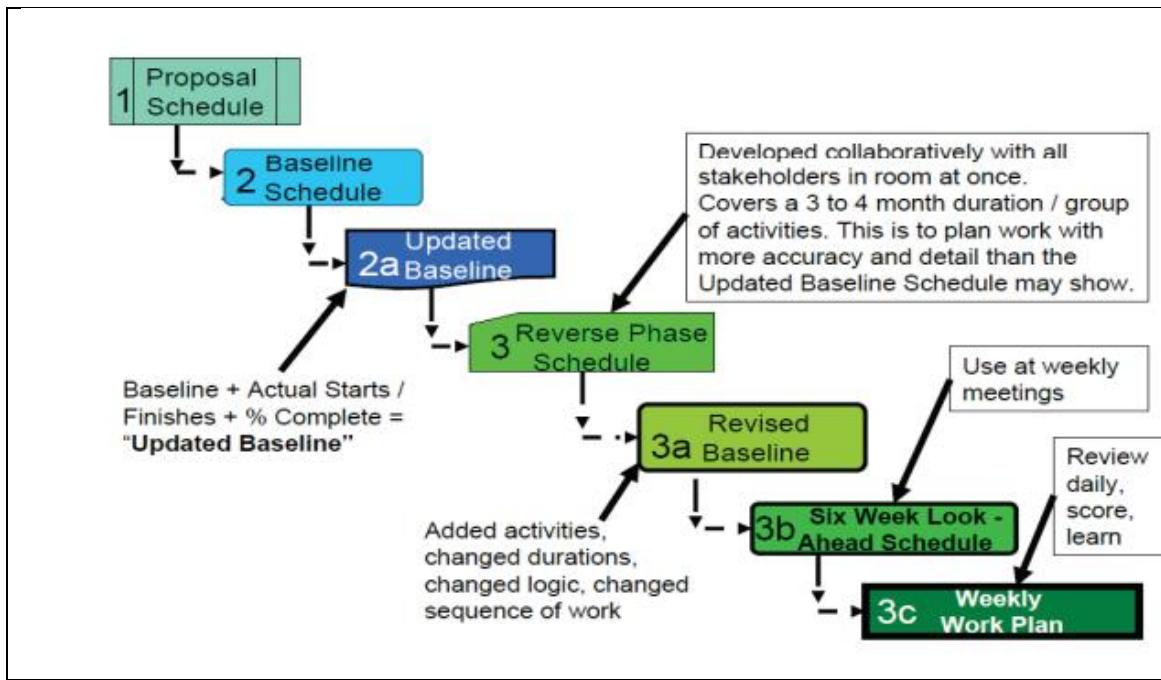


Figure 5 | The LP system procedures

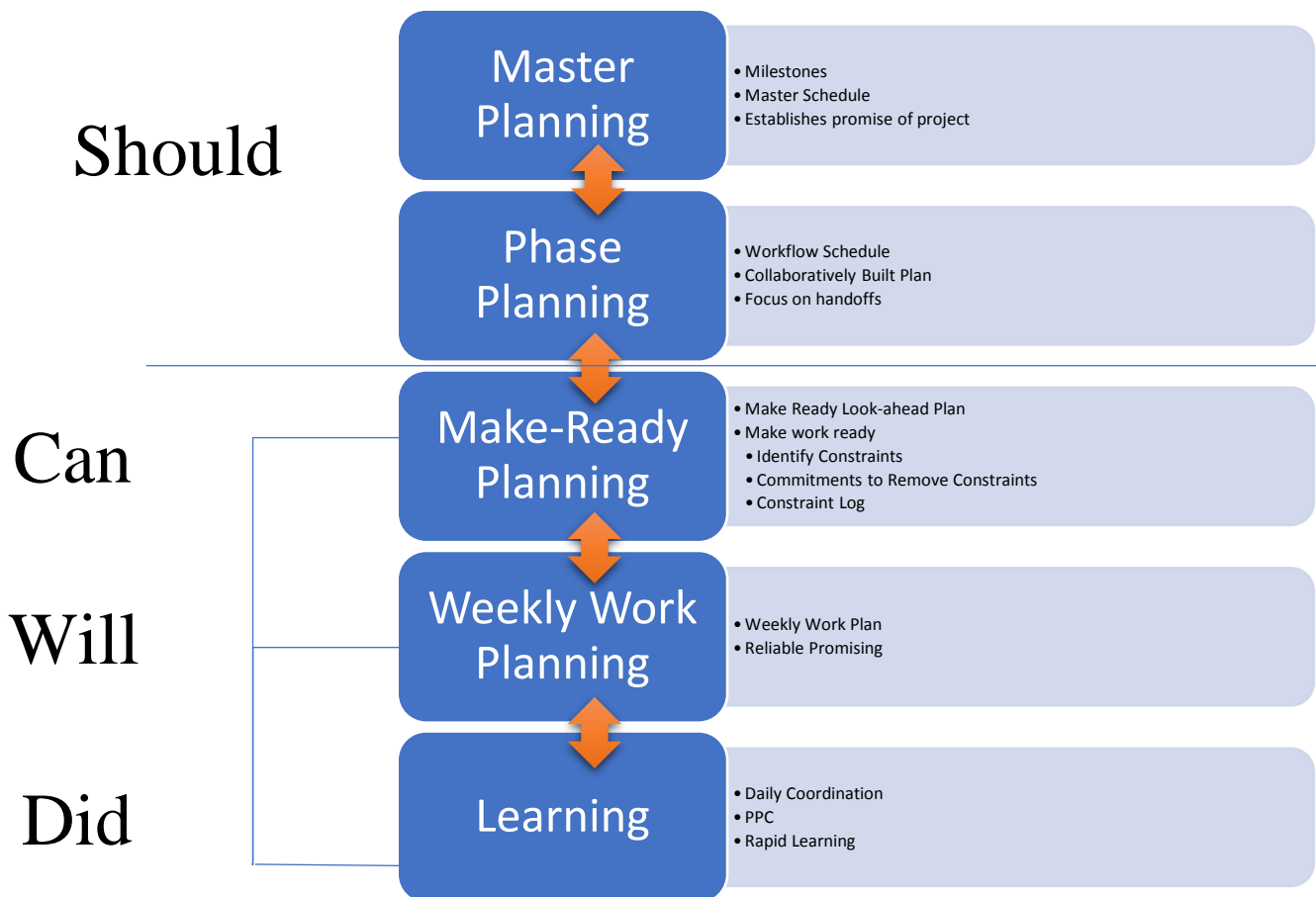


Figure 6 | The Last Planner System

This needs a collaborative environment where the subcontractors and contractors define their responsibilities, specify their deliverables (what they will accomplish), and

determine the phases that needs to be finished before start of a new phase in the project. The advancement of workflow based on the preparedness of the next stage and timing is commonly known as pull planning; which is adapted from just in time(delivery). [43]

The last planner system has a collective nature, though it assigns a heavy responsibility to a few individuals over others. In LPS, all the workers and personnel on a construction project are stakeholders, which is ensured by the help of tracking and assigning responsibility/accountability throughout the entire workflows. Consequently, workers are eager to finish their assignments since all the phases are set to be interdependent and interrelated. [43]

4.6.2. Five Steps of Last Planner System are as follows:

1.Create Master Schedule

Generally, the first step of last planner system is preparing a master schedule which will dictate flow of the whole construction project. This is where the subcontractors and contractors cooperate to mark milestones and objectives for the construction project. In this step, the planning team strives to outline the entire project in detail. All the tasks from the commencement to delivery will be examined. [46] [43]

Master Plan is made up of multiple milestones, which are the start date, finish date, and other important ones which are for specific projects. Apparently, these milestones clarify the path, formulate a strategy, and therefore bring stability to the given project. Milestones are considered as goals of the project, they are tasks that are planned to be finished by a certain date. Following these rules would not only expedite the progress and improve the productivity, but also clarify the path, prevent inactivity, and put the project on-time and on budget. Even impeccable planning could save the resources and make more profit. In addition, Master plan should receive updates regularly, as a consequent of any unprecedented change/information. [43]

2.Crease Phase Schedule

In this step, for each task, responsibilities will be divided between workers, subcontractors, and contractors. Schedulers determine the project's workflow and all the Last Planners start working together in order to find out about the duration of their assignments. Once they determined the mentioned duration, a project schedule will be established precisely. In the meeting that phase planning is developed, all the personnel would get involved, which means their opinions and matters would be considered in planning. Generally, phase planning sessions are organize to find the best task sequence and how to finish the assignments. [45][43]

One important step to take in phase planning is to find the suitable float for the project. This step is performed to recognize some tasks as units, and hand-offs. The units are in-between the milestones which are set in the master plan. Hand-off is when an employee give the control and responsibility of a task to another employee. Another important aspect of phase planning is to identify and predict the conflicts in operation in case of any probable constraints.

3.Hold Meeting with the purpose of ‘Make Work Ready Planning’

This vital step is all about making sure that all the personnel in the construction site have enough resources to finished what they have been assign to. Usually this type of meeting occurs when the deadline was soon approaching, normally around five weeks after the meeting.

Besides, any obstacle or constraints that might happen during the execution of the project would be discussed and identified. Then, the identified issues would be enlisted in a logbook where certain individuals are assigned to take care of the problem as a definite time.

‘Make Work Ready Planning’ meetings could help prevent unforeseen problems during the operation, such as unavailability of certain tools, delay in the arrival of materials, and etc. Most of these problems are potential to derail the project, thus going over-budget and over-time would be highly probable. [43]

4.Hold Check-ins Weekly

While the construction project is being worked on, this step would take place on a weekly basis. Weekly check-ins are designed to confirm that all personnel are familiar with their future tasks each week. In the meeting, the individuals who are assigned to a task would certify that their assignments would be finished on-time. Although the deadlines and durations are already defined and negotiated, yet it is important to make sure that the given expectations will be met. In case of any contradiction to the defined deadlines, the entire project would be at stake, including getting off the desired schedule, causing material waste, financial loss, and lengthening of the duration. [43]

5.Hold Learning Meetings each day for Last Planners

This step takes place daily at the end of each working day. All Last Planners gather to confirm their daily tasks were fully finished, before leaving the workplace. In case of any problems that impede the progress, last planners could cooperate in order to find and tackle the matter. It’s generally better to fix the problems as soon as possible in any projects. This, tackling issues, is in fact one of the main advantages of lean. Even minor

errors in scheduling needs to be address immediately, otherwise they could accumulate and damage all the planning and strategies which were carefully developed previously.

To make sure that this project is fully progressing as it was planned, within budget and on-time, these meeting are indeed an opportunity to carry out multiple statistical analysis. [43]

- **Percent Plan Complete (PPC)** – It determines what percentage of the given tasks were completed weekly. This could help Last Planers picture the issues so that adjustments could be developed for the following week.

$$PPC = \frac{\text{Number of assignments completed at the beginning}}{\text{Total number of assignments made for the week}} \times 100$$

- **Tasks Made Ready (TMR)** - Last Planners could check if the scheduling phase functions flawlessly and follows as it had been planned. They also need to carry out the root-cause-analysis to find out the problems and how they could solve them and improve the process.
- **Tasks Anticipated (TA)** – T.A. is made to clarify the upcoming tasks for the next week, which would help Last Planners to identify the amount of assignments they are being expected to finish weekly and problems that might arise through the progress. They could also improvise ways to improve the results for the upcoming weeks.

Evidently, Last Planner System is one of the efficient techniques lean thinking offers. It manages and controls the workflow as well as all the personnel based on the amount of work they have been given. [31] Similar to any other techniques is life, LPS demands practice and learning, through the past experiences, so that it could produce the desired results.

4.6.3.Lessons Learned:

Each Experience is an asset for the leaders to learn from it. Nowadays, there's a system involved in which all the events are recorded. Looking through these pieces of information would not only provide the management team with a great vision and comprehension of ideas, but also they could improve their performance for the future projects. Collecting data and writing reports from the previous projects could prevent making the same mistakes in the next projects. This would improve the productivity, performance, and quality. [46] [31]

4.7. The Five S

The five S introduces a new system for workplace standardization and organization [47] It is a methodology that leads to a workplace which is uncluttered, clean, safe, efficient, well-organized, and friendly to help optimize productivity and eliminate waste. It's primary designed to lend a hand building a quality-work environment, mentally and physically. The 5S principles applies in almost any work area that is suited for lean production and visual control. Its condition of a work environment is pivotal to employees and is inherently the foundation of clients' first impressions. It is derived from some Japanese terms which are listed below:

Seiri – Sort (Organize)

Seiton - Set in order

Seiso - Shine

Seiketsu - Standardize

Shitsuke - Sustain

Each of these terms has its own scope of influence with a distinct objective.

