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Investigating the impact of lean philosophy for identification and reduction of delays associated with performance of production line

Final Report – Group T2009

PAPER WITHIN: *Production Systems*

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Abstract

In the present world scenario, the rapid industrialization and growth of manufacturing sector has led to the rise of large number of companies focusing on increase in profitability for sustaining the company's profit margin at a higher level. While most of the companies fail to differentiate between productivity, profitability and performance as all the three growth indicators have different factors affecting them. The productivity of a system is evaluated through the ratio of output and input whereas the profitability is evaluated by measuring the capital flow. But the performance of any system is measured by the speed, quality and time consumed for delivery of a product. Thus, the preliminary growth indicator to be focused by any company must be productivity as it defines the effective input and efficient output of a system or production line and further provide attention for performance. Any productive system to function smoothly must include less amount of wastes, these wastes need not be a particular form. According to lean philosophy there are basically eight wastes arising in a system which has to be considered for elimination or reduction preferably. These wastes not only affect a particular process, while causes negative effects on the performance of entire system by causing delays in the process which increases nonvalue added time and reduces the actual operating time of a process. The present study focuses on exploring lean philosophy for identifying the existing delays of a production system and to further investigate the root causes influencing these delays which effect delivery of product. This study involves a deductive approach of qualitative type of research and the methods used for data collection includes a single case study with systematic literature review of data on which analysis is carried out and derived results are concluded in the final chapter of this research. The conclusion will be based on the results obtained from analysis of data carried out with the aid of tools existing under lean philosophy. The research is concluded by suggesting the solution for reducing delays utilizing simple tools of lean philosophy which can be utilized by manufacturing firms with effective utilization of existing machinery, men and methods and low investment of capital.

Keywords: Lean Philosophy, Delays, Bottleneck, Time variables, Lean tools, 7+1 wastes of lean manufacturing.

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1 Introduction

This chapter introduces the subject of study conducted with a concise introduction on delays, their occurrence and effects on manufacturing firm. In problem description importance for identification and reduction of delays is discussed which supports the main purpose of this project followed by research questions, delimitations and an outline of the report.

1.1 Background

In a continuously growing industrial sector, manufacturing firms are focusing to achieve both efficient and effective production (Feldmann, et al., 2013). But these rapid developments will increase time involved for production of any product which varies constantly based on its demand. The demand of product is constantly fluctuating and cannot be predicted accurately by the companies, while the companies must be flexible to handle such demands arising in the market (Nagle, et al., 2018). Variation in demand will influence the nature of production by influencing speed of delivery and time involved in production, thus affecting the time variables like process time and cycle time. These time variables influence the processing of product to a larger extent (Li, et al., 2018; Nagahara & Nonaka, 2018). Time variables could be affected for various reasons including varying demand, improper processing, inadequate planning or scheduling, less availability of resources etc. (Mourani, et al., 2008; Nagahara & Nonaka, 2018). Amongst these factors improper processing will immensely affect production activity as processing of input into output forms the basis of any transformational action in production.

Occurrence of delays will extend the time involved in transformation of raw materials into finished goods (Veeger, et al., 2010). Thus, even though products are produced there is variation in its speed of delivery. Delays could occur because of various reasons, for example material delay, order delay, transportation delay, delay due to improper handling of machine codes, delay due to excess setup time (Mourani, et al., 2008). These delays not only affect the time variables like process time and cycle time by extending them but also hinders the productivity of line (Veeger, et al., 2010). Decrease in productivity of line will lead to decrease in performance of line (Tangen, 2005). Hence, sustaining high productivity in production line by reduction or elimination of delays arising in line must be prioritized. Delays are associated with wide number of factors and root causes which influence adversely towards the smooth functioning of a system (Mourani, et al., 2008). In order to avoid such adverse effects, it is very much essential to identify the root cause of a problem or factor which is responsible in increasing delay. Adverse effects on system includes excess utilization of time compared to that of normal processing time which further leads to increase in nonvalue added time. Such nonvalue added time has to be resolved in any kind of process (Mourani, et al., 2008). The activities associated with such nonvalue added time are considered as wastes and corresponds to functions related to production (Cancado, et al., 2019).

Eliminating nonvalue adding activities and wastes from production line will significantly reduce cause of delays (Patidar, et al., 2017). Wastes in a production facility have been categorized under eight categories as per lean philosophy (Hill, 2018). Lean as a philosophy influences way of thinking, as it encourages production of goods with zero nonvalue adding activities and elimination of resources which adds no value to end product (Sternberg, et al., 2013). Lean philosophy also promotes effective input and efficient output of a line by eliminating wastes of the line (Zhang & Chen, 2016). Along with promoting elimination of wastes, lean philosophy also encourages just in time production for producing right products at right quantity in right time with ensured quality and focuses on cost reduction of products (Pinto, et al., 2018; Lyonnet & Toscano, 2014). Lean philosophy also aids in identification of root causes of problem through various tools like 5whys, fishbone diagram and pareto chart (Ashok Sarkar, et al., 2013). Thus, tools of lean philosophy can be utilized to identify the root cause arising in production line which are adversely affecting performance of line by increasing time involved in production of goods (Zhang & Chen, 2016; Ahmad & Soberi, 2018). According to Zhang & Chen (2016) lean philosophy involves reduction of wastes utilizing lean tools in order to increase productivity (Zhang & Chen, 2016). Lean philosophy is a technique utilized for process improvement by identifying unnecessary actions and elements and eliminating them (Sternberg, et al., 2013). Hill (2018) claims that adopting lean approach aids in reduction of wastes in manufacturing and improving productivity (Hill, 2018).

As outlined above, majority of previous studies referred lean philosophy as a principle which focuses on reducing nonvalue adding activities with the aid of lean tools and also encourage just in time production in manufacturing firms along with reduction of 7+1 wastes. But the areas pertaining to influence of lean philosophy on reducing delays associated with performance of line is unexplored. Hence, it is important to explore the influence of lean philosophy in reduction of delays caused during any process and investigate how exactly the reduction of delays will aid in achieving high performance of line. Along with the necessity for investigating the research gap discussed above, it is also highly important to consider the impact of research on production firms. As basic criteria for majority of the production firms is associated with earning profits from products delivered. Focusing on such production firms, it is widely essential to identify simple tools for reducing delays with efficient utilization of existing machinery, methods and men with a negligible investment of capital.

1.2 Problem description

As number of nonvalue adding activities increases in production line the total operating time reduces drastically and the time required for controlling these activities increases (Mourani, et al., 2008). This increase in time involved for control activities will reduce performance of line due to unnecessary stops. Stops generally include set up time, break time, cut off time and other predefined stops for the maintenance (Al-Najjar & Alsyouf, 2003). The unexpected stops occurring in the line apart from the reasons mentioned above add no value to the process and hence causes decline in performance of production line due to low productivity. Stops are associated with delays as number of stops together cause delay in delivery of products. Hence, it is essential to identify its root causes which are influencing delay (Abdellatif & Alshibani, 2019). Delay might occur due to various reasons, one among them is presence of nonvalue adding activities or materials which are considered as wastes (Patidar, et al., 2017). Thus identifying the wastes existing in an production system and eliminating source causing their occurrence will influence strongly on reduction of delays.

Lean philosophy promotes the reduction of wastes in an production line (Zhang & Chen, 2016). Hence, it will be utilized for identifying and reducing the wastes which are preliminary causes for delays (Brown, et al., 2008). The research gap identified is to examine if lean philosophy could be used to reduce the delays, as this philosophy usually promotes reduction of wastes. With the help of simple tools under this philosophy which will aid in reduction of delays, the most common problem of late delivery of products from a process due to excess utilization of time can be controlled. Reduction of delays enables restriction of process within the cycle time of the line, which in turn influences performance of line (Mourani, et al., 2008; Abdellatif & Alshibani, 2019). Hence it is important to explore tools of lean philosophy which aims at identification of the source causing delays and reduction of the same. This specific problem is identified and chosen for the current study as it is important to explore the influence of lean philosophy in optimizing delays whilst majority of the previous existing researches have addressed the influence of lean philosophy on reduction of wastes.

1.3 Aim and Research questions

The purpose of this project is to investigate the influence of lean philosophy in identification and reduction of delays associated with performance of production line. Based on this purpose following research questions have been formed,

1. *How does lean philosophy aids in identifying root cause of delays in production line?*

The second research question is essential in the analysis stage of research and is helpful in exploring the effects of lean tools in investigating the root causes of a delay. This research question also helps in identification of most common cause of delays.

2. *What are the major root causes of delays in production line?*

Research question 3 is framed with a necessity of identifying right lean tools under lean philosophy which aids in reduction of delays. This research question also helps in exploring the impact of reduction of delays on performance of production line.

3. *How does lean philosophy influence reduction of delays and enhances performance of production line?*

1.4 Delimitations

This project aims in exploring the impact of lean tools for reducing the delays in a process but does not promote any other operational tools from different production strategies. This study involves a suggestion of solution regarding increase in performance of line through reduction of delays, but the lean tools proposed in the current research only promotes effective use of men, machinery and methods without any aid of automation. The results of this study promote the positive impacts of using certain lean tools for increasing performance in production line and does not include all the lean tools as some of the lean tools are associated with automation and high investment for implementation.

1.5 Outline

This report includes six chapters depicting the study conducted. The first chapter provides information on background of lean philosophy and delay. This chapter also describes the purpose of this research and associated research questions of the study. It also outlines the delimitations of the study conducted. The second chapter describes the research approach adopted and methodology through which research is conducted. The third chapter in this report highlights on the theoretical framework of the lean philosophy and principles associated with it. This chapter also outlines certain tools of lean philosophy used in the research for identifying the source of occurrence delays and also recommended tools for solving them. In the fourth chapter findings of the research has been presented from the empirical data collected during research, further analysis is carried out in the next chapter to identify the suitable solution for root cause of the problem. In the discussion chapter majority of research questions are answered along with the discussion of methods chosen for study. Research is concluded with a future scope in the final chapter.

2 Methods and Implementation

2.1 Research Process

A qualitative research setup is selected for this study and deductive approach is used which will promote theory generating study as the subject of the study requires a deeper understanding for the analysis to be carried out (Williamson, 2002). This study also involves certain quantitative data from the company which has to be analyzed before producing results or providing solutions for the problem. As a part of qualitative study literature study, a case study under which semi structured and unstructured interviews and observations were conducted (Gill, et al., 2008). Triangulation method is adopted to increase the external validity and reliability of the research in this study (Leedy & Ormrod, 2019). A single case study is used for the research which involves both qualitative and quantitative data from the case company which will be used along with the data available from the previous researches to analyze the problem from the case and provide solution to connect the gap identified in the research. Data is also collected by conducting a literature review for analyzing the problem from case study and recommending solution. According to Saunders (2012), the overall strategy adopted to satisfactorily answer the research questions framed ensures the research quality (Saunders, et al., 2012). The flow of data in the research is explained below schematically in the Figure 1 which provides a view on strategy adopted for the research approach.

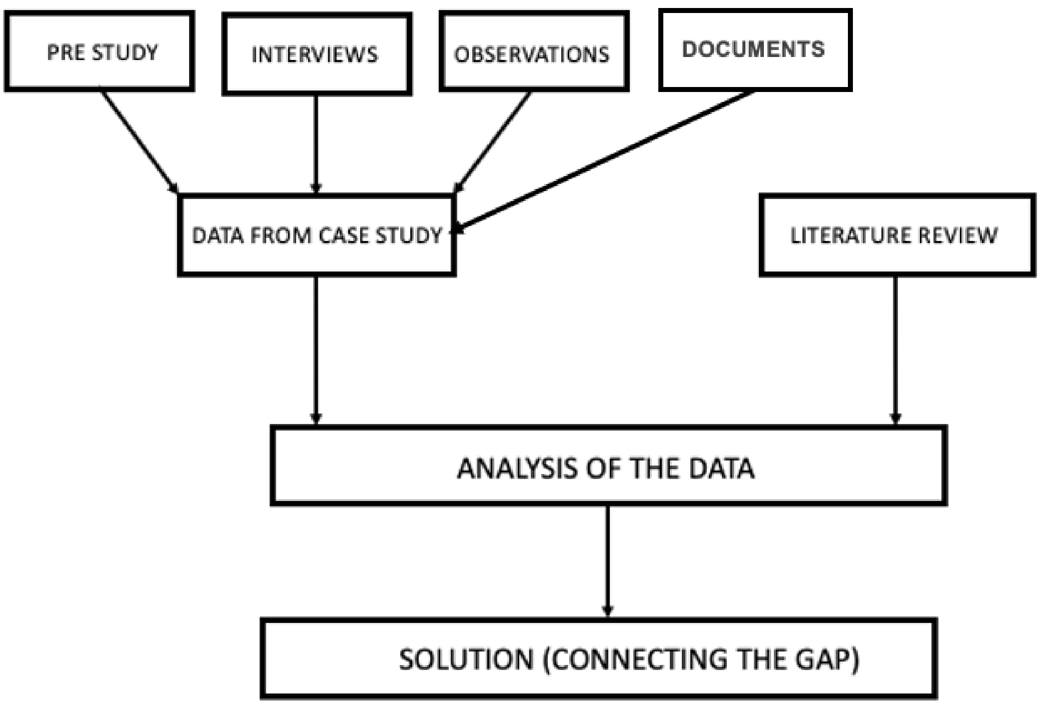


Figure 1: A schematic representation of flow of data in the research.

The process of research adopted for answering the research question is inspired from front half of aircraft structure which is explained in a schematic representation below in Figure 2 the three research questions are considered as different parts of an aircraft which drives the aircraft in one direction. The first two research questions form an essential part of research like wings of an aircraft to balance the movement of aircraft in one direction. This research involves three research questions which sums up to fulfil a major purpose of research out of which each will be answered during different stages of research. The first research question will be answered by utilizing data from observations and interviews carried out at case company along with the information acquired from existing literature sources. The second research question will further be resolved during the case study analysis of the report with the help of data obtained from literature sources and will also investigate the influence of lean tools in identifying the root causes of a delay. The final research question framed will be answered through a discussion regarding the synthesis of RQ1 & RQ2 which will be essential in providing a solution for the problem defined in the research. All three research questions summed up together will resolve the main purpose of the research and will help in investigating the impact of certain lean tools under lean philosophy on identifying the delays and reducing them to increase performance of line.

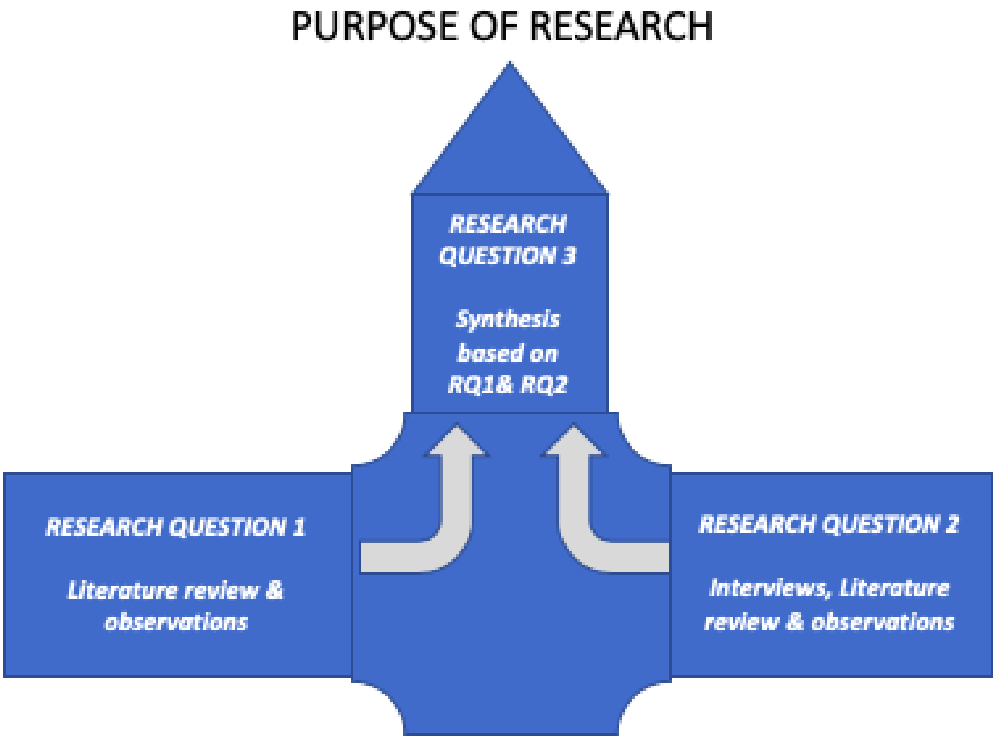


Figure 2: A schematic Representation of Research Process.

2.2 Literature Review

The literature review in this study is used for exploring theoretical background related to the area of study and also for data collection as a research strategy (Armitage & Keeble-Ramsay, 2009). The literature search was conducted using databases like

Scopus, Google Scholar along with “Primo”, a search engine of Jonkoping university library. A snow balling technique was utilized to identify right source of data, because of which Scopus was selected as suitable database for majority of data collection. It was also convenient to carry out a systematic literature search under a single platform. The following keywords, “lean tools”, “delays”, “process time”, “productivity”, “performance”, “lean wastes management” to produce number of hits. Adopting snowballing technique and using bibliographic search fliers enabled ensuring quality of research (Booth, et al., 2016). Further different search combinations were used along with Boolean method to filter the search. Initially literature sources were filtered based on language (English), subject area (Engineering) and publication stage (published and peer reviewed). Secondary screening was carried out by skimming through the title and abstract of the literature obtained from first stage to produce literature relevant to the subjects required for research. This requirement of the subjects for conducting research was considered as theoretical framework and has been represented in Figure 5. Data obtained from the Literature review was used primarily for identification and analysis of a problem pertaining to area of research, specifically for the current case. But it was also used to gain a deeper understanding on certain topics related to area of research. Complete screening process has been explained schematically below in Figure 3 followed by the list of number of selected articles with respect to keyword used for search in Table 1.

