IMPLEMENTING LEAN MANUFACTURING IN PLASTIC CHAIR INJECTION MOULDING PRODUCTION PROCESS USING VALUE STREAM MAPPING APPROACH

By

Eliza Vania

ID No. 004201400020

A Thesis presented to the Faculty of Engineering President University in partial fulfillment of the requirements of Bachelor Degree in Engineering Major in Industrial Engineering

2019
THESIS ADVISOR
RECOMMENDATION LETTER

This thesis entitled “IMPLEMENTING LEAN MANUFACTURING IN PLASTIC CHAIR INJECTION MOULDING PROCESS USING VALUE STREAM MAPING APPROACH” Prepared and submitted by Eliza Vania in partial fulfillment of the requirements for the degree of Bachelor Degree in the Faculty of Engineering has been reviewed and found to have satisfied the requirements for a thesis fit to be examined. I therefore recommend this thesis for Oral Defense.

Cikarang, Indonesia, May 28th, 2019

[Signature]

Anastasia Lidya Maukar, S.T., M.Sc., M.T.
DECLARATION OF ORIGINALITY

I declare that this thesis, entitled “IMPLEMENTING LEAN MANUFACTURING IN PLASTIC CHAIR INJECTION MOULDING PROCESS USING VALUE STREAM MAPING APPROACH” is, to the best of my knowledge and belief, an original piece of work that has not been submitted, either in whole or in part, to another university to obtain a degree.

Cikarang, Indonesia, May 28th, 2019.

[Signature]

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By
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ID No. 004201400020

Approved by

Anastasia Lidya Maukar, S.T., M.Sc., M.T.
Thesis Advisor

Ir. Andira Taalim, M.T.
Program Head of Industrial Engineering
ABSTRACT

This research integrates Value Stream Mapping with considering the reduction of its Non Value Added time. A Value Stream Mapping provides a blueprint for implementing lean manufacturing concept by showing information and flow of materials. The total Non-Value Added time of current Value Stream Mapping is 3 days and mostly caused by transportation activity from cooling to packaging area. The objective of the research is reducing the Non-Value Added time and wastes in PT. X from current Value Stream Mapping, then redesigning future Value Stream Mapping with result of improvements. After implementing the improvements and redesigning future Value Stream Mapping, the result of Non-Value Added time reduced the lead-time from 3 days to 2 days, and the total cost were reduce to

Keywords: Lean Manufacturing, Value Stream Mapping, Kaizen, Process Activity Mapping
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<th>Term</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>Injection Moulding</strong></td>
<td>The manufacturing process of injecting molten materials into a mould.</td>
</tr>
<tr>
<td><strong>Polypropylene (PP)</strong></td>
<td>A thermoplastic polymer used in a wide variety of applications. Usually a raw material of plastics.</td>
</tr>
<tr>
<td><strong>Value-Added</strong></td>
<td>Activity that does not add value to product and process. It should be eliminated or reduced.</td>
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CHAPTER I
INTRODUCTION

1.1 Problem Background

The development of the service industry and manufacturing industry is growing rapidly. This triggered the service and manufacturing industries to continue to improve their production, both in terms of quality or service to consumers. To be able to compete to win the existing market, the company must have a good strategy to maintain the continuity of the company, maintain its existence in the community and provide satisfaction to consumers.

Achieving the efficiency and effectiveness in production process is not easy, because it is influenced by several factors, but it can be achieved when companies try to minimize wastes and lead-time. Therefore the effort to eliminate or reduce waste and minimize production lead-time is required. According to Gaspers and Fontana (2011), lean manufacturing can be defined as an approach to identify and eliminate waste or non-value added activities through radical continuous improvement. Lean manufacturing has several tools to identify waste and non-value added activities and Value Stream Mapping is one of them.

The research was conducted at one of the production companies that produce chairs. This company uses a make to order system where the company will operate (production) if there is an order. As an industry that uses the make to order system, this company is required to complete the order at the specified time and specific amount of goods. But the problem is, this industry has a bad Due date, so some orders have to be delayed because the company is unable to produce the products on time. This delay is caused by work that is not in accordance with the procedure. By doing some interview and research, the problem that affect the
current condition of the manufacturing process are based on the cycle time, uptime, and lead-time.

The cycle time is taken from the time taken by the work-station in processing the material to completion and moving to the next work station. In this production process, the total cycle time in the plastic chair production process is 27552.68 seconds or 7.653522 hours.

Up time is the percentage where the machine is used per amount of time available per day. Shift time available every day is 6.5 hours or 23,400 seconds. In processing raw material, the up time is 9%; in the heating process 5%, in the injecting process 27%, in the molding process 30%, in the process of cooling 17%, and uptime in the packaging and delivering process by 30%. This happens because usually the production is done a maximum of 2 times, so the engine is idle.

The lead-time is the waiting time from the order received, until the product reaches the consumer. The raw material lead-time order until the material is received is 1 day, the whole production process is 1.29 days, and the delivery process lead-time takes 1 day, so the total production lead-time is 3.3 days.

One method that can be used to determine the flow of activities and aims to map the production and information flow is Value Stream Mapping (VSM). VSM is one of the concepts in lean manufacturing that can be used to see and identify activities carried out within the company.

According to Akbar (2011), VSM is a tool to map the value stream value in detail and identify the wastes. By using this tool, the place where the improvement should be conducted in the production process can be identified more accurate, because, the non-value added activities and waste will be identified directly.
1.2 Problem Statement
There are several statements that will be focused on this analysis, which are:

1. What is the current condition in the production process in VMS?
2. How does the company improve the times and wastes in the current production process?
3. How is the improvement in the future VSM?

1.3 Objectives
The research objectives are established to keep the research on track, so here are the objectives in conducting this research:

1. To identify and analyze the company’s current condition using Value Stream Mapping.
2. To define the results and application of the proper methods to reduce time and wastes in the current production process and its results.

1.4 Scope
Due to limitation of this research, there will be some scope of observations:

1. The annual demand data was collected from January until December 2018
2. The machine type used in the process is Injection Moulding machine type UP-860
3. Observation is in September 2018 until December 2018 with company’s current condition

1.5 Assumption
Assumption is made in order to ensure the implementation of method is accurate. The assumptions are:

1. All raw materials condition does not affect the production process since the condition is all good.
2. Manpower and machine also in a good condition. This research will focus more on the production process.

3. All price in materials and products are constant.

4. The lead-time of the suppliers is constant.

1.6 Research Outline

Chapter I INTRODUCTION
This consist problem backgrounds of the research, problem statements, objectives, scopes, assumptions, and research outline.

Chapter II LITERATURE STUDY
This delivers explanation of the study and methods in this research. There are, Value Stream Mapping, Process Activity Mapping and Kaizen. The methods use is going to help identify the problems in the research and giving solution for the problems occurred.

Chapter III RESEARCH METHOD
This chapter explains the flows of the research consist of problem backgrounds, literature study, objectives, data collection, data analysis, and conclusion and recommendation.

Chapter IV DATA COLLECTION AND ANALYSIS
This chapter consists of the data that has been collected for the research and the analysis of the data that will support in finding the solution for the problem in this research.

Chapter V CONCLUSION AND RECOMMENDATION
This chapter explains the conclusions as a result of the whole research and also given recommendation for future research.
CHAPTER II

LITERATURE STUDY

2.1 Lean Management

Lean Management is an erudite method consisting of scheme that measures and considers the potential things in system and carries it out in order to accentuate companies; competitive advantages (Neni et. al, 2014).