- **Sort:** To separate necessary tools, instructions, and parts from unneeded and useless materials and to get rid of the unneeded ones.

In a workplace, it will ensure that every item is exactly in the best place it could be and all the unnecessary items are identified and taken away. Simply by sorting out, the working area would be transformed into a free of disturbance or obstacles from unnecessary items that were previously there. This step consists of a series of waste elimination to keep the environment clear and clarified all the time. For instance, sometimes rubbish wheelie could be a key item which needs to be placed at the defined spot. [47]

- **Set in order:** To identify and arrange tools and parts neatly so that they could be easy-to-use.

Organize materials and equipment in order to find them easier, work more efficiently, and use them with ease. Prevent wasting time and losses by organizing the working area, in the way that all the tools are arranged in a way that based on their priority and usage their proximity is defined. [47]

- **Shine:** To launch a cleanup operation/campaign.

Keeping the working area clean and organized all the time would not only help spotting the defects and problems, but also is a great assistance for safety reasons. The work area should always be kept safe and clean in order to indicate ease and pleasure. The most important objective of the given step is to make even the little mistakes of a working area obvious to anyone.

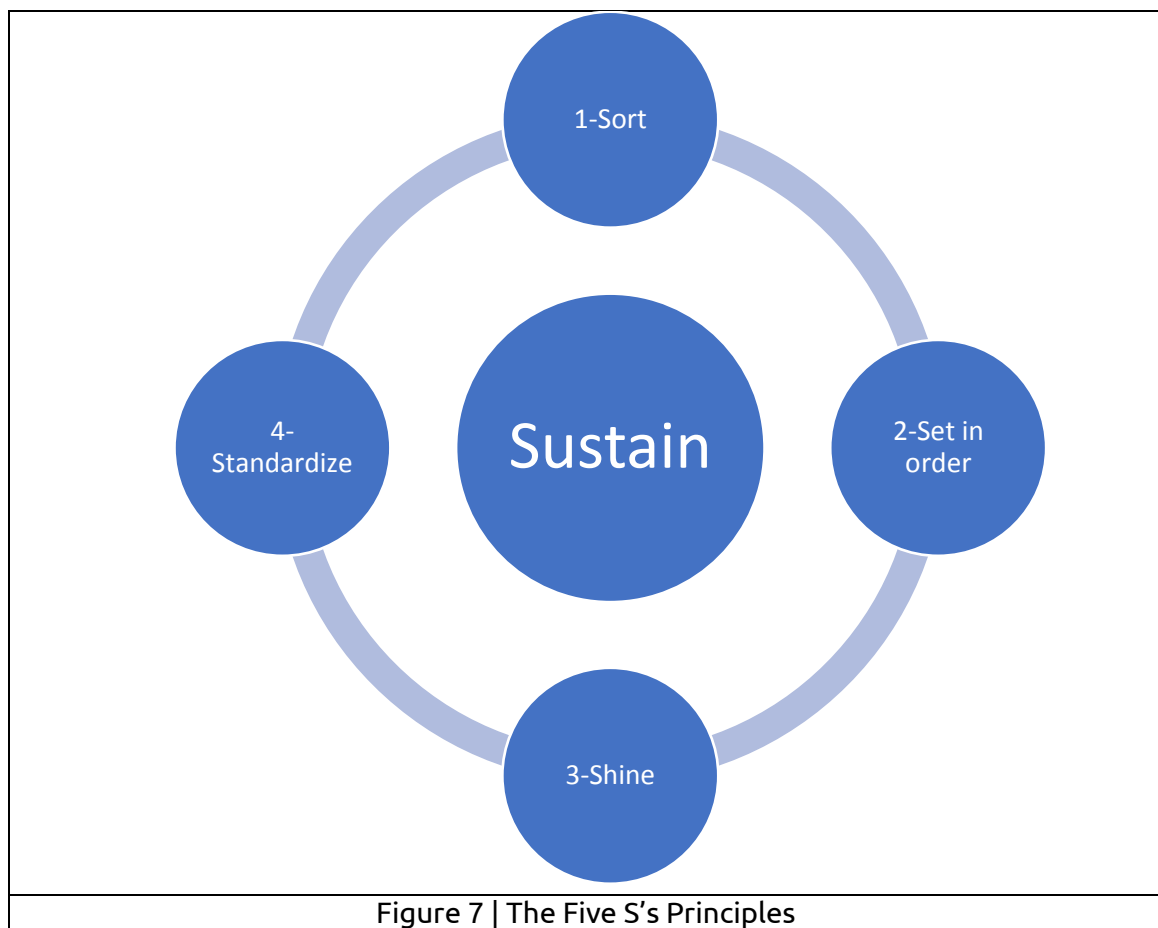
- **Standardize:** To run the above-mentioned practices on a daily basis to keep a workplace in the best ever condition.

To achieve consistency and make sure that everything is carried out correctly, the previously-mentioned procedures are to be formalized and defined as standards through the entire organization.

- **Sustain:** To form and better establish the habit of constantly following the first four S's.

The entire process made up to this item have be kept going all through communication, regular audits, and trainings. The aim here is to obtain a "do without the need of being told" manner, which could be achieved by rewarding good behaviors, and exchanging regular feedbacks.

Each item has its unique frequency of use based on their complexity. The first three are required to be carried out and monitored daily, whilst the other two are just mindsets to be instructed and sustained amongst the personnel. This technique though might sound simple in terms of its principles, it is indeed one of the hardest to follow. As an advice, instead of repressive methods to teach the workers, it is suggested that good and open communication techniques or through posters in the working area could propagate the cause to everyone.



4.8. Push Planning

By definition Push type is a production system which does not rely on the actual demand from the market, in other words, it means make to stock. Push Planning is a way of planning

in which earlier activities produce what later activities in the process need, thus the products would be pushed through the production line. In construction industry, project managers used to employ the push planning system. [43]

Traditional approaches of push planning are widely utilized by project teams. The push planning system requires forward sequencing of tasks and activities from the start date. Activities, no matter if a group of activities or just a kickoff activity, leads to the sequencing and identifying new successor activities. The plan is formed in forward motion. Consequently, a plan is established which is pushed through the entire project phases unto completion; in this method, earlier activities push the later activities. However, the mentioned schedule lacks critical inputs, such as responsible supervisors and interface of the end-users. [48][43]

One of the major disadvantages of push planning is that plans are pushed forward by the sequencing and arranging the activities. Project schedulers utilize complex CPM scheduling techniques in order to prepare a thorough schedule which is detailed with lag periods, logical relations, start and end dates. [48][43]

Push planning is a quick method, and this is why it is popular and widely used. Plans could be made from templated schedules. Buy-in is rapid since each team is only in charge of collecting input only for themselves. [48][43]

Push plans are similar to puzzles pieces that could fit together. But the problem is that sometimes these pieces will not fit, particularly through the progress of the project. The scheduler should strive to compile these plans, adjust and level resources, ensure plan achievability, and recognize conflicts. [48][43]

4.9. Kanban

Kanban is a method for workflow management for the purpose of managing, defining, and improving services which deliver knowledge work. It intends to provide a great assistance in terms of visualizing the work, increasing efficiency, and enhancing continuously. At first it Originated from the manufacturing industry. Lately, it is recognized by various business units in different industries.[2][16][50]

4.9.1.Kanban Method

Early in the 21st Century, Kanban's ability in changing the way services and products were delivered, was recognized. [2][16]

A Kanban system could be built simply by setting up the Kanban board that has three pillars – Demanded, In-Progress and completed. When built, managed, and performed properly, it serves as a repository that highlights bottlenecks in a system. [2]

4.9.2.Kanban Principles

Anderson, who is among the founding fathers and regarded as a pioneer in Kanban/Lean for knowledge work) has devised the Kanban method as a method to evolutionary, incremental process and systems transform for knowledge work businesses. It is targeted on carrying out the tasks with the help of its fundamentals that are mentioned below: [2][16]

4.9.3.Principles of Change Management

Blending with the existing processes with a non-disruptive manner, seeking continuous improvement and evolutionary changes. Below mentioned are the principles involved in Change management: [2]

- 1- Begin with what you are currently doing
- 2- Agree to pursue evolutionary and incremental change
- 3- Persuade acts of guidance and leadership in All the Levels

4.9.4.Service Delivery Principles

Kanban intends to develop a service-oriented method; it needs you to thoroughly understand your client's needs, make a network of all the services where the people self-organize on every side of the work, and make sure that the system constantly evolves. [52]

- 1- Concentrate on client's expectations and needs
- 2- Manage the work
- 3- Repeatedly review the network of all the services

4.9.5.Kanban Practices

When trying to execute Kanban, each company have to consider its practical stages. 6 major practices are required for a successful execution: [52]

- 1- Visualize the workflow
- 2- Limit WIP - Work in Progress
- 3- Manage the flow
- 4- Render all the process policies explicit
- 5- Feedback loops
- 6- Enhance Collaboratively with the help of utilization of scientific method and models

4.9.6.Six Important Advantages of Kanban

- 1- Boosted Flow Visibility
- 2- Enhanced Delivery Speed

- 3- Alignment between execution and business objectives
- 4- Advanced Predictability
- 5- Enhanced ability to Manage dependencies and scale
- 6- Increased client satisfaction

By hearing the word “Kanban”, everyone remembers those sticky notes with different colors on the wall. In order to better perceive Kanban, applying it to the everyday work as well as embracing its philosophy, could be really helpful. By understanding its core principles and techniques, the transition would seem more logical. The mentioned Kanban Practices will enhance the processes and continue doing it beyond the limits. Organizing feedback loops could be helpful in terms of revealing Kanban’s capabilities. [52]

- Digital and physical Kanban boards will help visualizing the work
- Kanban is one of the easiest to adopt, and it will start with what we have
- Work in progress restrictions will enable us to increase the efficiency
- Kanban practices and its principles provide a road to agility without disturbing the processes

4.10. Pull Planning

Pull planning system is based on customer demand, and the production is regulated by it. This system of planning is somehow the exact opposite of the push planning system. A brief history of Pull planning system comes back at the time Taiichi Ohno learned about the U.S. supermarkets. The story was all about customers purchasing items they need at a time, and stores only stockpile the products on which has a great demand. For the products that are not popular, the supermarket either stop resupplying or buy less. This system of management is commonly known as Kanban, which was the idea behind the pull planning system. [48]

Generally, the goal of pull planning in the industry is to make nothing before getting actual demands. It means there would be no finished products without an order from the customer. This system of planning produces good results when there is a high demand from the market. A pull system allows to reduce waste, optimize storage costs, and decrease overhead in any production process. [48]

Construction Manager is responsible for the development of pull planning, simply by just asking the contractors about the duration of tasks and the preceding activities which should be finished before the start of their tasks. For instance, before the electricians could start their work, tasks of the carpenters should have been done. Questioning the personnel on-site would bring clarity to the vision of project managers, so the plan they are developing would be more realistic, and the likelihood that they keep being on-schedule will increase. [48]

Advantages of Pull Planning System:

- 4- Improve flow efficiency
- 5- Increase Productivity
- 6- Reduce Waste of almost all the resources
- 7- Delivering products faster

- 8- Scale an optimal capacity for the team
- 9- Easily adapt to changes that might occur in work process
- 10- Eliminating non-value-added activities
- 11- More Predictability for the system
- 12- Allows Collecting historical data about the workflow as well as the average cycle time of tasks

4.11. Poka Yoke

The literal meaning of Poka Yoke is Mistake Proofing, or in other words inadvertent error prevention, which primarily refers to any mechanism that helps avoid mistakes by correcting, preventing, and bringing more attention to human error in a process. This method is mostly aiming to prevent and avoid human errors. An example to this would be how a computer hardware technician make sure he has tightened all the bolts in the computer piece he was repairing earlier. They usually use a box where they collect all the pieces and bolts they temporarily remove from the item they are working on, and after the item is fixed, they put them all back. At this moment, the box should be empty, otherwise technicians would need to open the computer piece again to put back everything he had taken away. [27]

In the construction industry, however, a new system was developed that is called Building Information Modelling, BIM, which also could be utilized for the matter of mistake proofing. What BIM does is similar to that explained bolt box, it show all the problems and defects in the structure so that it could be noticed and solved as soon as possible. [27]

4.12. Just In Time

Just in Time is a principle which is commonly used in procurement that strives to find a proper answer to the following questions:

- 1- What do we need?
- 2- When do we needed it?
- 3- How much/many do we need?