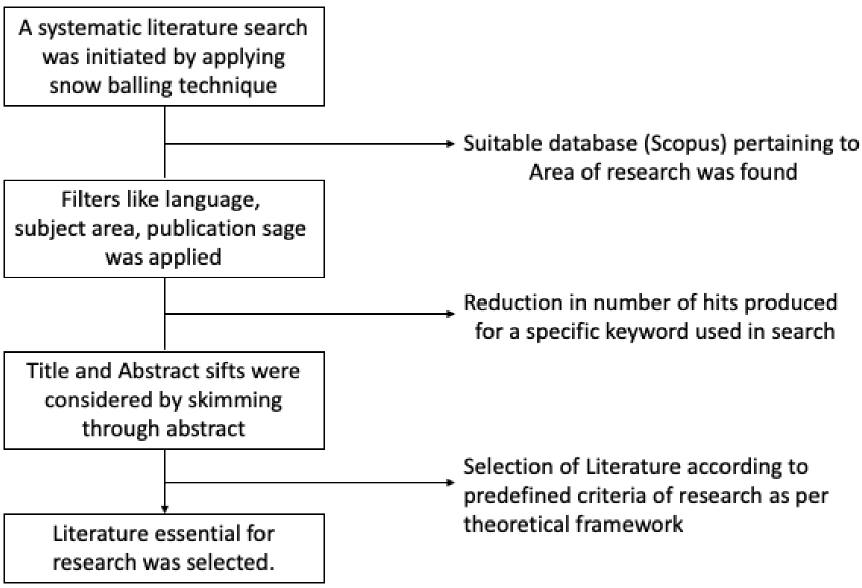


Figure 3: A schematic representation of screening process adopted to find literature sources.

Table 1: A table representing number of hits produced throughout screening process

Sl.no	Keyword used for search	Number of hits produced without screening	Number of hits produced after first screening	Number of selected literatures for research
1	Lean Wastes	4287	2604	9
2	Lean Tools	6791	3544	5
3	Bottleneck Analysis	23671	6608	7
4	Delays	4837	1634	5
5	Spaghetti Diagram	64	62	1
6	PDCA	1375	450	3
7	5 Whys	21879	1802	2
8	SMED	481	448	4
9	Root Cause Analysis	20999	7165	3

2.3 Case study

A case study is an essential type of qualitative research method which can be used for exploring a contemporary case in a real-life condition (Yin, 2002). Case study carried out has to be clearly investigated and a fine examining must be conducted (Bryman & Bell, 2011). Exploring deeper in a single case study will help in increasing the quality of the research instead of exploring multiple cases (Dubois & Gadde, 2002). In this current study it has been essential to support the problem addressed through a practical case from any manufacturing firm thus a case study is adopted which includes data collected through observations and interviews for a specific case and will support the analysis of the problem with the help of data from a practical scenario related to a manufacturing company.

2.3.1.1 Case company

KABE Husvagnar is a caravan production company located in Tenhult, Jonkoping region of Sweden. This industry is known for its service and cost for products quality along with achieving customer requirement. Amongst several departments in KABE, project will be carried out in the production line because academically major stream of research was restricted to production. In the production line the current study was conducted prominently in press line where the important parts like walls and floors were built using press line and a milling machine further sent out to assembly line. This company has been chosen for the case study because the company includes operations with no automation and works with push strategy of production which provides a platform for developments and identification of problems associated with delays. The current study only involves an single specific case from company KABE Husvagnar AB and does not include any other cases from the company.

2.3.1.2 Pre study

Rapid plant assessment was carried out at the company by one of the researcher in order to understand the current working condition of the company (Goodson, 2002). Although one of the researcher possessed a view of the company from previous study conducted during the previous spring as a part of internship. The other researcher was unaware about the functioning of company and previous study conducted. After the rapid pant assessment was conducted, the results were discussed among the researchers of this study to further understand the functioning of the company, prominently the press line. Data from the previous study and rapid plant assessment conducted was summed up to define a problem in the press line which was considered a bottleneck of the whole assembly line as this is the initial process of the assembly line where the floors and walls are built utilizing press machine and milling machine and variations in delivery from this line could affect functioning of whole assembly line. A short interview with the production manager also confirmed that the defined problem was considered as a bottleneck by the company. Further this problem identified was discussed with the supervisor in order to analyse the scope behind this subject, after a couple of meetings held the proposed problem was modified into a subject for the research and the company problem was considered to be a case to be solved by analysing data from the company along with the data available from literature sources. The pre study was concluded proposing subject of the research, further study focused on identifying the major causes of this problem.

2.3.1.3 5 Whys

Ensuring collection of relevant data essential for the research plays an important role, as unnecessary data collected reduces the trust worthiness of the study. Thus, a comprehensive definition and breakdown of problems identified was carried out through 5 whys technique considering its ease for implementation. This lean tool has been essential in identifying the root cause of the problem defined by a simple procedure of inquiring any problem with the aid of why several times in a row (Borkowski, et al., 2012). The reason for adopting this technique relies on ease of handling tool and efficiency of results (Borkowski, et al., 2012). The tool basically includes several steps until root cause of a problem is identified by inquiring and answering the same through logical thinking. In the current study, during this process an important area (delay) of research was identified and also its root causes were located. This demonstrates the process of 5 why analysis conducted and highlights the utilization of a lean tool in problem identification. The process adopted in the current study was predominantly an initial step in data collection which was essential to increase the relevancy of data collected and also to identify the major root cause of problem as unwanted wastes or excess wastes existing in the press line. Based on the evidence of existing wastes each waste was further inquired with this tool at second stage to identify source of its occurrence which has been presented in analysis section of report and has also been tabulated in Table 21. Thus, basically study involved two stages of 5 whys where first stage was conducted prior to analysis and second stage was conducted during analysis of study.

2.3.2 Data collection methods

2.3.2.1 Observation

Observations includes a physical setting where in the researcher is closely involved to ensure the method and quality of data collected (Bryman & Bell, 2011). Observations for this study has been carried out by researchers in the press line to identify the delays and reason for the delays caused by closely observing the activities around the press line and also noting operator movements with the help of spaghetti diagrams, time study and operator risk analysis. A sophisticated observation carried out supported by interview will increase the quality of research conducted and will ensure collection of secondary data (Saunders, et al., 2012). In the current study, observations were carried out in a press line which included a press machine followed by milling machine where the floors and walls were produced for different models of caravan. Observations were also carried out during daily meeting between supervisor and operators to identify whether the flow of information was encouraged from both the ends. After the root cause of problem was defined it was important to identify existence of these root causes in the line for the purpose of which initially observations were carried out in the press line to identify wastes which are visible. The findings from observations made has been presented in section 4.1.2 of this report.

2.3.2.2 Interviews

Interviews are one of the highly efficient methods used for data collection as the interviewer gets an opportunity to explore specific subject with personnel closely related to subject or activity carried out (Bryman & Bell, 2011). Interviews can be categorized into structured, semi structured and unstructured interviews (Williamson, 2002). For this study semi structured and unstructured interviews are adopted as they promote qualitative research and help the researcher to carry out an explorative study in the field of research (Saunders, et al., 2012; Williamson, 2002). In the current study interviews were carried out with operators, supervisor of the press line and production manager.

Production manager was the major source of data from the case company and was often interviewed about the queries arising regarding case, but the major outcome from the production manager was during initial interview where he specified about bottleneck of the line and also added how performance is often low in the line due to late delivery. Short structured interviews have been carried out with operators of the line to understand the problems associated with the line and also to analyze certain root causes arising which affects strongly on delays. These structured interviews were carried out by providing operators certain questions to be answered and has been disclosed in 9.1. Operators of the line were also quickly interviewed about the problems often faced by them because of which unnecessary stops occur in line. Further supervisor of the line was interviewed to confirm the results from observations and previous interviews. During this interview questions regarding percentage of defects occurring in the line, quantity of parts produced per day by the line when compared to its utilization and other areas pertaining to education and training of operators in the line were answered.

Table 2: A table representing interviews and its duration

Sl.no	Interviewee	Type of Interview	Issues addressed	Duration	Date
1	Production Manager	Unstructured	Problems in the line	15 minutes	30/01/2020
2	Production Manager	Unstructured	Identification of Bottleneck	10 minutes	13/02/2020
3	Operator	Structured	Knowledge about other operations in the line	10 minutes each	02/04/2020
4	Operator	Unstructured	Problems faced in the line	5 minutes each	02/04/2020
5	Supervisor	Unstructured	Training and assigning roles of operators, production varieties and quantity, percentage of defects	20 minutes	24/04/2020

2.3.2.3 Production Records

Conducting a document analysis will aid increasing quality of research through triangulation method as it is considered as a quantitative method (Williamson, 2002). Although this study did not involve complete analysis of production documents, data received from the company with respect to stops occurring in the press line was analyzed to identify stops which occur frequently and their time intervals. A excel data sheet received from production manager portrayed the existence of number of stops in the press line which was considered a bottleneck as the line itself initiates completely assembly line by production of walls. This data confirmed the existence of stops and frequent occurrence of stops due to lack of resources available. Analyzing this data as per production manager guidance, stops occurring due to personal breaks, stops due to elements missing and stops pertaining to maintenance were identified. Although a number of unidentified stops were observed from the data it was informed by the production manager that at most of the times operators failed to input the reason for the stop which was materials missing or error in program code for the milling machine. The data from document analysis confirmed the existence of stops due to unavailability of the materials which was also observed during observations as operators were waiting for the resources from previous station and were also found looking for materials during process.

2.3.2.4 Spaghetti diagram

Spaghetti diagram as a lean tool generally is utilized to identify the movement or motion of an activity or operator and further to reduce the unwanted movements carried out during the process to increase value added time (Gladysz, et al., 2017). The procedure also involves recording of time along with spaghetti diagram to accurately verify the time consumed for an activity performed (Gladysz, et al., 2017). Through spaghetti diagram the rectification in movements can be carried out by elimination of unnecessary movements in a process. In the current study spaghetti diagram was only used to identify the problem of unnecessary movements in case of their existence and hence was technique used in collection of data and was not utilized for solving the problem. As discussed above it was essential for the research only to identify if excess or unnecessary movements are created by the operator in the line at case company which did not involve any time studies. The process involved depiction of operator movements around the press line by drawing curves on a view of plant layout and further analyzing movements of operator by comparing the pattern obtained for different operators from two different shifts. The procedure utilized for this process was derived from Gladysz (2017) and is similar to it apart from the time studies and resolution of problem. The analysis of the derived pattern of curves from spaghetti diagram for different operators is further conducted in findings and analysis chapter of this study.

2.4 Analysis

As mentioned before study involved implementation of 5 whys tool at two different stages of report. When problem of delay was identified in the line first stage of 5 whys was carried out to identify root cause which produced existence of (7+1) wastes as result. Data collected requires effective analysis to produce an efficient output of results. Hence, the collected data regarding 7+1 lean wastes existing in the line was rated by considering its way of impact on delay, effects on the line and occurrence. The rating was provided as a collective input from both the researchers by considering all three factors discussed above. For each of the waste identified rating was provided in between 1 to 5, where 1 highlights no direct impact on delay and effect on the line, 1 also highlights waste unidentified in line and 5 highlights direct impact on delay and effect on the line by influencing nonvalue adding activities. Table 19 represents the rating criteria adopted for analysis and the factors influencing the rating provided for each waste is explained further in analysis chapter. After rating the identified wastes, second stage of 5 why analysis was carried out to further inquire root cause of each waste which was influencing delay in delivery of products. The second stage of 5 why analysis was carried out on each waste based on their evidence of existence and rating provided. At the end of second stage of 5 whys root causes of delay were identified which has been presented in section 5.1.3, for which recommendations have been provided in this study for minimizing them.

A figure below outlines process of analysis adopted for current study in a nutshell and provides a clear view on process of analysis. This figure also outlines all the methods utilized for collecting data from case company and analyzing them.

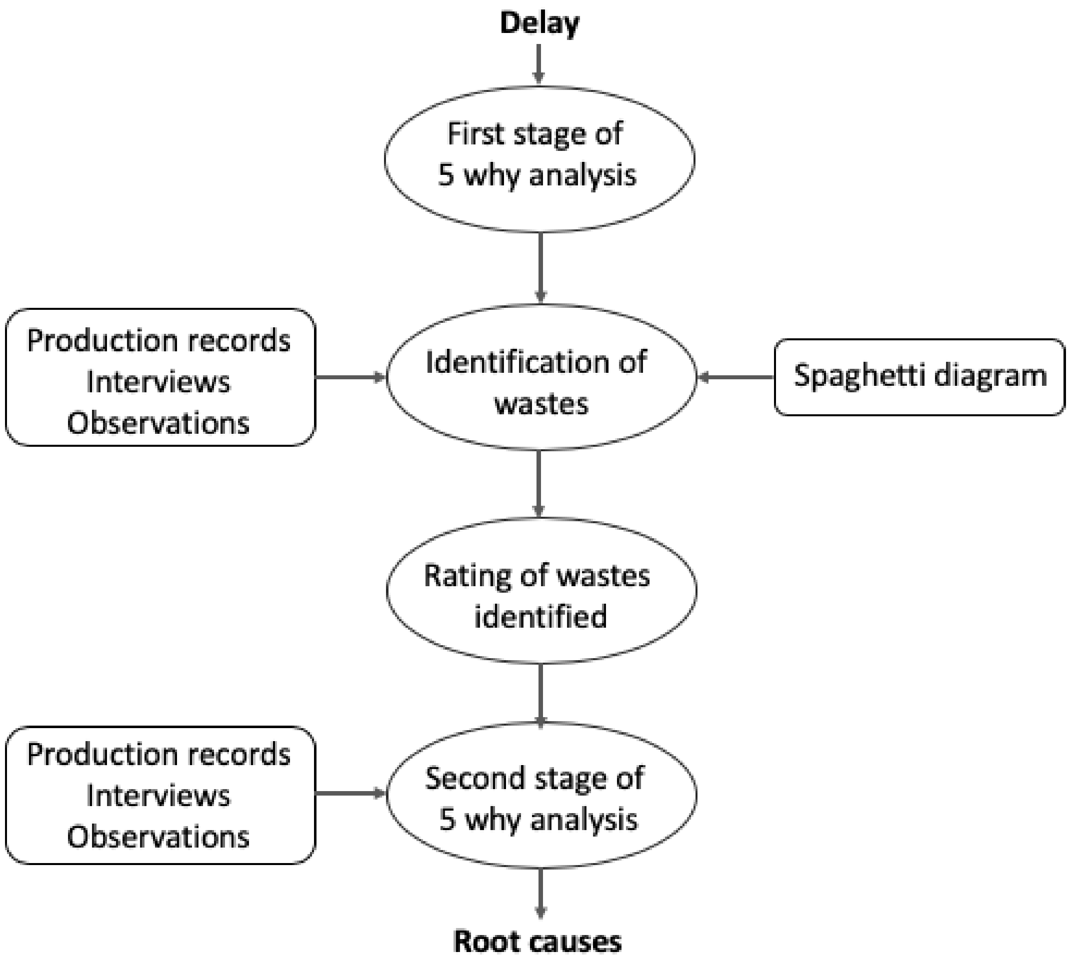


Figure 4: A schematic representation of analysis of data from case.

2.5 Research Quality

The study includes a systematic process of data collection within a framework developed for this purpose ensuring the research quality and trustworthiness of the report to be maintained at higher standards. Internal Validity of the research will be high as the research involves qualitative data from a single case study (Williamson, 2002). Triangulation method is used for mixed approach (qualitative and quantitative data) in this study which will also influence in increasing the validity of the study (Williamson, 2002). Utilizing quantitative methods like spaghetti diagram analysis and document analysis along with observations and interviews from the case has provided grounds for triangulation method which increases quality of research. Systematic literature review technique has been adopted to explore literature from different sources and identify the precise data necessary for the study which adds on to external validity and reliability of the research. But the reliability of study could vary because of unstructured interviews conducted which has been controlled by conducting observations and analyzing production records.

3 Theoretical Background

This chapter briefs the theoretical background of the area of research. In this project the theory is used basically for two different reasons the first one is to provide a clear and deeper knowledge about the area of research and the factors influencing them. Later is used to analyze the problem with help of existing tools of lean philosophy in production system which enables solving the current problem.

The Figure 5 portrayed below demonstrates the requirements of theories discussed in this chapter and also explains how they are further utilized during research process in identification of problem and also solving that problem.

