Lean Concept to Reduce Waste of Process Time in the Plastic Injection Industry in Indonesia

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ABSTRACT: The mapping that has been done previously shows that there is a high processing time for the injection molding and shaft assembly processes in the S/A worm gear-type plastic industry. The purpose of this research is to identify and reduce waste in the injection molding process and the shaft assembly process to increase the amount of production. The research uses the lean concept approach method with the identification of causes carried out using the What-Why-Where-When-Who-How (5W+1H) method in focus group discussions (FGD) with competent parties in their fields. This study found that the type of waste obtained from the length of processing time (PT) from the injection molding section was 83.69% or 120.18 seconds and the shaft assembling section was 15.58% or 49.13 seconds, in total the processing time before improvement was 194.87 seconds. This research resulted in the injection molding processing time being reduced by 32.70% and the shaft assembly process by 37.82% with the change in processing time reduced by 26.40% so production results increased by an average of 103% per month.

KEYWORDS: Focus Group Discussion, Injection Molding, Lean Concept, Plastic Manufacturing, Value State Mapping

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I. INTRODUCTION

In the Southeast Asia region, especially Indonesia, per-capita plastic consumption per year is 10 kg, and it is predicted that it will increase in other ASEAN countries can reach 40 kg per capita each year such as Singapore, Malaysia, and Thailand (Rozak *et al*., 2020). The Ministry of Industry noted that the growth of the plastic and rubber industry in 2018 grew by 6.92% on an annual basis, an increase compared to the previous year which was recorded at 2.47%. The number of plastic industries to date has reached 892 companies that produce various kinds of plastic products. This sector employs a workforce of 177,300 people and has a total production of 7.23 million tons which has increased by five percent in the last five years. This industrial trend is also triggered by market growth in Indonesia, where the plastic and rubber industry is a sector that has priority development from the Indonesian government following the national industry development indication plan (Indonesian Ministry of Industry, 2020).

Sales of plastic products in the global market in 2019 were valued at USD 568.9 billion and are expected to increase by 3.2% from 2020-2027 (Indonesian Ministry of Industry, 2020). Plastic sales that dominated the market by 25.70% in 2019 are plastic that is applied for packaging or as packaging (Indonesian Ministry of Industry, 2020). This sale was due to increased demand from the packaging sector, which includes containers and bottles, plastic bags, plastic films, and geomembranes. The top four biggest global plastic market sizes come from the food and beverage industry, cosmetic industry, electronic, and automotive industries (Gaikindo, 2020).

In the automotive industry, regulations to reduce vehicle weight and improve fuel efficiency to reduce carbon emissions have encouraged the use of plastics as a substitute for metal base materials, including aluminum and steel. Plastic materials are used as raw materials for the manufacture of automotive components. is expected to support the increasing demand for plastics in the automotive industry (Krishna, 2018), (Hertwich *et al*., 2019), and (Trinks *et al*., 2020). The demand for plastic from various industries such as the infrastructure, automotive, electrical, and electronic industries is also the reason for the increasing consumption of plastic in the global market (Aisyah *et al*., 2021).

Injection molding is a manufacturing technique for making products derived from thermosets into thermoplastics that have complex characteristics with varying sizes, high production speeds, and accurate dimensions (R. A. Siregar *et al*., 2017), and (Gomes *et al*., 2017). Injection molding is one of the common methods used by plastics companies because of its high efficiency and durability (Patel *et al*., 2021). The intense competition in the plastics industry encourages companies to respond quickly and precisely to problems that occur in their operational activities (Desai and Prajapati, 2017).

Based on the phenomenon, some of the problems that have occurred so far at this company are the low productivity resulting from the wasting of too long processing time in the production department so that the target is not achieved in meeting customer demands. The company needs to streamline the production process so that a more effective and efficient

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production line will be created by reducing waste on activities that are too long in the process it will increase the amount of production (Kumar *et al*., 2016), (Khairunnisa *et al*., 2020), and other research related to the results of improvements that can increase torque production in single-phase induction motors (Olarinoye *et al*., 2018). Based on some of these problems, the company needs a strategy or method that can reduce the waste of process time in the production section, namely the lean concept for solutions to eliminate waste, reduce non-value-added operations, and increase value-added operations so that the results are as desired (Nallusamy and Ahamed, 2017).

The gap analysis in research (I. Siregar *et al.,* 2018) has explained that process time waste can be eliminated in fan production, while research (Kaneku-Orbegozo *et al*., 2019). has succeeded in reducing the process of production time on kitchen equipment. While this research will focus on discussing how the lean concept can reduce time wastage in the production process of S/A worm gear products in the plastic injection industry. This study seeks to increase production by reducing waste of time in the injection molding and shaft assembly sections. The new approach of this research method used the Lean concept approach with the identification of the causes carried out using the What-Why-Where-When-Who-How (5W+1H) approach and why-why analysis in Focus Group Discussions (FGD) with competent parties in their fields. This study aims to identify and reduce processing time (PT) waste in the injection molding process and shaft assembling process to increase the amount of production.

