

Production Process Optimization with Lean Manufacturing Integration to Reduce Waste in Manufacturing Industry

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Abstract

This research aims to optimize the production process by integrating Lean Manufacturing to reduce waste in the manufacturing industry. The methods used are case studies and quantitative data analysis using statistical techniques and Lean Manufacturing methods. The research results are expected to improve production efficiency, productivity, and product quality, while reducing production costs. The company's targets have often fallen short in recent periods. This occurs due to frequent errors in the packaging manufacturing process, particularly during the cutting stage of the material thickness. These errors lead to overprocessing, resulting in less effective and efficient performance. The implementation of problem-solving strategies that fail to address the root cause of the problem is due to the company's inability to utilize all its resources more efficiently. This inefficiency will result in long-term losses and make it an easy target for other, more competitive industries, both in terms of production capacity, quality, price, and delivery. Waste leads to longer production times for a company to produce a certain number of products, resulting in lower production volumes than company targets.

Keywords: production process optimization, lean manufacturing, waste reduction, manufacturing industry, process efficiency.

INTRODUCTION

In the era of the global economy, companies strive to create high-quality products at affordable prices. However, this objective is often hindered by high raw material prices and operational costs. Consequently, companies must adopt sustainable strategies, such as enhancing productivity. Productivity can be improved by optimizing raw material usage and reducing waste in production processes, thereby maximizing output.

Sun (2011) defines Lean as a business philosophy centered on minimizing resource consumption including time across various corporate activities. Lean focuses on identifying and eliminating non-value-adding activities within design, production (in manufacturing), or operations (in services) that directly impact the customer. To deliver high-quality products while keeping costs low, companies must minimize errors, such as product defects, and eliminate non-value-adding elements that would otherwise drive-up production costs. Product packaging is the final stage in ensuring that the finished product reaches the consumer in good condition. Styrofoam is required for packaging radiators, and the material used must be tailored to the specific characteristics of the product. However, errors frequently

occur during the packaging manufacturing process, particularly during the step where the Styrofoam is cut to the required thickness. These errors lead to excessive processing, resulting in reduced operational effectiveness and efficiency.

Cutting the Styrofoam material is a finishing step performed before the radiator is packed into a box; this process determines the dimensions of the Styrofoam required for the radiator being packed. The cutting process involves several stages: cutting the Styrofoam to the appropriate length, width, and thickness.

The presence of waste extends the production time required to manufacture a given volume of products, resulting in output levels that fall short of company targets. Low production volumes make it difficult for the company to meet customer demand within established timeframes. Transitioning from a traditional company to a lean enterprise requires a comprehensive approach. This process begins with production the area where value-added activities are most critical, as streamlining operations in this sector significantly impacts overall company performance. Therefore, to minimize waste in the production process, the researcher employs the lean manufacturing method using the DMAIC (Define, Measure, Analyze, Improve, Control) approach and VSM (Value Stream Mapping). By implementing lean manufacturing through DMAIC and VSM, the company can reduce waste across various conditions by maximizing value-added activities.

Table 1. Production Process Targets and Actuals

No	Year	Month	Dev. Mold Target Amount	Dev. Mold Actual Achievements	Target Mold Development Percentage (%)	Mold Development Achievement Percentage (%)
1	2022	January	6	5	93%	83%
2		February	6	6	93%	100%
3		March	6	4	93%	67%
4		April	6	6	93%	100%
5		May	6	0	93%	0%
6		June	6	6	93%	100%
7		July	6	3	93%	50%
8		August	6	4	93%	67%
Average				4,5		75%

This research uses a quantitative approach with a case study method in the manufacturing industry. Data will be collected through observation, interviews, and document analysis. The Lean Manufacturing approach will be used to identify and reduce waste in the production process.

Problem-Solving

Concept:

1. Waste Identification: Using the Value Stream Mapping (VSM) technique.
2. Root Cause Analysis: Using the 5 Whys and Fishbone Diagram techniques.
3. Solution Development, Implementation, and Evaluation (DMAIC).

