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Implementation of Lean Manufacturing To Reduce Waste in Calliper Bracket Production

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ABSTRACT

Initial observations at PT. PPE showed that the production of calliper brackets failed to meet monthly targets for four consecutive months. Investigations carried out by the team showed that the inability to meet production targets was caused by waiting and transportation activity, which can cause longer production lead times. Some wastes were found, such as waiting for a forklift, and transportation of material movings between workstations. To overcome this problem, PT. PPE uses 5S, one of the lean manufacturing tools. The research began with direct observation to determine the actual production floor situation. The next stage is the problem identification process using Value Stream Mapping (VSM), Process Activity Mapping (PAM), spaghetti diagram, and fishbone diagram. Some 5S-based corrective actions implemented include sorting unused goods, arranging materials, maintaining cleanliness, updating work instructions, and creating a 5S check sheet. The result of implementing 5S in calliper bracket production was that lead time decreased from 8.05 days to 5.53 days or 31.30%. Sales losses can be reduced from IDR 1,936,100,000 to IDR 111,150,000 or decrease by 94.26%.

Keywords: *lean manufacture, waste, lead time, output, VSM, PAM, 5S methodology*

ABSTRAK

Pengamatan awal di PT. PPE menunjukkan bahwa produksi calliper bracket gagal memenuhi target bulanan selama empat bulan berturut-turut. Investigasi yang dilakukan oleh tim menunjukkan bahwa ketidakmampuan untuk memenuhi target produksi disebabkan oleh aktivitas menunggu dan transportasi, yang dapat menyebabkan waktu tunggu produksi yang lebih lama. Contoh menunggu yang tidak efisien adalah menunggu forklift, sedangkan contoh transportasi adalah memindahkan material antar stasiun kerja. Untuk mengatasi masalah ini, PT. PPE menggunakan 5S, salah satu alat lean manufacturing. Penelitian dimulai dengan observasi langsung untuk menentukan situasi aktual di lantai produksi. Tahap berikutnya adalah proses identifikasi masalah menggunakan *Value Stream Mapping (VSM), Process Activity Mapping (PAM)*, diagram spaghetti, dan diagram fishbone. Beberapa tindakan korektif berbasis 5S yang diterapkan termasuk memilah barang yang tidak digunakan, mengatur material, menjaga kebersihan, memperbarui instruksi kerja, dan membuat lembar cek 5S. Hasil penerapan 5S dalam produksi calliper bracket adalah waktu tunggu berkurang dari 8,05 hari menjadi 5,53 hari atau 31,30%. Kerugian penjualan dapat dikurangi dari IDR 1.936.100.000 menjadi IDR 111.150.000 atau berkurang sebesar 94,26%.

Kata kunci: *lean manufacture*, *waste*, *lead time*, output, VSM, PAM, metodologi 5S

1. Introduction

One manufacturer that produces sub-parts of vehicles in Indonesia is PT. PPE. This company is in Cikarang. The products produced are intended for two- and four- wheeled vehicles. Examples of products for two-wheeled vehicles are brake calliper brackets, calliper pistons, reinforcement, brake pressure plates. While for four-wheeled vehicles have backing plates, hub flanges, plate cranks. This research is focused on two-wheeled parts that are calliper bracket products. That is because this product is the most widely produced among the others. The calliper bracket or brake support calliper is a brake component that has a critical function in brake work. The calliper bracket is used to attach the calliper, which will keep the calliper in place so that it will not move and ensure that the braking process runs well in various road areas.

The average percentage of deficiency in actual production compared to the target in January to April is 16.23%. The data for the last four months shows that the company's actual production cannot reach the monthly production target. The first step taken by the company was to form a team consisting of members of the production department and writers to investigate the cause of the problem by observing the production floor directly.