With this method, the demand for a storage is reduced which is done through a long-term agreement with a few suppliers that had developed a good reputation with your organization. [50] [51]

4.13. Takt time

In lean management, instead of paying attention to pushing the new work, pulling it in progress is what brought success into this concept. With the help of this method, in the presence of a demand, creating and delivering value to the clients is allowed. But, pull system management is impossible without proper maintenance of a continuous workflow. The difficulty of this task is all because of the fact that demand has a changing nature, and there are always fluctuations involved. Defining takt time for a work process is what could bring a considerable assistance in terms of running the process and meeting the demands efficiently. [50] [27]

4.13.1.What is Takt Time?

A definition of Takt time is the completion rate of a product in order to meet the client's demand, this means that by receiving orders every 3 hours, the product should be made in less than 3 hours to complete the clients' demand.

Takt time is the sell rate. It can be easily categorized as the metacenter of a work process. Without having reserved much inventory, it would appropriately optimize the capacity so that the demands could be met smoothly. [17]

The word "takt" itself is a German term for pulse or beat. Takt time was initially utilized as a metric system for airplane manufacturing in Germany in the 1930s. It also changed the course of action of Toyota from a small, local manufacturer to a massive producer, and global automobile company. [50] [5]

4.13.2.How to Define Takt Time?

Simply by dividing the total available production time by the average customer demand, you can calculate the Takt time. This statement is often used as a definition to this term. [53]

$$Takt\ Time = \frac{Total\ Available\ Production\ Time}{Average\ Customer\ Demand}$$

Putting both of these parameters into frames is what makes the result of this formula more accurate. It is suggested that the time that is spent on creating value for clients should only be included here, without the shift changeovers, breaks, and scheduled maintenances. There should be a short time frame included at the time of defining the takt time. It is apparent that defining takt time needed to satisfy the client's demand. According to the client's demand, and with the help of available data, well-informed decisions and choices could be made for better managing a team's capacity. [53]

4.13.3.Takt Time vs. Cycle Time vs. Lead Time

There are always some conclusion involved when introducing the lead time, cycle time, and takt time. A thorough definition of the given terms are listed below. Worth noting that lean managers should consider these metrics as their workflow performance indicator. [53][54]

- **Takt time:** The maximum period of time that is required to comply with the client's demand.
- **Lead time:** The period of time (time frame) between receiving an order and delivering the value to the client.
- **Cycle time:** The time that is spent on working actively on an order

4.13.4.Why is Takt Time Important?

Firstly, for better optimizing a team's capacity. It is also crucial for cutting down on the wastes of a process. Maintaining a continuous work flow and reducing unevenness (Mura) is

what takt time could help with. By avoiding overproduction, it will also help you to optimize storage costs. [53][54]

4.14. Hoshin Kanri

It is an important technique of Lean management for the purpose of making sure that an organization's strategy is implemented all across the hierarchy. Hoshin Kanri constantly strives for continuous improvement with the help of various techniques including catchball and PDCA. With an efficient implementation of Hoshin Kanri, breakthrough objectives and a new vision will be found. Creating multiple complementary objectives as well as presenting a useful leverage for a better implementation are among the other advantages and results of this method. Portfolio Kanban could provide a great assistance in terms of executing Hoshin Kanri planning and the real implementation of the objectives. By cutting the communication cycles short and making the flow of information sharing easier, Hoshin Kanri could be adapted to the modern world businesses. [69]

5. Lean Transformation

5.1.Introduction

The process of introducing a change to an establishment in order to increase the flow of value made for clients, is called Lean transformation. Consequently, this process could help by spotting, eliminating and optimizing wasteful activities. The only purpose of lean is to produce more value for clients, and waste elimination is the end result of that process. Only by having a perspective of Lean as a waste reduction method, mixing up a lean initiative with budget reduction or cost-cutting, would be easy.

In the following context, you will be introduced to the lean transformation models, methods to form a transformation roadmap, and its stages. [55][56]

5.2.Lean Transformation Model

Prior to transforming an establishment into a lean machine, realizing what is ahead of you and understanding the process is vital. Below mentioned are the five elements throughout the transformation phase. Situational Method, Process Improvement, Capability Development, Responsible Leadership, Basic Thinking-Mindset-Assumption. [58]

Clarification on the reasons behind the lean transformation should be made to those involved in the process. It is necessary to have an unwavering support in all the levels of an organization for this purpose. Clearing up the air among the personnel about which problems are going to be resolved with lean could also bring more support. [58]

There might be some opposition involved in the process from the majority of the people in an organization as most of lean's techniques and methods are against the conventional practices. To avoid such resistance, Clarifying and properly communicating about what will happen before, through the process, and after the lean transformation is of great importance. [58]

Nothing will change if the mentality of those involved as well as how they operate remains untouched, therefore it is necessary that they get enough training regarding this matter. It is important to embrace and fully welcome a culture of shared leadership through the levels of an organization where everyone feels valued, and free to make decision to a defined extend without the need and the necessity of asking for permission from the supervising authority. Besides, a lean transformation needs the organization to evolve in aligning with the rules and methods of lean, and what it stands for. [57]

5.3.Roadmap (to Implementation)

The first step through the transformation of an organization is to understand the model of Lean transformation. Since this process takes time, a roadmap should be prepared for the journey ahead. Typical stages of lean transformation are Evaluation, Initiation, Training and Toolings, Flow all across a service, Optimization and Analysis, Flow all across several connected services, establishing administrative methods, and Constantly improving services and processes. [58] [57] [56]

Evaluation

Spotting the underlying problems, evaluating them, and finding potential solutions is the first step toward the lean transformation roadmap. Here, choosing whether to spread Lean through the time and start small or initiate the transformation immediately with major changes, are expected to be made.

Initiation

Getting C-suite on board beside transformation as well as funding and providing the needed tools and training is called for in this stage. The transformation need someone with an unquestionable authority to stand by it even if nothing go according to the plan.

Training & Tooling

Providing enough training for the people involved specially the management staff is part of what is expected to be done in this stage. Having an experienced advisor whom could bring guidance through the process of transforming the company, help with providing practical knowledge, and coach the ones involved in implementing the philosophy and techniques of lean.

Flow all across a service

The definition of a single service is a function which receives an input, process it, and make a certain output. It is also of a great importance to visualize the required stages through the production of the given output, this would bring more efficiency and as a result we could get the most of implementing lean. In this step, mapping the engaged team's process as well as introducing the concept of flow is necessary to get started with the process of continuous improvement.

Optimization and Analysis

Shortly after gathering enough data, workflow analysis should be carried out in order to find more room for enhancement. In this level, unified performance indicators are to be established for the process as well as getting the entire organization on board with them.

Flow all across several connected services

At this stage, value stream mapping is ready to get expanded throughout the entire organization, from the product management directly to value delivery

Establishing administrative models

After having the value stream completely placed, properly managing it would be the next step. Portfolio Kanban Method could provide a great assistance at this stage since it brings transparency to all the hierarchies of an organization. For the purpose of better managing the value stream of an organization, a variety of metrics should be tracked such as work items completed and tasks in progress.

Constantly improving services and processes

Adopting continuous improvement as a culture for the organization is the last step toward a complete lean transformation. It is important that processes get improved to increase the efficiency.

5.4. Lean Transformation Model in detail

5.4.1. Introduction

A simplistic, profound guiding method to initiate and execute a change initiative is called The Lean transformation model, mostly regarded as a practice that is easily learnt and beared in mind.

According to statistics, around seventy percent of transformation programs are not successful, therefore having a clear and thorough understanding of the risks involved might help the process. The Lean Transformation Framework or Lean Transformation Model is what L.E.I. or the Lean Enterprise Institute had came up with in order to present the needed structure for the sake of this endeavor.

While, Lean Framework have never been a prescriptive approach, since it does not require strict practices and rules and put more space for experimentation and thinking, which is an invaluable aspect unlike other management methods that are currently being used. It also is compatible with most of the lean management techniques like Portfolio Kanban, A3, PDCA, etc. [55][56]

5.4.2. Lean Transformation Model

An important note here is that lean has not been regarded as a reserved territory only for production and manufacturing companies. In fact, lean is a vision, a thinking that is applicable to any industry.

Soon after the introduction of Kanban, Lean thinking was on the rise for marketing, product development, operations, software, and many other businesses. Though lean was firstly started at Toyota, it became an international way of management, hence the lean transformation model was made relevant to the whole world. [57][58]

The CEO of the Lean Enterprise Institute, John Shook, the one who helped introduce Lean, depicts a house a representative to the model which is constructed of five columns as its core elements. They are, Situational Method, Process Enhancement, Capability Development, Responsible leadership, Basic Thinking-Mindset-Assumptions. [57][58]

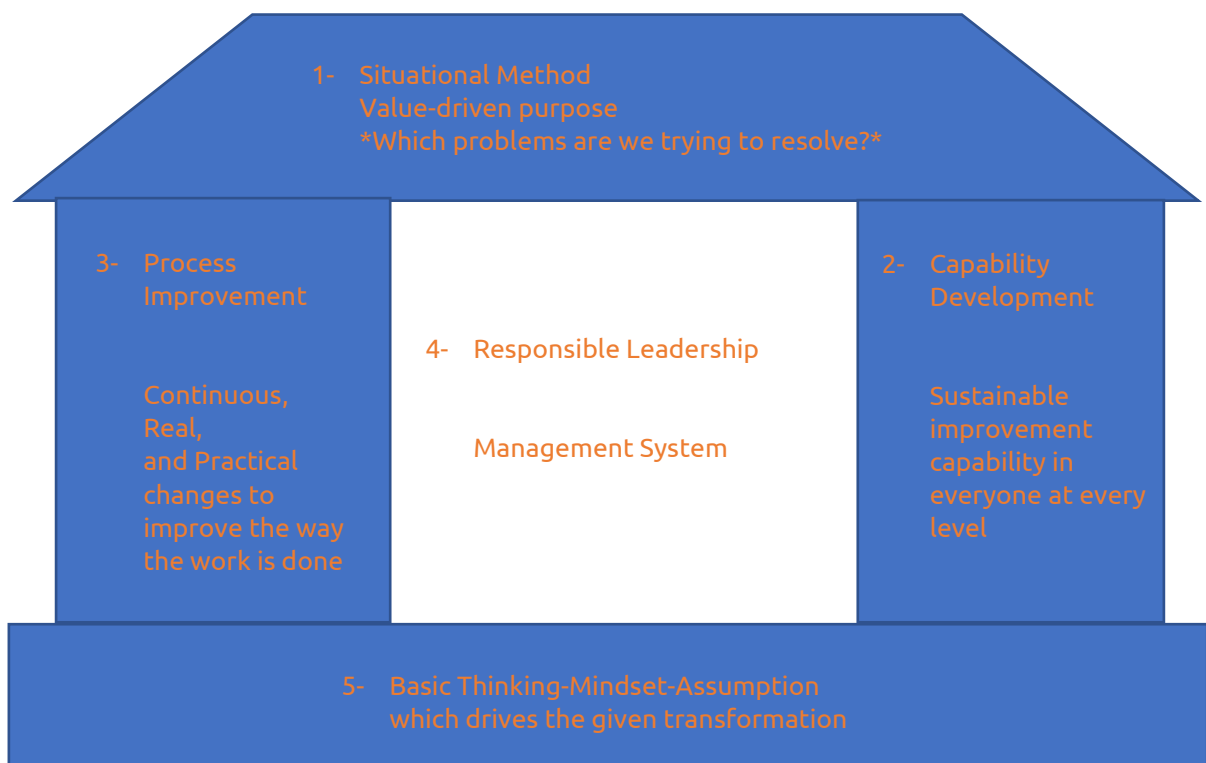


Figure 8 | Lean Transformation Model (Framework House), adopted from LEI

To better understand this concept, Shook raised five questions corresponding to each dimension of Lean Framework.