II. THEORETICAL ANALYSIS

In this section, a theoretical analysis that is relevant to the object and method used will be discussed, because it is to support this research reference.

A. *Injection Molding*

The injection molding process begins with inserting the plastic ore into the hopper. Injection molding is divided into 4 main stages: filling, cooling, packaging, and injection (Gunturu *et al.,* 2020). Plastic injection is a method in which using extruder plastic granules are injected into a hole with high pressure and temperature to produce a strong plastic material (Rahimi *et al.*, 2018). The plastic ore is then melted and goes to the barrel, which contains a screw that functions to flow the melted plastic ore material to the nozzle (Ramakrishnan & Nallusamy, 2017). Plastic manufacturing is one of the important industrial sectors because the process starts from upstream to downstream, the plastic industry also plays an important role in the supply chain process for other industrial sectors (Oktavilia *et al.*, 2020), (Chauhan *et al.*, 2020), and (Dănuţ-Sorin *et al.*, 2020).

B. *Lean Manufacturing*

Production activities that focus on reducing waste in all aspects of a company's production activities are called lean manufacturing methods in fan products (I. Siregar et al., 2018), used VSM (Zahrotun and Taufiq, 2018), (Maria et al., 2019), and can be combined with the Six Sigma method to reduce manufacturing defects (Kurnia & Hardi Purba, 2021). Lean thinking is lean because it provides a way to do better things by using as few resources as possible, namely less human effort, less equipment, less time, and less space by continuously approaching what customers want (Engelseth & Gundersen, 2018), and the removal of carbon dioxide (CO2) from natural gas (Salaudeen *et al.*, 2022). The application of the lean concept is one of the sustainable strategies that can be used by various industries to improve manufacturing performance and reduce waste, this is based on research (Kaneku-Orbegozo *et al.*, 2019), and can be applied in healthcare (Sukma *et al.*, 2022). This lean method is a sustainable strategy to reduce waste and can provide effective results to optimize production costs efficiently (Liker and Meier, 2006), company's productivity will increase by eliminating waste (Prayugo & Zhong, 2021).

III. METHODOLOGY

In this section, the steps of the lean concept can be implemented in the plastic injection industry. The limitation of this research is only on the dominant process in producing waste of time in the process of making S/A worm gear. The application of the lean concept in the manufacturing industry is carried out in the form of case studies and analyses of effectiveness in manufacturing companies (Mahato *et al.*, 2017), and (Zahoor *et al.*, 2018). The improvement tool used to eliminate waste is Value Stream Mapping (VSM), this tool analyzes all identification activities that do not have added value (waste) (Ikatrinasari *et al.*, 2018). Furthermore, improvements are designed so that waste is reduced or even eliminated (Figure 1).

Based on Figure 1 it can be explained that this research started with old PT injection molding and shaft assembling so that production was disrupted, then data collection was carried out in the form of monthly report documents for 6 months. After that, a Pareto diagram is made of the most dominant product family in production, then the demand from customers is broken down every month for the dominant product family item. The next step is Current State Mapping (CSM) by determining the uniformity of the data, data adequacy test, and data sufficiency that appears in each process taken from 30 trials. The formula that has been used can be seen below:

$$\text{Cycle time (CT)} = \overline{X} = \frac{\sum X_i}{n} \quad (1)$$

$$\text{Standard deviation (SD)} = \sigma = \sqrt{\frac{\sum (X - \overline{X})^2}{n-1}} \quad (2)$$

Upper control limit (UCL) and lower control limit (LCL)

$$\text{UCL} = \overline{X} + 2(\sigma) \quad (3)$$

$$\text{LCL} = \overline{X} - 2(\sigma) \quad (4)$$

$$\text{Normal time (NT)} = \overline{X} \times p \quad (5)$$

$$\text{Standard time (ST)} = \text{NT} + \frac{100\%}{(100\% - 5\%)} \quad (6)$$

$$\text{Data adequacy test} = N' = \left[\frac{\frac{k}{s}\sqrt{(N \times \sum X^2) - (\sum X)^2}}{\sum X}\right]^2 \quad (7)$$

After the CSM diagram is determined, the next step is to analyze the identification of waste starting from the activation process which is Value Added (VA), Non-Value Added