The investigation results show that the types of waste that occurred were waiting and transportation. Examples of waste that occurs on the production floor are waste of waiting. For example, when an operator picks up a die, he must wait for the forklift first because the intensity of forklift use is high, and the number is insufficient for production activities. An example of transportation waste is when an operator moves WIP from the stamping station. Operators have difficulty moving WIP because, at the stamping station, there is much scrap scattered around, the placement of items is messy, and oil is spilt. The consequences of the two types of waste previously explained are high production lead times, so actual production output cannot reach the target. Therefore, to overcome waste problems, lean manufacturing is necessary. One of the lean manufacturing tools that can be applied to high lead time problems is the 5S (Sort, Set, Shine, Standardise, Sustain).

From the previous research, to identify the reason for the long lead time, Phuong et al. (2023) closely monited the whole manufacturing process, and a Gemba walk helped to find issues or waste on the factory floor.According to Batwara et al. (2023), it may be concluded that the environmental effects of manufacturing processes can be identified using VSM. Value stream mapping was also proven to work well with other lean techniques, including simulation modelling to increase adoption and continuous improvement methodologies like Just-In-Time and 5S, as demonstrated by the research conducted by (Imtinan & Cahyaputri, 2024)

The research of Putri et al. (2023) and Akram et al. (2023) shows that 5S technique is a lean tool that may boost productivity through better workplace organisation. Also, according to Roy et al. (2021, it is evident that 5S can dramatically cut waste and improve the effectiveness and productivity of all operations if implemented.

Similar research by Jokiel et al. (2023) found that businesses used Lean and other improvement tools and methods, such visual control, Poka-Yoke, and 5s, to assist them discover places where waste could be reduced and manufacturing process efficiency could be increased. The enhanced productivity gains inside the organization have been positively impacted by the improved outcomes.

2. Literature Review

2.1 Lean Manufacturing

Lean thinking is a process optimization methodology that creates new employment rather than eliminating jobs for efficiency. Lean thinking's core idea is to produce value as determined by customers (Yeh et al., 2021). Since the manufacturing process delivers value to customers, lean thinking must be applied to both production and service processes. Waste elimination can occur at different stages, from product development and process design to ensuring worker compliance and managing the finished factory (Melton, 2005).

According to Hines & Taylor (2000), manufacturing activities are classified as value-added, non-value-added, and Necessary but Non-Value-Added Activities. Value-added activities, such as material processing, can add value from the consumer's perspective. Non-value-added activities are activities that do not add value and should be minimized, such as product movement. Necessary but Non-Value-Added activities that do not add value but are required to prevent process disruptions, like inspections with uncalibrated machines (Tebiary et al., 2017). Value-added activities create products or services customers desire, while non-value-added activities, or waste, must be eliminated (Joosten et al., 2009) (Smith A, 2015).

Lean Manufacturing systematically identifies and eliminates waste through continuous improvement, producing products efficiently according to customer requirements (Arifin et al., 2013). For optimal results, lean methods must be consistently applied (Gupta & Jain, 2013). Eliminating non-value-added activities can significantly enhance performance and customer service. Womack & Jones (1996) described the five main principles of lean thinking: specify the value, identify the value stream, make the value flow, implement a pull system, and strive for perfection.

2.1.1 Waste

Lean aims to reduce waste, improve quality, lowering costs, and shorten lead times (Zakaria & Rochmoeljati, 2020). Melton (2005) categorizes waste into seven types:

1. Overproduction: Producing goods without customer demand, leading to excessive Work in Process (WIP) and increased storage costs.
2. Waiting: Inactivity of operators or goods, disrupting production flow due to inconsistent work methods or inefficient layouts.
3. Transportation: Moving goods without processing, wasting time and costs, often due to improper workstation layouts.
4. Inventory: Excessive storage of raw materials, WIP, and finished goods, increasing storage costs and decreasing efficiency.
5. Overprocessing: Unnecessary and inefficient work processes, leading to defects and high lead times.
6. Motion: Poor workplace conditions and layouts, reducing productivity and causing quality issues.
7. Defects: Errors requiring rework, increasing production costs and lead times.

2.2 Visual Stream Mapping

Value Stream Mapping (VSM) is a Lean Manufacturing method popularized by Toyota and the book Learning to See by Rother and Shook (Wilson, 2010). It uses symbols, metrics, and arrows to illustrate and improve inventory and information flow in product or service manufacturing (Suhendi et al., 2019). VSM's flowcharts help analyze and design the necessary flow of materials and information, promoting understanding within the company (Zakaria & Rochmoeljati, 2020).