- 1- What is the reason of a change? Which problem are we striving to resolve? (Situational Method)
- 2- How the actual work can be enhanced? (Process Improvement)
- 3- How capability is raised? (Capability Development)
- 4- Which management systems and leadership behaviors are needed to provide a support for this new working method? (Responsible Management Systems and Leadership)
- 5- Which mindset is driving the given transformation and constitutes this culture? (basic thinking-mindset-assumptions)

If you could answer the above-mentioned questions, it proves the feasibility in successful implementation of the lean transformation model in an organization. Though it might sound like answering some simple questions could not be reasonable proof to this, however, being unable to answer even one of them shows there must not be any attempt to change the organization yet. Starting the transformation process without having early considerations and studies on the potential risks involved, proves the system to fail eventually, and this will push the program out of balance. [57][58]

5.5. Answering the Questions of Lean Transf. model

Always, the first step is considered as the most difficult one. Usually dealing with a tough issue that is considerable sensitive and big, put us in a condition where we do not even know where to start from. Below, some instructions are listed on how to properly answer the LT model questions. [58]

1. Which issues are we striving to resolve? What is the reason of a change? (situational Method)

Usually, Lean transformation happens as a sort of top-down change, which means that it is launched by the senior management or the higher-ranking management team. With That being said, the issues that are targeted are actually the ones which the senior managers deal with:

- 1- Enhancing productivity
- 2- Decreasing the delivery times
- 3- Taking out the project delays
- 4- Maximizing profit
- 5- Boosting customer satisfaction
- 6- Raising quality
- 7- Managing and controlling complexity

All the pain points should be documented and showcased to everyone involved during the rollout. For this reason, it is better to always make sure that managers and employees are aware of the objectives behind the transformation, that is why it is necessary to have a detailed wiki page or a living document. Be careful not to put too many problems to solve

and too many aims to fulfil at the same time. It is well appreciated if the purpose is quality improvement.

There shall always be transparency; in order to get the full support of the people engaged in the process, it is suggested that by feeding them all the information they need, they'll show more trust and engagement to the matter. Therefore, it is necessary to invite everyone to engage, expecting them to do their best while there is transparency in our objectives. Sometimes, the input they are giving us are surprising like an easier method to tackle the issue while no one else has ever thought of it. Also, it is suggested that we should always evaluate the situation and see if the problem still worth spending time on. Agility on changing the course of action with the flow is what is needed here. [57][58]

2. How the actual work can be enhanced? (Process Improvement)

A list of the process improvements should be made by answering this question. It is a general outline of all the processes that are to improved.

Improving processes just for the purpose of improving them is not what we should go after, it means that the solid process improvements being executed have to assist the major goal. Also, the success criteria should be always listed, as the individuals doing the work require to be aware of what is satisfactory and what not.

It is always said that process improvement is one of the important columns of the LT model, by that it means "process improvement" pillar supports the roof that demonstrate the issue being resolved. Here, the solid process improvements being executed have to assist the major objective. Improving things just for the reason of enhancement should not be the main cause. [57][58]

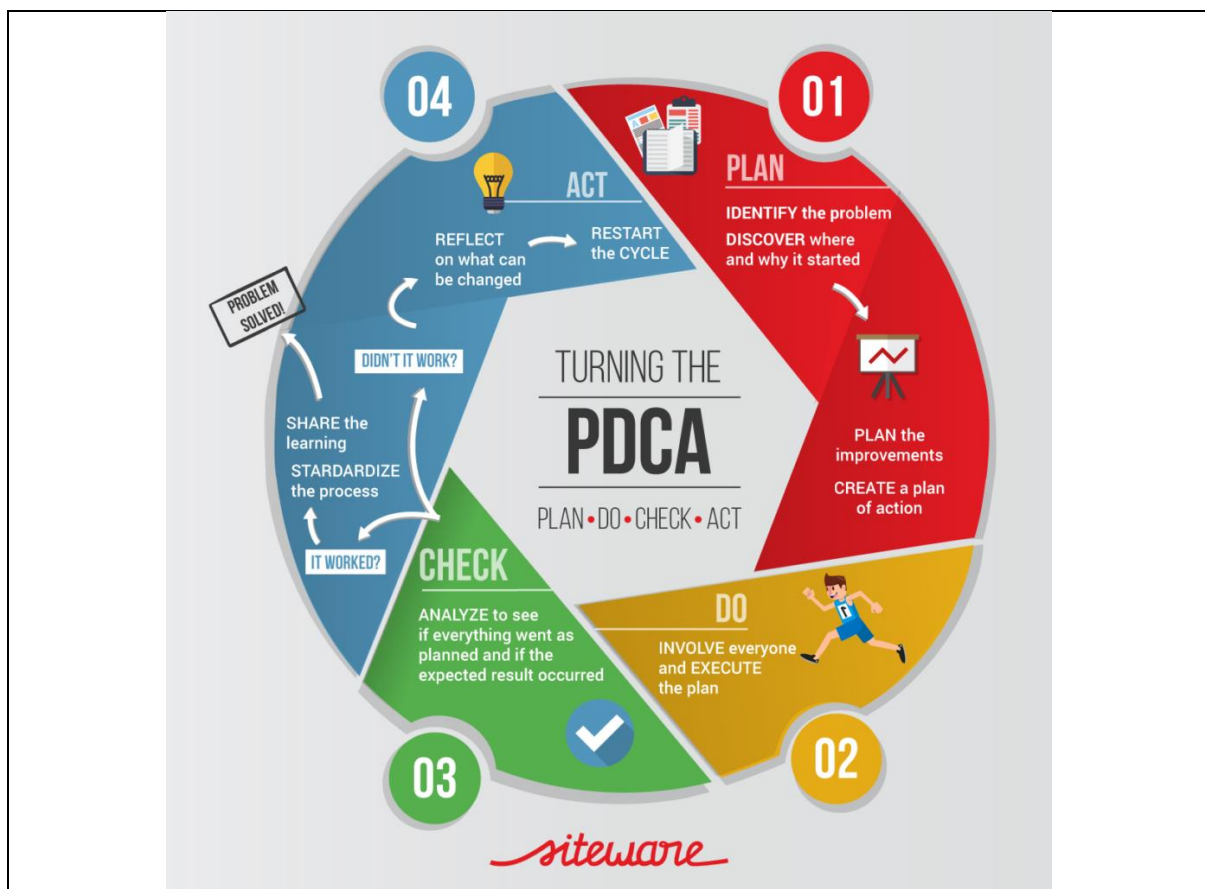


Figure 9 | PDCA Cycle | Ref: www.siteware.co/en/methodologies/what-is-the-pdca-cycle/

Process improvement is all about performing small experiments, result benchmarking, and changing based on the end results. In its very root and origin, there is nothing but the famous PDCA cycle. [57][58]

This is closely related to many startup theories of Lean. Make a MVP of a process improvement, endorse it with colleagues and clients, and scale it if it was successful.

This will most likely be the most arduous aim to achieve – Changing everyone’s thoughts to an investigative and experimentation mindset. Investigating and experimenting needs a great energy level, and usually everyone is trying to avoid that. This needs a shift in culture and ethics.

With that being said, it is much better to always be doubtful about suggestions to adopt a specific framework. [57][58]

As we all know, shortcuts never actually work, then the solution is to start small where we are. Here, lean management tools are the only techniques that could help us in this situation and get us closer to the future desired state. After some lean management tools are mastered in some parts of an organization, it would be the time think bigger and scale the lean principles all across the organization; which is usually done with the help of Portfolio Kanban that was earlier explained. [57][58]

3. How capability is raised? (Capability Development)

Developing capability is a synonym to the term of developing people. People are the ones whom get the work done. The second important pillar of Lean Framework is developing people since without improving the people, there will not be any improvement to the organization. They are running multiple experiments, executions and continuously enhancing the processes. It means that if the personnel does not get the training to think Lean, regardless of all the efforts, there will not be any changes to the company itself.

It’s common for the employees to get enough training, while the responsible managers and supervisors do not. This fuels a situation where the outcomes are suboptimal, and there would be a communication vacuum in between the people involved. It is mostly suggested that either everyone get training or if managers are the ones that agreed to get the training, they are required to instruct their people; this has been reported to result in the best possible results. Toyota Exactly did the same way; their managers trained their personnel instead of a third-party company that has no experience as an insider in this business. This also helps in terms of developing the relationships between the managers and their employees that eventually make their commitment to the business more solid and long-term. It’s a saying among all the professionals in this field that the better a company becomes at sharing, generating, and reusing knowledge and expertise, the faster that business will develop. [57][58]

4. Which management systems and leadership behaviors are needed to provide a support for this new working method? (Responsible Management Systems and Leadership)

Undoubtedly, leadership plays an important role in successful implementation of Lean transformation. That is why it involves all the internals of the LT house, as it was depicted in the picture. It closely interacts with the whole system to improve it.

Organizational management is what makes everything work. However, in the lean philosophy, everyone should be given a chance to have some authority and make their own decisions to some degree, which means everyone is regarded as a Leader.

For this purpose, an organization needs to foster adaptation and experimentation rapidly in order to change the environmental factors.

This cannot solely happen in circumstances where the common leadership style is strict and authoritarian. As mentioned before, in lean, everyone is a leader. Leaders and managers in a Lean company should be data-driven. If they force their own beliefs and opinions on others, they will not be able to obey the culture of continuous improvement; it's because they would admit their failure, and because of that, they will not learn from the previous mistakes. In this context, the most important responsibility of a manager should be developing capability. The more experienced and accomplished a Lean director is, the more they can assist in terms of mentoring and coaching the future generation. Professional Lean managers should teach their teams to be self-organized, independent, and analytical; their employees need to think differently with the hope of a more detailed and precise analysis. The lean leaders should always be regarded as the ones who build the culture, change it if needed, and gain the trust of those involved until everyone looks up to them. [57][58]

5. Which mindset is driving the given transformation and constitutes this culture? (Basic thinking-mindset-assumptions)

This stage is the most critical and the most important part of LT model. It's framed as a big name "culture " and the other names are just there to describe it, such as set of assumptions, basic thinking , and mindset. Culture is the only important asset of a business. Without a change to the company's culture, nothing can carry out a smooth Lean transformation; that is why it is of a great importance to first fully assess the existing culture of a company as well as all the related challenges. After the given assessment, identifying the desired future state would be the next step, then simply by changing the values, it would be possible to change the entire culture of that company. Of course, it does not mean to only change the propaganda while changing values should be initiated from the management and leadership, which then it could be demonstrated through a subtle change in the behavior. It might take a while before everyone feels comfortable to adopt the new behaviors, but usually as soon as the leaders show some signs of change, everything changes. It's worth noting that without their commitment, this change in culture will not be possible even if there are thousands of attempts behind it. [57][58]

6. Implementation of Lean Principles

In this chapter, the implementation of lean principles as well as the implementation of new processes are thoroughly discussed. The means to better implement and possible obstacles are also mentioned. [59]

6.1. Implementing new Processes

Based on what is defined in the English Dictionaries, Implementation means the processes in which a new plan or decision is put into work. In fact, the implementation of a new ideology is necessary for any organization that is willing to change their current way of operation. The willingness to make use of a new method, way of thinking, or technology could introduce change to the system. This could also be defined as an improvement in the system which has the capacity to change the end product to a new state. [59][60]

Listed below are the Eight stages of implementation which are mainly identified by Slaughter. [60] These stages are closely linked. They are parts of a cycle that continuously strives to improve the process, and that is why the term used for them is Continuous Improvement:

1. Identification

The project's objectives need to be compared with the possible innovation in the future. A team should be responsible to identify the objectives as well as providing more information such as potential issues that brought the need to utilize new technology. [60]

2. Evaluation

After identifying the objectives, new technology, and innovation, evaluating them is the next step. The evaluation is carried out with respect to cost reduction and performance improvement in the design and construction process. The criteria for the evaluation are different based on the scope of implementation, whether it is implemented in a large scale(company) or in a project scale. In the project scale, the main focus would be on duration, cost, performance of the innovation, feasibility, risk of failure, and complexity. On the other hand, in the company scale, the focus is on initial commitment, compatibility with the methods/materials, and most importantly, they concern about their reputation. [60]

3. Commitment

Company demonstration through public announcement, acknowledgement to pursue the innovation, and resources allocated. Electing a "champion" with a hope to implement

innovation is considered as a steppingstone. Commitments could be translated by the use of resources for the innovation purposes, which mostly the resources are related to human resources, equipment, material, and financial. [60]

4.Preparation

Everyone with the responsibility to implement the innovation process must be trained properly. They have to be completely familiar with the new working methods. Team leaders and managers are supposed to coordinate their teams and everything related to them. Cooperation of multiple teams and syncing their activities with each other is also an essential part of the team leaders' responsibility. [60]

5.Use

Implementing the new processes would introduce many changes and adjustments that arise the need of controlling and monitoring, which is usually appear at an early stage. The complexity level of a system determines how much possibilities for adjustment would arise. [60]

6.Feedback & Redesign

Discovering unplanned and random opportunities and accidental destructive effects would rise the need of recoding and compiling the data files through the implementation process. The reason of having the given step among stages of this process is because the feedback process follows the principles of Lean in terms of constant improvement. [60]

7.Final Evaluation

To be fully prepared for the implementation process, the relevant pieces of information and data files should be collected. This process continues during the implementation step to monitor and control the performance. The evaluation begins with comparing the actual results and expectations. Among the recorded information, the method of implementation, modifications, measurements, encountered problems, commitments, and other important details are found. [60]

8.Diffusion

The stage is all about propagation of the new system through the entire organization. For instance, at the company level, it could be utilized in another project, and in the project level, it is used in another phase of the process.