Based on Hossain’s study (2014), Lean is outstanding with concept of reducing cost, increasing the product quality, decreasing wastes with desirable outcomes. Lean word means the comprised approach of practices and tools that has purpose to improve all of the production process effectively and efficiently, from the supplier until the product goes to customers.

Hook and Stehn (2008) found that lean principles can be used in any business, and these principles are identifying the value stream map for every product, making production flow smooth without interference, the customers pull value from produces. According to Hossain (2014), there five main lean principles which are:

- Identify the requirement from customers. Specify the necessary thing what is non-value added, what is the value added for both customer perspective and company perspective.
- Specify the value stream of production, the design, order, production, products and the whole system to highlight the non-value added waste and reduce it.
- Ensure the remaining value-added process work continuously, create process without interruption, backflows, waiting and wastes.
- Explain about the pull system in the steps.
- Conduct efficient and effective management, and eliminate the number of process step, information and time.

Source (Hook & Stehn, 2008, p 20-23)

**Figure 2.1 Lean Production House**

Lean Production House is an illustration model and popular symbol of lean principle and goals regarding production performance. The visual model was invested by Taiichi Onjo and Eiji Toyoda at Toyota Motor Company (Hook & Stehn, 2008).
The first concept is Just-in-Time concepts Dalci (2006) stated JIT production system is a system that make companies are able to manufacture products in required amount when the demand is happened. Using this concept, the companies can offer the products on time. Within this concept, companies can minimize the raw material, WIP, and finished goods inventories. JIT production also creates the better quality and shorter lead-time, therefore, this concept can increase the customers’s satisfaction.

The second approach is built-in quality or Jidoka. Referring to Rosenthal’s statement (2002), Jidoka is automation with human touch. Jidoka’s pillar is labeled as “stop and respond the abnormality”. Whether human or auto machine are unable to detect the abnormality in process and stop. There are four steps in Jidoka. The first us detecting the abnormality, the second is stopping it, the third is giving the correct action or fixing this condition immediately, and the last is investigating the root cause to install countermeasure.

The last is work standardization concepts. This action is fundamental of today’s industrial plants in order to make the process of production efficiently and effectively. Work standardization comes under Toyota Production System to ensure the better production flow and decrease error. Working standardization is required appropriately plan, position of employees, materials, machine and other manufacturing supports. This is based on two philosophies, which are eliminating the wastes and respecting people (PG, 2015).

Regarding the study from Hossain (2014), lean is about reducing the waste. These wastes are categorized as 8 types. Different kinds of production wastes can be concluded as follows:
Overproduction – producing the products more than required point of demand and time, this can create excess inventories, staffs, storage area, transportation, etc.

Waiting – it can occur in various ways, i.e. unmatched worker/machine, machine breakdowns, lack of employees knowledge, etc. This can make the next process idle.

Unnecessary Transportation – this is because of long distance from one process to another and insufficient transportation.

Over Process – working on a product more than actual process should be is over processing. This can be cause by improper tools, procedures and lack of employee’s knowledge.

Excessing of Raw Material – this include the raw material, WIP, or FG that cause long lead time, obsolescence, inventory cost, transportation cost, day of inventory, and delay.

Unnecessary Movement – the example of this waste is movement for search tools and shifting WIP.

Defects – the parts that turn into scrap and waste. Defect can be caused by many reason, one of the examples is machine breakdown. Repair and rework for defect are also waste for time and effort.

Unused Employee Creativity – losing the better improvement idea, skills and learning activity from presence of employee is assumed as waste.

2.2 Value Stream Mapping as Lean Tools

Based on Modi and Thakkar (2014), Value Stream Mapping is entire set of production activities from supplier of raw materials until coming to customers in finished foods form, Value Stream Mapping is powerful visual tool to specify the wastes of production and understand the material and information because it shows the required actions in map form. Value Stream Mapping focuses on value added and non-value added.
2.2.1 Value Stream Mapping Parts

According to Akbar (2011), Value Stream Mapping has three main parts. These categorized parts are explained as below:

1. Process and Material Flow
   This part is located between information flow and timeline. Process and Material Flow is drawn from left to the right. Subtask and parallel process is drawn with unique shape in the bottom of main flow. Process and Material Flow is drawn to make a clear process big picture.

2. Information Flow
   This part is located in the top side. This information flow is created to enable reader seeing all information and communication process either formal or informal. Information flow can detect the unnecessary information that become non-value added.

3. Timeline
   This part is located in the bottom of the map in the form of line that consist of information total time.

   There are two types of lines, the first is Production Lead Timeline and the other one is Cycle Timeline.
   - Production Lead Timeline is counted as the product that pass through all process from raw materials until becoming finished goods, this line is counted as Non-Value Added.
   - Cycle Time is line that counted the real Value Added time. These two lines will be calculated, and from the total of NVA and VA, the analysis of proposed VSM can be known.
2.2.2 Value Stream Mapping Process

The first step of Value Stream Mapping is to understand the initial state manufacturing process. VSM provide the useful and important information for analysis of decision problems.

The second is identifying the key areas of wastes, the problems in production process. Next is developing the future VSM of process, this map is shown the result of reducing waste (NVA), Inventory and Production Lead Time (Dighe & Kakirde, 2012).

2.2.3 Value Stream Mapping Data

Akbar (2011) stated that to make Value Stream Mapping, there are several data that
must be collected. This data is collected to create the process and material flow, information flow, and timeline. These data are:

1. Information about the suppliers, actual demand in daily/month/year, forecast demand, cycle issue, ordering frequency and detail shipment information.
2. Data about suppliers, cycle of order, raw materials, lead time, procedure, and ordering.
3. Working hour, shift, over time, break and holidays.
4. Production control information system.
5. Production process data, the workstation characteristic, total operator, machine and equipment, process flow, defect rate, set up time, cycle time and OEE.
6. Total Inventory from raw material, WIP from each process, safety stock, buffer stock and Finished Goods.

\[
Total \ Inventory \ Day = \frac{Daily \ Demand \ Unit}{Unit \ Stock}
\]

7. Value Added Time and Non-Value Added Time.
8. Takt time calculation is required.

\[
Takt \ time = \frac{Available \ Time}{Daily \ Demand}
\]

2.3 Time Study
According to Akbar (2011), time study is conducted for each workstation that has production process repeatedly. Time study approach uses stopwatch in measuring the time. The first thing to do is the observer collect the time of specified workstation. After that there are some calculation required to determine the limits.

1. Average sample

\[
\bar{x} = \frac{\sum x}{N}
\]

2. Standard Deviation
\[ \sigma = \sqrt{\frac{\sum(x - \bar{x})^2}{N - 1}} \]

3. Low Control Limit and Upper Control Limit

\[ LCL = \bar{X} - Z_{\alpha/2}\sigma \]
\[ UCL = \bar{X} + Z_{\alpha/2}\sigma \]

The next is Adequacy test to identify the result of data already enough or not using Equation below,

\[ N' = \left[ \frac{k}{S} \sqrt{\frac{N\sum x^2 - (\Sigma x)^2}{\Sigma x}} \right]^2 \]

After the data is enough based on Adequacy testing, the next is determining the rating process based on Westinghouse rating. Table below will show the score for each Westinghouse Rating.