Assumptions that need to be proven:

1. Waste is the main cause of production process inefficiency.
 2. Lean Manufacturing Integration (reducing waste and increasing production process efficiency).
 3. Implementation (improving product quality and reducing production costs).
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1. Integration of Lean Manufacturing with current technology can improve production efficiency.
 2. Production systems that are more environmentally friendly.
 3. Previous research studies relevant to the title of this research include:
 - Kosasih et al. (2023): This research improves production efficiency and reduces waste.
 - Younnes (2023): Implementation of Lean Manufacturing can improve production efficiency.

Efforts to identify and eliminate waste or non-value-added activities through the implementation of continuous improvement. This applies to work processes, resulting products, and internal or external information flows, with the aim of gaining a competitive advantage and achieving a performance level of 3.4 defects per million opportunities (Gaspersz, 2007, cited in Munandar & Permana, 2019; reaffirmed in Kholil, 2023).

Waste

Waste refers to any form of activity that does not add value during the process of transforming inputs into outputs (Gaspersz, 2002, cited in Munandar & Permana, 2019). In the book **"The Toyota Production System: Beyond Large-Scale Production,"** Taiichi Ohno outlined seven categories of waste: Overproduction, Waiting, Transportation, Defects, Inventory, Overprocessing, and Motion (Kholil, Suparno et al., 2021).

Quality Control

Quality control is a systematic technical measure employed to achieve, maintain, and enhance the quality of products and services, ensuring adherence to standards and customer satisfaction (Amrina & Firmansyah, 2019).

Value Stream Mapping (VSM)

The Value Stream Mapping approach is a tool used as an initial step in improving company processes; it provides a visual overview (a "Big Picture") of material and information flows from the beginning to the end of a process, aiming to establish lean manufacturing conditions within the company (Goriwondo et al., 2011, cited in Kholil, Haekal et al., 2021). The elements incorporated into the Value Stream Mapping method include activity steps, information flow, cycle time, and work-in-process (Abdelwanis & El Feitouri, 2020). The steps involved in Value Stream Mapping include creating a current state map, identifying waste, analyzing the causes of waste, and creating a future state map. (Kholil, Haekal et al., 2021).

Six Sigma DMAIC

This method serves as a standard problem-solving approach for quality enhancement and process improvement; it is regarded as a data-driven Six Sigma method that utilizes statistical tools to achieve performance levels based on the Sigma scale of 3.4 defects per million opportunities (Haekal, 2021; Kholil, 2023). DMAIC functions as a methodology aimed at minimizing process variance and product or service defects through intensive problem-solving tools (Koeswara & Ardianto, 2013).

The 5W+1H Concept

This concept is employed by companies to evaluate quality improvement measures, utilizing statistical tools that facilitate control (Rinjani et al., 2021). It involves describing and analyzing problems to ensure detailed identification prior to conducting further analysis (Knop & Mielczarek, 2018).

METHOD

This research aims to optimize production processes by integrating Lean Manufacturing, VSM, root cause analysis, and DMAIC to reduce waste in the manufacturing industry. The method is organized into measurable stages so that each stage has a clear activity, output, achievement indicator, and role of UMB and the international partner. The research object is the production process, with emphasis on packaging/cutting-related inefficiencies, defects, rework, waiting time, and non-value-added activities.

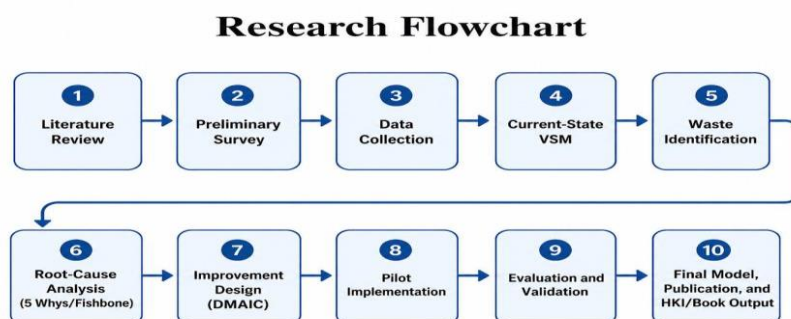


Figure 1. Research Flowchart

This research integrates the Six Sigma DMAIC concept with Lean concepts, specifically Value Stream Mapping (VSM) and process activity mapping to identify waste in the mold development process. The steps undertaken are as follows.