Facilitating the development of a process with the help of implementing a new system is done in this step. [60]

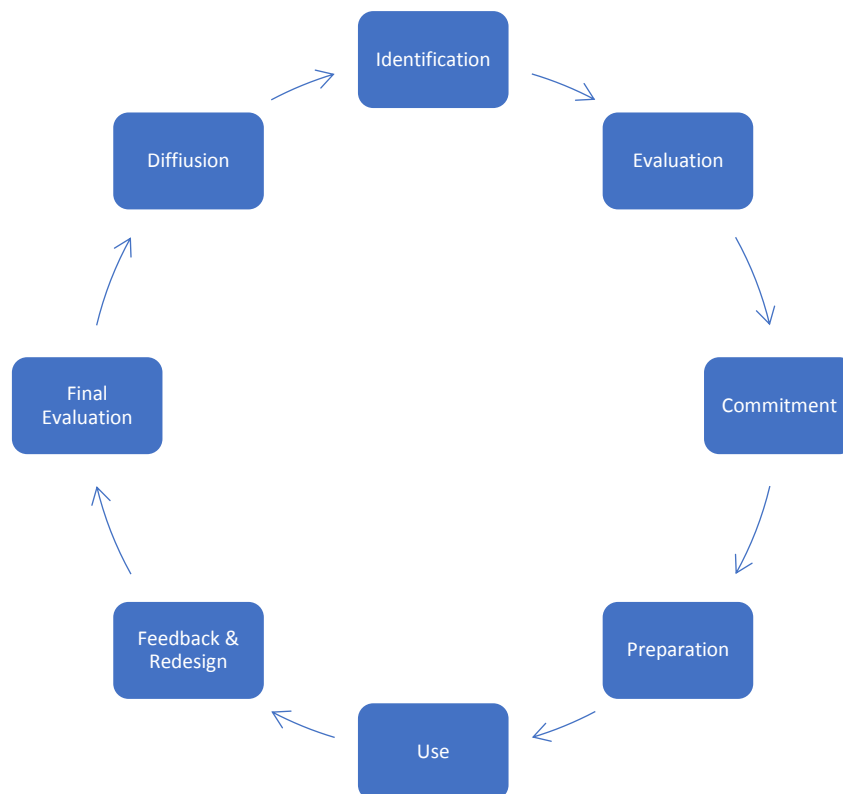
Throughout the implementation process, rewarding should be considered with respect to the people involved in the process and their achievements. Incentives and rewards could be given, though some rewards are without any charge, such as the feeling of achievement, overcoming a challenge, etc. But, it is advised that the rewards should be given based on

situation and at a proper moment, and not everyone deserves similar rewards, which mean what is rewarding for someone might not be for another. [60]

Implementing Lean principles in complex systems like a construction project would be challenging. Implementations could be portrayed as system innovation that due to multiple interfaces resulting from numerous actors involved in various organizations. The given system innovation is effective while it is implemented by a source which has control over the entire system, that is the general contractor. [60]

The complementarity of various innovations implemented in such innovation could be a important factor to reach the objectives set in the assessment phase [60]

Though it is argued by Slaughter [2000] that innovations executed in a system innovation may overlook the overall performances and achievements when assessed individually. In Lean construction, every tool which is developed should be assessed both individually (for the sake of assessing their impact and relevance) and generally. [60]



The intricacy of processes executed makes it demanding to assess the obtained performances to other layouts and configurations, whether it is without adoption of Lean construction or any other management philosophy.

The implementation and execution of such systems would have different requirements with respect to commitments demanded and the role of "champion" [60]

The functionality of the processes to execute and the gradual implementation of changes are associated with a successful implementation [59]. All the project members will be needed to integrate and embrace the innovations for desired results, while "the champion"

will be required to promote the innovations throughout various project teams as they enter the given system.

An effective collaboration between the actors is correlated to benefits and success from the implementation [60]

During the early stages of implementation, decision makers and planners are required to control the direction of the newly-implemented processes and keep focusing on the previously-set objectives. Throughout the implementation phases, all the encountered challenges and assessments have to be recorded in order to be utilized a basis for a better implementation in any future projects. [60]

6.2. Implementation of Lean Construction

6.2.1. Introduction

Lean thinking is a novel approach that is recently used to better manage construction projects. It was initially born in the manufacturing industry, which the defined goals needed a new method to organized actions, something that is applicable for a broad range of industries. Implementation oblige the actions that are shaped by a thorough understanding of the objectives and tools. This chapter explains the implications of objectives, production principles, and how they could bring about a better way of management. Then, implementing lean construction come to be a matter of advancing and acting on a brand new knowledge. Advice on execution is offered.

6.2.2. Implementation

The Lean construction implementation is related to system innovation, but the mentioned implementation will be performed in a complex system where the results of implementation and improvement potential is highly linked to the phase of a project. Generally, a construction project is divided in two phases which overlap during the project: Designing Phase and Building Phase.

6.2.3. The design phase

In this phase, the prerequisite processes would occur before the commencement of any other activities on-site, including planning, scheduling, procurement of materials, etc. In this stage, the maximum-possible results could be expected since everything is to be made for the implementation. Though the construction industry is considered as a traditional and slowly-evolved business, the design phase is potential enough to bring the changes when innovations or new processes are implemented. Lean construction techniques could be presented in this stage since they help the designers and planners to find the future needs and predict any probable issues. Also, in the early stages of a construction project, strings

could be pulled that in the long run would lead to the reduction of wastes, hence an early finish with positive finances could be expected.

6.2.4. The construction phase

In this phase, the project starts on-site, most designs for packages are done and no room for improvement is available. It is due to the fact that any changes here would lead the process to delay and cause financial loss. However, the design phase and the construction phase could be working concurrently and at the same time, but on different plans since the design phase is not required to be completely done for the entire project prior the commencement of implementation. Accordingly, an implementation in the early stages of construction could provide considerable results. Furthermore, lean construction techniques that are previously mentioned could only be utilized during the construction phase for the purpose of having a smooth and safe run.

Whether Lean construction was utilized in the design or construction phase, it will introduce different challenges and outcomes along with the resistance from the environment and users. The Lean construction techniques provide certain processes and methods with impact to design. The given changes are depicted on the graph below which is named as the McLeamy curve, it shows the relationship between changes impact and the costs based on the phase in which it occurs. It is recommended that there should be enough time spent in the design phase so that the construction phase could run smoothly without getting impacted by any possible change which alter the direction of the process.

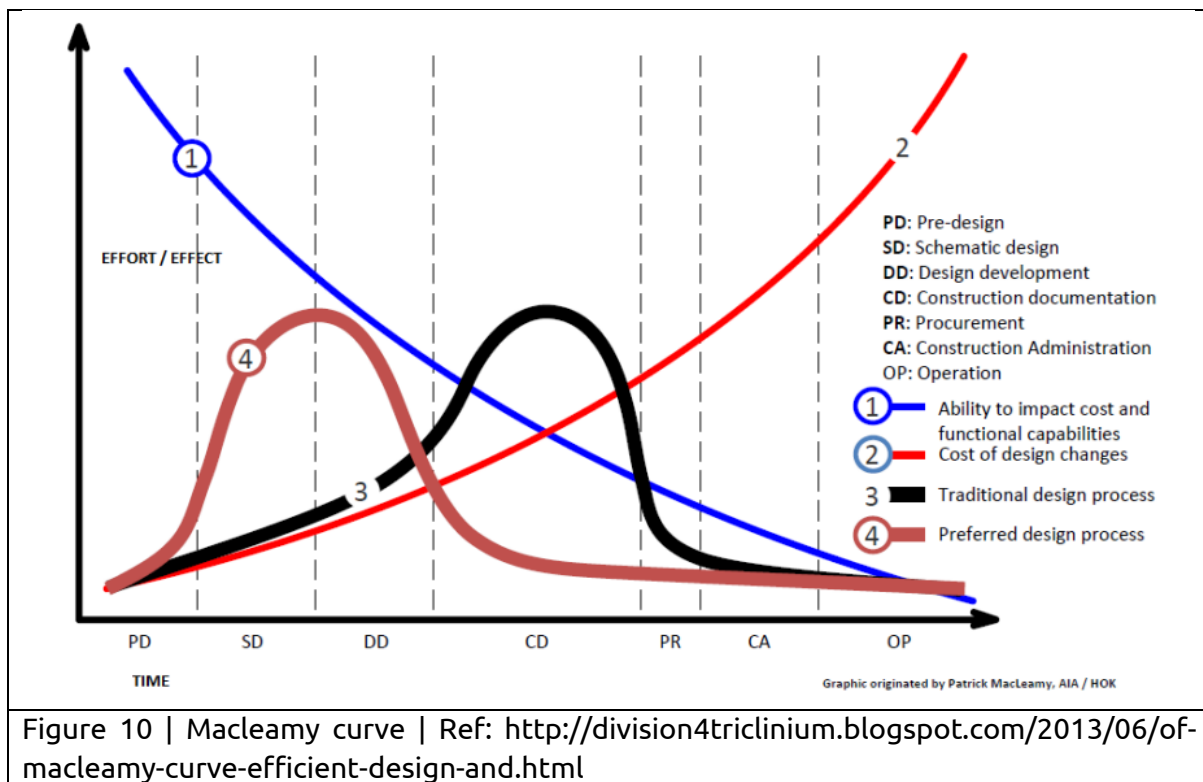


Figure 10 | Macleamy curve | Ref: <http://division4triclinium.blogspot.com/2013/06/of-macleamy-curve-efficient-design-and.html>

6.3. Implementation barriers

The implementation of new methods and systems could be met with problems. These barriers might happen because of human factors that could be either deliberate or not. But they are also originated by other processes in the system. Often, there is a resistance toward any change that is brought up to an organization since they shift processes and the system which actors are already accustomed to. When encountered with a situation to utilize a new tool in Lean construction, strong resistance and defensive reactions are expected. [31]

- **It is unnecessary**

Members of any hierarchical position in a system might claim that the new techniques are not exactly what is needed, and everything had been running flawlessly, or there could be improvements even without the implementation of new tools. Based on methods and tool to implement, personnel could be introduced to the future outcomes, data, and other explanations that proves how the utilization of these methods could make a difference in the process so that these reactions could get subdued.

- **It is impossible**

Participants may mention that new tools are difficult to use or they are not user-friendly; the promised results are not that easy to achieve; or they are simply counter intuitive. A tool like the last planner might appear to be counter intuitive; it allows the activity's prerequisites get finished prior to the commencement of the later ones (shielding preaching).