VSM visualizes product flow, detects waste, and prioritizes problems. It details material flow, information flow, lead time, yield, uptime, delivery frequency, workforce, batch size, inventory, setup time, process time, and overall efficiency (Kholil & Arifin, 2018). Identifiable issues include excessive inventory, high scrap, low uptime, large batch sizes, poor information flow, long waiting times, and inefficiency. VSM involves validating operational data in the field (Gemba) to ensure data accuracy and improve business process efficiency (Heravi & Firoozi, 2017) (Maulana, 2019) (Rohac & Januska, 2015). Information/Communication Flow ensures clear communication among employees, suppliers, and customers. The timeline is to show lead time and cycle time for product processes. According to Damanik et al. (201), there are two types of VSM mappings: current and future.

According to Chaeron et al. (2020), the steps are:

1. Identify Product Families: Focus on products with similar manufacturing processes and issues.
2. Create Current State VSM: Observe current conditions to identify waste.
3. Prepare Work Plans: Categorize activities and design solutions to reduce waste.
4. Create Future State VSM: Describe desired future conditions with reduced waste and lead times.
5. Implement Final Plan: Apply solutions to reduce waste and compare results before and after implementation.

2.3 Process Activity Mapping

Process Activity Mapping, part of Value Stream Analysis Tools (VALSAT), details the entire production process from material arrival to consumer delivery (Lisano & Susanto, 2016). Industrial engineers use this tool to map all activities, aiming to eliminate waste, inconsistency, and irrationality, thereby improving product quality, speeding up processes, and reducing costs (Mahendra et al., 2023). Activities are classified into operations, transportation, inspection, delay, and storage, with only operations and inspections being value-added. Transportation and storage are necessary but non-value-added, while delays are non-value-added activities (Haekal, 2022).

2.4 5S Methodology

The 5S concept consists of five Japanese words: Seiri (sorting), Seiton (ordering), Seiso (sweeping), Seiketsu (standardizing), and Shitsuke (maintaining). Originating in Japan in the mid-1950s and used in manufacturing (Gupta & Jain, 2014), 5S is a method for organizing and maintaining a clean workspace to enhance efficiency by eliminating disorder. It 5S also aids warehouse layout design, inventory cost control, and quality and process efficiency (Shahriar et al., 2022).

5S motivates employees and reduces downtime and non-value-adding activities. For tools like TPM, SMED, System Dynamic Model, or AHP to be practical, a solid 5S system is essential. The main goal of 5S is to ensure cleanliness and enhance operational performance by identifying and eliminating inefficiencies in the production cycle(Shahriar et al., 2022).

1. Seiri (Sort)
   The first step, Seiri, involves removing non-essential items from the workspace to enhance efficiency. Sorting identifies necessary items and discards those that are not.

2. Seiton (Set in Order)
   Seiton organizes items in the most suitable locations to prevent clutter. This step employs visual management, like labelling, to minimize search time and reduce errors.
3. Seiso (Shine)
   Seiso involves cleaning the work area regularly to maintain tidiness, reduce waste, and prevent accidents. All employees participate to ensure ongoing cleanliness.
4. Seiketsu (Standardize)
   Seiketsu develops standard procedures to maintain organization and cleanliness. It involves creating routines, schedules, and visual guidelines to ensure consistency in maintaining the work area.
5. Shitsuke (Sustain)
   Shitsuke emphasizes discipline and motivation to sustain the 5S program. Continuous efforts, rewards, and frequent monitoring help maintain the benefits and prevent reverting to disarray.

3. Research Methodology

3.1 Research Framework

Six stages are carried out to conduct research, as can be seen in Figure 1. The research started with the first initial observation by determining the product focused on for research, conducting direct observation or Gemba Walk, analyzing general production process problems, and collecting supporting data, for example, monthly production, sales losses, and workplace availability times. Secondly, problems can be identified by creating Visual Stream Mapping, Spaghetti Diagrams, Process Activity Mapping, and Fishbone Diagram. Thirdly, plan specific improvements for each waste that occurs by making a table. Fourthly, an improvement plan should be implemented using the 5S method. The fifth compares the conditions before and after the repairs used. Sixth, conclusions and recommendations for further research should be made.