<table>
<thead>
<tr>
<th>Skill</th>
<th>Effort</th>
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<tbody>
<tr>
<td>+0.15 A1</td>
<td>Superskill</td>
</tr>
<tr>
<td>+0.13 A2</td>
<td>Superskill</td>
</tr>
<tr>
<td>+0.11 B1</td>
<td>Excellent</td>
</tr>
<tr>
<td>+0.08 B2</td>
<td>Excellent</td>
</tr>
<tr>
<td>+0.06 C1</td>
<td>Good</td>
</tr>
<tr>
<td>+0.03 C2</td>
<td>Good</td>
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<tr>
<td>0.00 D</td>
<td>Average</td>
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<tr>
<td>-0.05 E1</td>
<td>Fair</td>
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<td>-0.10 E2</td>
<td>Fair</td>
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<tr>
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<td>F1</td>
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<tr>
<td>-0.22</td>
<td>F2</td>
</tr>
<tr>
<td>-0.12</td>
<td>F1</td>
</tr>
<tr>
<td>-0.17</td>
<td>F2</td>
</tr>
</tbody>
</table>

After determining the Rating, the Normal Time is calculated. The last calculation is calculating the Standard Time. The allowance is basically determined by the company

\[
Normal\ Time = Total\ Rating \times OT
\]

\[
Standard\ Time = NT(1 + Allowance\ percentage)
\]

### 2.4 Process Activity Mapping

Process activity mapping (PAM) is used to find out all the activities that take place during the production process and then classify those activities based on the type of waste. This tool aims to eliminate unnecessary activities, identify whether a process can be more efficient, and look for improvements that can reduce waste (Misbah, et al., 2015). Process activity mapping consists of five steps that need to be done, namely:

1. Identify the process flow and do the initial analysis.
2. Identifying waste.
3. Consider the rearrangement of sequence processes to be more productive.
4. Consider a better flow pattern
5. Consider eliminating hard work and only what really matters (Hines & Rich, 1997)
Table 2.1 Process Activity Mapping Templates

<table>
<thead>
<tr>
<th>No</th>
<th>Kegiatan / Tools</th>
<th>Distance (m)</th>
<th>Time (min)</th>
<th>Operator</th>
<th>Activity (O T I S D) (NNVA/NVA/VA)</th>
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Whereas:

D = Delay
O = Operation
VA = Value Added
T = Transportation
NNVA = Necessary but Non Value
I = Inspection
Added
S = Storage
NVA = Non Value Added

2.6 Kaizen

Kaizen is a Japanese term for the concept of continuous cumulative enhancement. Kai means change and Zen means good, Kaizen means enhancement. So that it can be interpreted kaizen as a continuous improvement and involves everyone. Kaizen philosophy assumes that our way of life, both ways of working, social upbringing, and household life need to be refined at all times (Ekoanindoyo, 2013).

In Japanese, kaizen means continuous improvement. (continuous improvement). The term includes the notion of improvements involving everyone, both managers and employees, and involves minimal costs.

Kaizen can be applied using seven tools in the production process and analysis of 5S implementation, waste analysis (Young), and standardization that can be applied by
companies on the production floor. In its usage in the company, Kaizen covers the notion of continuous improvement and involves all workers, both top-level management to lower-level operators (Hitoshi Takeda, 2006: 82).

Broadly speaking there are eight main keys to implementing just in time or kaizen in industrial activities namely (Paramita, 2012):

1. Produce products according to a schedule based on demand customer. The Kaizen system produces production according to customer orders with a pull system that is assisted by using kanban cards.

2. Producing in small lot size. In addition to timely production, production is also carried out in small quantities according to demand consumers so that it will save costs and resources. Production of small quantities can also eliminate the supply of goods that are waste by using an evenly mixed production pattern, which is producing various products in one production line (heijunka).

3. Eliminating waste. To avoid wasting on inventory due to purchases, scheduling is done using a kanban card system that supports the pull production system. The Kanban system will make it easier for management to manage scheduling from the start so that it will reduce the number of items that come, eliminate buffer stocks, reduce purchasing costs, improve handling of raw materials, achieve inventory in small quantities and get reliable suppliers.

4. Improve product quality. Maintaining product quality can be done by looking at the management principle of maintaining process control and making everyone responsible for achieving quality, improving management's view of quality, fulfilling product quality control firmly, giving employees the authority to carry out product quality control, requiring correction of product defects by employees, achieving 100% inspection of product quality and
achieving commitment to long-term quality control. The core of this activity is to avoid products that are of less quality in the hands of consumers.

5. Responsive people. In the implementation of the Kaizen system no longer uses the pillars of finance, marketing, HR, but uses cross-disciplinary functions so that all employees are required to master the entire field in the company according to their level and position. Errors in the process are always marked by turning on the andon lights and the process is stopped. Then all employees are focused on reparation responsibilities to achieve good products and prevent future errors.

6. Eliminating uncertainty. For example, such as raw material leadtime, so that there is no delay in trying suppliers that are located nearby. In the production process, eliminating uncertainty can be done by applying pull production system with the help of kanban cards and evenly mixed production (Heijunka).

7. Emphasis on long-term maintenance. Perform maintenance of raw material suppliers with long-term contracts, improve production SOPs, flexibility in holding goods orders, make continuous and continuous improvements.

8. Improve production flow. Production arrangement is carried out based on five disciplines (5S) in the workplace, namely:

   a) Seiri (Concise) Seiri is separating the required objects from those that are not needed, then getting rid of those that are not needed (concise), making it easier to find the items sought.

   b) Seiton (Neat) The Japanese word seiton (整頓) literally means arranging things in an interesting (neat) way. Arrange items neatly and make it easy for recognize the object you want to use. This means arranging things so that everyone can find them quickly. Seitons allow workers to easily recognize and retrieve tools and materials, and easily return them to locations near the point of use. The pointing
plate is used to facilitate the placement and retrieval of the required materials.

c) Seiso (Resik) Always prioritize cleanliness by maintaining neatness and cleanliness (rehearsal). In addition to maintaining cleanliness, Seiso also includes analysis because of the appearance of dirty symptoms. With a clean work environment, workers will feel comfortable in doing their jobs.

d) Seiketsu (Caring) Seiketsu is an activity to maintain personal hygiene while adhering to the previous three stages. In principle, Seiketsu means that the workplace that has become good can always be maintained.

e) Shitsuke (Diligent) Shitsuke is a method used to motivate workers to continuously carry out and participate in maintenance activities and improvement activities and make workers accustomed to obeying the rules.

2.7 Flow diagrams
A flow diagram usually shows the study of the process in people and materials of the company. The flow diagram helps identify several problems such as:

1. Cross traffic – the cause of clogs and delays.
2. Backtracking – The material in reverse. Not starting from the receiving to shipment process in the company.
3. Distance travelled – Distance that materials and people have to travel in the plant. In order to save time, the distance should be as short as possible, so machines and departments should be arranged accordingly.
4. Procedure – If the layout is not suitable for the sequence of operations, it can originate backtracking and cross traffic. When the sequence cannot be changed, rearranging the location of the equipment should be considere
CHAPTER III
RESEARCH METHODOLOGY

3.1 Research Methodology

The following methodology determines the method used for analyzing this research.

- **Initial Observation**
  - Observing the production process in PT. X
  - Collecting data.

- **Problem Identification**
  - Identifying the existing problem.
  - Setting research objective, scope, and assumptions.