- **It is done already**

Participants sometimes state that Lean techniques are set in place. It is advised that an evaluation of the current situation, regular visits of site, and monitoring the PPC is beneficial for the sake of gathering enough data to properly evaluate the situation.

Reactions are considered as the first barriers to encounter which is expected from participants of a project, when the Lean questions arise. But, the rest of the barriers could appear and last during the implementation. For the sake of having a better preparation, the management team is in a great need of a comprehensive list of reoccurring barriers:

- People might think that they are controlled during the evaluation process/assessment of an implementation. Human being is generally not in favor being controlled or assessed. Effective communication eases the tensions throughout this vital process. [62]

- Time is among principal factors which affects the implementation. On the other hand, It is a known implementation barrier as well since change actors might always think they do not have enough time to concentrate properly on an implementation [61]. The key to solve such barrier is through a Lean champion that focuses on the techniques and tools to implement as well as providing assistance to other participants.
- An organization that a system is integrated in, might delay the implementation process [61]. The administration can influence responsiveness at the time of encountering any unexpected event and challenges.
- The first step to improve the mentioned circumstances is Self-Criticism. In Lean construction, participants might overlook some aspects of a process, reducing any probability for improvements.
- A mal utilization of the pieces of collected information is a key barrier to a successful implementation since they are not employed to enhance and learn the lessons [62]. Data made by various tools should be analyzed and utilized for improvement, otherwise they will be seen as a wasteful activity themselves, although these tools were assumed to be the waste removals.

Some barriers could be described as deficiencies. They (barriers) are related to an execution process and might not be fixable, but for the purpose of improvements like providing training for the techniques that are to be utilized, improve the participants communication, and integrate various actors through the chain (client; subcontractors; suppliers). [61]

Participants cooperation is always the most element of an efficient implementation. Creating a cooperative environment among participants and lean instigators is essential for the purpose of removing barriers and progressing toward a better implementation. A learning atmosphere is necessary to gain participants' support and suggestions so that the entire team could move forward with ease and a mentality that drive them to the desired outcome.

6.4. Strategies to Implement

Lean construction principles and techniques symbolize a modern way of thinking with the aim of improving productivity and efficiency. This mindset has been used by forward-thinking organizations whose objective is to enhance profitability and remove unnecessary factors of their process. Lean construction takes a high-level and detailed overview of the given project and involves analyzing the contractors' work as well as architects, engineers, and suppliers, etc. This section reviews some of the strategies and methods an organization will have to consider implementing lean efficiencies, increase profitability, and reduce waste. [60]

Understanding Waste

When enacting and implementing lean principles, the primary aim is to study, identify, and analyze the value of a specific segment of a process. The ultimate goal for this philosophy is to eliminate parts which are inefficient and remove them from the project. The primary step starts with perceiving the role of waste. Common examples of waste in projects related to the construction industry include physical items like defects, excess materials, and overproduced parts. Waste, on the other hand, could also be seen as the time wasted waiting for instructions or materials and misusing or underutilizing employees. From the lean perspective, waste is considered as fundamentally anything which avoids having acceleration in a project. By analyzing and assessing the processes, you could spot weak points where waste could be cut down that will eventually enhance efficiency, spare money, and save time. [60]

Flexibility and Commitment

Adopting lean principles needs a stronger sense of openness and flexibility as each job might be differently approached. Largely-scaled tasks might entail pre-construction planning and will need longer than smaller services or jobs. Nonetheless, applying lean tools and principles might take many errors and trials before an organization could perfect the desired plan which works for them. This line of thinking could radically change how an organization operates and can probably take years of incremental and slow progress before they could see the results. Also, organizations must be ready to make some changes which bring about long-term development and growth while handling short term end results. [60]

Evaluate Organizational Principles

To implement lean principles, an approach called top-down is required, and high-ranked managers and executives have to be at the leading point of this movement. Since there is not any particular guideline for its execution, a number of considerations have to be considered to better apply lean efficiencies, which includes a devotion to enhancing and changing workflow and eliminating waste wherever it's present. Besides, this method compels contractors and managers to make sure they're keeping up to stay efficient and productive in ordering the right amount of materials, and having that delivered at an optimal time. But, a change in the mindset of all personnel is paramount, and recognizing those lean principles must be reminded throughout the course of a project. [60]

A Step in the Right Direction

The primary step in implementing and executing the lean ideology needs taking the time to collaborate and communicate with the people involved and ensuring every person is on board. This change in mindset involves honing in on productivity and discovering

opportunities for enhancement, rather than looking at efficiency and results. If lean is executed appropriately, improved efficiency turns into enhanced productivity so that there would be a growth in profitability. [60]

6.5. Tips for a Better Implementation

These days, many construction companies are including toward finding ways to implement lean management tools and principles. Most managers in this field recognize that by implementing these principles, there would be many positive results, among which improvement in safety, adherence to budgets, cost reduction, delivering/adding more value, are observed. [60]

The list below are some of the most important tips which are learned from the implementation of lean principles in construction projects:

Take the time to assist the responsible personnel in understanding the point of Lean Principles

Many react negatively to the notion of Lean thinking since the word "lean" generally implies in doing more with less jobs. That is the reason why it is necessary to present this concept in a way that highlights the need to provide the highest value to the users and customers, with the most productive use of resources throughout the way. Lean Thinking could only be efficient over a long-term period if it take root in culture. It happens when everyone see more than just the lean techniques and tools. These trappings are substantial; however, it is the main idea that there is a necessity for daily enhancement, everyone is responsible for that improvement. [60]

Do not put the cart before the horse

The Lean philosophy is paramount comparing to the techniques. By rolling out the utilization of Lean techniques and making them a main part of how the company operates, you will realize how quick lean is. When the responsible personnel learn how to used the lean techniques proficiently, it would then be easier to see the impacts that lean made throughout the time. Aristotle once mentioned that we are defined by what we do repeatedly. Therefore, it is important to learn the techniques properly and let it prove how it could bring positive changes to the organization. [60]

Do not put the Top-Down Thinking among urgent priorities

The majority of construction companies utilize strict top-down style for operation. However, Lean management uses another method that allows the front-line employees to identify and react to the opportunities and problems themselves in order to reduce waste. Preferably, the ones in the top hierarchy levels are to manage and lead the strategic direction of an establishment. They are also required to provide enough

resources that the front-line workers demand for the success of the tasks they are responsible of. [60]

Be hasty in terms of noticing success and documenting the effects of change

Realizing and noticing quick wins and using them properly is considered as one of the most important aspect of success. People are always afraid of complaining in public about a certain issue, but when they become aware of the successful improvement cycle and observe how respected those that were involved are becoming, they suddenly become interested in the cause. Documenting positive impacts of a change will promote the importance of Lean and will demonstrate what we could expect. [60]

Align accountability and goals

The prosperous companies that are utilizing lean construction have clear business objectives. For instance, Hoshin Kanri could be a useful method to better carryout the strategic planning. Strategy deployment also concerns about making sure that everyone knows how to help achieving the objectives better [60]

Establish a framework for project management and collaboration

It is of a great importance to have a structure for the improvement work. Some softwares in Lean construction allow for a central repository for the improvement opportunities as well as providing a chance for cross-functional cooperation, active alerts, on-time notifications to ensure that a progress will not stall. Also, it provides a bank to store all the lessons learned so that the previous mistakes will not occur again.

If these principles are applied properly, they could bring a life-changing transformation to keep the clients satisfied while the incidents and costs are reduced. Always remember that a successful implementation of lean needs a determined team with the appropriate tools along with a solid foundation to build everything upon. [60]

7. Lean Project Management

Lean Project Management is a proof that Lean principles could apply in many, different areas. Waste elimination, continuous improvement, and adding value has helped project managers to improve the projects efficiency. Lean management allow teams to speedily deliver with the help of better managing the workflow and focusing on delivering value from customers' perspective, while the traditional project management is organized in phases, that divides planning from execution. [63]

7.1. Applying Lean Project Management?

Lean management was first developed in 1940, and through decades it has been utilized as a management tool for the sake of optimizing the work processes. The core principles of Lean management stayed untouched through this time, which are depicted below: [63]

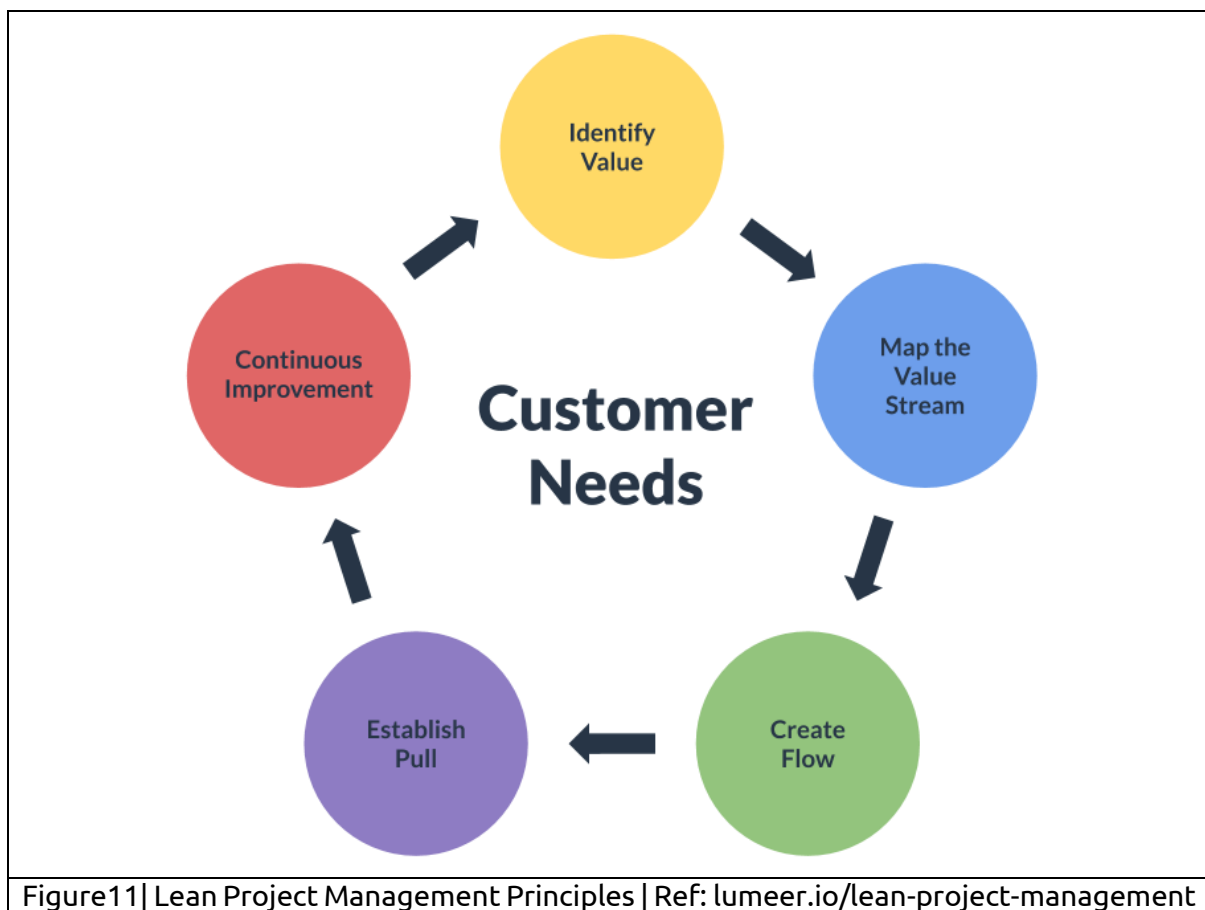


Figure11 | Lean Project Management Principles | Ref: lumeer.io/lean-project-management

1. Identify Value from Your clients' Perspective

To summarize, identifying value is equal with progressing to deliver what customers need rather than what they had asked for. The value that is being produced is inherited in customers' issue. [64]

Lean managers specify and identify value from clients' perspective simply by identifying requirements, objectives, acceptance criteria, and deliverables. The value is what the client had agreed to pay for. It has to be mentioned in the clients' words, and it should come from them. [64]

This is considered as one of the primary differences between the traditional project management and Lean, where the concentration is on business case.