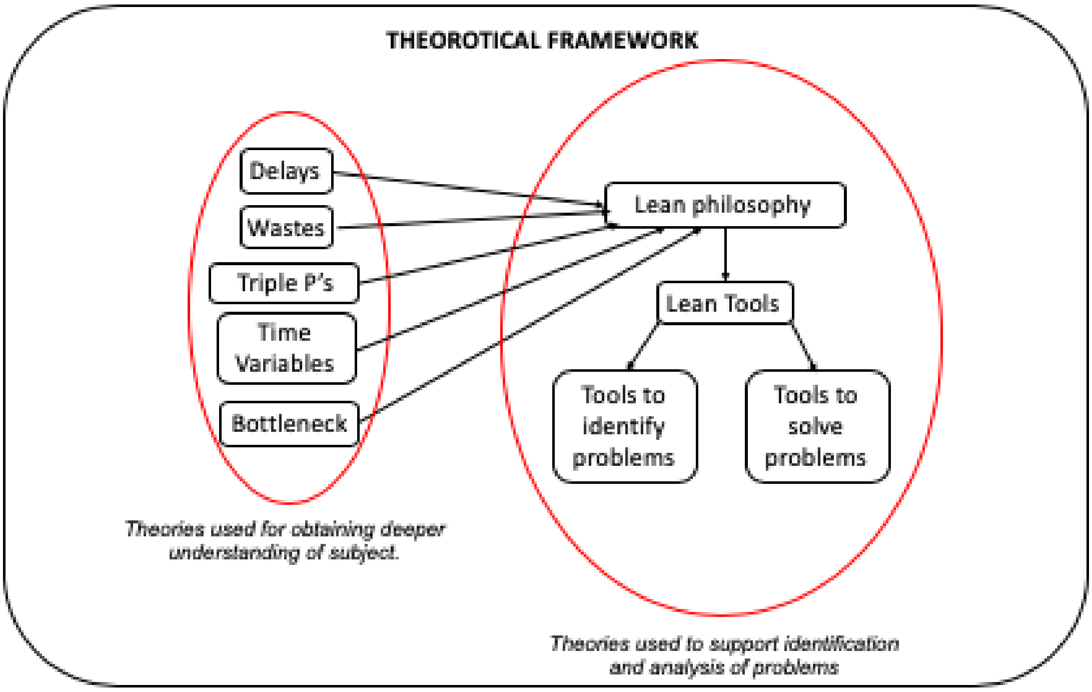


Figure 5: A schematic representation of theoretical framework of the research.

3.1 Lean Philosophy

The ever-growing competition among the firms in the global market is increasing due to which companies are bending towards an approach which gives more flexibility to face challenges (Zhang & Chen, 2016). Lean philosophy is an approach which focuses on improving processes, practices, quality, and performance (Hicks, 2007). It is a kind of framework which can be applied to a system to identify the critical areas of improvement in the form of wastes and defects. The lean philosophy deals with continuous improvement and hence identify different tools which can help in the process (Hicks, 2007). The philosophy hence focuses on eliminating the unnecessary actions and linking all the steps in creating value (Nurcahyo & Kristihatmoko, 2010). Lean philosophy also encourages just in time production for delivering right quantity of products at right time, along with elimination of actions which do not create any value to end product (Lyonnet & Toscano, 2014). In general transformation, it applies techniques such as 5 why's, SMED and other lean tools to eliminate the 7+1 wastes. This philosophy also helps in reducing the non-value adding activities and ultimately generating value to the process (Sternberg, et al., 2013). The advantage of adopting lean philosophy is it improves quality, speed, efficiency and cost reduction (Pinto, et al., 2018).

3.2 Lean Wastes

"Waste is defined as any and all resources spent beyond what is strictly necessary to perform a service or make a product (raw material, materials, human resources, time, money, energy, etc.)" (Cancado, et al., 2019). The companies today focus on productivity and the ways through which it is improved. To achieve higher productivity the focus is primarily on minimizing the activities those are non-value adding (Cancado, et al., 2019). To eliminate these wastes manufacturing companies are adopting the method of lean manufacturing. This lean approach helps in minimizing the unevenness of workload, wastages in terms of time, money and resources. Overall lean approach will help in improving productivity, speed, delivery etc. With the implementation of lean manufacturing several lean techniques are applied in which concepts of seven wastes can be taken (Hill, 2018).

3.2.1.1 Defects

The one of the most frequently occurring type of wastes is the product defects. The important factor to eliminate these kinds of wastes is to identify the reasons or causes for these defects to occur. These defects thus cause delays during the process having an adverse effect in the productivity and performance. Hence finding the essential solutions to eliminate the defects is equally important. Before finding the solutions, it is important to find the defects in the product, failing to do can result in decrease in brand value leading to loss for the firm (Nurcahyo & Kristihatmoko, 2010). Main reason for the defects is the process design (Essid, et al., 2018). Also, defects can be due to rework or scraps, to solve the problem identification of the issue that occur more frequently needs to be identified. Rectifying the process design, making the process smart to eliminate the defects can also be introduced. Defects results in extra cost as well and time which will decrease the productivity of the manufacturing firm. This kind of wastes do not add value for the money which will hence increase the manufacturing cost (Hill, 2018).

3.2.1.2 Transport

Movement of materials from a position to another position is generally referred as transport. Transport can lead to waste which occurs due to the movements of machines, tools, employees, inventory etc. Excessive Transport can have an adverse effect which can lead to financial loss. More transportation leads to greater time taken, this will in turn lead to delays hindering the further process. It is very essential to reduce the travel distance as to avoid any damage or failure in process or a product. More the distance covered by humans, quicker is the probability to get exhaustion. Transporting a material is not value adding activity for a product, hence it is essential minimize the distance that is being covered for transporting the product. Lesser the transportation time, the production process also takes less time (Hicks, 2007).

3.2.1.3 Overproduction

Companies around the world different ways in production. Since companies prioritize time and money companies are leaning towards a lean approach. But when companies have idle workers it is a common approach companies adopt where they start producing without any order. This leads to producing products in more numbers rather than producing in exact quantity that is required (Hicks, 2007). Generally, companies have varied principles in production, however in a lean approach production is done based on the exact number of components that are required. Overproducing components can lead to increase in inventory and gradually leads to decrease in the value of the product. Producing components in the number that is required is a way to reduce overproduction. The possible reasons for over production to occur is due uneven scheduling and unbalanced workloads. Moreover the problem of overproduction can be dealt with use of takt time where takt time ensures that time taken for manufacturing is even between the workstations (Douglas, et al., 2015).

3.2.1.4 Waiting

Waiting refers to the lagging or halt occurring in a production process. This is also sometimes referred to as queuing. Waiting leads to increase in takt time and ultimately decreasing the efficiency and productivity of the manufacturing company. Waiting can be due to various reasons such as machine breakdown, different kinds of errors, insufficient availability of materials. The wastes in waiting also includes the waiting time of people for receiving the raw materials. Waiting thus leads to delay between the workstation bring down the efficiency of the process. Generally, the reason for these wastes to occur is due to the uneven production process which can also lead to inventory and overproduction. With lean approach it is possible to eliminate the waste. Use of effective lean tools to solve this type of problem is mandatory. Also, it is important to find the reasons that lead to these wastes and try eliminating it (Hicks, 2007).

3.2.1.5 Extra Processing

Extra operation that needs to be done for a component is termed as extra processing. In other words, extra processing is doing more work than required. In a manufacturing firm it can be due to addition of a process, component etc. Operations such as rework, reprocessing, handling of storage which are the consequence of defects, overproduction and excess inventory. The reduction of these extra processing adds value to the product and hence minimizing the non-value adding activities carried out during the manufacturing. To prevent these problems, one way to deal with it is to have more precision in the tasks that is being performed. Having a flexible approach is another way to deal with extra processing, this is performed with having more functionalities in the processes. More significantly producing items looking at customer requirement and quality for which production takes based on the quantity required (Hicks, 2007).

3.2.1.6 Motion

An unnecessary or an unwanted motion that an employee needs to perform such as looking around, reaching for items or piling up tools or components results in delay. This accounts to a nonvalue adding activities. Walking around the shop floor also accounts to the unwanted motion (Sternberg, et al., 2013). The waste can also be generated from unnecessary movement of machinery. The human waste created can be from lifting, stretching, walking, bending etc. Motion waste are seen as a negligible kind of waste but in reality, they play an immense role in improving the manufacturing firm. The strategy which can be applied to eliminate the waste is creating more in less space. This will help in less movement of workers which in turn results in decrease in manufacturing time as well as increasing productivity (Hicks, 2007).

3.2.1.7 Inventory

Inventory process is an having a great value in a manufacturing company. Inventory are generally classified into three categories the raw materials, work in process and the finished goods. Inventories are used to improve the productivity and profitability of the manufacturing firm. However, having a poor inventory can have an adverse effect. This can be due to the lack of idea on the amount required and already available in the warehouse. It is also important from the company to have proper and efficient communication between the departments to address the inventory problems (Cheng, 2017).

3.2.1.8 Non-Utilized Talent

From a long time, it has been stated that lean manufacturing is termed as doing more with less. Lean manufacturing has dealt with continuous improvement and the latest waste to be recognized is the skilled or the non-utilized talent. This is considered due to underutilization of the human talent in the manufacturing firm. Under-utilization occurs when there is bridge between the management and the employees. Some of the reasons for non-utilization can be due to poor training, lack of communication, pay structure (D'Antonio & Chiabert, 2018).

3.3 Lean Tools

The most common challenges today the companies face is the increased inventory, delays and other non-value adding activities (Meade, et al., 2006). Lean manufacturing will help in facing these challenges with the help of lean tools such as spaghetti diagram and single minute exchange of dyes (SMED). Lean tools help in improving knowledge and helping in turn with solving constraints and making further improvements (Zhang & Chen, 2016). Also, it helps drastically in eliminating the non-value adding processes and reduce other wastages that occur during the production (Benjamin, et al., 2013). With the help of lean tools, it is possible to improve productivity in a production process by changeover time reduction (Ahmad & Soberi, 2018). These tools also assist in picturing the possible causes leading to the specific problem and will be essential in improving the performance of the production process (Marius, 2012).

3.3.1.1 Root cause analysis

Companies all over the world deal with problems to which they try to find the solution. Identifying the reasons for the cause of these problem is an ideal way to deal with these problems. The best possible way to deal with this is to find the root cause for the problems to arise. Root cause analysis is a tool designed to help recount what happened during an incident. Root cause analysis can be made through different analysis tools such as pareto chart, 5 whys and the fishbone diagram (Ashok Sarkar, et al., 2013). The best definition to describe root cause analysis is quoted as follows:

> *"The most basic cause that can be reasonably identified and that management has control to fix"* (Paradies & Busch, 1988).

The above statement mentions three terms which needs to be extracted further to get a conclusive to deal with the problems.

- **Basic cause**: Tries to identify the reason to why the problem occurred and drives to a corrective plan to rectify the failure. This is done to prevent the recurrence of the failure that happened (Paradies & Busch, 1988).
- **Reasonably identified**: makes sure the investigation for the failure that occurred is completed in the legit time frame (Paradies & Busch, 1988).
- **Control to fix**: It involves the management and higher level employees who have the rights to establish the controls, protocols and ways through which recurrence of the incident can be avoided (Paradies & Busch, 1988).

3.3.1.2 Five why's

Lean philosophy today is at the center of operation management and quality improvements in the manufacturing firm. The driving force of the lean philosophy is the goal to eliminate the lean wastes that generated which can help in improving the productivity and reduce the non-value adding activities (Brown, et al., 2008). To eliminate these wastes identifying the root cause is an essential factor. To identify these causes in lean manufacturing 5 whys analysis is made. The 5 whys method is a way through which identification of causes of problems and failures are detected by asking a question why. By asking the question why, the greater number of times it becomes easier to understand the reason and come to a solution (Borkowski, et al., 2012). This helps in getting to the root causes of the problems. It will then help to get remedies to eliminate the problems faced by the manufacturing firm. The main advantage of this method is its ease of doing and the efficiency in terms of results. The method can be implemented in all the companies. Although, the it requires the logical thinking and problem identification (Borkowski, et al., 2012).

3.3.1.3 PDCA Cycle

In a lean philosophy, the major concern is the lean wastes such as defects and process that are being generated. To reduce it various tools, need to be used to get hold of these wastes (Maruta, 2012). The PDCA cycle plays a decisive role in implementation of cleaner production. The PDCA cycle is a tool used to improve the quality of the products, eliminate defects and to develop improvements in the organizations. It is simple tool used for continuous improvements in the production processes in the organization (Sokovic, et al., 2010).

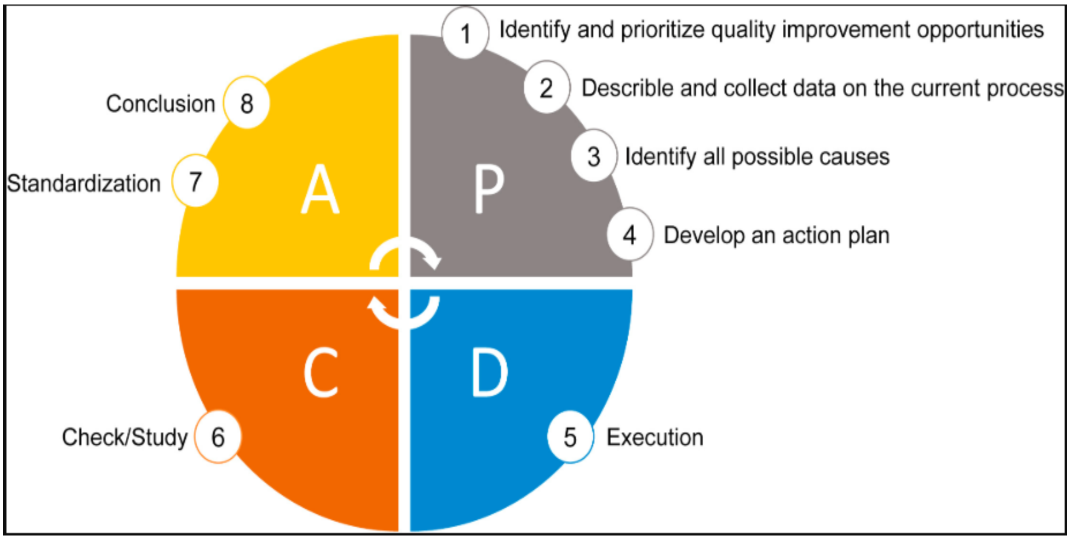


Figure 6: A figure explaining the process of PDCA cycle (Silva, et al., 2017).

PDCA is a stepwise change and can be understood as follows:

Plan: It is the initial phase of lean manufacturing where the management leadership must provide the necessary support in terms of money, manpower, resources and time to the lean team for successful implementation. This phase highlights the prospects for improvements are identified. The current approach is investigated with the help of data and probable reasons for the problems are identified for which possible actions to mitigate are provided (Silva, et al., 2017).

Do: This stage is the execution phase where the requires tools, concept and practices are identified and trained to the employees. This step is for implementation of the action plan. Here selection of the documents containing data are made. Also, the unexpected events that take place are also noted down (Silva, et al., 2017).

Check: This step acts as a check point to evaluate the lean performance. This is to analyze whether the lean changes made are effective and providing with the expected results. The expected results are analyzed. The new results are compared to that with the old results and decision is taken whether to continue with the new approach. This is decided based on the objective and goals that needs to be met (Silva, et al., 2017).

Act: This is the post implementation phase where the lean practices are seen whether they can sustain lean outcomes for long term. This to standardize the improvements if the results are met and repeat to gather new data and reassess the interventions based on the amount of data required or the situation that exists. Another way is to abandon the current project and start with the new beginnings if the results obtained are not effective (Silva, et al., 2017).

3.3.1.4 5S

5S stands for sort, set in order, shine, standardize and sustain. Conventionally, 5S methods are used for setting the physical workspace and items by eliminating the waste. This method symbolizes set of practices which are ideal in developing workspace organization and productivity by adding value to the process (Gapp, et al., 2008). This method is employed as it is a low-cost implementation and a simple approach where it is considered a starting point for an improvement. When it is inspected on the geographical context it is important to look at the factors that affect the performance such as product type, size of the company, attitude in the organization towards quality and continuous improvements (Bayo-Moriones, et al., 2010).

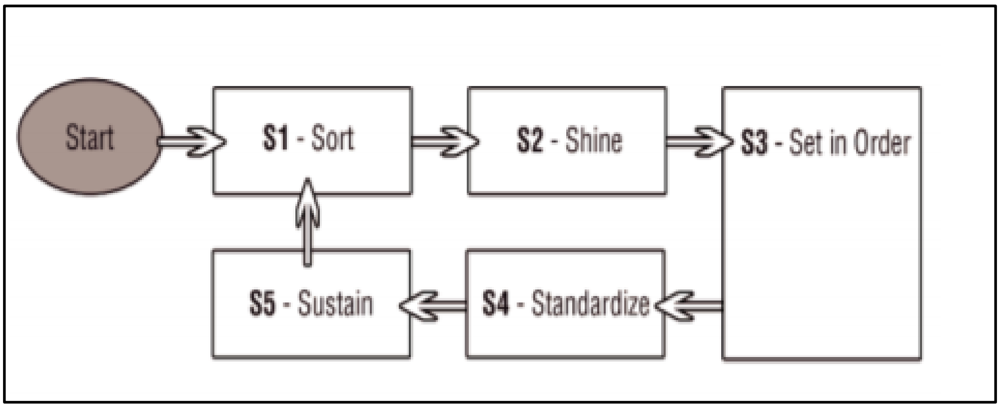


Figure 7: A flow chart representing steps of 5S lean tool (Rojasra & Qureshi, 2013).

The 5S can be explained as follows,

- **Sort**: This means the removal of needless materials, tools, equipment's and furniture's from the shop floor. A criterion needs to be used to identify the rate of their use. As a result of this there is free floor space, an improved product flow, improved mobility and better communication is attained (Pinto, et al., 2018).
- **Set in order**: In this stage the idea is to keep everything in its place. Here it deals with the placement sequencing of items after the sort step. This in turn helps in eliminating the different types of wastes, also helping in improving the quality and reducing the level of inventory (Pinto, et al., 2018).
- **Shine**: This stage deals with the cleanliness of the workspace. There is a requirement of 5S job cycle chart list where the different tasks are represented. The frequency with which these tasks are to performed is listed in the chart. This step is essential in terms of creating a safer environment, reducing defects and also reducing equipment downtime (Pinto, et al., 2018).
- **Standardize**: The main purpose of this step is to maintain the previous steps by giving some time every day in order to maintain cleanliness, prevention of extra inventory and unwanted items in the shop floor. This will help maintaining the space around the workspace which can help free movements of workers (Pinto, et al., 2018).