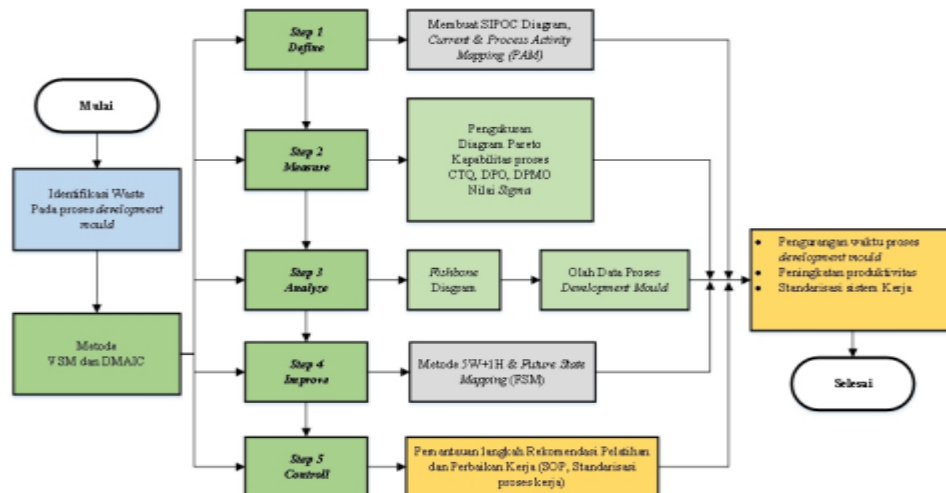


Figure 2. Research Flowchart DMAIC Method and VSM

RESULT AND DISCUSSION

The following outlines the approach integrating the DMAIC method with the application of Value Stream Mapping (VSM). The steps involved are as follows:

1. Define Phase

The identification of waste in the mold shop department is carried out using a SIPOC diagram, followed by the application of Value Stream Mapping (VSM) through several stages, including:

In the Define phase, the production process flow or the new mold development process is mapped out with the aim of improving the processes being performed.

Table 2. SIPOC Diagram of the Production Process

Suppliers	Input	Process	Output	Customers
Mold Shop Department	(Mold)	CNC	(New Mould)	Production department
	Steel materials and components	Milling		
	Heater & sprue bush	Bubut (Turning)		
	Nipple	Grinding		
	Cutting tools	Polishing		
	In-Mold Label (IML)	Assembling		
	Working drawings & tool list program	Trial		

This step involves visualizing the activities and processing times, based on Current State Mapping (CSM) for the production of new molds, spanning design and material procurement, milling, CNC machining, turning, grinding, polishing, assembly, trials, and quality inspection.

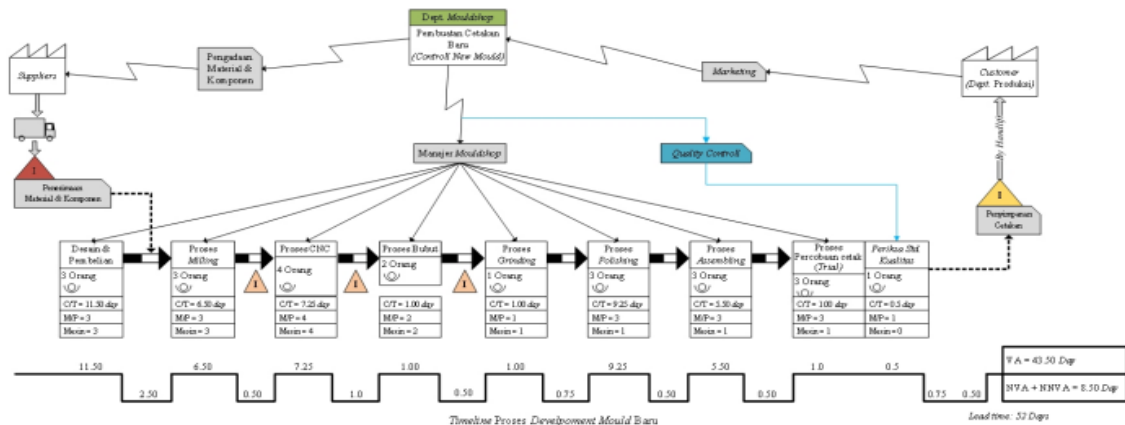


Figure 3. Current State Mapping

Next, the failure rate percentage is determined.