In addition, in Lean, activities which are not directed at fixing the issue and delivering project's outcome is considered as wasted resources. In order to prevent causing waste, an effective communication and relationship with the client is vital.

These will assist managers bring clarification to requirements which might be unclear at the start of the project and settle any potential conflict through value statements with the client's cooperation.

As a rule, concentrating on identifying and recognizing value from the clients' perspective will improve their satisfaction, reduce project waste, and decrease project risk. [64]

2.Value Stream Mapping

The next step in the traditional project management will be to create a project plan which comes with a work breakdown structure and its tasks. But, applying the principles of lean thinking in project management implies in concentrating on the value.

Making a value stream map is what is needed to be done for the next step. This step is being carried out with the hope of demonstrating where value is being added in the organization. More notably, the entire process will be clarified so that the unnecessary steps and flaws could be spotted and eliminated as a result. This will help us to save more resources, "deliver more with less", and most importantly it will affect the delivery time in a positive way.

Sometimes, regarding the value stream visualization, Kanban would be our first choice. Plotting on a Kanban board will demonstrate the big picture, which would then allow us to optimize both the global operational efficiency and even small divisions of our performance. [64]

Because the value that is being generated results from a special, cumulative skill set and a target market, the value stream map will usually look identical for different projects on which a team is working, this means by making any optimization on project execution process, the future projects will be gain benefit and be positively affected by the optimization steps that were initiated in the earlier projects.

3.Create Continuous Workflow

By now, the value that the client is seeking is identified, and how it is going to be generated is also mapped. Therefore, the next step will be making sure that the project could run

smoothly in the absence of blockages, waiting times, or interruptions throughout the system. Achieving a continuous workflow in the project, is what is important in this step. To start this process, all the wasteful activities should be eliminated from the entire process. In lean, any process or step that use resources and generates no value is considered as a waste. [64]

Seven lean wastes are Inventory, Waiting, Defects, Overproduction, Motion, Transportation, and Overprocessing.

Removing waste sources from the process will let the value to flow smoothly through the project. But, in order to be ensured about a continuous workflow, being aware of bottlenecks is needed.

Bottlenecks are considered as a stage of work process that because of shortages in capacity, work get stuck. Having a bottleneck means that the work stage cannot process the work items with a satisfying speed, even when it is working in fully capacity. Therefore, the flow will be interrupted. [64]

In order to spot process blockages and bottlenecks, visualizing the workflow and mapping the value stream is highly recommended. By removing them, the process could get more stable, and the project resources could be utilized efficiently. The more stable a process becomes, the more predictable it gets. [64]

4. Create a Pull System

Pull System is identified and characterized by work getting into the workflow when there are demands for it. Work items will not start unless there is a need for them. What the client wants and when they are putting their deadlines are the priorities here. Thus, causing more waste is avoided throughout the project and bring predictability and efficiency to it. The pull system also imply on the fact that the work items could only be pulled when there a free capacity for them. This system allows the personnel to work efficiently simply by better prioritizing their tasks, and because of this, an employee can start working on the next task only when they can really work on it. Work in Progress Limits or WIP is made to bring a control system to the work process. It is an important element of Kanban thinking, which has been proven to have a positive influence on the productivity. restricting the maximum number of the work items in various stages of a work process reduces the chance of context switching and multitasking. Therefore, all the members could concentrate on a specific task and complete it quickly afterward. Work in Progress Limits is also beneficial in terms of regulating new works that are to be pulled in a specific work stage. Hence, overburdening and interruptions are minimized, and none of the tasks are to be pushed over. [64]

5. Continuous Improvement

Integrating principles of the Lean thinking in the way projects are managed, make the transition from the traditional project management to lean management more viable. Continuous improvement make sure that the work space is always capable for improvement

since in the lean theory, it is suggested that achieving perfection should be a on-going and continuous effort.

Any effort in continuous improvement will make the organization and team to be a continuously learning system. With this mentality, even the optimization of a team's performance is considered as an effort in the continuous improvement. This way, the built-in quality of a project and project's performance are ensured by continuous improvement, and in the smaller picture, by improving teams' performance. [64]

7.2. Lean Management Tools

A successful integration of the principles of Lean thinking in the project management routine of an organization, takes a long time and effort from everyone involved in that process. [64]

PDCA in the Lean Project Management

Plan-Do-Check-Act cycle is also known as Deming Cycle, which is one of the most important lean instruments.

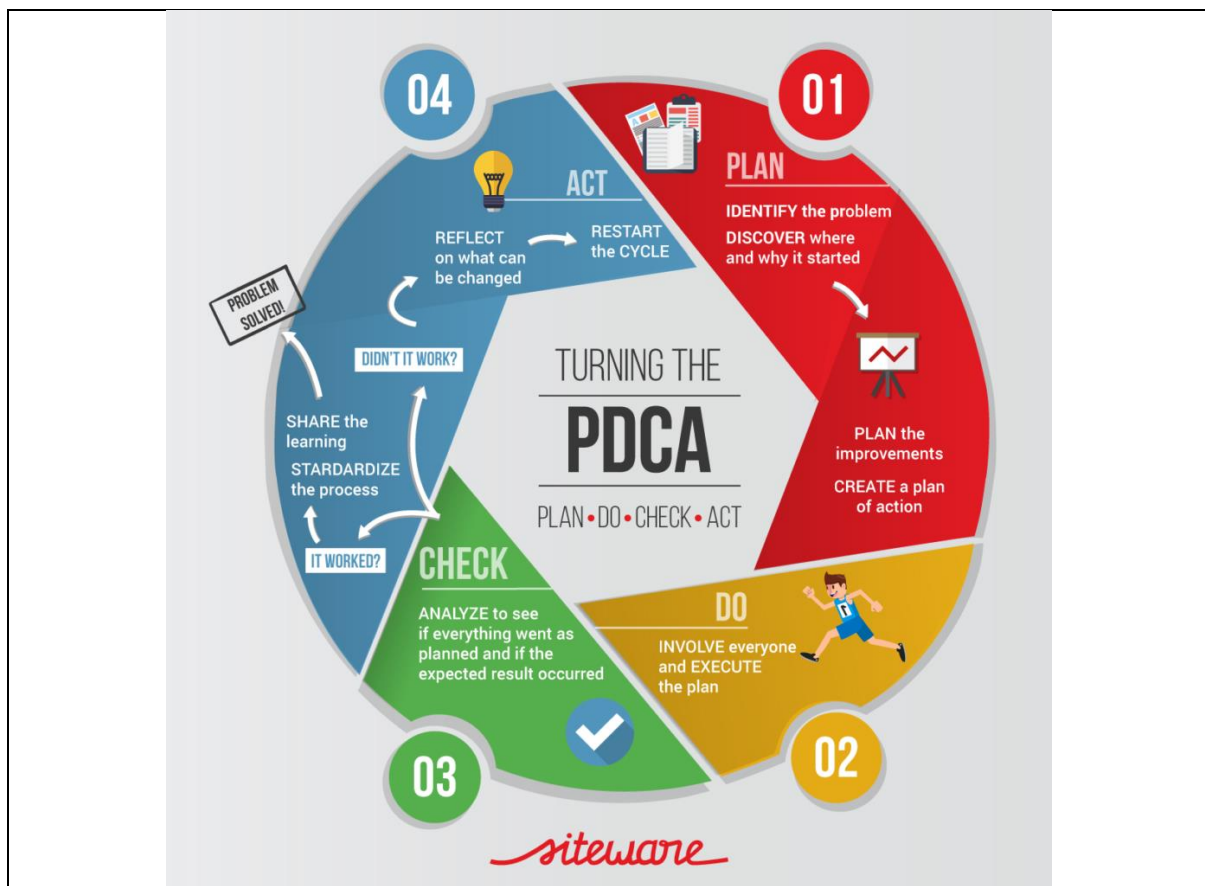


Figure12| PDCA Cycle | Ref: www.siteware.co/en/methodologies/what-is-the-pdca-cycle/

As it is depicted here, Plan-Do-Check-Act cycle is a four-step technique which is consist of:

- 4- Solutions testing
- 5- Analyzing results

- 6- Improving the process in order to allow teams to evade recurring problems
- 7- improve operations

With the help of its iterative method, this technique is proven to be instrumental in terms of continuously improving services, products, and even a team’s performance.

In the Lean management, PDCA is a great path toward minimizing the risk of any potential re-work, increasing the customer’s satisfaction, and supporting a mentality of continuous improvement. [64]

Its objective is to allow us plan accurately, execute it properly, then test the potential solutions, and finally analyze the customers’ perspective in order to determine whether there is a need for change, optimization, and repetition of this cycle. As a result, it will ensure the project’s build-in quality.

Kanban (for Lean Project Management)

Kanban is a method for workflow management which provide a great assistance in terms of improving the work flow, visualizing the progress/work, and ultimately increasing the efficiency. [64] [65]

Kanban Principles	Kanban Practices
Start with what you are doing now	Visualize the workflow
Agree to change in incremental steps	Limit the work in process
Respect the current process	Manage flow
Encourage leadership in your organization	Make process policies explicit
	Implement feedback loops
	Improve collaborative & evolve experimentally

Adapting Kanban principles will reshape the way an organization organize and execute tasks. Kanban utilizes a soft approach in introducing any change, this means that by respecting the current method, it suggests incremental steps toward the ultimate change. Consequently, though transition to lean is gradual here, the process could go one step at a time and smooth. [64] [65]

Kanban boards could be utilized in project management, and as a consequent, it will help centralizing communication in a single place, unhide work, and make the work environment more transparent with less interruptions. It plays the role of a status reporter by demonstrating what is happening in the project to let the members better perceive the status quo of the project and uncover the potential bottlenecks. [64]

Kaizen and Kairyo

The combination of continuous improvement applications in both personal and organizational levels, are represented by Kaizen and Kaiyuro, which could bring about efficiency improvements and actual performance. In project management, however, this means that by regularly taking Gemba walks, new potentials for process improvement could be found, and by assessing the project, productivity could be maximized, and wastes will be eliminated. [64][65]

Gemba walk is a technique that allow us to observe the work as it takes place and where it occur. The important point here is that improvement potential of work processes in both the real-time and actual environment. In Lean's thinking, Gemba walk's aim is to monitor, engage, and enhance and should take place where the critical activity occurs. Gemba walk is really a tool that is primarily developed for businesses more alike the manufacturing industry which there is a production line that could be observed, however, yet it is an effective technique in project management. [63]

The checklist of Gemba walk could provide a great assistance for managers to enhance the project process and remove any potential impediment for the workflow.

7.3. To cut it short; Lean Project Management is ...

- ❖ Lean Project Management consider the project more like a value stream. It is more focused on eliminating project waste, constantly enhancing the project process, optimizing efficiency, and value delivery from clients' perspective.
- ❖ Different from the traditional project management, in lean thinking, there is no differentiation between the project phases. The focus is mostly on the five principles of lean management. [64]
- ❖ Making a pull system and cutting down on project wastes are necessary for improving the project's efficiency.
- ❖ Creating stability and making the project delivery less interrupted are lean management's primary objective, which would then bring about more predictability.
- ❖ Combining various techniques of lean thinking will ease the process of transition from the traditional management.

8. Conclusion

The lean thinking originates from Toyota and their engineering team. Ohno as the fathering father of this ideology, significantly contributed to the cause. The main reason behind the development of lean thinking was to eliminate wastes in a process, increase efficiency and productivity, keep the projects on time and within the budget, boost clients' satisfaction, etc. Although in the beginning, this method was primarily established for the manufacturing industry, it was gradually upgraded to new versions that are compatible with the needs of other practices. Lean is now implemented all around the globe in different work areas such as governments, ministries, manufacturers, the construction industry, and many others. The translation of this philosophy to the construction industry was initiated by a comprehensive evaluation of traditional practices of construction management.