- **Literature Study**
  - Theory of Lean Manufacturing Concept and VSM as the Lean Tool.
  - Method of Economic Order Quantity and Vendor Manager Machine.
  - Failure Distribution Function and its Probability.
  - Time Study Approach.

- **Data Collection**
  - Collected data from Injection Moulding process.

- **Data Analysis**
  - Implementing Value Stream Mapping.
  - Analyzing results of implementation.

- **Conclusion and Recommendation**
  - Deducing the analysis of the research.
  - Give recommendation for further research.

*Figure 3.1 Research Methodology*
3.1.1 Initial Observation

The observation was conducted in chair manufacturing company to identify the current problem happening. The observation was focused on the one type of product that is plastic chair. A depth understanding about company’s product and process is pretentious in order to get proper research and solution of problem. This observation was directly conducted.

This direct observation was conducted through Gemba as one of Lean Tools. Gemba is observing directly the initial situation of production process. Another way to conduct the observation was with data of production, i.e. performance report and red string from analyzing data.

3.1.2 Problem Identification

After observation, the problems in current production can be identified. The deep understanding of problems can be clear in order to get accurate research.

The Value Stream Mapping is created when the observation is conducted to know the location of problems. And it is found that there are several problems in production plastic chair, which cause delay in lead-time.

This research focused on analyzing the problems that cause big impact in producing plastic chair. The problem in production must be eliminated to achieve the good performance. The mess of production can cause wastes. Furthermore, the objectives of research in order to keep the research in the track are:

1. Mapping the current situation using Value Stream Mapping (VSM).
2. Identify every performance of process and workstation and decide the target of improvement.
3. Reduce the wastes in production and lead-time.
4. Find the proper methods in improving current problems.
5. Compare current VSM with proposed improvement of VSM.

The limitation of time, therefore the scope and assumption of research are created. The scope of this research is to only produce the plastic chair, and data was observed. The assumptions of this research are all of material and manpower in good condition.

3.1.3 Literature Study
Literature study of this research, are taken from journals and books referring to suitable methods for improvement. The details of citation details are listed in references sections. This was used as theoretical concept for improving the current problems. The literature study in research, are:

1. Lean Manufacturing concept and principles.
2. Value Stream Mapping as the tools of Lean Manufacturing to map and identify the location of problem.
3. Distribution Function for failure, to determine and measure the schedule of replacement equipment components.
4. Time study to find the standard time of each process, it will be used for Value Stream Mapping.

3.1.4 Data Collection
After determining the support knowledge, data collection is needed as the fundamental source of the analysis. The data collected was from the month of September until December 2018. The data collected are related to the topic of the research, which are:

- Injection molding machine type.
- Interview results from injection moulding area.
- Annual demand in 2018
- Defects, and machine breakdown in injection moulding.
3.1.5 Data Analysis

After all the required data has been collected, the next procedure is to find the problem that has the biggest impact in decreasing performance of business problems. Here are the illustration of data that will be examined and improved using Lean Concept:

2. Analyzing the solution of current problems and proposed Future Value Stream Mapping. Finding the proper method to solve the problems. To solve the problem in Injection Moulding. Calculating the results of using methods and proposed improvements. Creating new Value Stream Mapping with improvements. Implementing the improvement in PT. X.
3. Comparing between current Value Stream Mapping and proposed Value Stream Mapping. Comparing the difference between Non-Value Added time between previous system of process and improved system in order to prove whether the improvement is already success or not.

3.1.6 Conclusion and Recommendation

The last phase is concluding the result of improvement. The conclusion refers to the objective of this research. In addition is recommendation is created to address for company and readers for future research.

3.2 Research Framework

Figure 3.2 will show the framework that describes flow process of Lean Concept in analyzing the improvement of this research to reduce wastes and lead time of producing plastic chair using injection moulding. The research began with analyzing the initial observation in the process of injection moulding. In this part, the research focused on explaining the processes in making plastic chair using injection moulding.
This part also helps identifies the current problems that happened in the whole manufacturing processes that needs to be enhance later in the future.

After the problem has been identified, the data is then collected. The collected data includes raw material inventory data, work in process data, work station and available time, time study in cycle time, lead-time, and processing time. After collecting the data, the next is analyzing the data collected by calculating the uptime and current process activity mapping.

After all the data has already analyzed, the next step is to create the current value stream mapping to summarize the data into the current stream map to see the whole production process and look into the cause of the problem. And creating waste identification.

From the analysis, the result of the calculation shows the cause of the current problems. Therefore the location of problems can be found. The detailed problem of the identification started from inventory data, then time study is conducted for current system to be compared with improvement using uptime and process activity mapping.

The results from the calculation in the analysis then improved using new calculation results. After the result of improvements are obtained, the next step is to create the Future Value Stream Mapping with improvement data calculation results.

The comparison is conducted between current system and proposed improvement of future value stream mapping in conclusion, but if the improvement is not success the analysis of problems and solution is conducted again but if the proposed improvement is success, the research is done.
Figure 3.2 Research Framework
CHAPTER IV
DATA ANALYSIS

4.1 Initial Observation

4.1.1 Production Process

PT. X is known for their chair production. Since the company is known for their plastic chair production, it is obvious that the production process include an important process in processing plastics, which is injection moulding. This process is the main and important part in the entire plastics processing industry.

![Injection Moulding Machine](image)

**Figure 4.1 Injection Moulding Machine**

Before the injection moulding processes begin, the company ordered the raw material from vendor. The material used in injection moulding is thermoplastics, that can be reused. The company use Polypropylene (PP) granules, which is part of thermoplastics as the raw material. After the PP has arrived, the material will soon proceed based on the process.
The first process is melting the raw material, polypropylene granules. The raw materials will be filled from a hopper into the injection moulding machine. Then the rotating screw that is within the barrel will bring the raw material from the barrel straight to the mold. The heat will circle the barrel that will melt the raw material as it travels ahead to the barrel. The screw is tighten as the melted raw material will converge at the cease of the barrel.

Once enough material have collected, the hydraulic ram pushes the screw forward injecting the material through a sprue into a mold cavity. The mould is warmed before the injection and the material is injected swift to make sure it is not hardened before the mold is full.

After that, pressure is alleged in a short time to make sure the material lagging back during hardening. This obviates shrinkage and hollows, which will results in a better quality product. The molding is left to cool before ejected from the mould. The moulding takes on the shape of the mold cavity. The Flow Process Chart of making the plastic chair will be shown in Figure below.
Figure 4.2 Injection Moulding Flow Chart
4.1.2 Work Station

From the sequence from figure 4.1, the processes were grouped into several work stations based on its production process. There are:

<table>
<thead>
<tr>
<th>Machine</th>
<th>No.</th>
<th>Total</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melting</td>
<td>1</td>
<td>1</td>
<td>To melt the raw material.</td>
</tr>
<tr>
<td>Injection</td>
<td>2</td>
<td>1</td>
<td>To inject the raw material to moulding.</td>
</tr>
<tr>
<td>Moulding</td>
<td>3</td>
<td>1</td>
<td>To shape the product.</td>
</tr>
<tr>
<td>Cooling</td>
<td>4</td>
<td>1</td>
<td>To cool down the product after moulding.</td>
</tr>
</tbody>
</table>

4.1.3 Current Production Problem

This chapter of the research will try to solve the problem stated below using the implementation of methods available. The current problems that the company faces are stated in the next paragraph. The cycle time is taken from the time taken by the work station in processing the material to completion and moving to the next work station. The total cycle time in the plastic chair production process is 27552.68 seconds or 7.653522 hours.