- **Sustain**: To have an attitude towards continuous improvements this steps executes auditing procedures in the area were the 5S is instigated, there is also a program were the group of people combining with the team leader visit other places of the shop floor to have proper inspection on the things around them (Pinto, et al., 2018).

3.3.1.5 Spaghetti Diagram

According to the recent trend the manufacturing firms are trying to minimize the non-value activities which are resulting in losses. One of the primary objectives the companies take is optimizing the plant which will help in attaining more profit and providing with necessary facilities to take best possible benefit in total manufacturing of a product. One possible way to deal for plant utilization is with the help of spaghetti diagram. Spaghetti diagram is a lean tool used for identifying the paths, items or a process by using visual representation. With the proper implementation of the spaghetti diagram it is possible to identify movements and the distance between various departments (Gladysz, et al., 2017).

The process to draw a spaghetti diagram is as follows:

1. Creating a layout diagram of the facility
2. Obtaining or creating the current routing sheet of the object movement through the facility
3. Drawing the continuous curve from the initial location to the remaining locations.
4. Total distance travelled is to be calculated.
5. Estimation of time required for the travel is made.
6. Study of the spaghetti diagram drawn is conducted and identification of common travel areas and rarely used travel areas are identified.
7. Rearranging the processes to reduce travel distance.
8. Repetition of 4-7 steps making different assumptions and using new layouts.

The above procedure for the drawing a spaghetti diagram has been derived from (Gladysz, et al., 2017).

3.3.1.6 Single-Minute Exchange of Dies (SMED)

Based on the global trend the manufacturing firms are experiencing significant development. There are also many reasons which drive the development in these manufacturing firms. Due to the flexible market where demands are not constant companies have a challenge of meeting these demands in the given time span. Companies offering different variant of products in other words customized products must deal with different changeover process. This leads to different products having different set up time which will then challenge the production facility to be more efficient in the process. To help deal with this SMED concept is adopted. SMED helps in reducing the scrap, inventory and thus helping in improving the efficiency of the production process (Sugarindra, et al., 2019).

SMED is a lean manufacturing concept which helps in improving the set-up time by reducing the time taken in order to help the improve the manufacturing firm. This tool does not require much investment. Hence, it is considered to be cost efficient tool (McIntosh, et al., 2000). The application of SMED can be done in three steps,

1. Splitting internal and external activities (Pinjar, et al., 2015).
2. Modifying the internal setup to external setup (Pinjar, et al., 2015).
3. Simplify all aspects of set up operations (Pinjar, et al., 2015).

The initial step is conducted to analyze the details of the basic operations while the latter two steps were performed simultaneously (Sugarindra, et al., 2019). Before splitting the internal and external activities it is important to perform interviews with the workers to understand the process of changeover time and the set up time (Sousa, et al., 2018).

3.4 Delays

Continuous flow in manufacturing is an essential part in making the production efficient. However, it is seen that majority of the companies all around the world face the problem from delay (Mourani, et al., 2008). Delay is defined as the outcome of ineffectiveness and inefficiency of the products in a process leading to poor performance of the production unit (Arunagiri & Babu, 2013). It is very important in a production setup to have a timely and accurate rate of supply of components, accurate information to oversee the delay (Caprihan, et al., 2013). Also, efforts need to be added to integrate the delay in continuous flow processes. Companies often find delays in material handling, design changes, improper scheduling, testing and any other non-value adding activities which occur during these processes (Mourani, et al., 2008). The causes for the delay to occur is also due to the production lead time and transportation delays which could have major impact on the production process (Mourani, et al., 2008). Delay also occur due to the delay in payments, late procurement of materials, slowness in decision making, late delivery of materials (Abdellatif & Alshibani, 2019). Unexpected stops occurring in line can lead to disturbances in process leading to case delay. Various tools such as failure mode and effects analysis (FMEA), event tree analysis (ETA) etc. are being used to either eliminate or reduce the impact of the delay (Jones, et al., 2009). The impact of delay is seen to be high as it can impact performance measures in the form of customer response and work in process (Abdellatif & Alshibani, 2019).

Reduction of delay can be accomplished by adopting the various process improvement methods as stated below:

- Process improvement by design: The process improvement seen here is as a result of changes made in the process design. A well-designed process provides results which are efficient, productive and keeps the customers happy. Solving problems does not relate to the changes in the design but it focuses on repairing the current design, reworks etc. This is a long process as constant changes need to be made depending on the type of problems (Arunagiri & Babu, 2013).

- Process improvement through prevention: To change a bad design root cause needs to be found out. Solving problems is a reactive approach wherein proper understanding of the problem to solve it is necessary. However, with the adoption of proactive approach a thorough understanding of the cause and the elimination of the reoccurrence of the problems is the priority. To eliminate these reoccurrences is to change the entire design. Higher percentage of companies however adopt the reactive approach due to factors such as deadlines, demand etc. In these situations, the priority will be to fix the problems. For this identification of the root cause of the problem is essential (Arunagiri & Babu, 2013).
- Process improvement through simplification: *"Process improvement is about process simplification. Reducing defects and variance or shrinking cycle times and speeding up a process involve removing needless activities, time delays or design flaws"* (Arunagiri & Babu, 2013). Contrarily, solving problem leads to addition of steps. However, process improvement is about prevention and avoidance (Arunagiri & Babu, 2013).

3.5 Time Variables

Production unit in companies are dependent on the various time variables such as process time, takt time and cycle time. These time variables are closely related to productivity and performance of the system and hence any sort of delay occurring in the process which effect the time variables will results in variation in performance in the system (Wu & Hui, 2008).

3.5.1.1 Process time

In the era of automation process time plays an influencing factor in a production set up. The effectiveness of production and the accuracy of cost which is been estimated is very much dependent on the process time (Nagahara & Nonaka, 2018). The process time is the actual time taken from the start of a process till the products have been transformed into finished products. Increase in process time inversely effects the overall production phase as well as the design area (Nagahara & Nonaka, 2018). The process time should be within the prescribed cycle time. The production rate also increases if the criteria is met. The reason for process time to exceed the cycle time is due the delays or que within the workstations (Veeger, et al., 2010).

3.5.1.2 Cycle time

With constant improvement around the global market and need for shortening the cycle time to boost up the production and to have a competitive advantage over the rival firms meaning cycle time is an important factor in today's production setup (Li, et al., 2018). Cycle time is the amount of time taken from the start of the work till the item is being delivered. Cycle time is also explained in terms of little's law where work in process is divided by the throughput (Turpin Jr, 2018). For having a good enterprise resource planning (ERP) in a company it is important to have an efficient production planning. A well-designed production plan is always dependent on the cycle time, which hence makes it more important to have this function (Wang, et al., 2018).

3.6 Bottleneck

In a production setup there are various kinds of managerial problems are found. One that creates lot of buzz is the bottlenecks within a production process. Bottlenecks have a negative effect on performance in the shop floor (Thürer & Stevenson, 2018). To solve the adverse effect, it very important to identify the bottlenecks. Bottlenecks create lot of variation in a production process. The common reason for having bottlenecks are due to lack of workforce and machine failures. Bottlenecks further creates downtime within a process which causes delay in the system (Li, et al., 2009). Reducing a bottleneck is considered as the most effective way to improve a manufacturing system.

In order to eliminate these bottlenecks, understanding the larger system is important as no system will move ahead than the slowest component (Slack & Lewis, 2005). Removing bottleneck can be either by eliminating or just acknowledge them (Johnston & Clark, 2005). The identification of the bottleneck areas and finding out the reason for their causes can be termed as bottleneck analysis (de Bruin, et al., 2005). The bottleneck analysis framework is dependent on four main factors: supply, demand, quality and the environment (Yawson, et al., 2017). Bottleneck analysis can be divided into two steps: to give importance to maintenance and production improvement activities. The first step includes the identification of machines in the production system which constitutes to the bottleneck. The second is to provide indicative insights into type of bottleneck (Subramaniyan, et al., 2018).

3.7 Just in Time (JIT)

Just in time is a concept which aims to meet the necessary requirements while offering perfect quality and zero wastes (Hirano, 2009). Also, just in- time production is one of the main lean principles under lean philosophy, which refers to producing only *"what is really needed, when it is needed, and in the amount needed"* (Lyonnet & Toscano, 2014). It also focuses on the pull flow production during the production based on the requirements of the customers. This system will help the manufacturing companies to manufacture products based on the exact number required. Thus, helping in minimizing the inventory space required, reducing the changeover costs and overproduction (Lyonnet & Toscano, 2014). Thus, manufacturing companies should improve their capability to produce maximum products at a high quality, within the required time and with the lowest costs (Thomopoulos, 2011). With the help of JIT it is possible to supply whatever materials is required and whenever required. JIT focuses mainly on reduction of 7+1 lean wastes which are present in the production process. JIT also emphasizes on continuous analysis of production line through lean tools such as 5S and SMED. This will further help in eliminating the non-value adding activities hence leading to value creation (Hou, et al., 2011).

3.8 Triple P model

Productivity and performance are the terms which are commonly used in academic and commercial sector however they are definitions are defined adequately. These terms are usually linked with terms such as effectiveness, efficiency and profitability. The three P involved in the triple model are productivity, profitability and performance. The description of the terminology helps in capturing the difference between them (Tangen, 2005).

Productivity: "*Productivity is defined as the relation between output quantity (i.e. correctly produced products which fulfil their specifications) and input quantity (i.e. all resources that are consumed in the transformation process)"*. Productivity also focuses on achieving efficient outcome through effective utilization of the resources. Effective utilization of resources intends exact quantity of materials, tools and machinery utilized without any excess or inadequate consumption of resources. Since it is difficult to measure the different quantities by the same standard, the productivity concept is thus considered to be a physical phenomenon (Tangen, 2005).

Profitability: The main reason for neglecting the importance productivity in companies is due to relating it to profitability. "*The term profitability is the overriding goal for the success and growth of any business; it can be defined as the ratio between revenue and cost (i.e. profit/assets)"*. Unnecessary investment of capital for the transformation process will affect the profits gained. Increased productivity does not necessarily lead to profitability in the short term however the effect of increased productivity can be seen in the long term by increased profitability (Tangen, 2005).

Performance: Performance is a multidimensional term which covers both economic and operational aspects. It includes manufacturing excellence whether it is related to delivery, speed, flexibility and dependability. Achieving performance in a system will also increase productivity and profitability however increasing productivity and profitability does not improve the performance. Quality of the products produces also effect the performance of the system. Performance is an umbrella term for all the concepts that considers the success of the company and its activities (Tangen, 2005).

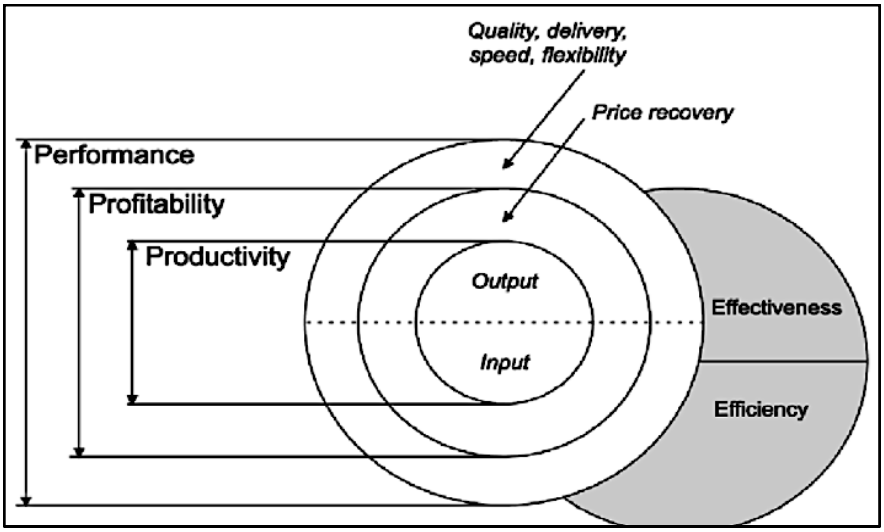


Figure 8: A schematic representation of triple P model (Tangen, 2005).

4 Findings

This chapter incudes all the empirical findings collected throughout the research from various data collection methods adopted and further lays a foundation for analysis of data to be carried out in the next chapter.

4.1 Empirical Findings

In this section all the empirical findings from the case have been presented. After conducting a pre study and identifying the bottleneck of the line as press line. Initial observations were carried out to identify types of wastes existing in the line and also the wastes identified were rated in order to classify them in order to conduct second stage of 5 why analysis and provide solutions for immediate control or handling of wastes. For the same purpose further in this section wastes identified have been presented along with their impact on delay and effect on the line.

4.1.1 Production flow at press line

At the case company continuous flow of products is seen in assembly line from one station to other initiated from manufacturing of walls in the press line to the finished caravan at the end of assembly line. Press line produced walls for caravan with the aid of press machine and milling machine. Current study was conducted at press line as bottleneck was identified in this line. Schematic representation of press line layout with the production flow has been depicted below. The following figure represents the part of case company where research was conducted.

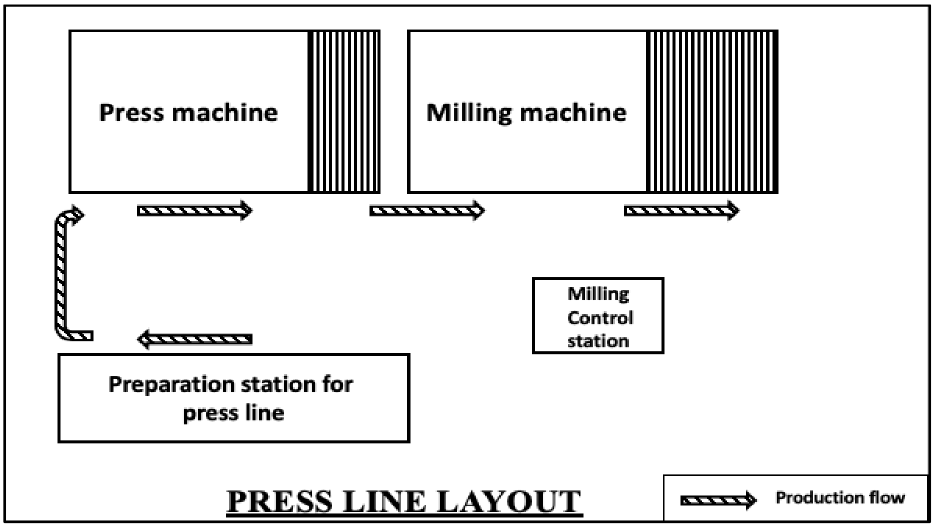


Figure 9: A layout of press line representing the production flow.

4.1.2 Results from first stage of 5 whys.

As stated earlier in the methodology chapter, before initiating the study a pre study has been conducted and an interview has been carried out with production manager which concluded providing results with low performance of the line also including large number of stops in the line. This problem identified was considered to be bottleneck of the line as it was initial stage of production and any problem associated with this stage will affect processes further down the line. First stage of 5 whys was conducted prior to findings from case company and has been presented in this section. Hence, root cause of the problem was initially identified through 5 why tool represented in Figure 10 which describes the different levels involved of identifying root cause of defined problem. The levels of identifying root cause initiated with analyzing low performance in the line, which was inquired, and it was found that performance of line decreased due to delay in delivery of products from line. Further inquiring the delay in delivery of products occurrence of more number stops in the line was found to be its cause. In the next step of inquiry, it was identified that these stops were arising as the process exceeded cycle time of the line. In the next level of 5 why analysis it was found that nonvalue adding activities arising due to existence of unwanted wastes caused the process to consume more time than predefined cycle time of line. Thus, through 5 Why analysis for bottleneck of the line root cause was identified as existence of wastes.

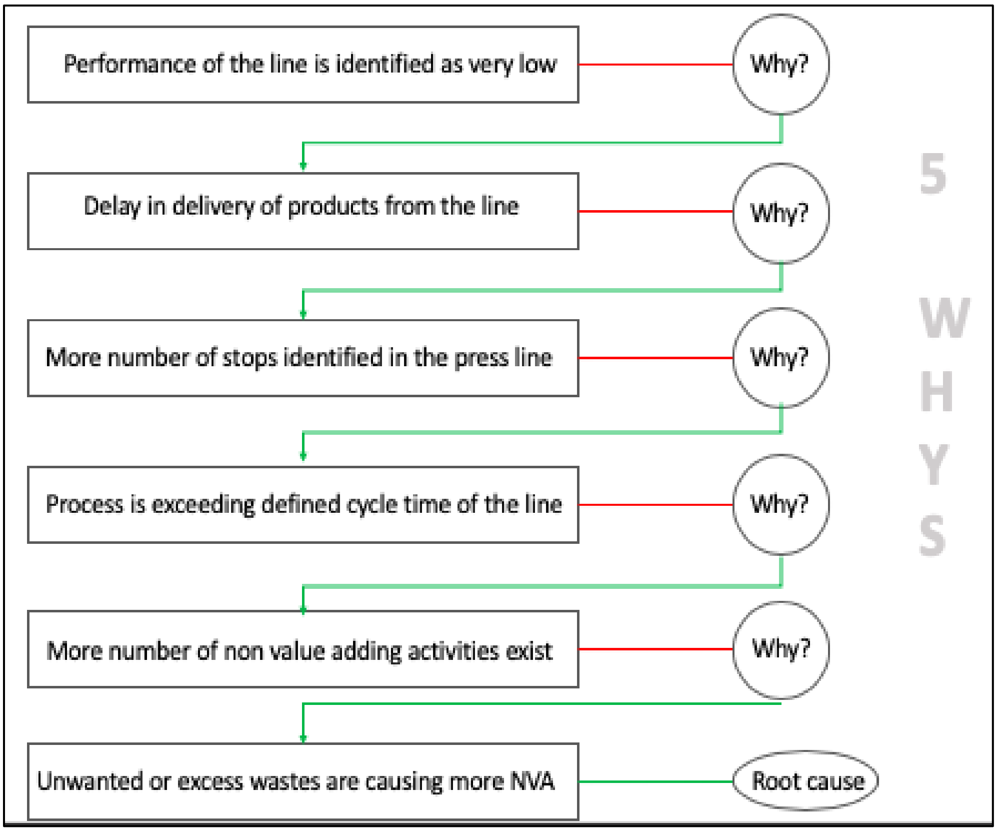


Figure 10: A flowchart representing breakdown of root cause through 5 Whys analysis.