After explaining the theory of lean thinking and its stages of development, the variant of lean for the construction industry was defined, and Lean project management techniques were discussed entirely. The lean techniques were explained with a complete definition of their usage, procedure, and future improvements. A great emphasis was put on studying their direct influence in the field of practice. Then the lean transformation was argued entirely, which introduced the reader to the processes to effect a change within an organization. A proper transformation was found to have a significant impact on boosting the flow of value added for the client. Consequently, it was found that this process will help to spot, eliminate, and optimize wasteful activities. Later, a chapter is dedicated to the implementation of lean principles, and every method that could be utilized for this purpose are mentioned. Implementation barriers, common mistakes, and the lessons learned from such execution were also added to give a clear vision of what operators might expect during this phase. It is discovered that an early execution is capable of significant impacts with considerably smaller expenses. At the very end, every detail was well summarized in chapter 7. Evidently, the primary focus of Lean Project Management is on continuous improvement, value delivery from clients' perspectives, and eliminating project waste as much as possible to optimize efficiency.

Throughout this article, enormous attempts were made to provide the reader with enough examples to perceive the concept better.

As a result of this study, the importance of Lean Management as a guiding light for establishing a reliable business that constantly evolves and helps to spot and eliminate actual problems, was proved. The primary objective of lean management is to add value to the clients with the help of resource optimization. Its principles are constantly striving to establish a reliable workflow that is based on clients' demands. From the results, we can reasonably infer that continuous improvement is an integral part of the lean ideology, ensuring that all the personnel are involved in the improvement process. Among other advantages to point out are the efficient use of resources, smarter process, and an improved focus on bringing value to the clients. Relationships in a working office between the supervisors and their team were improved, and as a result of the open communication strategy, a significant improvement in working efficiency was reported. Also, according to what has already been discussed, Lean helped sustainable development as a result of an efficient management system.

9. References

- [1] R. Mastroianni and T. Abdelhamid. (2003) "The challenge: The impetus for change to lean project delivery"
- [2] Womack, D. Jones and D. Roos. (1990) "The machine that changed the world. ISBN: 1847370551. Simon & Schuster UK; New Ed edition
- [3] S. Ikovenko and J. Bradley. (2004) "TRIZ as a Lean thinking tool"
- [4] BNR (2012). BNR. Retrieved November 05, 2012 from Toyota voorziet hogere winst: <http://www.bnr.nl/feeds/anp/221777-1211/toyota-voorziet-hogere-winst>
- [5] Liker, K. (2004). "The Toyota way - 14 Management principles from the World's Greatest Manufacturer." New York: McGraw-Hill. ISBN 978-0071392310.
- [6] J. Mee, "Frederick W. Taylor," Encyclopedia Britannica, <https://www.britannica.com/biography/Frederick-W-Taylor>
- [7] M. Kranzberg and M. Hannan, (1999) "History of the organization of work - State-organized farming," Encyclopedia Britannica. <https://www.britannica.com/topic/history-ofwork-organization-648000/State-organized-farming>
- [8] M. Rabben, "Henry Ford," Store norske leksikon, (2018) https://snl.no/Henry_Ford
- [9] W. Deming, Out of the crises, Cambridge, Mass: MIT Press, (2000).
- [10] J. Womack and D. Jones. (1996) Lean thinking: Banish Waste and Create Wealth in your Corporation. ISBN: 978-0-6848103-5-5
- [11] Ho, S., & Fung, C. (1994). Developing a TQM excellence model. The TQM Magazine
- [12] Thomke and Fujimoto (2000) "The Effect of Front-Loading Problem-Solving on Product Development Performance," Journal of Product Innovation Management
- [13] S. Shingo and A. P. Dillon, (1989), "A Study of the Toyota Production System: From an Industrial Engineering Viewpoint", Productivity Press.
- [14] Milberg, C., and Tommelein, I., (2003). "Role of tolerances and process capability data in product and process design integration", Proceedings of the Construction Research Congress. ASCE, Honolulu, HI, https://www.ce.berkeley.edu/~tommelein_pub.html
- [15] G. Ballard and G. Howell. (2003) "An update on last planner". Proceedings of the 11th annual Conference of IGLC.
- [16] Ohno, Taiichi (1988), Toyota Production System: Beyond Large-Scale Production, CRC Press, ISBN 978-0-915299-14-0

- [17] Womack, James P.; Jones, Daniel T. (2003), "Lean Thinking: Banish Waste And Create Wealth In Your Corporation, Simon and Schuster, ISBN 9781471111006
- [18] G. Howell. (1999), What is lean construction. Proceedings IGLC-7, 7th conf.of Int. group for Lean Construction
- [19] Mao and X. Zhang. (2008), "Construction Process Reengineering by Integrating Lean Principles and Computer Simulation Techniques." Journal of Construction Engineering and Management
- [20] J. Nicholas and H. Steyn. (2012), "Project management for Engineering, Business and Technology." ISBN: 978-0-08-096704-2
- [21] T. Beary and T. Abdelhamid. (2005) "Production planning process in residential construction using Lean construction and Six Sigma principles."
- [22] Matthews, Daniel D. (2011). "*The A3 workbook: unlock your problem-solving mind.* A Productivity Press book." New York: CRC Press/Productivity Press. ISBN 9781439834893
- [23] Arditi, D. and Gunaydin, H. M., (1996) TQM in the home building process. Proceedings of the 24th IAHS World Housing Congress
- [24] Krafcik, J., (1988). "Triumph of the lean production system", Sloan Management Review, 30(1), 41-52.
- [25] Bartezzaghi, E., (1999). "The evolution of production models: is a new paradigm emerging?", International Journal of Operations and Production Management, 19(2), 229-250.
- [26] Murman, E., Allen, T., Bozdogan, K., Cutcher-Gershenfeld, J., McManus, H., Nightingale, D., Rebentishch, E., Shileds, T., Stahl, F., Walton, M., Warmkessel, J. Weiss, S., and Windall, S., (2002). Lean Enterprise Value: insights from MIT's Lean Aerospace Initiative. Palgrave, New York, NY.
- [27] L. Koskela. (1992)"Application of the New Production Philosophy to Construction"
- [28] Moore, D., (2002). Project management: designing effective organizational structures in construction.
- [29] T. Beary and T. Abdelhamid. (2005), "Production planning process in residential construction using Lean construction and Six Sigma principles."
- [30] G. Ballard and G. Howell. (1994). "Implementing lean construction: Stabilizing work flow. 2nd workshop on lean construction"
- [31] G. Ballard and G. Howell. (1998). "Shielding Production: Essential Step in Production Control. Journal of construction engineering and management"

- [32] Gunaydin, H. M., (1995), TQM in the Construction Industry. MS Thesis, Illinois Institute of Technology
- [33] Koskela, L., (2002). "The theory of project management: explanation to novel methods", Proceedings of the Annual Conference (IGLC-10) by C. Formoso and G. Ballard
- [34] L. Alarcon. (1997) Lean Construction. ISBN: 978-0-2033458-2-5
- [35] Taking the first step with PDCA, (2009)
- [36] Deming, W. Edwards (1986). "*Out of the crisis*. Cambridge, MA: Massachusetts Institute of Technology, Center for Advanced Engineering Study." ISBN 978-0911379013
- [37] Tague, Nancy R. (2005). "Plan–Do–Study–Act cycle". *The quality toolbox* (2nd ed.). Milwaukee: ASQ Quality Press. pp. 390–392. ISBN 978-0873896399
- [38] O. Salem, J. Solomon, A. Genaidy and I. Minkarah. (2006) "Lean construction: From theory to implementation. Journal of Management in Engineering"
- [39] M. Rother and J. Shook. (2009), "Learning to see: Value Stream Mapping to Create Value and Eliminate Muda." ISBN: 978-0-9667843-0-5.
Lean Enterprise Institute
- [40] Serrat, Olivier (2017). "The Five Whys Technique". *Knowledge Solutions*. ISBN 978-981-10-0982-2.
- [41] Womack, Jim (2011). "*Gemba Walks*. Lean Enterprise Institute, Inc. ISBN 978-1-934109-15-1.
- [42] Shook, John (2008). "*Managing to learn: using the A3 management process to solve problems, gain agreement, mentor and lead*. Cambridge, MA: Lean Enterprise Institute." ISBN 9781934109205.
- [43] Herman G. Ballard. (2010), "*The Last Planner System Of Production Control*". PhD thesis submitted to the university of Birmingham.
- [44] G. Howell and G. Ballard. (1994), "*Lean production theory: Moving beyond "Can-Do"*. Proceedings of the 2nd annual Conference of IGLC.
- [45] Luis F. Alarcon and Rodrigo Calderon. (2003), "*Implementing Lean Production Strategies in Construction Companies*. Construction research congress,"
- [46] G. Ballard. *Improving workflow reliability*, (1999). "Proceedings of the 7th annual Conference of IGLC."
- [47] J. Evans and W. Lindsay. (2010) *The Management and Control of Quality, International Edition*. ISBN: 978-0-5384526-0-1. South Western College; 8th revised edition,

[48] Hopp, Wallace J.; Spearman, Mark L. (2004). "To pull or not to pull: what is the question?". *Manufacturing & Service Operations Management*.

[49] A. Oswald, E. Proto and D. Sgroi. (2015) "Happiness and Productivity. *Journal of Labor Economics*"

[50] M. Rother, *Toyota kata*, (2010), "managing people for improvement, adaptiveness and superior results, New York: McGraw Hill

[51] Toyota Inc., "Toyota,"
<https://global.toyota/en/company/vision-and-philosophy/production-system/>

[52] Anderson, David J.; Carmichael, Andy (2016). *Essential Kanban Condensed*. Seattle, WA: Lean Kanban University Press. ISBN 978-0-9845214-2-5.

[53] Hopp, Wallace J. (2011). *Factory physics*. Spearman, Mark L. (Third ed.). Long Grove, Illinois. ISBN 978-1-57766-739-1

[54] Abbasi, Saman; Taghizade, Katayoon; Noorzai, Esmatullah (2020). "BIM-Based Combination of Takt Time and Discrete Event Simulation for Implementing Just in Time in Construction Scheduling under Constraints"

<https://ascelibrary.org/doi/abs/10.1061/%28ASCE%29CO.1943-7862.0001940>

[55] Håkansson, M., Dellve, L., Waldenström, M. & Holden, J. R. (2017). *Sustained lean transformation of working conditions: A Swedish longitudinal case study.*"
"Human Factors and Ergonomics in Manufacturing & Service Industries"

[56] Håkansson, M., (2019). "Lean Transformation of Industrial Work
Understanding what supports socially sustainable working conditions during lean manufacturing "

[57] Koenigsaecker, G., (2012). "Leading the Lean Enterprise Transformation"
ISBN: 9780429248597

[58] Tiwari, A., Xu, Y., (2015) "Towards lean transformation: The analysis of lean implementation frameworks"

https://www.researchgate.net/publication/282965734_Towards_lean_transformation_The_analysis_of_lean_implementation_frameworks

[59] P. Goodman and T. Griffith. (1991), "A process approach to the implementation of new technology. *Journal of Engineering and Technology Management*"

[60] E. Sarah Slaughter. (2000) "Implementation of construction innovations. *Building Research & Information*"

[61] Luis F. Alarcon, Sven Diethelm, Oscar Rojo and Rodrigo Calderon. (1994) "Assessing the impacts of implementing lean construction. *Revista ingeniera de construccion*"

[62] Luis F. Alarcon and Rodrigo Calderon. (2003) "Implementing Lean Production Strategies in Construction Companies. *Construction research congress*"

- [63] Eric Gabriel, "The lean approach to project management." *International Journal of Project Management* 15.4 (1997): 205-209.
- [64] Lloyd, G. (2013). "Lean Project Management – It's all about value" *Journal*
- [65] Anderson, D. (2010), "Kanban: Successful Evolutionary Change for Your Technology Business"
- [66] Project Management Institute, *PMBOK® Guide 6th Edition* (2017)
- [67] *A Guide to the Project Management Body of Knowledge, edition 4 2008* ISBN 1-933890-51-7
- [68] Frank Voehl, H. James Harrington, Chuck Mignosa, Rich Charron, (2013), *The Lean Six Sigma Black Belt Handbook: Tools and Methods for Process Acceleration*
- [69] Waldo, William "Wes" (2016) "7 Steps of Hoshin Planning". *BMGI Problem Solved*. BMGI.
- [70] Knopf, Jeffrey W. (2006) "Doing a Literature Review"
Calhoun: The NPS Institutional Archive