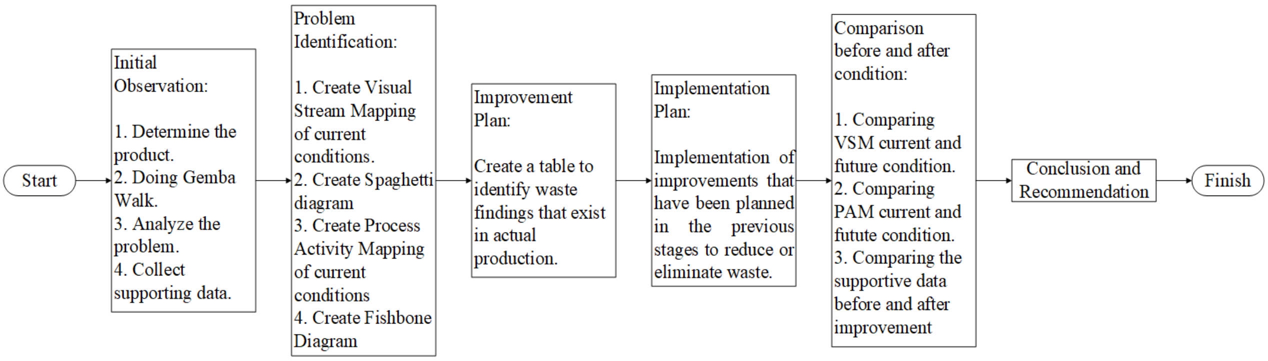


Figure 1. Research Framework

The initial observation started by selecting one product for research to streamline the process and maintain focus. The product chosen should have the highest demand, as it generates the most revenue. After discussions with the production manager, it was found that the calliper bracket is the most produced item. A Gemba Walk, or direct observation, will be carried out to understand the actual conditions. This observation helps gather supporting data, like the production flow, which consists of nine steps: storage, stamping, trimming, deburring, chamfering, tumbling, tapping, inspection and packing, and delivery. The data will also highlight monthly production and sales losses due to unmet production targets.

Identifying problems in research is crucial because it helps find accurate solutions. This process allows the researcher to pinpoint issues and determine effective solutions. There are three key steps in the problem identification stage:

1. Visual Stream Mapping: This helps visualize the production process from raw material storage to delivery, showing data for each production line and lead times.
2. Spaghetti Diagram: This diagram maps out the layout of workstations and the paths used by operators, making it easier to understand the workflow.
3. Process Activity Mapping: This mapping breaks down the activities of operators, identifying the time spent on each task, and categorizes them into value-added, non-value-added, and necessary but non-value-added activities.
4. Fishbone Diagram: This diagram helps identify the root causes of waste at each workstation, aiding in effective improvement planning.

Once problems are identified, the next step is to create an improvement plan. Identifying problems first makes it easier to gather data on waste, ensuring that the improvement plan can effectively address all waste on the production floor. The improvement plan outlines the steps needed to enhance production processes' efficiency, effectiveness, and overall performance. It serves as a road map for implementing improvements. To create an improvement plan, list current PAM conditions that fall into each production line's NVA and NNVA categories. Then, an improvement plan will be developed based on this waste data.

The next step is putting the last section's improvements into action to reduce or eliminate waste in production using the 5S method. Additional improvements include proposing new equipment like a hand lift machine and updating instructions for cleaning dies. After implementing these changes, the next step is to create Value Stream Mapping (VSM) and Process Activity Mapping (PAM) to evaluate if the improvements reduce production lead time and eliminate waste.

Comparing before and after the improvement phase is crucial to evaluate the effectiveness of solutions and show the impact of improvement efforts. It involves looking at various aspects of the production process before and after changes to measure benefits and identify any remaining issues. The goal of comparing Visual Stream Mapping (VSM) current and future conditions is to highlight changes in workflow and efficiency visually. Comparing current and future conditions of process activity mapping (PAM) focuses on analyzing changes in specific activities, emphasizing value-added and non-value-added activities. Evaluating supporting data before and after improvements helps measure the impact of these changes using collected data.