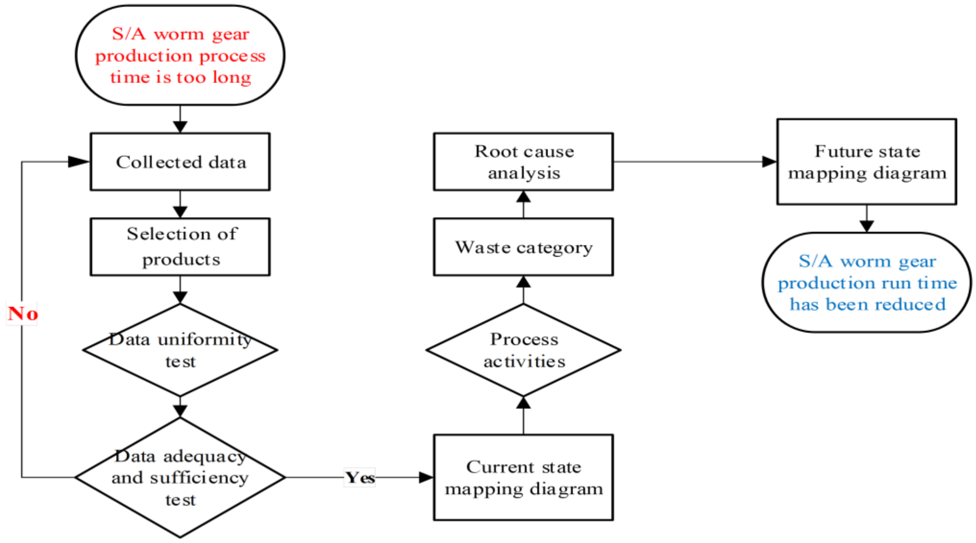

Figure 1. Study Framework

(NVA), and Necessary but Not Value Added (NNVA). After that, you can determine the waste category from the injection molding process and the shaft assembly process. After data collection, data analysis, and the dominant causes of PT from injection molding and shaft assembling have been known, the next action is to make improvements starting with conducting FGD to determine the root cause analysis with why-why analysis and 5W+1H, This method has also been applied when determining 5W+1H in reducing elastic tape defects (Kurnia *et al.*, 2022). After all corrective actions have been taken from the two processes (injection molding process and shaft assembling process), the next step is to measure FSM to determine the decrease in processing time.

IV. RESULTS AND DISCUSSION

A. Collected Data

The data collected is only for products that have been produced for at least 1 year, this criterion is used to obtain products that are still produced in the long term so that the development carried out is right on target. For more details related to the results of the production can be seen in Figure 2.

In Figure 2, In the Pareto chart, the bar graph on the left is the most dominant problem that must be corrected (Sjarifudin & Kurnia, 2022). It can be seen that in the daily data collection above, the decision was taken to make a VSM of the D17D type S/A worm gear product because this product has a percentage of 47.8% from other types of product families. This product goes through the entire production process starting from material and compound, material receiving the check, injection molding, visual check, and packing. After getting the type of S/A worm gear product that has the highest production percentage, then the current status flow mapping is carried out on the D17D type product. More details about the total production for S/A type D17D gear worm can be seen in Figure 3.

Based on Figure 3 that this production amount is obtained from company data based on customer requirements for the D17D type S/A gear worm. The average production for S/A gear worm type D17D is 257,500 pcs per 6 months or an average of 42,917 pcs per month. This means the average production per day is equal to 2,145 units per day (20 working days/month).

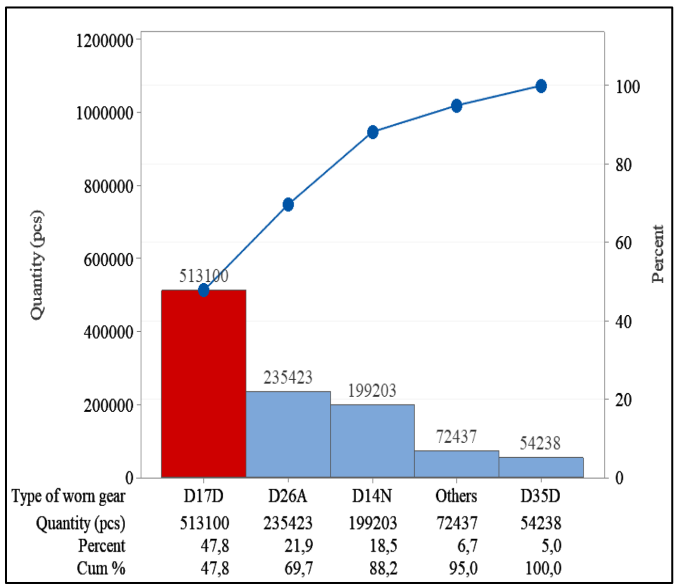

Figure 2. Production of Gear Worm S/A

B. Selection of Products

The selection of products whose process is mapped can be determined by selecting based on the number of products or based on the production route that has the most frequency. The approach used in the case study of this company is based on the number of products. This research has indicated that the determining factor in the selection is not only in terms of quantity but also considers the selling value of the product and the A/R ratio (the ratio between the level of production and the level of demand). The selection of products whose process flow is mapped is based on two criteria, namely the number of orders and the selling value. Production process and time: At this stage, the flow of the S/A gear worm production process