These wastes existing in the line were influencing delay but were not the actual root cause of it. Hence, further inquiry on these wastes was conducted as second stage 5 why analysis, prior to which identification of 7+1wastes was carried out with the help of data obtained from observations, interviews and production documents and has been presented further in this section. Following are the major outcomes which outlines observations carried out in the line:

1. Operators of the line were often seen waiting for the materials from preassembly station of press line where wooden frames and metal sheets were initially placed together before sending into the press.
2. Tools and materials utilized by the operators were not placed at right place and also excess materials were found around the line which were hardly being used in a day.
3. Walls produced by the press line were piled up at the end of the line and the number of walls exceeded the actual capacity of plant.
4. It was also noticed that at times operator would search for materials which had to be delivered to the line from warehouse showcasing improper planning and scheduling of materials.
5. Operators moving around the line were involved in risky operations unaware of their safety.
6. Operators were involved in the same operation throughout their shift and switching between operators was not visible.
7. Operators were encouraged during daily meetings to provide their suggestions on improvements which was collectively discussed during meetings.

4.1.3 Identification of wastes

In this section different wastes identified in the line from case company will be presented and also the process of identifying wastes will be addressed. As mentioned before data obtained from observations, interviews, spaghetti diagrams and production documents will be utilized for identification of wastes.

4.1.3.1 Over production

When the quantity of product exceeds the requirement, it is considered as overproduction. While requirement is considered contrarily in different production strategy used. In pull strategy over production occurs only if the production exceeds demand of product. In push strategy over production always exists if the products are unable to fulfill market requirements. In the current study, through interviews it was identified that case company follows push strategy for delivering products because of which over production existed. Through mere observation, it has been able to recognize large number of walls piled up after the press line which exceeds current daily production capacity of the line. In an interview with supervisor of the line, it was mentioned that they produce around 14 number of walls in the press line per day, while the actual capacity of the production line is producing 10 caravans currently per day. The 14 walls produced per day does not only include actual side walls required for a cab production, as each cab requires two side walls and each of front and back walls. The production is carried out as per resource availability and either of these walls are produced, hence are in excess quantity compared to actual requirement.

Table 3: A table representing overproduction and its problems

Type of waste	Problem identified
Over production	• Improper planning with respect to production quantity. • Number of products produced in a day exceeds overall production capacity.

4.1.3.2 Extra processing

Activities carried out on a material during a process, which does not add any value to product is considered to be extra processing. Reducing these non-value adding activities due to rework, improper handling of materials will reduce the occurrence of extra processing which increases quality of a product. There were no evidences for occurrence of extra processing from the case either during observations, production data assessment or interviews conducted. Thus, extra processing has been considered as unidentified from the case.

Table 4: A table representing extra processing and its problems

Type of waste	Problem identified
Extra processing	No problems identified

4.1.3.3 Defects

Defects occurring can either be reprocessed, recycled or disposed. Majority of the products produced are either recycled or reprocessed unless there is an extreme necessity for disposal. The major problem with this kind of waste is it increases time and cost of production. Occurrence of defects in the case company at the press line is very low and it was determined to be less than 2 percent per month as addressed by supervisor of the line during an interview. During the interview with supervisor, it has been also specified that although 3 to 4 percent of defects are found in the line per month, rework could be carried out on few of the products approximately 1-2 percent and hence scrap rate or products which are considered as defects are low with a percentage less than 2-3 percent per month.

Table 5: A table representing defects and its problems

Type of waste	Problem identified
Defects	1-2% of defects per month in comparison to quantity of products produced.

4.1.3.4 Motion

Motion in a production line refers to any movement carried out by the operator to control or handle the operation. Unwanted Motion effects indirectly on cost of the product but it increases time required for processing of a product also increasing the risk of safety for operators due to repetitive movements. Through spaghetti diagram movement of operators around the line was traced and compared between operators from two different shifts (Operator A & B). It was evident that operator of one shift consumed less time and was involved in comparatively lesser movements around the line when compared to operator of another shift**.** Although time studies were not conducted in the line with operator movements, spaghetti diagrams presented below provides a view on difference between operators movement, where one of the operator was involved in excess movements around the line while the other operator did not carry out excess movements .Thus, it is evident that unnecessary motion and variation in motion exists in the line among operators which increases time for production and also increases workload on certain operators. This unnecessary motion increases nonvalue added time in between process and increases delay of process in the press line thus having intense negative effects on the line.

Table 6: A table representing motion and its problems

Type of waste	Problem identified
Motion	Operators involved in excess and unnecessary movements

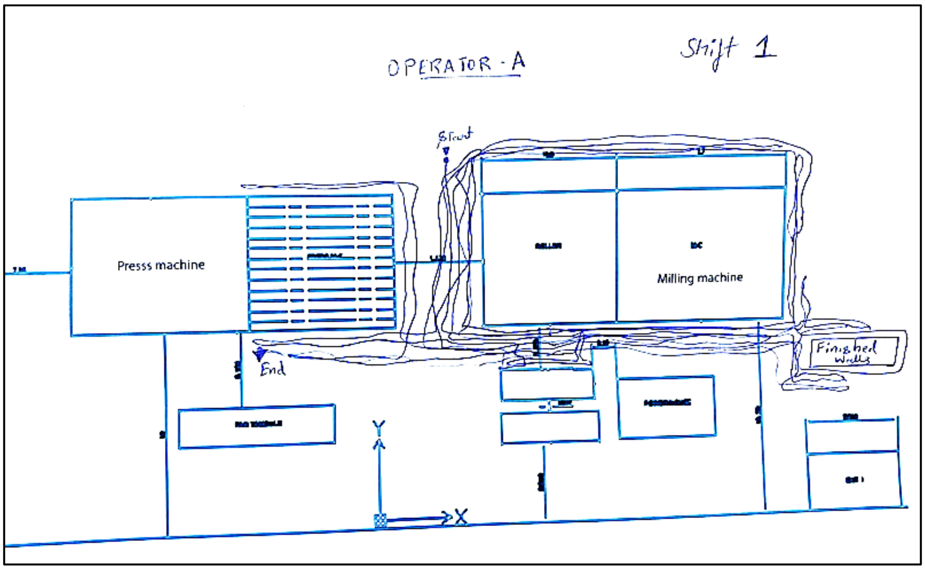


Figure 11: Spaghetti diagram depicting movement of Operator A from case company.

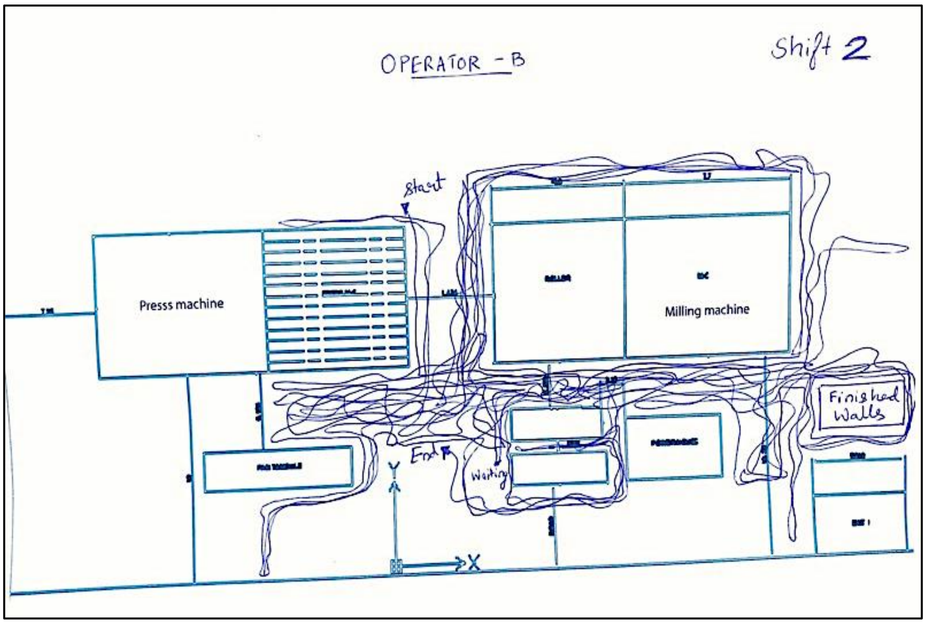


Figure 12: Spaghetti diagram depicting movement of Operator B from case company.

4.1.3.5 Waiting.

Waiting can either lead to lagging of subsequent process or also halt of process which strongly imposes negative impacts on productivity of line. During observations carried out it was clearly noticed that there was waiting for materials from the previous preassembly station. In the production records it has been able to identify majority of the stops were pertaining to material and order unavailability. The problem of increase in set up time was highly noticeable. Because despite of hundred percent machine availability input for the machine was not provided by operators. As the current study did not involve any time studies accurate information on waiting time has not been produced. However closely observing production document and number of stops arising due to unavailability of resources stated as “element sakning” in the document. This unavailability of resources identified was either due to improper delivery from preassembly station or unavailability of materials in press line. Average waiting time due to unavailability of resources was found to be 17-18 minutes during each stop which influences greatly on delivery of products. These stops related to unavailability of resources occurred two times per day on an average.

Table 7: A table representing waiting and its problems

Type of waste	Problem identified
Waiting	• Delay in delivery of materials from previous station. • Time involved for set up was high.

4.1.3.6 Excess Inventory

Inventory in a production facility will include both raw materials utilized for production and finished product as an outcome of production. At the case company during initial visit large quantity of finished caravans was identified, further during time of data collection observations carried out proved the existence of excess inventory in the line too which were rarely utilized. Unwanted tools which were hardly utilized by operators, excess materials than required quantity, unnecessary materials which could be stored in warehouse were identified in the line. Existence of excess inventory was also noticed during rapid plant assessment conducted (see appendix section 9.2)**.** This type of excess unnecessary inventory increases nonvalue adding time involved in transportation and storage of materials from the press line.

Table 8: A table representing excess inventory and its problems

Type of waste	**Problem identified**
Excess Inventory	Large quantity of rarely utilized materials and tools were identified in the line.

4.1.3.7 Transportation

Transportation of goods and materials from one place to another involve number of nonvalue adding activities which can lead to severe financial losses of a company. Transportation also increases time required for delivery of a product. Thus, identification and reduction of unnecessary activities pertaining to transportation is necessary for increasing profitability of production firm. As the press line in the case company is constructed with stations close to each other with products moved on conveyer at very shorter distance. Also, with the availability of required tools for operation close to operator, existence of non-value adding activities were not evident although there were minute movement of essential materials in the line.

Table 9: A table representing transportation and its problems

Type of waste	**Problem identified**
Transportation	No major movements were identified.

4.1.3.8 Non utilized talent

Nonutilized talent is considered as a waste in case of improper training provided or unbalanced work distribution carried out at the company especially among operators at the shop floor. Underutilization of operators will lead to decline in productivity of a line in long run, hence it is essential to train and assign operators effectively before assigning their role in company. At the case company, during daily meetings observations were carried out identifying that operators were encouraged for providing inputs regarding their problems associated with line. But during unstructured interviews operators mentioned that only some of the inputs provided by operators were considered by supervisor of line. Structured interviews were carried out among operators to identify their knowledge in the current operation they are involved. Also, operators were interviewed about their knowledge and interest for other operations in the line (see appendix section 9.1). These results were further compared with interview of supervisor of line to increase reliability of the data collected. Supervisor was interviewed with some of the similar questions which were questioned to operators, one such question is switching of operators in the line between different process where the operators were interested into. But it was mentioned by supervisor during interview that there were certain operators with physical disabilities working in line because of which switching of operators was not performed as the operators with physical disabilities were trained and effective in particular operation. The results of these interviews enabled identification of non-utilized talent but there was no effect on delay and also on the line, as the operators were trained about the process in which they were involved and suggestions from operators were collectively discussed during meetings to implement the same for achieving improvements in the line.

Table 10: A table representing non utilized talent and its problems

Type of waste	**Problem identified**
Non utilized talent	Operators were skilled in other operations but were not utilized effectively at shop floor.

All the identified wastes are also represented schematically over layout of press line in Figure 13 below to provide a clear view on identified of wastes. Although all the wastes have not been identified in the line, analyzing effects of each waste for providing a rating which further aids in inquiring its root cause plays an important role. Thus, rating of each waste has been carried out in the next chapter providing them rating according to their impact on delay, effects on the line and occurrence.

In the figure below each waste identified has been represented with a number as follows,

1- Overproduction,
3- Defects,
4- Motion,
5- Waiting,

6- Excess Inventory.

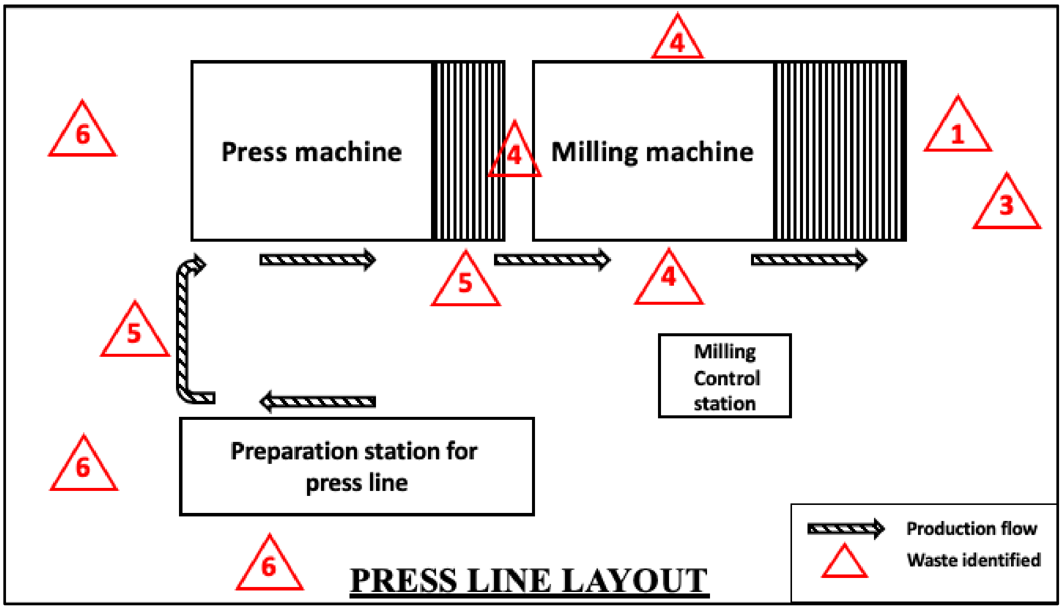


Figure 13: A layout of press line representing the production flow along with wastes identified.

5 Analysis

This chapter includes analysis of data collected from case company along with the data from literature review. As discussed in section 2.1, data collected from different methods will be analyzed in this chapter to identify solution for the problems addressed.

5.1 Rating of wastes and second stage of 5 whys analysis

After identifying the wastes existing in the line it is important to analyze these wastes in order to find their effects on delay and line. In the first stage of 5 why analysis root cause of delay influencing low performance inline has been identified as existence of wastes. In section 4.1.3 these wastes have been identified and the problems associated with them have been presented. Further, for inquiring root causes these wastes influencing delay, it is important to identify the impact of wastes on delay and classify them based on their intensity of effects. Although majority of lean wastes are identified, some of the wastes are not existing in line and are unidentified, also amongst the wastes identified all the wastes do not have same impact on influencing delay. Thus, authors of this study analyzed each waste identified in the line and provided a rating for each waste. The process of providing rating for each waste identified is discussed further in this section along with the reason for rating.

Table 20 depicts the final rating provided for each waste and has been tabulated. Based on the rating provided each waste will be further inquired using 5 why analysis to identify cause of its occurrence which is influencing delay in line.

5.1.1 Rating criteria for identified wastes

The rating criteria for identified wastes is inspired from rapid plant assessment model proposed by (Goodson, 2002). Although the developed rating criteria model is not similar to Goodson (2002) RPA model, the ideology for rating is inspired from the same model. For rating the wastes authors of the study considered numbers from 1 to 5 as they are easily quantifiable compared to other figures. A waste identified was graded number 1 if it was unidentified because of no evidence for existence. It was also graded 1 if there was no direct impact on delay identified and also effect on the line. Further each higher number provided highlights existence of a waste in the line and its impact on delay. The impact of a waste could be direct causing severe delay or could be indirectly influencing delay. Number 5 in the rating criteria model represents a waste with severe effects on delay having a direct impact. In this scenario eliminating waste with higher rating number will be considered important than solving a waste with lower rating number, because the waste with a higher rating number is severely influencing delay and requires immediate action for controlling it. In

Table 20 different rating numbers explained above have been utilized for rating each waste identified. Further in this section the reason for providing a rating number for each waste is discussed along with factors influencing the rating provided.