4. Result and Discussion

4.1 Initial Observation

The first step of this research is to decide which product to focus on. Through interviews with the production manager, it was identified that the Calliper Bracket is the most produced item. A Gemba Walk, or direct observation of the production floor, was conducted. A "Gemba walk" involves on-site management to spot waste and improve production (McClam Liebengood et al., 2013). Gemba walks offer two key benefits. First, they support continuous improvement and process standardization by involving leaders and supervisors, helping resolve problems and quickly enhancing team performance. Second, they ensure team alignment, increasing effectiveness and uncovering improvement opportunities through questions and active listening (Tyagi et al., 2015).

4.1.1 Process Flow Chart

After directly observing, several pieces of data can be gathered for this research, starting with the process flowchart. According to Listyoningrum et al. (2023), a process flowchart depicts a systematic sequence of processes or steps to run a program. Flowcharts are essential for illustrating the production process, making it easier to understand by showing the sequence of steps from one process to the next. Figure 2 shows that the calliper bracket production process includes nine steps, beginning with storing raw materials and continuing through seven main processes: stamping, trimming, deburring, chamfering, tumbling, and tapping. The process concludes with the delivery of goods to consumers. Each process is described as follows:

1. Incoming Storage: Receiving and storing raw materials from suppliers before production begins.
2. Stamping: Shaping raw material (usually sheet metal) into the basic form of the calliper bracket using a stamping machine.
3. Trimming: Removing excess material from the stamped pieces to ensure precise edges and dimensions.
4. Deburring: Eliminating sharp edges or burrs from the trimmed pieces, either manually or with automated equipment.
5. Chamfering: Creating bevelled edges on the deburred pieces to ensure proper fit and function in assembly.
6. Tumbling: Polishing and smoothing the chamfered pieces in a tumbling machine to improve surface finish.
7. Tapping: Creating threads in the necessary holes of the tumbled pieces for assembling the bracket with other components.
8. Inspection & Packing: Thoroughly inspect the tapped pieces for quality standards and specifications, then pack them neatly to prevent damage during delivery.
9. Delivery: Shipping the inspected and approved goods by truck to the customers.

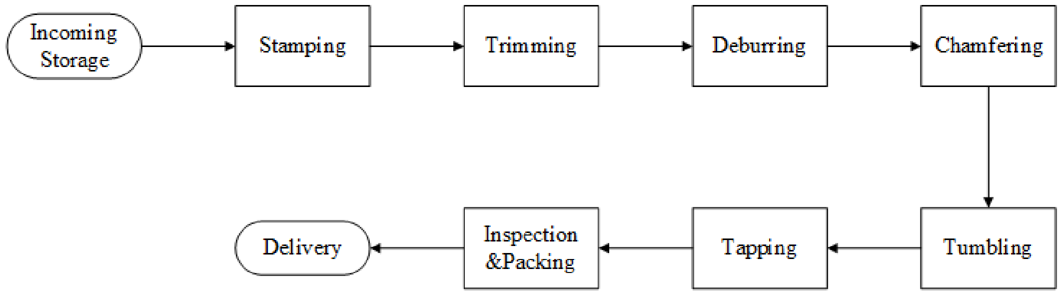


Figure 2. Process Flowchart

4.1.2 Monthly Production Data

The data of the calliper bracket actual and target production and loss sales from January to April 2024 can be seen in Table 1. The calliper bracket production cannot achieve the target, leading to potential sales losses for the company.

Table 1. Loss Sales of Calliper Bracket January-April 2024

Month	Actual	Target	Price per Unit	Sales Loss (in million)
January	137,170	160,457	IDR 50,000	-IDR 1,164.35
February	158,919	190,414	IDR 50,000	-IDR 1,574.75
March	156,511	189,390	IDR 50,000	-IDR 1,643.95
April	195,956	234,678	IDR 50,000	-IDR 1,936.10

4.1.3 Time Availability, Cycle Time and Lead Time

The workers have an 8-hour workday, which equals 28,800 seconds. Each workstation also has 28,800 seconds available, calculated by multiplying 8 hours by 3,600 seconds. This time allocation is achieved by assigning 2 operators to each of the following: the stamping machine, the trimming process, the deburring machine, the chamfering machine, the tumbling process, the tapping machine, and the final production stage, Inspection and Packaging.