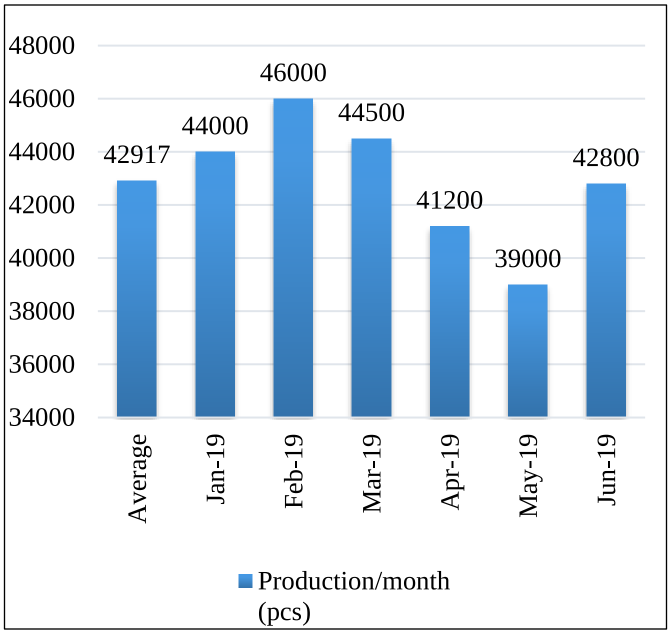

Figure 3. Total Production for Gear Worm S/A Type D17D

can be seen in the operational process chart which can be seen as the chart in Figure 4 (operation process: 3, checking process: 2, storage: 2). For more details about operation process chart of gear worm S/A can be seen in Figure 4.

Based on Figure 4 the production process cycle time: At this stage, we explain the cycle time of the D17D type S/A gear worm production process. There are several stages in the production process of type S/A D17D dental worms with the number of CT for 30 trials of 2,936.9 seconds.

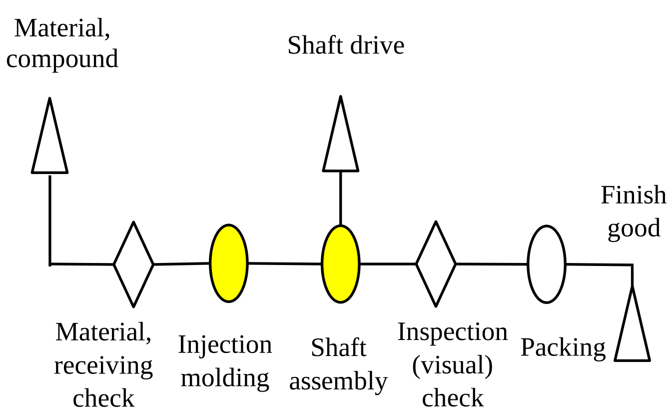

Figure 4. Operation Process Chart of Gear Worm S/A

C. *Data Uniformity Test*

Data uniformity test, this test is a test to ensure that the data cycle time comes from the same system. The following is an observation of the time of each production process for the D17D type S/A gear worm.

1) CT = $\overline{X} = \frac{2{,}936.9}{30} = 97.90$ sec

2) SD = $\sigma = \sqrt{\frac{4.55}{30-1}} = 0.40$ sec

3) In this calculation using a 95% confidence level with a value of k = 2 with the following calculation results:

$\mathrm{UCL} = 97.90 + 2(0.40) = 98.69$ sec $\quad \mathrm{LCL} = 97.90 - 2(0.40) = 97.10$ sec

4) Normal time = In this calculation using the Westinghouse approach:

$$\begin{aligned} \text{Skill} &= \text{Average (D)} = 0.00 \\ \text{Effort} &= \text{Average (D)} = 0.00 \\ \text{Condition} &= \text{Fair (E)} = -0.03 \\ \text{Consistency} &= \text{Fair (E)} = -0.02 \\ \text{Amount} &= -0.05 \\ \text{then, } p &= 1 - 0.05 = 0.95 \end{aligned}$$

Normal time = $97.90 \times 0.95 = 93.00$ sec

5) Standard time is calculated by 5% leeway from normal time with the following calculation results: ST = $93.00 + \frac{100\%}{(100\% - 5\%)} = 94.05$ sec

6) Adequacy test result: $N' = \left[\frac{\frac{2}{\frac{1}{10}}\sqrt{(30 \; x \; 351.00) - 9801.00}}{99}\right]^2$

$$N' = \left[\frac{20\sqrt{729}}{99}\right]^2$$

$$N' = \left[\frac{540}{99}\right]^2 = 29.75$$

Based on the time observation of each production process of the D17D S/A type worm gear, as an example of calculation using the formula specified in the second part. The results of other measurements can be entered into Table 1. More details about data uniformity test results can be seen in Table 1.

Table 1 is the result of the data uniformity test from the measurement of the production process time of the S/A gear worm for the D17D type. Data adequacy test, this test is a test to ensure that the cycle time observation data has sufficient data. The following is an observation of the time of each production process for the D17D type S/A gear worm.