5.1.2 Factors influencing rating of identified wastes.

5.1.2.1 Over production

Over production was identified in the case company during initial visits for data collection through rapid plant assessment and also during observations and interviews carried out. Press line produced different variety of products like side walls front wall and back wall, but the quantity of walls produced varied each day. Each day the line produced either of the four walls in larger quantity ranging from 3 to 4 compared to the production requirement and the rest of the walls in lower quantity which resulted in piling up of walls at the end of a process as an excess inventory. This leads to increase of non-value adding time as the excess product adds no value until further consumed by succeeding process. Series of such nonvalue adding time increases cause of delay in the press line and includes a direct impact on it. Considering its direct impact on delay effect on the line, it was provided with rating 5.

Table 11: A table depicting rating provided for overproduction

Type of waste	**Problem identified**	**Effect on the line**	**Impact on delay**	**Rating Provided**
Over production	• Improper planning with respect to production quantity • Number of products produced in a day exceeds overall production capacity	Increases nonvalue adding time by producing excess goods	Direct impact on delay	5

5.1.2.2 Extra processing

Extra processing is a waste which increases the time involved for producing a component, as it includes chain of non-value adding activities which occurs due to unwanted processing of product than requirement. In the case company press line included a press and milling machine which produced components as per actual requirement and did not involve any extra processing of materials. Thus, extra processing being unidentified was rated with a lower rating number of 1.

Table 12: A table depicting rating provided for extra processing

Type of waste	**Problem identified**	**Effect on the line**	**Impact on delay**	**Rating Provided**
Extra processing	No problems identified	No effects on the line	No impact	1

5.1.2.3 Defects

Existence of defects in the line was enquired with supervisor during an interview. Although total percentage of defects produced was 4 percent per month, on certain quantity (1-2%) of defective parts rework was carried out to match the actual requirements of a product and deliver the same. Thus, total defects ranged in between 2-3 percent per month. Comparing the percentage of defects with number of products produced from the line and variety of products produced from the same line, although defects existed in the line it was provided with a rating of 3 as it is considerably small percentage of defect in comparison with total production of the line and has lower impact on delay on long run.

Table 13: A table depicting rating provided for defects

Type of waste	Problem identified	Effect on the line	Impact on delay	Rating Provided
Defects	1-2 percentage of defects per month in comparison to quantity of products produced	Increases nonvalue added time as products cannot be recycled	Impact during long run	3

5.1.2.4 Motion

Movement of operators in the shop floor is hard to identify, but unnecessary movements of operators must be reduced as it is a waste pertaining to motion. Using spaghetti diagram operator movements around the line was traced and comparison of obtained pattern of curves was carried out. There was a clear view on unnecessary movement of operator of one shift when compared to another. These unnecessary movements influence delay as operator involved in unnecessary motion around the shop floor will be continuously involved in process and there is a tendency of decline in efficient working of the same operator throughout the day. At the same time these unnecessary movements can influence delay in delivery of product on long run. This minor delay occurring due to unnecessary movements in the line leads to a major increase in process time also affecting operator through excess workload. Thus, analyzing its direct impact and strong influence on delay motion was rated with number 4.

Table 14: A table depicting rating provided for motion

Type of waste	Problem identified	Effect on the line	Impact on delay	Rating Provided
Motion	Operators involved in excess and unnecessary movements	Increases nonvalue added time in between the process	Direct impact	4

5.1.2.5 Waiting

Waiting in a production line can occur because of several reasons like unbalanced delivery time of preceding process, improper setup before initiating process and unavailability of resources for manufacturing product. In case company at the press line waiting was identified through observation where delay in the delivery of products from preceding process (preassembly station) was identified. Also, in production records it was seen that often materials were unavailable for the process which caused the major delay in process resulting in stops at the line. Average waiting time for unavailability of materials was found to be 17-18 minutes for each stop from production documents. Hence, waiting was provided with rating 5 analyzing its direct impact on delay and intensity of its effects.

Table 15: A table depicting rating provided for waiting

Type of waste	**Problem identified**	**Effect on the line**	**Impact on delay**	**Rating provided**
Waiting	• Delay in delivery of materials from previous station • Time involved for set up was high	Increases nonvalue added time during initiation of process	Direct impact	5

5.1.2.6 Excess Inventory

Excess inventory is closely related with over production as any production firm involved in over production will require excess inventory to produce and store the finished goods. In the case company excess inventory was most commonly seen in the shop floor where majority of materials were rarely utilized like tools used by operator and certain raw materials used for process. Also, excess goods were produced with at least 3-4 excess products per day compared to actual production requirement. This kind of excess inventory will increase non-value adding time as majority of the goods produced is not as per market demand and will decrease value of product over storing for a longer period of time. This reason for its influence on delay and low impact on increase of non-value adding time provided excess inventory a rating of 3.

Table 16: A table depicting rating provided for excess inventory

Type of waste	**Problem identified**	**Effect on the line**	**Impact on delay**	**Rating Provided**
Excess Inventory	Large quantity of rarely utilized materials and tools were identified in the line	Increases nonvalue added time in storing and transportation	Partial low impact	3

5.1.2.7 Transportation

Transport of materials from one place to another in a shop floor plays a vital role on increasing delivery time and hence eliminating non-value adding activities pertaining to transport is necessary. In the case, there were no major transport activity addressed in the press line as press line and milling machine were closely constructed including rollers and there was no transport of materials found in the line. Although few movements of tools and materials were identified, closely observing these actions it was considered to be a required motion and not transport. Hence, transport was provided a rating of 2.

Table 17: A table depicting rating provided for transportation

Type of waste	**Problem identified**	**Effect on the line**	**Impact on delay**	**Rating Provided**
Transportation	No major movements were identified	No effects on the line	No impact	2

5.1.2.8 Non-utilized talent

Along with controlling of activities carried out in a manufacturing system, educating and training of employees with required knowledge of operation is also essential. Education and training include understanding capability of each operators and their skills on all the operations in a shop floor. Through interview with operators it was identified that some of the operators were partially skilled in other operations at the shop floor apart from their regular routine operations. But periodical switching of operators between different operations was not encouraged in the shop floor because the line included operators with physical disability and were trained for particular process. Also, during interviews with operators and supervisors it was confirmed that suggestion for improvements in the line was partially encouraged from operators. Such minute actions which are not considered important by the case company will also influence delay as insufficient training and education of employees will lead to improper operating procedures increasing time involved in manufacturing process. Thus, non -utilized talent was provided with a rating of 2 analyzing its indirect impact on delay with lower effects.

Table 18: A table depicting rating provided for non-utilized talent

Type of waste	**Problem identified**	**Effect on the line**	**Impact on delay**	**Rating Provided**
Non utilized talent	Operators were skilled in other operations but were not utilized effectively at shop floor	No direct effects on the line	No impact	2

All the wastes rated based on their impact on delay, effect on the line and occurrence has been presented under a single table below, along with source of data used for identification of wastes. Rating provided for each waste is also tabulated in

Table 20. Based on the rating provided these wastes has been further inquired for identifying its root cause which is influencing delay in line and has been presented further in section 5.1.3.

Table 19: A Table representing rating criteria of all the identified wastes

Sl.no	Wastes	Identified through	Impact on delay	Occurrence
1	Over production	Observation & Interview	Direct impact	3-4 excess quantity per day
2	Extra processing	Unidentified	No impact	Unidentified
3	Defects	Interviews	Low impact on long run	2-3% per month
4	Motion	Spaghetti diagram	Direct impact	Large Differences in movements between operators
5	Waiting	Interview and Production data	Direct impact	Average of 17-18 minutes per stop
6	Inventory	Observation & RPA	Partial low impact	Rarely utilized materials and tools in line
7	Transport	Unidentified	No impact	Unidentified
8	Non utilized talent	Interviews	No impact	Limitation for implementing suggestion

Table 20: Rating of types of wastes found in the line

Sl.no	Type of waste	Rating
1	Over production	5
2	Extra processing	1
3	Defects	3
4	Motion	4
5	Waiting	5
6	Excess Inventory	3

7	Transport	2
8	Non utilized Talent	2

5.1.3 Second stage of 5 why analysis

The first stage of 5 why analysis was conducted, and results have been presented in section 4.1.2 from which wastes were identified as root cause of delay. But 5 why tool helps in identifying root cause of a problem by inquiring in several steps until breakdown of a problem into its root cause (Borkowski, et al., 2012). Thus, identification of root cause of delay with the aid of 5 why tool, further these wastes have been inquired. This second stage of 5 why analysis will include wastes rated from 3 to 5 because of their impact on delay and effect on press line. As other wastes identified in the line rated from 1 to 2 does not have an impact on delay and some of the wastes are unidentified further inquiry was not conducted on these wastes. Further in this section each waste having an impact on delay will be further inquired in second stage of 5 why analysis until root cause is identified.

5.1.3.1 Second stage of 5 why analysis on Overproduction

Over production has been rated 5 considering it direct impact on delay and occurrence per day. When companies adopt a push strategy for production, forecasting for quantity of production becomes complex and companies tend to produce without any order being placed (Hicks, 2007). In the case company, over production occurring was further inquired to identify its root cause which was in turn influencing delay in line. Inquiring the cause of over production in next step of 5 why analysis the cause for this was identified as insufficient planning with respect to quantity of production. Further inquiring this cause in next step, root cause was analysed to be production strategy adopted by the company which is a push strategy. This resulted in production of goods without any order being placed by customer and thus resulted in over production of goods.

5.1.3.2 Second stage of 5 why analysis on Defects

Defects has been provided with rating 3 considering it low direct impact on delay on long run. Inquiring defects in the next step of 5 why analysis it was identified that process has been unaltered or improved for longer period of time. According to Hill (2018) one of the major reasons for defects arising in production line is due to poor and improper process design adopted (Hill, 2018). When production manager was interviewed regarding process involved in press line, it was mentioned that process was designed during initial stages of company start up and has been used since then without altering. This unchanged design of process or no improvements in process for longer period of time as production manager stated has not provided platform for identification of errors occurring in process due to its design, because of which defects are occurring in line. Thus, improper or poor process design was identified as its root cause because of which 2-3% percentage of defects were arising in line.

5.1.3.3 Second stage of 5 why analysis on Motion

Motion has been rated 4 analyzing its direct impact on delay and occurrence in line. Inquiring this unwanted or excess motion in the next step of 5 why analysis it was identified that there is no standard procedure developed for operators to carry out process in press line. Minimizing unwanted movements of operators in shop floor, also implies providing a standard working procedure for operators (Gladysz, et al., 2017). These unnecessary movements occurring in line included a direct impact on delay and also increasing workload on operators. Hence, due to unstandardized working procedure adopted in press line of case company unnecessary or excess motion raised in line.

5.1.3.4 Second stage of 5 why analysis on Waiting

Waiting has been provided with rating 5 analyzing its direct impact on delay and frequency of occurrence per day. Waiting in line can occur due to various reasons like insufficient availability of materials, machine break down, errors occurring in between process and also due to improper set up procedure adopted (Hicks, 2007; Pinjar, et al., 2015). Inquiring waiting in the next step of 5 why analysis it was identified that waiting occurred both when materials were unavailable and also when operators did not provide input for machine despite of hundred percent machine availability. In the next step these causes were inquired, and their root cause was identified. For unavailability of materials improper distribution of materials in line was identified as root cause because materials were available in inventory and were not distributed as per requirement because of which waiting occurred. For operators not providing input despite of machine availability improper setup procedure in preassembly station was identified as root cause as preassembly station was constructed in order to prepare materials as an input to press line. Thus, two major root causes for waiting was identified to be adopting improper set up procedure and improper distribution of materials in line.

5.1.3.5 Second stage 5 why analysis on Excess inventory

Excess inventory has been rated 3 considering its low impact on delay. According to Cheng (2017) excess inventory includes materials utilized for production, raw materials, finished products and work in process (Cheng, 2017). In the case company excess inventory in the form of finished goods and materials utilized for production was identified. On inquiring excess inventory in the next step of 5why analysis it was identified that rarely utilized materials existed in line and also excess goods were produced. As production of excess good has been previously analyzed in over production due to utilization of push strategy, existence of unwanted and rarely utilized materials was further inquired in the next step for which improper arrangement and distribution of materials in line was identified as root cause.

All the root causes of each waste identified during second stage of 5 why analysis has been tabulated below which outline root causes of delays. Although delay in delivery of products is occurring in press line and affecting performance of line there are several root causes because of which delay is occurring and each root cause can contribute to delay causing multiple delays at the same time which influences negative performance of press line. Further in this study, recommendations are provided for reduction of these root causes influencing delays and achieving high performance in line.

Table 21: A table representing root cause of wastes after 5 why analysis

Sl.no	Type of Waste	Existence in line	Root causes
1	Over production	Existed	Utilization of Push strategy
2	Defects	Existed	Improper/poor design of process

3	Waiting	Existed	Improper distribution of components and adoption of improper setup procedure
4	Motion	Existed	Unstandardized procedure for operation
5	Excess Inventory	Existed	Utilization of push strategy and Improper arrangement and distribution of components

5.2 Answering research question 1

Identification of delays and their root causes is necessary, as delays often cause negative impacts on performance of a system. As performance of a system is mostly measured with delivery, quality, and speed of outcome in a system, delay influence negative performance of a system as delivery of the output will exceed expected time because of its existence. Identifying delays includes identification of its root cause and effects on the line, because delays which are closely affecting bottleneck will have high impacts when compared to normal delays existing in the line. Thus, identifying root cause of delay will result in identifying actual source of that problem. This method of identifying root cause of problem also promotes process improvement through prevention (Arunagiri & Babu, 2013). Lean philosophy although focuses on reduction of nonvalue adding activities and elimination of wastes, it also includes several tools for like 5 whys, fishbone diagram and pareto chart for identifying root causes. As lean philosophy encourages increase in speed of delivery and efficient outcome of products it is highly essential to identify root cause of delay effecting speed of delivery and efficiency of line (Pinto, et al., 2018). In the current study identification of root cause of delay was carried out through 5 why analysis because of ease in implementation and efficient results (Borkowski, et al., 2012). This 5 why analysis was conducted in two stages, where in the first stage root cause was identified as wastes and in the second stage based on their existence each waste was further inquired to identify its cause. Spaghetti diagram analysis was utilized to identify delay arising due to unstandardized working procedure in line, which was resulting in excess, unwanted motion of operators around line. Both the lean tools utilized include simple procedure for implementing and identifying cause of problem and has been adopted in current study. With identification of root cause of delay these tools aid in identifying cause behind excess time utilized by process before delivery of product. Hence, utilizing these simple tools under lean philosophy increase in efficiency of process along with reduction in cost can be achieved (Pinto, et al., 2018). Thus, root causes of delay have been identified with aid of lean tools which illustrates the necessity of these lean tools under lean philosophy for identification of delays and its root causes. This also outlines the requirement of tools under lean philosophy in identifying root cause of delays in production firm especially if delay is strongly influencing towards bottleneck of the line.

5.3 Answering research question 2

There can be several reasons for existing of delay in production line. Delays can originate because of improper planning and scheduling of activities, time utilized for a process exceeding actual pre-defined cycle time of line, unnecessary breakdowns or even due to series of non-value adding activities occurring in the line (Mourani, et al., 2008). In the current study amongst several reasons discussed above, delay in delivery of product was caused due to excess utilization of time by process than predefined cycle time. Further through 5 whys tool, in the first stage identification of its root cause was carried out which produced result as existence of 7+1 wastes influencing nonvalue adding activities. Although certain wastes like over production, waiting, defects, unwanted motion, excess inventory existed in the line and influenced delay during delivery of product. Root causes of these wastes influencing delay were identified during second stage of 5 why analysis and has been presented in Table 21. Major root causes which influenced delay were utilization of push strategy resulting in over production, adoption of improper set up procedure resulting in waiting, unavailability of resources in line resulting in waiting, unstandardized working procedure adopted by operators in press line resulting in unwanted motion, improper distribution and arrangement of materials in line resulting in excess inventory and poor unaltered process design adopted in line resulting in defects. These root causes resulting in existence of wastes, were in turn influencing delay in line. As various root causes have been identified in line for occurrence of delay, these root cause can occur at same time causing multiple delays in line. Along with influencing existence of delay in production firm, all these root causes also contribute to wastes in the line which decreases productivity of line along with increase in delays. This decline in productivity will reduce the performance in firm considerably because delay in speed of delivery of product along with hinderance to quality. Hence, these root causes could be considered as major root causes which influence delays in production line because majority of production line include common problems associated with improper distribution and arrangement of materials, excess time utilized for set up and unavailability of resources.

5.4 Addressing Influence of lean tools on reduction of delays.

In the previous section root cause of delays existing in the line have been identified. For identifying the wastes along with observation and interviews certain lean tools like 5 whys and spaghetti diagram has been used. Further in this section other lean tools which will aid in reduction of delays by minimizing its root causes has been presented. Selection of these tools has been grounded based on requirement of research gap addressed where efficient utilization of men, machinery and methods for reduction of delays with a very low investment of capital. In this section influence of lean tools on reduction of delays will be addressed as suggestions for further implementation, considering problems from case company and suggestion of solutions for majority of root causes influencing delay has been provided.