Up time is the percentage where the machine is used per amount of time available per day. Shift time available every day is 6.5 hours or 23,400 seconds. In processing raw material, the time up of the time is 9%; in the heating process 5%, in the injecting process 27%, in the molding process 30%, in the process of cooling 17%, and uptime in the packaging and delivering process by 30%. This happens because usually the production is done a maximum of 2 times, so the engine is idle.

The lead-time is the waiting time from the order received, until the product reaches the consumer. The raw material lead-time order until the material is received is 1 day,
the whole production process is 1.29 days, and the delivery process lead-time takes 1 day, so the total production lead-time is 3.3 days.

4.2 Data Collection
There are several data required to create the value stream mapping. The data are the information of the cycle time for each workstation (injection time, holding time, and cooling time), raw material inventory, the OEE, and production output.

4.2.1 Raw Material Inventory Data
The calculation of the Day of Inventory measures number of days required for company to sell the current stock of the inventory. In other words, the Days of Inventory shows the time duration the company needs to sell all of the company’s current inventory stock.

For plastic chair production using injection molding, the only raw material needed is polypropylene (PP). To calculate the Days of Inventory, material demand data is needed. Since the company is using a make to order system, the demand of the material will be in a different amount in every month. The production demand data will be shown in table 4.2.

<table>
<thead>
<tr>
<th>No.</th>
<th>Month</th>
<th>Production Demand (pcs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>January</td>
<td>133</td>
</tr>
<tr>
<td>2</td>
<td>February</td>
<td>125</td>
</tr>
<tr>
<td>3</td>
<td>March</td>
<td>227</td>
</tr>
<tr>
<td>4</td>
<td>April</td>
<td>180</td>
</tr>
<tr>
<td>5</td>
<td>May</td>
<td>152</td>
</tr>
<tr>
<td>6</td>
<td>June</td>
<td>124</td>
</tr>
</tbody>
</table>
Required material for each plastic chair is 1.10 kg. To find the material demand each month, the calculation of multiplying production demand with material required per chair is conducted. The example calculation for January is shown below.

\[ \text{Material Demand} = \text{Production Demand} \times \text{Required Material} \]

\[ \text{Material Demand} = 133 \times 1.10 \text{ kg} \]

\[ \text{Material Demand} = 146.3 \text{ kg} \]

<table>
<thead>
<tr>
<th>No</th>
<th>Month</th>
<th>Production Demand (pcs)</th>
<th>Material Demand (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>January</td>
<td>133</td>
<td>146.3</td>
</tr>
<tr>
<td>2</td>
<td>February</td>
<td>125</td>
<td>137.5</td>
</tr>
<tr>
<td>3</td>
<td>March</td>
<td>227</td>
<td>249.7</td>
</tr>
<tr>
<td>4</td>
<td>April</td>
<td>180</td>
<td>198</td>
</tr>
<tr>
<td>5</td>
<td>May</td>
<td>152</td>
<td>167.2</td>
</tr>
<tr>
<td>6</td>
<td>June</td>
<td>124</td>
<td>136.4</td>
</tr>
<tr>
<td>7</td>
<td>July</td>
<td>220</td>
<td>242</td>
</tr>
<tr>
<td>8</td>
<td>August</td>
<td>212</td>
<td>233.2</td>
</tr>
<tr>
<td>9</td>
<td>September</td>
<td>210</td>
<td>231</td>
</tr>
</tbody>
</table>
Based on table above, the total production demand annually is 2120 pcs for chair production process. So the daily demand for chair is 6 pcs (daily demand is the annual demand divided by 365 days).

### 4.2.2 Work In Process

Work in process is the inventory of semi-finished materials in the production flow, both those that will be processed and being processed. To calculate the stock of WIP, the data collected based on actual stock in WIP process between each workstation.

The calculation of total inventories of raw material in a day, will be results of daily demand unit divided by WIP inventory stock unit. Based on table 4.3, the calculation of raw material needed to make plastic chair in a month from January until December 2018. And each plastic chair needs 1.10kg of PP in the process.

### 4.2.3 Work Station Available Time

The table below will show the amount of operator in each process and the available time in each work stations in injection moulding of plastic chair:

<table>
<thead>
<tr>
<th>Month</th>
<th>October</th>
<th>November</th>
<th>December</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>220</td>
<td>162</td>
<td>155</td>
</tr>
<tr>
<td>Total</td>
<td>2120</td>
<td>178.2</td>
<td>170.5</td>
</tr>
<tr>
<td>Average per month</td>
<td>176.667</td>
<td>194.333</td>
<td></td>
</tr>
</tbody>
</table>
Table 4.4 Work Station Available Time

<table>
<thead>
<tr>
<th>No.</th>
<th>Activity</th>
<th>Operator no.</th>
<th>Available time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Raw Material</td>
<td>2</td>
<td>23,400</td>
</tr>
<tr>
<td>2</td>
<td>Melting</td>
<td>2</td>
<td>23,400</td>
</tr>
<tr>
<td>3</td>
<td>Injectiion</td>
<td>2</td>
<td>23,400</td>
</tr>
<tr>
<td>4</td>
<td>Moulding</td>
<td>2</td>
<td>23,400</td>
</tr>
<tr>
<td>5</td>
<td>Cooling</td>
<td>4</td>
<td>23,400</td>
</tr>
<tr>
<td>6</td>
<td>Packaging and delivery</td>
<td>7</td>
<td>23,400</td>
</tr>
</tbody>
</table>

The shift in a day is 6.5 hour/day. The available time is 6.5 hour x 3600s = 23,400s

4.2.4 Processing Time Time Study

Processing time is the total time needed to process raw materials from the beginning until the finished product. Lead time is the period of time between a customer's order and the time the order was completed.

Lead time consists of waiting time and cycle time, while cycle time is the time needed for a work station to process material. Observation at process time is done 10 times using a stopwatch. The cycle time of each tool and machine at the work station in producing chair can be seen in Appendix. From the results that has been calculated, the cycle time of processing time is 27552,68 seconds = 7,653522 hours.

The table below shows the total lead time and cycle time from plastic chair process.

Table 4.5 Total Lead Time and Cycle Time

<table>
<thead>
<tr>
<th>No.</th>
<th>Activity</th>
<th>Cycle time</th>
<th>Lead time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(s) (H)</td>
<td>(s) (D)</td>
</tr>
<tr>
<td></td>
<td>Raw Material Order</td>
<td>0 (0)</td>
<td>86400 (1)</td>
</tr>
<tr>
<td>1</td>
<td>Heating</td>
<td>2216,56 (0,615711)</td>
<td>2233,55 (0,0258513)</td>
</tr>
</tbody>
</table>
The lead time is calculated from the order received by the company, until the product reaches the consumer. The production lead time is 3.3 days, while the cycle time is calculated from the raw material is received, until the finished product is entered in storage. The cycle time needed to produce plastic chair is 7.65 hours.