D. *Data Adequacy and Sufficiency Test Results*

This section discusses the results of the Adequacy and Sufficiency tests. The results of these measurements and calculations start at each stage of the process where these calculations prove that the number of samples produced represents a comprehensive report. The data sufficiency test results can be seen in Table 2.

Table 2 is the result of the data adequacy test from the measurement of the production process time of the S/A D17D type worm gear that has been obtained, with the results N' < N can be stated the total number of observations is sufficient. Based on the amount and time of production, business process re-engineering production (VA and NVA), production cycle time, and the number of rejects for the production of D17D type S/A worm gears, a current state mapping is formed in the S/A worm gear production process. type D17D.

Table 1. Data Uniformity Test Results

No	Work station	Activity	Cycle time (sec)	UCL (sec)	LCL (sec)	Normal time (sec)	Standard time (sec)
1	Injection molding	Setting machine	97.90	98.69	97.10	93.00	94.05
2	Injection molding	Running machine	17.72	18.27	17.18	16.84	17.89
3	Injection molding	Check F/G	4.56	4.69	4.42	4.33	5.38
4	Material receiving check	Material check	9.56	9.69	9.42	9.08	10.13
5	Shaft assembly	Setting machine	9.52	9.69	9.34	9.04	10.09
6	Shaft assembly	Setting Jig	25.51	26.86	24.17	24.24	25.29
7	Shaft assembly	Setting product & running process	14.10	15.17	13.02	13.39	14.44
8	Inspection (visual check)	Visual check	10.39	11.53	9.24	9.87	10.92
9	Packing	Placement product inbox	5.62	6.63	4.61	5.34	6.39

Table 2. Data Sufficiency Test Results

Workstation	Activity	Σx	$(\Sigma x)^2$	Σx^2	$N\Sigma x^2$	N'
Material receiving check	Material check	99.00	9,801.00	351.00	10,529.83	29.75
Injection molding	Setting the program	97.00	9,409.00	335.00	10,050.00	27.25
	Running process	107.00	11,449.00	405.00	12,150.00	24.49
	Check Finish Good	111.00	12,321.00	437.00	13,110.00	25.61
Shaft assembly	Setting the machine	105.00	11,025.00	389.00	11,670.00	23.40
	Setting the Jig	92.00	8,464.00	302.00	9,060.00	28.17
	Setting the product & running the process	94.00	8,836.00	314.00	9,420.00	26.44
Inspection (visual check)	Visual check	91.00	8,281.00	295.00	8,850.00	27.48
Packing	Placement of product in the box	92.00	8,464.00	302.00	9,060.00	28.17

E. Current Value State Mapping

The number of production requests has been known, namely the production demand data for the S/A D17D type worm gear product as input in the CSM design. This number of production requests is used as the basis for reference to the value-added time of the entire production process in producing S/A type D17D gear worm products. More detail can be seen in Figure 5.

Figure 5, about the results of the CSM diagram, the injection molding process has a reject ratio of 83.69% with a cycle time of 120.18 seconds and the shaft assembly process has a reject ratio of 15.58% with a cycle time of 49.13 seconds as a critical process for further analysis and can be increased in the production of type D17D S/A worm gears. Based on the high processing time on the production line, corrective action is needed to minimize the process and streamline the production process to support high customer demand. Thus the production process needs to apply the concept of lean manufacturing to get a fast processing time and increase productivity. CSM is part of the VSM method where the current conditions must be known in advance how much processing time is wasted (Setiawan *et al*., 2022).

F. Waste Identification

The results of observations regarding process activities in the injection molding process and the shaft assembly process are shown in Table 3.

Based on Table 3 about the activity data on the molding injection and shaft assembly processes, there are 2 VA activities with a total activity time of 31.82 seconds and 4 activities that are NNVA with a total activity time of 137.49 seconds. Based on the identification of activities that have been found in the Injection molding and shaft assembly processes, 4 activities are necessary but not added value. At the stage of each activity that is not value-added and activities that are necessary but not added value can be categorized as every type of waste that occurs. The following are categories of waste that occur in the Injection molding and shaft assembly processes from non-value-added activities and necessary but NVA activities. More details related can be seen in Table 4.

Based on Table 4 the type of waste processing in the program setting activity, jig, and fixtures on the machine has the largest weight, namely 95.55% for the injection molding process and 72.82% for the jig setting activity for the shaft assembly process from the total processing time. Other research discusses waste on injection molding machines only by using the Lean Six Sigma (LSS) approach with the VSM method and root cause analysis (Alshammari *et al*., 2018).

G. Root Cause Analysis

Based on the waste category found with the highest weight in the Injection molding and shaft assembly processes, an analysis was carried out to find the root cause of the process. The analysis in finding the root of the problem uses the why-why analysis and the 5W+1H methods. This why-why analysis is carried out by maintenance, production, engineering, and quality control parties in an FGD. More details related can be seen in Table 5.