Cycle time is the duration needed to complete one full cycle of an operation or task within the production process. This cycle time data was collected through direct observation on the production floor, covering 20 repetitions. Lead Time refers to when a product or raw material is ordered until the product is finished, delivered to the customer, or ready for use. The results from 20 observations indicate that each operator's repetition time varies for each process, so the average time should be used to determine the cycle time for each process. The average times observed are as follows: stamping takes 1444 seconds, trimming 1461 seconds, deburring 75 seconds, chamfering 178 seconds, tumbling 58 seconds, tapping 182 seconds, and Inspection and Packaging 64 seconds. Table 4 provides data on each production process's total cycle time and lead time.

The production time for the calliper bracket is measured from when raw materials are received until the finished goods are delivered to the customer. The total production lead time is 8.054 days, whereas the cycle time, which is the duration from the initial stamping process to the inspection and shipping of the finished product, is 0.96 hours.

Table 2. Cycle Time and Lead Time

No.	Activity	Cycle Time		Lead Time	
		Second	Hour	Second	Day
1	Storage	0	0	604800	7
2	Stamping	1444	0.401	173	0.002
3	Trimming	1461	0.406	173	0.002
4	Deburring	75	0.0283	173	0.002
5	Chamfering	178	0.0494	173	0.002
6	Tumbling	58	0.0161	173	0.002
7	Tapping	182	0.0505	173	0.002
8	Inspection and Packing	64	0.0188	3629	0.042
9	Delivery	0	0	86400	1
Total		3462	0.9617	736128	8.054

4.2 Problem Identification

4.2.1 Current State Visual Stream Mapping

According to Figure 4, the total processing time is 57.70 minutes, broken down as follows: stamping takes 1444 seconds, trimming takes 1461 seconds, deburring takes 75 seconds, chamfering takes 178 seconds, tumbling takes 58 seconds, tapping takes 182 seconds, and inspection and packaging take 64 seconds. The total production lead time including production and storage times, amounts to 8.05 days. This indicates a high production lead time.

4.2.2 Current State Process Activity Mapping (PAM)

The current state visual stream mapping (see Figure 3) illustrates the calliper bracket production process from raw materials to delivery based on direct observation. It includes details like production flow, cycle time, processing time, availability time, storage time, total production lead time, and operator count at each workstation. As shown in Figure 3, the total processing time is 57.70 minutes, with specific times for each stage: stamping 1444 seconds, trimming 1461 seconds, deburring 75 seconds, chamfering 178 seconds, tumbling 58 seconds, tapping 182 seconds, and inspection and packaging 64 seconds. The total production lead time is 8.05 days, indicating a long lead time. The research suggests using the 5S method to reduce this lead time, with future comparisons to evaluate its effectiveness.

Table 3 displays the operator's activities in their current state. Rows highlighted in green indicate activities categorized as waste. For a clearer understanding of these waste activities, refer to Table 6, which summarizes the waste data from the current PAM state, providing an easier overview of the waste information.