4.3 Data Analysis

After all the required data is obtained, then processing the data includes the following:

4.3.1 Up Time Calculation

Up time is the percentage where the machine is used per amount of time available per day. The equation below will show the example of the uptime calculation. The following table is the up time for each workstation:

\[
Uptime \text{ Availability} = \left[ \frac{Actual \ Production \ Time}{Total \ Available \ Time} \right] \times 100
\]

\[
Uptime \text{ Availability for Raw Material} = \left[ \frac{2216.56}{23400} \right] \times 100
\]

\[
Uptime \text{ Availability for Raw Material} = 9\%
\]
<table>
<thead>
<tr>
<th>Stasiun kerja</th>
<th>Mesin / alat</th>
<th>Lama digunakan (s)</th>
<th>Available Time (s)</th>
<th>Presentase</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Raw Material</td>
<td>2216,56</td>
<td>23.400</td>
<td>9%</td>
</tr>
<tr>
<td>2</td>
<td>Melting</td>
<td>1176,9</td>
<td>23.400</td>
<td>5%</td>
</tr>
<tr>
<td>3</td>
<td>Injection</td>
<td>6419,34</td>
<td>23.400</td>
<td>27%</td>
</tr>
<tr>
<td>4</td>
<td>Moulding</td>
<td>7046,37</td>
<td>23.400</td>
<td>30%</td>
</tr>
<tr>
<td>5</td>
<td>Cooling</td>
<td>3888</td>
<td>23.400</td>
<td>17%</td>
</tr>
<tr>
<td>6</td>
<td>Packaging + Delivering</td>
<td>7075,51</td>
<td>23.400</td>
<td>30%</td>
</tr>
</tbody>
</table>

Table 4.6 Up Time Calculation

### 4.3.2 Process Activity Mapping

Process activity mapping is used to find out all the activities that take place during the production process and then classify those activities based on the type of waste.

<table>
<thead>
<tr>
<th>No</th>
<th>Distance (m)</th>
<th>Time(s)</th>
<th>Activity</th>
<th>Keterangan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>O T I S D</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>56,64</td>
<td></td>
<td></td>
<td>VA</td>
</tr>
<tr>
<td>2</td>
<td>1,5</td>
<td>31,85</td>
<td>T</td>
<td>NNVA</td>
</tr>
<tr>
<td>3</td>
<td>24,44</td>
<td></td>
<td>O</td>
<td>VA</td>
</tr>
</tbody>
</table>

This tool aims to eliminate activities that are not needed, identify whether a process can be more efficient, and look for improvements that can reduce waste (Misbah, et al., 2015).
From the calculation that has been calculated in table 4.7, the results from the Process Activity Mapping shown on the table below:

Table 4.8 Process Activity Mapping Results

<table>
<thead>
<tr>
<th>Activity</th>
<th>Total</th>
<th>Time (s)</th>
<th>Time (hour)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation</td>
<td>7</td>
<td>18772,77</td>
<td>5,2147</td>
<td>16,83%</td>
</tr>
<tr>
<td>Transportation</td>
<td>2</td>
<td>2275,15</td>
<td>0,6320</td>
<td>2,04%</td>
</tr>
<tr>
<td>Inspection</td>
<td>1</td>
<td>694,8</td>
<td>0,1930</td>
<td>0,62%</td>
</tr>
<tr>
<td>Storage</td>
<td>1</td>
<td>56,64</td>
<td>0,0157</td>
<td>0,05%</td>
</tr>
<tr>
<td>Delay</td>
<td>5</td>
<td>89756,4</td>
<td>24,9323</td>
<td>80,46%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>16</strong></td>
<td><strong>111555,8</strong></td>
<td><strong>30,9877</strong></td>
<td><strong>100%</strong></td>
</tr>
<tr>
<td>VA</td>
<td>13</td>
<td>102446</td>
<td>28,457225</td>
<td>91,87%</td>
</tr>
<tr>
<td>NVA</td>
<td>5</td>
<td>6834,6</td>
<td>1,8985</td>
<td>6,13%</td>
</tr>
<tr>
<td>NNVA</td>
<td>17</td>
<td>2231,79</td>
<td>0,619941667</td>
<td>2,00%</td>
</tr>
</tbody>
</table>

In the implementation of plastic chair production, there are activities that resulting in added value (value added / VA). Then for activities that are pretentious but do not results added value (Necessary but Non Value Added / NNVA). Necessary but Non Value Added activities consist of 2 transportation processes and 1 storage process with a time of 2231.79 seconds (0.619 hours) or 2% of the total operations performed. Non Value Added activity consists of 3 delay processes with a total time of 6834.6 seconds (1.89 hours) or equal to 6.13% of the total operations performed.
4.3.3 Current Value Stream Mapping

The cycle time is taken from the time taken by the work station in processing the material to completion and moving to the next work station. The total cycle time in the plastic chair production process is 27552.68 seconds or 7.653522 hours.

The calculation results of the up time are the percentage where the machine is used per amount of time available per day. Shifts available per day are 6.5 hours or 23,400 seconds. From the calculation of the uptime and the results in processing raw material, the time up of the time is:

<table>
<thead>
<tr>
<th>Work Station</th>
<th>Machine</th>
<th>Process Time (s)</th>
<th>Available Time (s)</th>
<th>Presentase</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Raw Material</td>
<td>2216,56</td>
<td>23.400</td>
<td>9%</td>
</tr>
<tr>
<td>2</td>
<td>Melting</td>
<td>1176,9</td>
<td>23.400</td>
<td>5%</td>
</tr>
<tr>
<td>3</td>
<td>Injection</td>
<td>6419,34</td>
<td>23.400</td>
<td>27%</td>
</tr>
<tr>
<td>4</td>
<td>Moulding</td>
<td>7046,37</td>
<td>23.400</td>
<td>30%</td>
</tr>
<tr>
<td>5</td>
<td>Cooling</td>
<td>3888</td>
<td>23.400</td>
<td>17%</td>
</tr>
<tr>
<td>6</td>
<td>Packaging + Delivering</td>
<td>7075,51</td>
<td>23.400</td>
<td>30%</td>
</tr>
</tbody>
</table>

This happens because usually the production is done a maximum of 2 times, so the engine is idle.

The lead time is the waiting time from the order received, until the product reaches the consumer. The lead time:

- order of raw materials until the material is received is 1 day;
- on the heating process of 0.025 days;
in the injecting process 0.014 days;
in the molding process of 0.073 days;
in the cooling process of 1.05 days;
in the finishing process of 0.046 days;
in the packaging process 0.082 days;
and the administration process and delivery lead time takes 1 day,
so the total production leadtime is 3.3 days. The current lead-time and cycle time is explained in the table below:

Table 4.10 Current Cycle Time and Lead-Time

<table>
<thead>
<tr>
<th>No.</th>
<th>Activity</th>
<th>Cycle time</th>
<th>Lead time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(s)</td>
<td>(H)</td>
<td>(s)</td>
</tr>
<tr>
<td>0</td>
<td>Raw Material Order</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>Heating</td>
<td>2216,56</td>
<td>0,615711</td>
</tr>
<tr>
<td>2</td>
<td>Injection</td>
<td>1176,9</td>
<td>0,326917</td>
</tr>
<tr>
<td>3</td>
<td>Moulding</td>
<td>6149,34</td>
<td>1,70815</td>
</tr>
<tr>
<td>4</td>
<td>Cooling</td>
<td>7046,37</td>
<td>1,957325</td>
</tr>
<tr>
<td>5</td>
<td>Packaging</td>
<td>7075,51</td>
<td>1,965419</td>
</tr>
<tr>
<td>6</td>
<td>Finishing</td>
<td>3888</td>
<td>1,08</td>
</tr>
<tr>
<td></td>
<td>Delivering</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td><strong>TOTAL</strong></td>
<td><strong>27552,68</strong></td>
<td><strong>7,65</strong></td>
</tr>
</tbody>
</table>

As seen from the table, the highest lead time goes to cooling. This happens because from the moulding process, the chair needs process of cooling. This will create the consistent finished goods of plastic chair without any defects. Hence, the time reduction can be done and will be explained in the future state.
Figure 4.3 Current VMS
4.3.4 Waste Identification

In the production of injection moulding of plastic chairs, some waste was found in accordance with 8 types of waste, namely overproduction, waiting, transportation, ineffective processes, inventory, defective products, unnecessary movements, resources that were not utilized properly.