This stage is conducted to assess the failure rate associated with the process in question. The Process Activity Mapping (PAM) for new mold production indicates a total lead time of 52 days for the activity, with the following activity counts: 28 instances of Value-Added (VA) activities, 13 instances of Necessary Non-Value-Added (NNVA) activities, and 8 instances of Non-Value-Added (NVA) activities. Subsequently, the failure rate percentage for these activity categories is calculated. As an example, the calculation for Value-Added (VA) activities is performed using Equation (1):

$$\%Failure\ Rate = \frac{Total\ Value - Added\ Value}{Total\ Available\ Time(LT)} \times 100\%$$

Thus, the failure rate percentage obtained for Value-Added (VA) activities is 53.85%.

The following table presents the failure rate percentage calculations for Value-Added (VA), Necessary Non-Value-Added (NNVA), and Non-Value-Added (NVA) activities:

Table 3. Percentage of VA, NVA, NNVA Values

No	Value Activity	Calculation	Value (%)
1	Value Added (VA)	$= \frac{28}{52} \times 100\%$	53.85%
2	Necessary Non-Value Added (NNVA)	$= \frac{13}{52} \times 100\%$	25,00%
3	Non-Value Added (NVA)	$= \frac{8}{52} \times 100\%$	15,38%

In applying the DMAIC approach, direct observation and analysis were conducted on the research data, identifying six (6) factors contributing to production process failures. These factors were then translated using the Value Stream Mapping (VSM) method into three (3) types of waste responsible for the failure to meet new mold production targets in the mold shop department: Defects, Inappropriate Processing, and Waiting.

The following table outlines the classification of these waste types, their integration into the DMAIC approach, and their respective frequencies:

Table 4. Identification of Waste

No	Waste	Integration of Causal Factors	Frequency
1	Defect	Functional locking of trial production results doesn't match	8
2		Flexibility of trial production results doesn't match samples	3
3		Mold mechanism is not smooth	1
4	Inappropriate Processing	Machining process time is too long (CNC, Machining, & Assembly)	10
5	Inappropriate Processing	Mold Polishing Process Exceeds the Schedule	1
6	Waiting	Machine Allocation for Mold Trials (Trail) Is Not Available	1
		Total	26

2. Measure Phase

In this phase, the failure percentage and its cumulative value are calculated.

This phase involves analyzing process failure (defect) percentages, arranged from highest to lowest, as shown in the calculation table and Pareto chart.

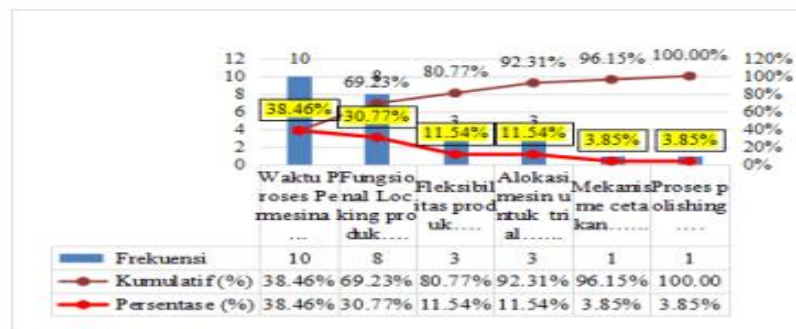


Figure 4. Pareto Diagram of Process Failure Causes

The diagram above illustrates that the most frequent process failures were caused by: (1) machining processes (CNC, general machining, and assembly) exceeding established targets, occurring 10 times (38.46%); (2) the locking function of trial products not matching the sample, occurring 8 times (30.77%); (3) the flexibility of trial products not matching the sample, occurring 3 times (11.54%); (4) unavailability of machines for molding trials, occurring 3 times (11.54%); (5) issues with smooth mold mechanism operation, occurring once (3.85%); and (6) the polishing process exceeding the established schedule, occurring once (3.85%).