Based on Table 5, the reasons related to program settings, and installation of molds, jigs, and fixtures on the injection molding machine table have been obtained. In addition, it has also been found that the reason for the shaft assembly is due to the varying dimensions and types of gears on the S/A worm shaft. To fix all of that, it is necessary to take action with the 5W+1H method carried out with FGDs between related parties who are experienced in overcoming these problems.

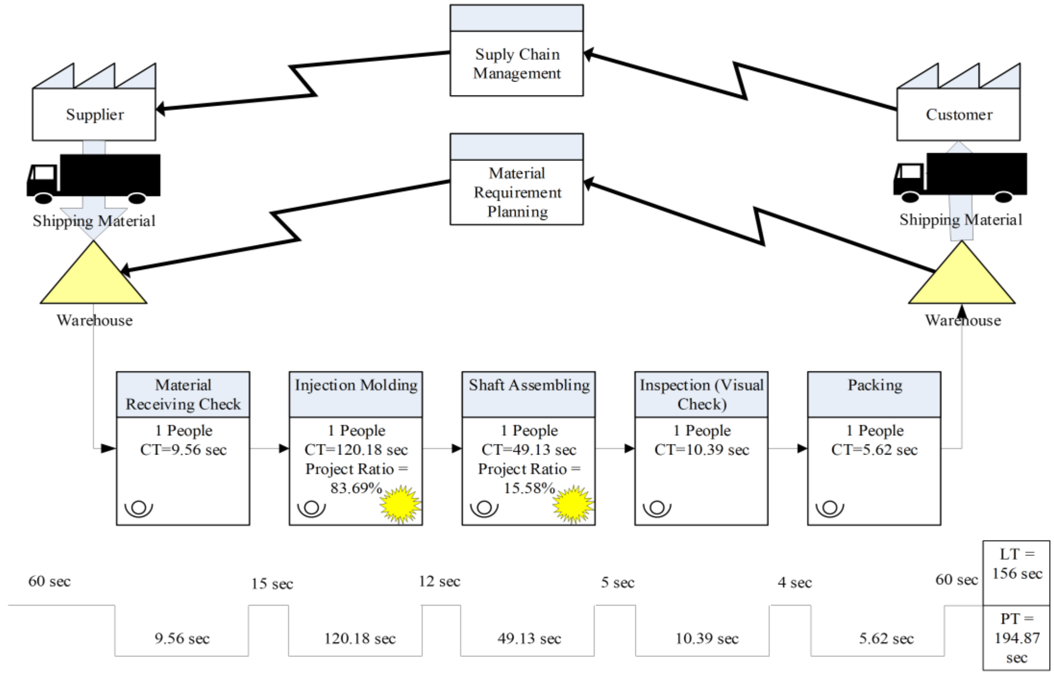

Figure 5. Current State Mapping Diagram

Table 3. Injection Molding and Shaft Assembly Process Activities

Process	**Activity**	**Activity identification**	**Time (sec)**	**Classification**		
				VA	NVA	NNVA
Injection molding	Setting machine	Setting the program or fixture on the machine	97.90			√
		Running process	17.72	√		
		Check finish goods	4.56			√
Shaft assembly	Setting machine	Setting the program on the machine	9.52			√
		Setting the Jig or fixture on the machine	25.51			√
	Setting product	Install the product on Jig, run the process, and check the finished goods	14.10	√		
Total				31.82 sec		137.49 sec

Table 4. Activity Identification of Waste in the Injection Molding and Shaft Assembly Process

Process	**Activity**	**Activity identification**	**Activity description**	**Time (sec)**	**Weight**	**Waste category**
Injection molding	Setting the machine	Setting the program or fixture on the machine	Setting up programs molds or fixtures for the Injection molding process on machines	97.9	95.55	Processing
		Check finish goods	Checking the results of the print	4.56	4.45	Motion
Shaft assembly	Setting the machine	Setting the Jig on the machine	Setting up the jig for the shaft assembly process on the machine	25.51	72.82	Processing
		Setting the programs or fixtures in the assembly process	Setting up programs or fixtures for the shaft assembly process on the machine	9.52	27.17	Processing

Table 5. Why-Why Analysis of Waste

No	**Issue**	**Why 1**	**Why 2**	**Why 3**	**Why 4**	**Why 5**
1	Setting the program, installing molds or fixtures for the process Injection molding	Manual process, and long time	Types of molds or fixtures for the injection molding process vary	Dimensions and types of S/A worm gears vary in the Injection molding process	-	-
2	Setting the program and installing jigs or fixtures on the machine table in the shaft assembly process	The installation process is manual, and long time	Types of molds or fixtures for the shaft assembly process vary	Dimensions and types of S/A worm gears vary in the shaft assembly process	-	-

Table 6. Analysis of 5W1H of Waste

Factor	What	Why	Where	When	Who	How
Man	The operator does not know the proper and correct installation and setting procedures for molds, jigs, or fixtures	There is no SOP	Injection molding process area and shaft process assembly	Every change in model	Production	Training and making point lessons on the station process
Methods	S/A gear worm products vary	S/A gear worm jigs and molds are different for each model	Shaft assembly process area	Every change in model	Production	Make SOP and list the use of jigs or fixtures
Machine	Molds, Jigs, or fixtures in the S/A worm gear production process vary	Dimensions of different S/A worm gears	Injection molding process area and shaft process assembly	Every change in model	Engineering	Create and add programs or fixture auto-change models that can facilitate and speed up each model change process

The following are the results of the discussion of these problems with 5W+1H which can be seen in Table 6.