1. Waiting (waiting) waste in waiting is on the cooling of the newly molded plastic chair which is generally still hot, so it needs to be left until the temperature is cool enough and then bring the finished goods to packing area and the packing activity can be done.

   There is also a change in delay in moulding process to cooling process of 67788.24 seconds, from the original 83432.64 seconds to 15644.4 seconds. The delay was originally 4h before, since the mould cavity has to be cool down before proceed to cooling process to avoid dent or defect in plastic chair, and it is also obtained to check the quality of the chair after moulding to see if there was any defect. If there was defect found, the process needs to be done again which consume times and materials.

2. Transportation (transportation) Transportation that occurs is the transfer of finished goods to the warehouse from the cooling machine to the packaging and finishing. The figure 4.4, help the improvement in cooling area. The plastic chair that is already made was brought to packaging area using hand truck to reduce the transport time. The distance from cooling to packing area is 6m (380,52s). By using the hand truck, the total time in moving the chair to packing area were reduced.

3. Unnecessary Motion Unnecessary movements occur during the process of injection and molding where the operator must always monitor and control the running of the engine because of frequent defects in the middle of the operation, so extra movement is needed to tighten the bolts and apply
lubricants, also helps keeping the temperature in the right number so the injection process can be done right without affecting moulding process.

4.4 Proposed Improvement

Future Value Stream Mapping consists of all summary of calculation analysis result during the research. Future Value Stream Mapping shows the result of improvement. Figure 4. 5 will show future Value Stream Mapping. The comparison between current Value Stream Mapping and Future Value Stream Mapping will be conducted to know the research is success or not.

4.4.1 Future Process Activity Mapping

Proposed improvements are made to reduce the time for each non-value added activity, based on the kaizen plan that has been prepared. The following table is the process of producing plastic chair after waste elimination:
### Table 4.11 Current PAM

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time (s)</th>
<th>Time (hour)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation</td>
<td>16856,06</td>
<td>4,6822</td>
<td>40,35%</td>
</tr>
<tr>
<td>Transportation</td>
<td>2086,66</td>
<td>0,5796</td>
<td>5,00%</td>
</tr>
<tr>
<td>Inspection</td>
<td>694,8</td>
<td>0,1930</td>
<td>1,66%</td>
</tr>
<tr>
<td>Storage</td>
<td>56,64</td>
<td>0,0157</td>
<td>0,14%</td>
</tr>
<tr>
<td>Delay</td>
<td>22076,4</td>
<td>6,1323</td>
<td>52,85%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>41770,56</td>
<td>11,6029</td>
<td>100,00%</td>
</tr>
<tr>
<td>VA</td>
<td>20578,75</td>
<td>5,716319</td>
<td>73%</td>
</tr>
<tr>
<td>NVA</td>
<td>6834,6</td>
<td>1,8985</td>
<td>24%</td>
</tr>
<tr>
<td>NNVA</td>
<td>638,53</td>
<td>0,177369</td>
<td>2%</td>
</tr>
</tbody>
</table>

From the table above, the results from the current Process Activity Mapping to Future Current Activity Mapping is different. The changes occur in operation process. Changes that occur between before and after the improvement are reduced operating activities with a total time of 18772.77 seconds to 16856.06 seconds, reduced by 1916.71 seconds.

Other changes that occur are in the transportation process with a total time of 2275.15 seconds to 2086.66 seconds. Reduced by 188.49 seconds. Another change that occurred was the delay process which was originally 89756.4 seconds to 22076.4 seconds. Reduced by 67680 seconds. By implementing kaizen, Value Added has increased in efficiency which originally took 28.45 hours to 5.7 hours. And Necessary Non Value Added decreased from 0.61 hours to 0.17 hours.

### 4.4.2 Future Value Stream Mapping

From the Future Value Stream Mapping in figure 4.5, it can be seen that there is a time savings of 619.22 seconds from the original 3393.46 seconds to 2774.24
seconds, and reduce operators by 1 person with an up time of 12% since the operator is unnecessary in the heating process.

From identifying the process, only 1 operator is enough to controls all the machine setup especially in setting up the temperature in heating the raw materials before it is injected. The other 1 operator is moved to the cooling process to help the process of moving the chair that is already cool down to the packaging area.

In the cooling process an improvement in processing time that originally took 7046.37 seconds to 5747.6 seconds with the help of hand truck. The hand truck makes it easier for operator to move the chair that has been cool down to packaging area. Since the handtruck can carry more goods and faster than the operator walking empty-handed carrying the chair to the packing area.

There is also a change in delay in moulding process to cooling process of 67788.24 seconds, from the original 83432.64 seconds to 15644.4 seconds. The delay was originally 4h before, since the mould cavity has to be cool down before proceed to cooling process to avoid dent or defect in plastic chair, and it is also obtained to check the quality of the chair after moulding to see if there was any defect. If there was defect found, the process needs to be done again which consume times and materials.

The most important process from the injection process is the cooling process. This usually takes 80% to 90% of the total cycle time in plastic injection. The right time the employee can open the mold depends on the machine temperature, the plastic melt temperature, the maximum plastic part wall thickness, the part shape and the type of the material being used. The injection mold can be opened and the plastic parts ejected when the parts are cool enough to hold their shape.
From the calculation results, the time on the cooling process also reduced. The reduce time happenend from the temperature change in the moulding process. By start to reduce the mold temperature settings in 5 degree increments until ejector pin, push is visible on the part.

When pin push is observed, the operator are allowed to increase the mold temperature in 2 degree increments until it is done. If the water lines in the injection mold were designed in a suitable way and in sufficient number, heat removal will be facilitated, which resulting in reduced cooling time process.

In the process of transporting the fnished products from cooling machine to the packaging section, the repair time was 61.95 seconds from the original 261.45 seconds to 199.5 seconds due to the addition of a hand truck, where previously the product was only moved empty-handed and consume time.