3. Analyze Phase

The analytical tool employed will be the cause-and-effect diagram. This diagram provides insight into the root causes of issues arising in relation to target achievement during the mold development process.

Cause-and-Effect Diagram

This diagram illustrates the factors contributing to delays. Based on the Pareto chart above, the primary cause of delay is the machining process exceeding the established target, accounting for 38.46% of the total. The analysis using the cause-and-effect diagram is as follows:

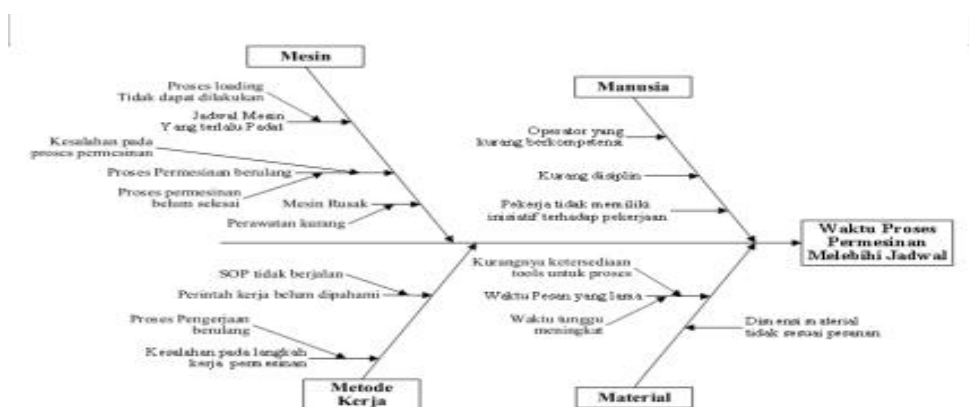


Figure 5. Fishbone Machining Processing Time Exceeds the Scheduled Time

A cause-and-effect analysis reveals the factors contributing to machining times exceeding the scheduled duration: regarding personnel, there are deficiencies in competence, discipline, and work initiative; regarding machinery, issues include tight scheduling that prevents loading, process repetition due to errors and unfinished tasks, and breakdowns caused by inconsistent maintenance; regarding materials, long lead times for ordering materials and tools result in shortages and increased waiting times, alongside issues with material specifications; and regarding work methods, complex and poorly communicated work orders, combined with machining errors, lead to the need for process repetition.

4. Improve Phase

Proposed Improvements Using the 5W+1H Method. This phase utilizes the Pareto chart and cause-and-effect diagram, applying the 5W+1H approach (What, Why, Where, When, Who, and How) to formulate recommendations or proposed improvement measures.

In this phase, the author develops an implementation plan using the 5W+1H approach to address the most significant process failure: machining operations exceeding the established schedule.

Table 5. The 5W and 1H Approach

No	Type of Process Failure	Factors	Causes of Process Failure	What	Why	Where	When	Who	How
1	Machining processing time exceeds the scheduled time.	Man	Lack of competence, discipline, and initiative regarding the work	Directly inspect and supervise work processes	To ensure operators are disciplined in completing assigned tasks.	Dept. moldshop & HRD	During working hours	Supervisor, foreman, and trial technician/operator	Creating schedules and providing training and guidance regarding work instructions, quality standards, and the importance of discipline and work motivation. Conducting periodic supervision.
2		Machine	Machining process errors, such as errors in the process itself or in the setup of workpieces or tools	Routinely inspect every machining process being performed	To ensure operators are disciplined in completing assigned tasks.	Dept. moldshop	During the setup process	Supervisor, foreman, and operator	Revisions to machining process work instructions (workpiece and tool setup) to accelerate machining operations (CNC and milling).

Developing a Future State Map

Proposed improvements to the process flow are based on the Current State Map, visually outlining enhancements to accelerate and integrate design and machining processes. This serves to reduce the time associated with Value-Added (VA), Non-Value-Added (NVA), and Necessary Non-Value-Added (NNVA) activities.