Based on Table 6 three main factors cause waste problems, namely human factors, machines, and methods. In the human factor, namely training and making learning points in the station process. Improvement of engine factors, namely creating and adding programs or models of automatic changing equipment that can facilitate and speed up each model change process. Improvements to the method factor, namely making SOPs and a list of jigs or fixtures that have been socialized to injection operators. Root cause analysis uses the why-why analysis method during FGDs by experts because this research is more focused on the main causal factors.

H. Future VSM

Based on the results of the previous analysis, a future state mapping was made on the production process of the D17D type S/A gear worm which has been root cause analysis with why-why analysis and 5W+1H in FGD. FGDs can be carried out for this type of qualitative research without statistical calculations because this FGD is a solution to the opinions of experts (Setiawan et al., 2022). For more details related to the results can be seen in Figure 6.

Based on Figure 6 the injection molding process was improved with a reject tolerance ratio of 23.37% with a cycle time of 88.17 seconds and the shaft assembly process was improved with a reject tolerance ratio of 4.96% with a cycle time of 45.53 seconds. critical for analysis and improvement. In the Injection molding process, improvements made in eliminating waste in the process of installing molds or fixtures as well as setting machine programs are creating and adding auto-change model programs/fixtures that can facilitate and speed up each model change process (Agung et al., 2018).

The total processing time from the previous injection molding was 120.18 seconds with the process of installing molds or fixtures and setting the previous machine program at 97.90 seconds, it is necessary to design and manufacture programs or fixtures to auto-change the model in this process to achieve the target set in the future state mapping of 66.00 seconds or a decrease of 33.00% from the previous time.

Improvements made to each process have an impact on processing time. Some processes are considered reduced because they do not provide added value so they can be maximized on activities that provide added value (Carvalho et al., 2019). The improvement process resulted in the efficiency of processing time from 194.87 seconds to 143.26 seconds, with changes in processing time reduced by 26.40%.

I. Comparation Result

This section discusses the comparison of the results before improvement and after improvement that has been analyzed through the VSM method. The results of this study indicate that lean manufacturing has a significant effect on the process of reducing process time waste in the production line. The comparison before and after the repair can be seen in Table 7.

Based on Table 7, it can be seen that there was an increase in the entire process time of making S/A D17D type worm gear, which was reduced from 194.87 seconds (CSM results) to 143.26 seconds (FSM results), with a change in the processing time of 26.40%. Based on Table 7, it can be seen that there was an increase in the entire process time of making S/A D17D type worm gear, which was reduced from 194.87 seconds (CSM) to 143.26 seconds (FSM), with a change in the processing time of 26.40%.

J. Production Result

In this section, the results of the product after improvement of the manufacturing process for the S/A type D17D worm gear. This production amount is obtained from company data based on customer requirements for type D17D S/A gear worms as shown in Figure 7.

Based on Figure 7 the average production for S/A gear worm type D17D is 265,200 pcs per 6 months or an average of 44,200 pcs per month. This means the average production per day is equal to 2,210 units per day (20 working days/month). From Figure 3 the average production is 42,917 pcs per month, so there is an increase in production every month by 1,283 pcs per month. The contribution of this research can reduce the processing time of the S/A D17D type worm gear