5.4.1 Importance of PDCA cycle

Plan do check act cycle helps in standardizing process also ensuring increase in quality of product. (Silva, et al., 2017). Identification of defects can be carried out end of each cycle measuring the quality of produced product and further understanding the cause of defect to rectify it in the next cycle of production. Through PDCA cycle a four-step procedure could be utilized in prevention of defects and thus improving quality of product (Silva, et al., 2017). With the aid of this cycle a process in press line could be designed executed and examined for results, further acting upon results either cycle could be repeated by maintaining standard of procedure or corrections could be proposed for change in design of process. This simple lean tool helps in utilization of existing manpower and machinery by efficient planning of activities which reduces maximum defects caused through proper design of process as the cycle itself is repeated until expected results are obtained. As process design is unaltered for longer period of time at case company and defects in press line are identified although having a lower impact on delay, they can be reduced implementing this technique and efficiently testing outcome for further improvisation of process. Thus, adopting PDCA cycle problem associated with defects in production line can be reduced to a greater level and processes can be standardized. This improvement in process design also promotes reduction of delays through process improvement (Arunagiri & Babu, 2013).

5.4.2 Importance of 5S method

This lean tool includes five different methods which include sort, set in order, shine, standardize, sustain (Benjamin, et al., 2013).Through sorting materials, tools and equipment, excess of inventory can be reduced (Pinto, et al., 2018). Setting them in order and standardizing process will help in solving problems associated with over production. Achieving the required results and sustaining it through periodic implementation of 5s tool will result in improving productivity and also maintaining shine in the shop floor with elimination of unwanted materials from the shop floor. Unwanted materials leading to excess inventory, rarely utilized materials in shop floor which cause imbalance in a product flow affecting smooth functioning of line through causing delay can be reduced by adopting this method at case company. Hence, reduction of unwanted materials from the line and sustaining an efficient product flow will reduce the cause of delay in the line and aids in achieving maximum space utilization around press line. As 5s tool also aims in achieving shine in the shop floor by sorting and placing materials in order, problems associated with poor distribution and arrangement of goods and materials in line can be achieved which leads to better mobility and communication in shop floor also reducing waiting and excess inventory causing delay to product flow. Achieving effective product flow will reduce the existence of unwanted materials in the shop floor. This improve in product flow will result in efficient production and reduces problems associated with over production. Adopting this 5s tool for prevention of problems associated with waiting, over production and excess inventory not only outlines influence of lean philosophy on reduction of delays, but also promotes process improvement through prevention (Arunagiri & Babu, 2013).

5.4.3 Importance of SMED

A manufacturing system to deliver efficient results it is also necessary to deliver at right time along with delivery of product with high quality. Delivery of product plays an important role to reach market demands and requirements but, increase in time involved in transformation process will exceed the process time above cycle time causing delay in the delivery of product. Hence, it is important to restrict the time involved in transformation of raw materials into finished goods within a predefined cycle time. In order to restrict the process within a predefined cycle time designing the process and preparation for initiating process must be standardized by eliminating needless operations involved. Before initiating any process, preparation time or set up time must be highly prioritized as any delay caused in setup will affect directly on delivery time of a process. Single minute exchange die process by eliminating needless operations and converting internal operations into external operations highly reduces time involved in setup which increases performance of manufacturing system by reducing the time involved in set up (Pinjar, et al., 2015). This reduction in time will strongly aid in restricting the process within predefined cycle time which aids in achieving high performance in line. In case company problems associated with poor set up procedure and waiting due to excess time utilized for set up can be controlled through implementation of SMED. As SMED also eliminates needles operations and converts certain internal operations into external operations which results in maximum reduction of time involve in manufacturing process in turn leading to lower causes of delay, performance of press line can be increased by utilizing this process.

5.4.4 Importance of Spaghetti diagram analysis.

Through spaghetti diagram movements of operators in the shop floor could be traced and suggestion for improvements could be provided. In section 5.1.2.4 identification of unnecessary movement of operators around the press line has been carried out. Although there is no benchmark for comparing the results of spaghetti diagram, it was visible that operator of one shift involved in movements more than that of operator from other shift. This scenario clearly explains that the process can be handled with minimum movements and operators must realize the necessity of minimizing the motion associated with process they are involved. Thus, spaghetti diagram could be further used to provide a benchmark of operator’s motion around the line which helps all the operators to be involved in less non-value adding activities and reduce the risks of excessive workload by providing them a simplified standard procedure for carrying out operations around press line. Through spaghetti diagram analysis it is also able to identify risks associated with ergonomics by filming the movement of operator with spaghetti diagram around line. Reducing the motion of operators in the line will lead to reduction of time involved in process and also decrease the delay caused due to excess workload on operators. By organizing activities and simplifying them along with reduction of cause of delay related to unnecessary movements in shop floor, process improvement through simplification is also encouraged (Arunagiri & Babu, 2013).

5.5 Importance of adopting JIT along with lean tools.

Just in time production aims in achieving product of high quality along with meeting market requirements of product (Hirano, 2009). Just in time also encourages zero wastes and aims in delivering right product in right quantity at right time. Thus, utilizing JIT product quality and speed of delivery is ensured which increases performance of production line indulged in delivery of product. Lean philosophy encourages JIT as this production strategy aims in elimination 7+1 wastes and enhances outcome of production line. When JIT is adopted along with implementation of lean tools it provides platform for continuous improvement in production line by analyzing problems occurring in line. At case company a push strategy is utilized for production which is mainly resulting in over production of products. Adopting JIT can reduce problems associated with over production, defects as this strategy aims in delivery of product at right time as per customer requirements. Implementing lean tools discussed in previous section along with JIT production strategy can eliminate majority of root causes influencing delay in press line and also help in achieving high performance in line with ensured quality and speed of delivery of products.

5.6 Variation in relation between Triple P's and time variables due to influence of delays.

In a manufacturing process there exists different time variable which are closely related to process and also one another. Different time variables have been addressed before in this study in section 3.5. The relation between these time variables are closely connected and will be discussed in this section. A process time is the actual time taken for the transformation of raw materials into finished goods (Nagahara & Nonaka, 2018). Whilst the cycle time is the total time from start of a product to delivery (Turpin Jr, 2018). In a production line there exists several processes for which cycle time does not vary. In order to achieve a higher production rate a process designed must restrict the process time within cycle time (Veeger, et al., 2010). Number of operators involved in a process will contribute to both process and cycle time and it varies accordingly with number of operators. The relation between these time variables has been schematically represented in the figure below as an example. Although cycle time is constant for all the four different processes process time varies for each process as per number of operators involved. In the figure first and third processes are carried out by single operator. Hence process time is equal to that of cycle time. But in the second process two operators are involved and hence cycle time is twice of process time. Similarly, in fourth process four operators are involved and hence cycle time is four times the process time. This can also be described as process time is equal to ratio of cycle time and number of operators involved in process. Takt time for all the process is same as the products must be delivered at the same time as per demand rate. The figure is inspired from Panneman (2017) and represented below in Figure 14.

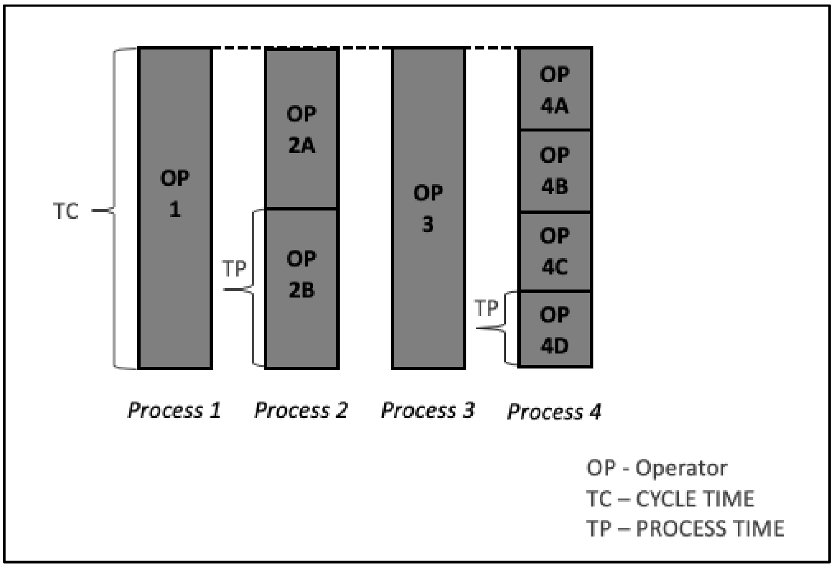
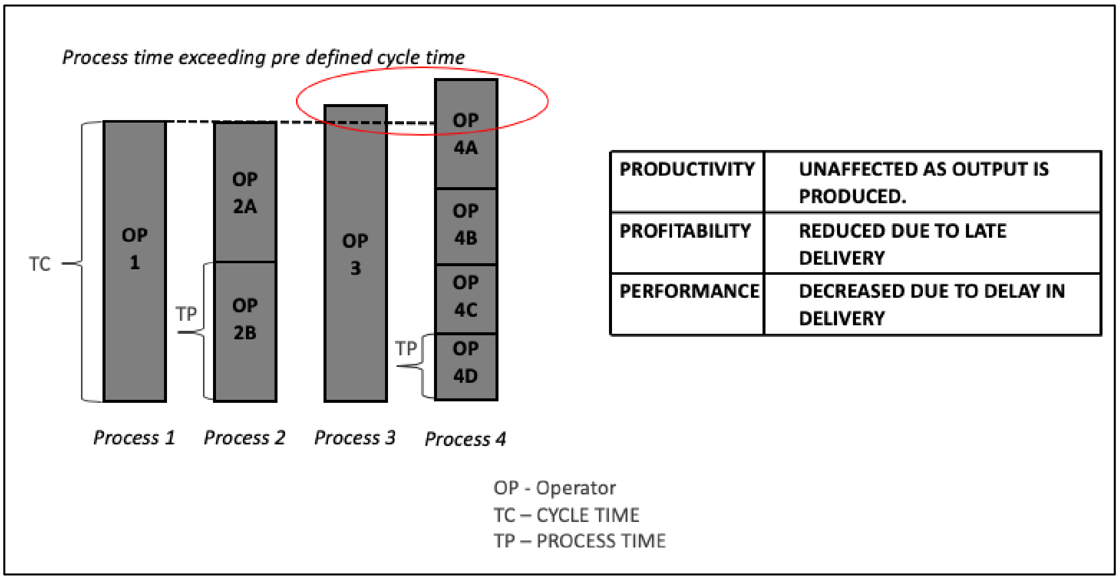


Figure 14: A figure representing different time variables inspired from (Panneman, 2017).

These relation between different time variables has been addressed because each time variable is closely associated with activities of production line. Increase in process time could occur either due to excess time consumed by single operator or different operators handling similar process. As cycle time of production line will be predefined in manufacturing firm considering all the processes, it is highly important for any process to be restricted within this predefined cycle time failing which lead to decline in performance of line. When excess time is utilized by process, process time increases beyond predefined cycle time which results in decrease in speed of delivery causing decline in performance of system. Although productivity of line will be high as products will be delivered by production line, performance drops because of exceeding delivery time and delay in delivery of product. Fluctuations in delivery time of product might also influence negatively on profitability of manufacturing firm as product will fail to reach market as per scheduled time. Thus, delays influencing increase in process time will lead in decline of performance of manufacturing firm.

In Figure 14 a schematic representation of relation between time variables has been represented similarly in Figure 15 because of influence of delay relation between variation time variables closely affecting Triple P's has been addressed. Even though process 1 and 2 does not exceed cycle time, in process 3 despite of one operator process time is exceeding cycle time and in process 4 one of the operators is influencing increase in process time which results in increase of process time beyond predefined cycle time. This excess time consumed by a process will not affect the productivity as the product will be produced after process is completed but will result in decrease of performance, which later effects the profits earned due to delay in delivery. The scenario is similar to that of case company were products are delivered from press line but there is decline in performance of line due to delay in delivery. Although several causes like over production, waiting in line and excess movement of operators are increasing time utilized for process and influencing this delay in delivery, major outcome of these causes is decline in performance. Considering process 3 as an example for milling operation in press line where only one operator is involved and process 4 as preassembly station where 3-4 operators were involved. A pictorial representation of this scenario of increase in process time and its effects on triple P model has been represented below in Figure 15.



PRODUCTIVITY	UNAFFECTED AS OUTPUT IS PRODUCED.
PROFITABILITY	REDUCED DUE TO LATE DELIVERY
PERFORMANCE	DECREASED DUE TO DELAY IN DELIVERY

Figure 15: A figure representing relation between time variables and triple P model.

6 Discussion

In this chapter the research questions framed to carry out research will be answered and the final conclusions for the research gap identified will be provided by fulfilling the purpose of research.

6.1 Answering research question 3

Reduction of delays can be conducted by changing the design of process, by preventing the occurrence of delay, by investigating its root cause or also by adopting simplified process (Arunagiri & Babu, 2013). Amongst these ways investigating root cause and prevention of occurrence of delays will be efficient in majority of problems as it breaks down problem to source due to which problem is caused. As lean philosophy encourages identification of root cause through various tools like 5whys, fish bone diagram, pareto chart utilizing these tools will promote reduction of delays through identification of root cause. In the current study 5 whys has been utilized for identification of root causes of delay and has been presented before. For majority of root causes influencing delays in production line outlined in section 5.3 tools under lean philosophy addressed as recommendations in section 5.4 which could be utilized for reduction of same. By adopting PDCA cycle along with reduction of defects and improvement in quality simplification of process for reduction of delay is also encouraged. By implementing 5s prevention of occurrence of delays is promoted as it encourages reduction of delays associated with waiting, over production and excess inventory. Utilizing spaghetti diagram a standardized working procedure for working of operators can be established which reduces delay occurring due to unwanted movements of operators around line which promotes reduction of delay. By implementing SMED delay arising due to improper setup and needless operations can be eliminated. Thus, utilizing tools under lean philosophy reduction of delays through process improvement, prevention of its occurrence and elimination of its root cause is encouraged. In section 5.5 merits of utilizing JIT along with lean tools in production firm for achieving high performance and reduction of delays has been presented because lean philosophy encourages adoption of just in time production strategy for delivering products at right time in right quantity with ensured quality. Hence, lean philosophy influences reduction of delays associated with performance of line by reduction of it root causes and also aids in achieving control on speed and quality of delivery which in turn leads to increase in performance.

6.2 Overview on selection of methods

The research involved different approaches for collection of data which included a systematic literature review process, observations and interviews from the case company along with quantitative methods like spaghetti diagram analysis and production document analysis. A systematic literature review process was carried out with snowballing technique to reduce the risk of generating irrelevant subjects pertaining to current study and several steps were involved in screening process which has been described in Figure 3. Adopting snowballing technique helped in identification of single source, where majority of data was acquired from. This method of adopting a systematic literature review with a framework aided in finding sources relevant to area of study and increased reliability of research also increasing transparency of the research.

Triangulation method involving both qualitative methods (observations, interviews) and quantitative methods (spaghetti diagram, document analysis) was adopted to increase the validity of research (Williamson, 2002). Some of the data obtained during observations and interviews were insufficient for study, but this problem was solved they were evident in data from production documents and spaghetti diagram. Along with these methods structured and unstructured interviews were carried out at the case company to increase reliability of research. A single case study was conducted to increase the validity of research but this method limits to low generalizability. Hence, the proposed solution connecting the research gap must be implemented in other non automized manufacturing companies to verify the results and increase generalizability of current research. After conducting interviews with operators at the shop floor, to understand the information flow and increase reliability of research these questions were further queried with supervisor of the line to verify the answers obtained and generate view from both the end.

Research questions framed to fulfill the purpose of research was answered through research methods discussed above. Research question 1 and 2 were answered based on the data obtained from literature review and observations, interviews from the case company while the research question 3 was answered after synthesizing the answers of research question 1 & 2 which is described in Figure 2. This method of answering research question at different stages helped in analyzing each research question and answering them to fulfil main purpose of research. All the research methods adopted to evaluate the purpose of study benefited the research increasing trustworthiness, while the only drawback of study was pertaining to generalizing the analyzed solution globally as the current study involved a single case study.

6.3 Discussion on purpose of research

Delays occurring in production line includes severe impact on occurrence of bottleneck and also affects the functioning of line by infecting its performance. Resolving these delays to deliver product at right time for increasing performance of production line is highly important, for the same reason purpose of research was focused on investigating the influence of lean philosophy in reduction of delays associated with performance of production line. Section and 5.2 and 6.1 and outlines the importance of utilizing lean tools in identification of root causes of delays and reduction of the same. These lean tools under lean philosophy although aims at elimination of wastes from production line, their impact has been identified on reducing delays by elimination of different root causes from production line. It has also been explained how reduction of delays can achieve delivery of product at right time and right quantity increasing performance of line. As lean philosophy also aims in achieving efficiency and reduction of product costs simplified lean tools for identification and reduction of delays in production line have been identified and outline during research. Importance of JIT and merits of utilizing JIT along with lean tools to achieve high performance has been outlined in current research as Lean philosophy encourages JIT production strategy. Different lean tools involving ease of implementation with effective utilization of men, machinery and methods with negligible investment of capital has been outlined during current research which promotes reduction of delays through identification of root cause, redesigning of process and also through prevention of its occurrence. Thus, lean philosophy aids in identification and reduction of delays in production line and also aids in achieving high performance in production line by controlling speed of delivery through reduction of delays.

7 Conclusion

7.1 Academic and industrial contribution of research

According to Zhang & Chen (2016) lean philosophy involves reduction of wastes utilizing lean tools in order to increase productivity (Zhang & Chen, 2016). Lean philosophy is a technique utilized for process improvement by identifying unnecessary actions and elements and eliminating them (Sternberg, et al., 2013). Hill (2018) addresses that adopting lean approach aids in reduction of wastes in manufacturing and improving productivity (Hill, 2018). Along with reduction of wastes lean philosophy also encourages just in time production for delivery of product at right quantity and at right time (Pinto, et al., 2018). As discussed above, previous researches carried out mainly outlines the importance of lean philosophy in reduction of wastes and improvement of process along with elimination of nonvalue adding activities. Majority of these previous researches focused on highlighting tools under lean philosophy along with the procedure of adopting them and importance of implementing these tools in manufacturing firms. Researches have also contributed for the process of identification of wastes utilizing lean philosophy and have addressed impact of existence of these 7+1 wastes in production line. But influence of lean philosophy on eliminating other problems occurring in production line like delay which affect performance of line by altering speed of delivery have not been addressed in previous researches carried out. In the current research the impact of lean philosophy on reduction of delays in production line is investigated along with identification of its root cause and also outlining how lean philosophy enhances performance of line along with reduction of delays.