The table below will shows differences in time reduced from the current state map and from the future state map:

<table>
<thead>
<tr>
<th>Time</th>
<th>Current Map</th>
<th>Future Map</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production Lead time</td>
<td>3.3 days</td>
<td>2.5 days</td>
</tr>
<tr>
<td>Total Processing time</td>
<td>7.65 hours</td>
<td>7.12 hours</td>
</tr>
</tbody>
</table>

By making several improvements, the leadtime can be reduced from the original 3.3 days to 2.5 days, and the original cycle time is 7.65 hours, reduced to 7.12 hours.
4.5 Summary of the Results Before and After Improvement

After the research is conducted and analyzed, there are several conclusions that can be formulated to answer the research objective as interpreted below:

1. Current condition of the process before implementing the method.
   - The cycle time is taken from the time taken by the work station in processing the material to completion and moving to the next work station. The total cycle time in the plastic chair production process is 27552.68 seconds or 7.653522 hours.
   - Up time is the percentage where the machine is used per amount of time available per day. Shift time available every day is 6.5 hours or 23,400 seconds.
   - In processing raw material, the time up of the time is 9%; in the heating process 5%, in the injecting process 27%, in the molding process 30%, in the process of cooling 17%, and uptime in the packaging and delivering process by 30%. This happens because usually the production is done a maximum of 2 times, so the engine is idle.
   - The lead time is the waiting time from the order received, until the product reaches the consumer. The lead time order of raw materials until the material is received is 1 day; on the heating process of 0.025 days; in the injecting process 0.014 days; in the molding process of 0.073 days; in the cooling process of 1.05 days; in the finishing process of 0.046 days; in the packaging process 0.082 days; and the administration process and delivery lead time takes 1 day, so the total production leadtime is 3.3 days.

2. After identifying the problems occurred using value stream mapping and calculating the results that can be improved from the current situation for the future, changes that occur in the proposed improvements are:
• Reduced processing time and work station activities due to the merger of 2 processes using 1 more effective tool, so that the processing time was reduced by 619.22 seconds to 2774.24 seconds from the original 3393.46 seconds.
• Save labor in the process of upgrading from what was originally done by 4 people, it became enough for one person with a decrease in time of 1298.8 seconds. So that 3 other workers can help in the packaging process.
• Decreased cycle time and lead time due to tool efficiency and incorporation of workstations, and utilization of old machines that have been damaged to be reused, thereby reducing cycle times from 7.65 hours to 7.12 hours, and reducing total lead times. 3.3 days to 2.5 days.

4.5.1 Comparison of the Lead-Time

![Diagram showing lead time comparison](image-url)

Figure 4.5 Current Lead Time
From the results of the calculation and prove from value stream mapping, the lead-time of the current process are changed in the improvement process. In the current process, the lead-time is 3.3 days. The lead time order of raw materials until the material is received is 1 day; on the heating process of 0.025 days; in the injecting process 0.014 days; in the molding process of 0.073 days; in the cooling process of 1.05 days; in the finishing process of 0.046 days; in the packaging process 0.082 days; and the administration process and delivery lead time takes 1 day.

While after improvement, the lead-time changes into 2.5 days. The lead time order of raw materials until the material is received is 1 day; on the heating process of 0.025 days; in the injecting process 0.014 days; in the molding process of 0.066 days; in the cooling process of 0.181 days; in the finishing process of 0.046 days; in the packaging process 0.0797 days; and the administration process and delivery lead time takes 1 day.
4.5.2 Comparison of the Cost

**CORRECTIVE**

<table>
<thead>
<tr>
<th>Component</th>
<th>Technician Salary (IDR)</th>
<th>Product Price (IDR)</th>
<th>Production Capacity/Hour (pcs/h)</th>
<th>Downtime (h)</th>
<th>Component Price (IDR)</th>
<th>Cp (IDR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling Pipe</td>
<td>33,854</td>
<td>3,000</td>
<td>3,512</td>
<td>0.65</td>
<td>650,000</td>
<td>7,520,405</td>
</tr>
<tr>
<td>Clamping</td>
<td>33,854</td>
<td>3,000</td>
<td>3,512</td>
<td>0.25</td>
<td>1,600,000</td>
<td>4,242,464</td>
</tr>
<tr>
<td>Nozzle</td>
<td>33,854</td>
<td>3,000</td>
<td>3,512</td>
<td>0.42</td>
<td>2,000,000</td>
<td>6,439,339</td>
</tr>
<tr>
<td>Rotary Encoder</td>
<td>33,854</td>
<td>3,000</td>
<td>3,512</td>
<td>0.33</td>
<td>680,000</td>
<td>4,168,052</td>
</tr>
</tbody>
</table>

Production loss = downtime x production capacity x product price  
= 0.65h x 3,512 pcs/h x IDR 3,000  
= IDR 6,848,400

Technician salary = Technician salary/hour x downtime  
= IDR 33,854 x 0.65  
= IDR 22,005

Cp cost = component price + production loss + technician salary  
= IDR 650,000 + IDR 6,848,400 + IDR 22,005  
= IDR 7,520,405

After corrective maintenance cost is calculated, the next step is calculation of preventive maintenance cost. The calculation frequency of maintenance replacement is considered.

**PREVENTIVE**

<table>
<thead>
<tr>
<th>Component</th>
<th>Technician Salary (IDR)</th>
<th>Product Price (IDR)</th>
<th>Production Capacity/Hour (pcs/h)</th>
<th>Downtime (h)</th>
<th>Component Price (IDR)</th>
<th>Cp (IDR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling Pipe</td>
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<td>2,000,000</td>
<td>6,439,339</td>
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<td>3,000</td>
<td>3,512</td>
<td>0.33</td>
<td>680,000</td>
<td>4,168,052</td>
</tr>
</tbody>
</table>

Production loss = downtime x production capacity x product price  
= 1.28h x 3,512psc/h x IDR 3,000  
= IDR 13,486,080

Technician salary = Technician salary/hour x downtime  
= IDR 33,854 x 1.28  
= IDR 43,333

Cp cost = component price + production loss + technician salary
Based on Figure 4.8, for cooling pipe replacement comparison, using preventive maintenance scheduling the cost reduction is 47% from IDR 14,179,413. For clamping, the cost reduction is 66% from IDR 12,521,830 into IDR 4,242,463.54. For nozzle, the cost reduction is 47% from IDR 12,114,759 into IDR 6,439,338.75. The last for rotary encoder component, the cost reduction is 68% from IDR 13,152,428 into IDR 4,168,051.88. The total cost reduced is from IDR 51,9868,430 TO IDR 22,370,259.
4.5.3 Current and Future VSM Comparison

![Figure 4.8 Current VSM](image)

From the Future Value Stream Mapping in figure 4.9, it can be seen that there is a time savings of 619.22 seconds from the original 3393.46 seconds to 2774.24 seconds, and reduce operators by 1 person with an up time of 12% since the operator is unnecessary in the heating process.

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By making several improvements, the leadtime can be reduced from the original 3.3 days to 2.5 days, and the original cycle time is 7.65 hours, reduced to 7.12 hours.
Figure 4.5 Future VMS
CHAPTER V
CONCLUSION AND RECOMMENDATION

5.1 Conclusion
After the research is conducted and analyzed, there are several conclusions that can be formulated to answer the research objective as interpreted below:

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- After identifying the problems occurred using value stream mapping and calculating the results that can be improved from the current situation for the future. Reduced processing time and work station activities due to the merger
of 2 processes using 1 more effective tool, so that the processing time was reduced by 619.22 seconds to 2774.24 seconds from the original 3393.46 seconds. Save labor in the process of upgrading from what was originally done by 4 people, it became enough for one person with a decrease in time of 1298.8 seconds. So that 3 other workers can help in the packaging process. Decreased cycle time and lead time due to tool efficiency and incorporation of workstations, and utilization of old machines that have been damaged to be reused, thereby reducing cycle times from 7.65 hours to 7.12 hours, and reducing total lead times. 3.3 days to 2.5 days.

### 5.2 Recommendation

For further research, the recommendations are:

1. To develop standardized work procedure to ensure good stable work result.
2. To implement the result from Process Activity Mapping’s identification and calculation.
REFERENCES