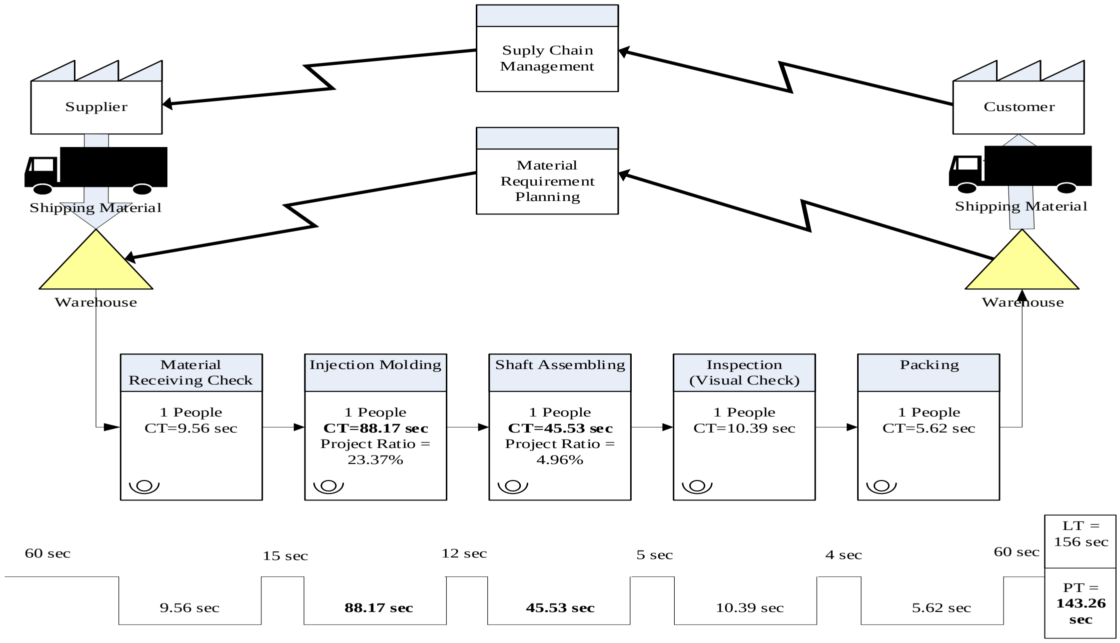

Figure 6. Future State Mapping

Table 7. Comparison of Percentage CSM and FSM

Type of Activity	Current state map Time (second)	Percentage (%)	Future state map Time (second)	Percentage (%)
Lead time	156.00	44.40%	156.00	52.00%
Process time	194.87	54.60%	143.26	48.00%
Total	350.87	100.00%	299.26	100.00%

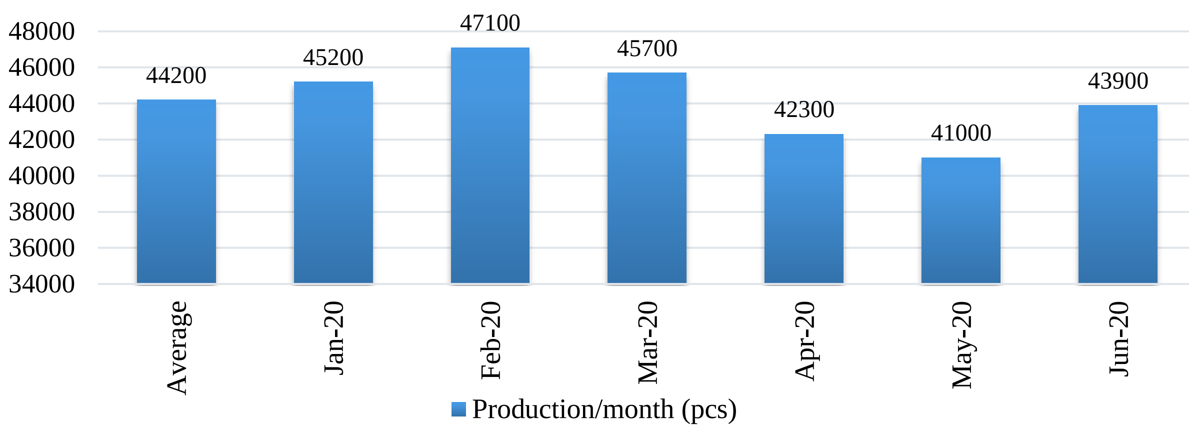

Figure 7. Total production for Gear Worm S/A Type D17D

manufacturing process so that it has an impact on increasing plastic production to meet customer demands.

V. CONCLUSION

This research has identified waste in the S/A worm gear production process for DC motor components which affects decreasing production quantities. This study found that there was a waste of time in the injection molding and shaft assembling sections. In the injection molding section, there is an activity that takes a long time, namely when setting the machine at 120.18 seconds or 83.69%. Meanwhile, in the shaft molding section, some activities take a long time, namely when setting the machine and setting the product by 49.13 seconds or 15.58%. Corrective actions that have been carried out by identifying causes are carried out using the CSM method, waste identification, and root cause analysis using the FGD approach carried out by experts then measuring results using the FSM method.

The results of this study the processing time for making worm gear type S/A D17D in injection molding can be reduced from 120.18 seconds to 88.17 seconds or 32.70% and the shaft assembly process can also reduce processing time from 49.13 seconds to 45.53 seconds or 37.82%. In total, the entire manufacturing process for worm gear type S/A D17D was reduced from 194.87 seconds to 143.26 seconds, with changes in processing time reduced by 26.40%. The implication of this research is to shorten the processing time for the manufacturing process of the S/A D17D type worm gear so that it has increased production yields by 103% which has an impact on fulfilling customer requests. In subsequent studies, researchers integrate the concept of lean manufacturing with green manufacturing so that companies suggest not only benefiting from reducing waste but also obtaining efficiency from reducing waste that pollutes the company's environment.

AUTHOR CONTRIBUTIONS

C. Jaqin: Conceptualization, Methodology. **H. Kurnia**: Validation, Sofware. **H. H. Purba**: Writing – review & editing. **T. D. Molle**: Writing – original draft. S. Aisyah: Supervision.

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