As an industrial contribution simple tools under lean philosophy have been addressed for both identification and reduction of delays in the current study. These tools do not encourage excess investment of capital instead focus on achieving effective utilization of existing resources in manufacturing firm like men, machinery and methods. In the current study all the tools addressed involve simple process for implementation ad also include very low investment of capital which is basic requirement for manufacturing firms to achieve profitability. Case company in the current study has been a non automized manufacturing firm where effective utilization of men, machinery and methods were encouraged at work environment.

7.2 Conclusion and Future scope

Achieving performance in production line is considered highly important by all manufacturing firms globally. Because despite of high productivity, failing to reach market requirement at the right time leads to strong impact on profits earned creating no value to the product. Achieving performance includes delivery of product at right time with sustained quality and delivery speed for which any disruptions arising in between process must be eliminated. One such disruptions commonly found in manufacturing companies is delay and must be highly prioritized for reducing or eliminating from production line. Because of the importance described, purpose of research was constructed for investigating influence of lean philosophy on identification and reduction of delays which in turn increases performance of production line.

A single case study adopted for the research along with increasing quality of research, also encouraged the purpose of study in identifying a bottleneck of the line which was occurring due to chain of delays existing in the line. For identifying root causes of delay lean tools like 5 whys in two different stages and spaghetti diagram were utilized along with observation and interviews which validated first research question. After identifying the root causes for delay, major root causes which most commonly occur in production line have been addressed in research question 2. For answering research question 3 simple lean tools which aid in reduction of delays has been identified and explained. These tools are provided as recommendations for company and has not been implemented. But importance of these lean tools in reducing majority of root causes influencing delay has been addressed which is applicable for majority of production firms having similar root causes associated with delay.

Different lean tools have been presented during current research which involves effective utilization of men, machinery and methods with a very low investment of capital from any manufacturing firm adopting these tools for reduction of delays in line. Although research was conducted in non automized manufacturing firm it does not conclude with this limitation because simple tools have been identified which influence reduction of delays and can be implemented by any manufacturing firm facing similar problems associated with root causes of delay. The case study adopted for current research was single case type which promotes low generalizability. Hence as a future scope, research involving multiple case studies could solve the issue pertaining to generalizability and also add more value for other automized or partially automized manufacturing firms in adopting these lean tools addressed for reduction of delays. Also, implementing different lean tools addressed in section 5.4 for reduction of delays occurring due to various root causes enhances scope for future.

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9 Appendices

9.1 Interview guide

9.1.1 Structured Interview guide operator A

Fragor

1. Känner du till något annat arbete eller station på KABE?

   Ja.

2. Om ja, Vilken station eller vilket arbete?

   1 – Golvlimning / 2 Fräsning golv

3. Om ja, Hur bra är du med på det arbetet?

   Hanterar det ☐
   Som genomsnittet ☒
   Mycket bra ☐

1. putting together all the diffrent parts of the floor and manuvering adhesive robot + manuvering the hydralic press,

2. Manuvering the milling machine.

Jag förklarar härmed att ovanstående svarade frågor är riktiga mot min kunskap.

2020-04-02

UNDERSKRIFT

Jan Gustavsson

9.1.2 Structured Interview guide operator B

Fragor

1. Känner du till något annat arbete eller station på KABE?

Ja

2. Om ja, Vilken station eller vilket arbete?

1. KOFFERT, 2. TAK, 3. VVS, 4. SLUTKONTROLLER

3. Om ja, Hur bra är du med på det arbetet?

Hanterar det ☐
Som genomsnittet ☒
Mycket bra ☐

1. Assembles of front hatch, outer door on the li
2. Assemble of roof on the line
3. Assembly of Water, oven, Propane connectors.
4. Finishing controll and control of the Caravans different systems.

Jag förklarar härmed att ovanstående svarade frågor är riktiga mot min kunskap.

2020-04-02 UNDERSKRIFT

Questions were framed in Swedish because of operator requirement, the same are listed below in English.

- Are you familiar with other operation or station in KABE?
- If yes, which station or operation?
- If yes, how skilled are you in that operation?
  Manageable/ good control/ completely skilled.

9.1.3 Unstructured Interview guide Production manager

- What are the major problems in assembly line?
- Is there any bottleneck in the whole assembly line?
- How often does the stops occur due to bottleneck?
- What are your thoughts on process involved in press line?
- What are your thoughts on performance of line where bottleneck is present?
- What kind of production strategy has been adopted by KABE?

9.1.4 Unstructured interview guide Supervisor

- How many products are produced in a day at press line?
- What kind of variants in products are produced in press line?
- How often defects are found in press line?
- What is the percentage of defects in press line?
- Are the defective products recycled?
- What is the percentage of defective parts on which rework is carried out?
- Where is waiting mostly found in the line?
- Why are operators not involved in rotational work or switching between stations?
- How much scope is provided for suggestions provided by operators regarding improvements?

9.1.5 Unstructured interview guide Operator

This section addresses a quick interview with operators which was actually carried out in Swedish and later has been listed in English as per academic requirement.

- Have you been involved in rotational work?
- Which are the tools and equipment rarely utilized by you?
- What are the major problems faced by you on a daily basis?
- Are these major problems discussed during daily meetings?

9.2 RPA Sheet

RPA Questionnaire

The total number of yeses on this questionnaire is an indicator of a plant's leanness: the more yeses, the leaner the plant. Each question should be answered yes only if the plant obviously adheres to the principle implied by the question. In case of doubt, answer no.

		yes	no
1	Are visitors welcomed and given information about plant layout, workforce, customers, and products?	●	○
2	Are ratings for customer satisfaction and product quality displayed?	●	○
3	Is the facility safe, clean, orderly, and well lit? Is the air quality good, and are noise levels low?	○	●
4	Does a visual labeling system identify and locate inventory, tools, processes, and flow?	●	○
5	Does everything have its own place, and is everything stored in its place?	○	●
6	Are up-to-date operational goals and performance measures for those goals prominently posted?	●	○
7	Are production materials brought to and stored at line side rather than in separate inventory storage areas?	●	○
8	Are work instructions and product quality specifications visible at all work areas?	●	○
9	Are updated charts on productivity, quality, safety, and problem solving visible for all teams?	●	○
10	Can the current state of the operation be viewed from a central control room, on a status board, or on a computer display?	●	○
11	Are production lines scheduled off a single pacing process, with appropriate inventory levels at each stage?	○	●
12	Is material moved only once and as short a distance as possible? Is material moved efficiently in appropriate containers?	●	○
13	Is the plant laid out in continuous product line flows rather than in "shops"?	●	○
14	Are work teams trained, empowered, and involved in problem solving and ongoing improvements?	●	○
15	Do employees appear committed to continuous improvement?	○	●
16	Is a timetable posted for equipment preventive maintenance and ongoing improvement of tools and processes?	○	●
17	Is there an effective project-management process, with cost and timing goals, for new product start-ups?	○	●
18	Is a supplier certification process – with measures for quality, delivery, and cost performance – displayed?	○	●
19	Have key product characteristics been identified, and are fail-safe methods used to forestall propagation of defects?	●	○
20	Would you buy the products this operation produces?	●	○

Total number of yeses **13**

Rating Leanness

Plant **KABE Husvagnar AB**

Tour date **30/01/2020**

Rated by **Vignesh Bhandarkar**

RPA Rating Sheet

Team members use the RPA rating sheet to assess a plant in 11 categories on a scale from "poor" (1) to "excellent" (9) to "best in class" (11). The total score for all categories will fall between 11 (poor in all categories) and 121 (the best in the world in all categories), with an average score of 55. Factors to consider to rate a plant in each category are described in this article; a more detailed list of evaluative factors appears on the Web at www.bus.umich.edu/rpa. The rating sheet also guides team members to questions in the RPA questionnaire (opposite) that relate specifically to each category.

When plants are rated every year, the ratings for most tend to improve. Ratings are usually shared with plants, and motivated managers first improve their plants in the categories that receive the lowest ratings.

Ratings

Categories	*Related questions in RPA questionnaire*	poor *(1)*	below average *(3)*	average *(5)*	above average *(7)*	excellent *(9)*	best in class *(11)*	category score
1 Customer satisfaction	1, 2, 20					■		9
2 Safety, environment, cleanliness, and order	3–5, 20			■				5
3 Visual management system	2, 4, 6–10, 20				■			7
4 Scheduling system	11, 20			■				5
5 Use of space, movement of materials, and product line flow	7, 12, 13, 20		■					3
6 Levels of inventory and work in process	7, 11, 20			■				5
7 Teamwork and motivation	6, 9, 14, 15, 20					■		9
8 Condition and maintenance of equipment and tools	16, 20				■			7
9 Management of complexity and variability	8, 17, 20				■			7
10 Supply chain integration	18, 20			■				5
11 Commitment to quality	15, 17, 19, 20				■			7

Total score for 11 categories *(max = 121)* **69**

9.3 Production Documents

	A	B	C	D	E	F	G
1	INVID IT-konsulterna vid din sida						
2							
3							
4							
5	Maskin	Vägg Tak line	Från och med	2020/02/06 00:00			
6	Användare	peter.lilja@kabe.se	Till och med	2020/02/17 07:33			
7	Datum	2020-04-02 07:36:52					
8	Artikelnummer	Start Tid	Slut Tid	StoppTid	Kod	Orsak	Notering
9	60	2020/02/17 07:30	2020/02/17 07:33	00:02:57	-1	Odefinierat stopp	
10	60	2020/02/17 06:51	2020/02/17 07:11	00:20:07	-1	Odefinierat stopp	
11	60	2020/02/17 05:52	2020/02/17 06:27	00:34:49	112	Fräs omställning	
12	60	2020/02/14 12:53	2020/02/17 05:52	64:58:35	-4	Strömavbrott	
13	60	2020/02/14 12:40	2020/02/14 12:53	00:12:50	-1	Odefinierat stopp	
14	60	2020/02/14 11:26	2020/02/14 11:52	00:25:21	13	Ledig/Rast	
15	60	2020/02/14 08:41	2020/02/14 08:55	00:13:48	13	Ledig/Rast	
16	60	2020/02/13 22:40	2020/02/14 05:59	07:19:02	13	Ledig/Rast	
17	60	2020/02/13 20:58	2020/02/13 21:11	00:13:29	112	Fräs omställning	
18	60	2020/02/13 20:47	2020/02/13 20:57	00:10:34	-1	Odefinierat stopp	
19	60	2020/02/13 19:27	2020/02/13 19:38	00:11:03	13	Ledig/Rast	
20	60	2020/02/13 15:06	2020/02/13 15:34	00:28:38	-1	Odefinierat stopp	
21	60	2020/02/13 14:32	2020/02/13 14:43	00:11:47	100	Element saknas	
22	60	2020/02/13 13:55	2020/02/13 14:10	00:15:30	100	Element saknas	
23	60	2020/02/13 08:32	2020/02/13 08:43	00:10:53	13	Ledig/Rast	
24	60	2020/02/13 07:10	2020/02/13 07:22	00:11:48	100	Element saknas	
25	60	2020/02/13 05:17	2020/02/13 05:58	00:40:49	13	Ledig/Rast	
26	60	2020/02/12 22:38	2020/02/13 05:14	06:35:52	114	Verktygsbyte/ verktygsjustering	
27	60	2020/02/12 21:33	2020/02/12 21:45	00:12:45	-1	Odefinierat stopp	
28	60	2020/02/12 21:19	2020/02/12 21:32	00:12:42	-1	Odefinierat stopp	
29	60	2020/02/12 21:09	2020/02/12 21:19	00:10:04	-1	Odefinierat stopp	
30	60	2020/02/12 18:06	2020/02/12 18:22	00:16:34	112	Fräs omställning	
31	60	2020/02/12 17:52	2020/02/12 18:05	00:13:10	-1	Odefinierat stopp	
32	60	2020/02/12 16:19	2020/02/12 16:36	00:17:18	113	Fel i fräsprogram	
33	60	2020/02/12 13:51	2020/02/12 14:26	00:35:00	112	Fräs omställning	
34	60	2020/02/12 12:17	2020/02/12 12:32	00:14:26	114	Verktygsbyte/ verktygsjustering	
35	60	2020/02/12 11:57	2020/02/12 12:15	00:18:03	-1	Odefinierat stopp	
36	60	2020/02/12 11:35	2020/02/12 11:50	00:15:48	13	Ledig/Rast	
37	60	2020/02/12 05:27	2020/02/12 05:57	00:30:12	13	Ledig/Rast	

38	60	2020/02/11 22:58	2020/02/12 05:20	06:22:07	-4	Strömavbrott
39	60	2020/02/11 22:28	2020/02/11 22:39	00:11:05	112	Fräs omställning
40	60	2020/02/11 18:59	2020/02/11 19:21	00:21:47	100	Element saknas
41	60	2020/02/11 16:40	2020/02/11 16:59	00:19:17	100	Element saknas
42	60	2020/02/11 16:10	2020/02/11 16:25	00:14:44	112	Fräs omställning
43	60	2020/02/11 15:40	2020/02/11 15:57	00:16:27	-1	Odefinierat stopp
44	60	2020/02/11 15:09	2020/02/11 15:21	00:12:37	-1	Odefinierat stopp
45	60	2020/02/11 13:54	2020/02/11 14:05	00:10:27	13	Ledig/Rast
46	60	2020/02/11 12:23	2020/02/11 12:34	00:11:07	114	Verktygsbyte/ verktygsjustering
47	60	2020/02/11 11:29	2020/02/11 11:47	00:17:26	12	Personalbrist
48	60	2020/02/11 05:51	2020/02/11 05:54	00:02:14	13	Ledig/Rast
49	60	2020/02/10 22:44	2020/02/11 05:21	06:37:00	13	Ledig/Rast
50	60	2020/02/10 19:27	2020/02/10 19:47	00:19:49	112	Fräs omställning
51	60	2020/02/10 17:42	2020/02/10 17:57	00:15:00	13	Ledig/Rast
52	60	2020/02/10 14:39	2020/02/10 15:05	00:26:15	100	Element saknas
53	60	2020/02/10 13:50	2020/02/10 14:17	00:27:17	112	Fräs omställning
54	60	2020/02/10 13:20	2020/02/10 13:33	00:13:15	-1	Odefinierat stopp
55	60	2020/02/10 09:48	2020/02/10 10:06	00:18:28	112	Fräs omställning
56	60	2020/02/10 06:01	2020/02/10 06:03	00:02:24	111	Fräs dator
57	60	2020/02/10 05:22	2020/02/10 05:57	00:34:41	13	Ledig/Rast
58	60	2020/02/08 11:55	2020/02/10 05:21	41:26:09	-4	Strömavbrott
59	60	2020/02/08 08:50	2020/02/08 09:02	00:11:40	-1	Odefinierat stopp
60	60	2020/02/08 05:59	2020/02/08 07:17	01:17:36	-1	Odefinierat stopp
61	60	2020/02/07 14:01	2020/02/08 05:59	15:57:14	-4	Strömavbrott
62	60	2020/02/07 13:21	2020/02/07 13:37	00:16:00	-1	Odefinierat stopp
63	60	2020/02/07 11:23	2020/02/07 11:52	00:28:33	13	Ledig/Rast
64	60	2020/02/07 10:24	2020/02/07 10:42	00:17:34	100	Element saknas
65	60	2020/02/07 09:24	2020/02/07 10:09	00:44:36	14	Underhåll akut
66	60	2020/02/07 08:02	2020/02/07 09:23	01:21:12	-1	Odefinierat stopp
67	60	2020/02/07 06:32	2020/02/07 06:47	00:14:11	100	Element saknas
68	60	2020/02/06 22:42	2020/02/07 05:52	07:09:24	13	Ledig/Rast
69	60	2020/02/06 13:39	2020/02/06 14:04	00:25:08	13	Ledig/Rast
70	60	2020/02/06 11:25	2020/02/06 11:55	00:30:06	13	Ledig/Rast
71	60	2020/02/06 10:31	2020/02/06 10:44	00:13:41	100	Element saknas
72	60	2020/02/06 09:39	2020/02/06 09:51	00:11:41	100	Element saknas
73	60	2020/02/06 08:56	2020/02/06 09:28	00:32:08	100	Element saknas
74	60	2020/02/06 08:30	2020/02/06 08:49	00:18:28	13	Ledig/Rast
75	60	2020/02/06 07:56	2020/02/06 08:19	00:23:05	100	Element saknas
76	60	2020/02/06 07:27	2020/02/06 07:37	00:10:15	100	Element saknas
77	60	2020/02/06 06:30	2020/02/06 06:54	00:24:32	-1	Odefinierat stopp
78	60	2020/02/06 05:47	2020/02/06 06:08	00:20:33	-1	Odefinierat stopp
79	60	2020/02/06 00:00	2020/02/06 05:47	05:47:12	-4	Strömavbrott

Stopp

9.4 Abbreviations

- PM – Preventive maintenance
- FMEA – Failure mode and effects analysis
- OEE – Overall equipment efficiency

Appendices

- PdM – Product data management
- TBM – Time based maintenance
- MTBF- Mean time between failures
- MTTR – Mean time to repair
- NVA – Non-value adding