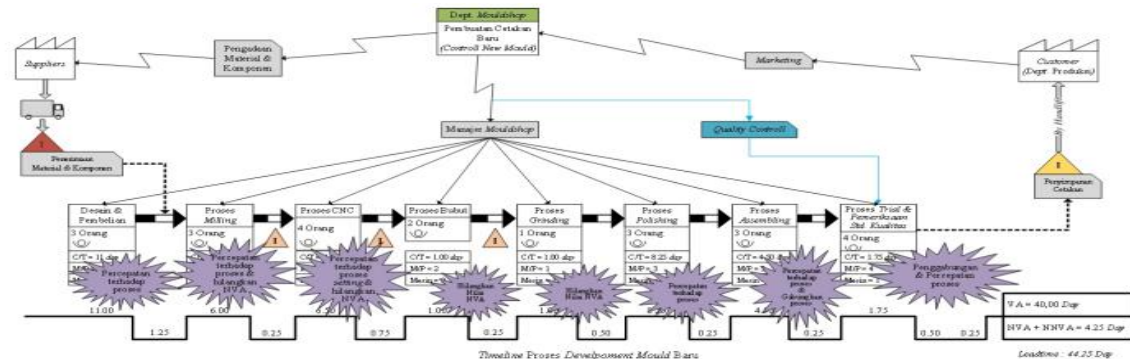


Figure 6. Future State Mapping

Comparison of Lead Time Percentages Before and After the Improvement Plan

The following table outlines the estimated activities categorized as Value-Added (VA), Non-Value-Added (NVA), and Necessary Non-Value-Added (NNVA), contributing to the production process lead time, along with a percentage comparison before and after the improvement plan.

Table 6. Comparison Before and After Improvement

No	Process	Before			After		
		VA	NVA	NNVA	VA	NVA	NNVA
1	Desain	11,50	0,50	2,00	11,00	0,00	1,25
2	CNC	7,25	0,50	1,50	6,50	0,00	0,75
3	Milling	6,50	0,25	0,25	6,00	0,00	0,25
4	Bubut	1,00	0,25	0,25	1,00	0,00	0,25
5	Grinding	1,00	0,50	0,25	1,00	0,25	0,25
6	Polishing	9,25	0,00	0,50	8,25	0,00	0,25
7	Assembling	5,50	0,00	0,50	4,50	0,00	0,25
8	Trial	1,50	0,25	1,00	1,75	0,000	0,75
	Total	43,50	2,25	6,25	40,00	0,25	4,00
	Total Lead Time	52,00			44,25		
	Value Percentage (%)	83,65%	4,33%	12,02%	90,40%	0,56%	9,04%

Based on the table above, a reduction in total lead time is evident; the processing time decreased by 7.75 days, from an initial 52 days to 44.25 days. Furthermore, the value-added percentage rose by 6.75% from 83.65% to 90.40% indicating a reduction in waste.

5. Control Phase

This is the final step in implementing the DMAIC methodology. Its objective is to control the processes already executed, ensuring that issues identified during the earlier analysis using Pareto and cause-and-effect diagrams do not recur in the future.

The control measures to be implemented are as follows:

1. Revising employee work instructions into language that is easy to understand and implement within the production process.
2. Introducing a checklist to verify the conformity of ordered materials, components, and tools against the goods actually received.
3. Assigning a person in charge for each process to ensure effective process control.
4. Establishing a training schedule for the implementation of work instructions, focusing on product quality awareness and the importance of discipline and initiative regarding assigned tasks and responsibilities.
5. Ensuring that the preventive maintenance schedule and machine maintenance checklists are accurately completed to maintain the condition of all machines.
6. Verifying the structural conformity of the finished product as a whole.
7. Conducting 5S audits to monitor the improvement measures and ensure their effective execution.

CONCLUSION

The DMAIC analysis identified six types of failures, with the most significant being machining times exceeding the established schedule (accounting for 38.46%). These failures were translated into three categories of waste using the VSM method: defects, inappropriate processing, and waiting. Furthermore, a Fishbone diagram analysis identified the root causes of these failures based on the 4M criteria (Man, Machine, Material, and Method). The proposed improvements involve applying the 5W+1H tool and developing a Future State Mapping (FSM) plan.

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