Table 3. Current State of Process Activtiy Mapping

No	Activity	Time (s)	Activity					(NNVA/NVA /VA)
			O	T	I	S	D	
1	Stamping							
	Waiting for the forklift	600					D	NVA
	Moving the raw material to Stamping station	180		T				NNVA
	Moving the die from rack to stamping station	360		T				NNVA
	Clean the remaining oil on the die	20					D	NVA
	Installing die to the stamping machine	180	O					VA
	Setting the stamping machine	70	O					VA
	Put raw material to the machine	1	O					VA
	Stamping process	2	O					VA
	Put WIP to the tray	1	O					VA
	Production sample inspection	30			I			VA
2	Trimming							
	Waiting for the forklift	600					D	NVA
	Move WIP to Trimming station	120		T				NNVA
	Moving the die from rack to trimming station	360		T				NNVA
	Clean the remaining oil on the die	20					D	NVA
	Installing die to the trimming machine	180	O					VA
	Setting the trimming machine	120	O					VA
	Put WIP to the machine	1	O					VA
	Adjust WIP position	2	O					VA
	Trimming process	5	O					VA
	Discard scrap	2	O					VA
	Put WIP to the tray	1	O					VA
	Production sample inspection	30			I			VA
	Move WIP to the storage	20		T				NNVA
3	Deburring							
	Move WIP to deburring station	30		T				NNVA
	Put WIP to the machine	1	O					VA
	Deburring process	13	O					VA

No	Activity	Time (s)	Activity					(NNVA/NVA /VA)
			O	T	I	S	D	
	Put WIP to the tray	1	O					VA
	Production sample inspection	30			I			VA
4	Chamfering							
	Move WIP to chamfering station	20		T				NNVA
	Put WIP to the machine	1	O					VA
	Setting the chamfering machine	120	O					VA

Note: O = Operation; T = Transportation; I = Inspection; S = Storage; D = Delay

Table 4 indicates that there are two main types of waste in the current production conditions: delays and transportation. Transportation waste is considered NNVA (Non-Value-Adding but Necessary) because it is necessary for production, though it doesn't enhance the product's value. Customers don't want to pay extra for transportation, and it doesn't improve the product's quality. Therefore, while NNVA activities like transportation should not be eliminated, their duration should be minimized. On the other hand, delay waste is classified as NVA (Non-Value Adding) because it is unnecessary and does not contribute value to the product. NVA activities should be eliminated to improve the efficiency of the calliper bracket production process. The most significant waste occurs at the stamping and trimming stations, with times of 1160 and 1120 seconds, respectively.

Table 4. Waste in PAM Current Condition

Waste				
Type	Activity	Location	Time (s)	Action
Delay (NVA)	Waiting for the forklift	Stamping	600	Eliminate
Transportation (NNVA)	Moving the die from rack to stamping station	Stamping	360	Reduction
Delay (NVA)	Clean the remaining oil on the die	Stamping	20	Eliminate
Transportation (NNVA)	Moving raw material to stamping station	Stamping	180	Reduction
Delay (NVA)	Waiting for the forklift	Trimming	600	Eliminate
Transportation (NVA)	Moving the die from rack to trimming station	Trimming	360	Reduction
Delay (NVA)	Clean the remaining oil on the die	Trimming	20	Eliminate
Transportation (NNVA)	Move WIP to trimming machine	Trimming	180	Reduction
Transportation (NNVA)	Move WIP to the WIP storage	Trimming	20	Reduction
Transportation (NNVA)	Move WIP to deburring station	Deburring	30	Reduction
Transportation (NNVA)	Move WIP to chamfering station	Chamfering	20	Reduction
Transportation (NNVA)	Move WIP to tumbling station	Tumbling	20	Reduction
Transportation (NNVA)	Move WIP to tapping station	Tapping	20	Reduction
Transportation (NNVA)	Move WIP to packing & Inspection	Packing	30	Reduction
Transportation (NNVA)	Move finished good to storage	Packing	30	Reduction

4.2.3 Spaghetti Diagram

According to Cantini et al. (2020) The spaghetti diagram called a spaghetti chart, is a tool used to map and visualize the physical movement of resources—such as materials, people, or documents—within a specific area. Typically employed in the early stages of planning improvement actions, the spaghetti chart is a lean philosophy tool that helps determine the optimal layout of a system by observing the distances travelled by resources and the material exchanges between departments (Shafee et al., 2024).

Figure 4 shows a spaghetti diagram with squares, arrows, and numbers. The squares denote workstations, arrows indicate operator movements and the numbers on the arrows represent the sequence. This diagram maps out workstation placement and operator paths. Despite the close proximity of workstations, materials obstructing transport routes force operators to navigate around, increasing transportation time. To identify waste sources in calliper bracket production, the next step is to photograph each workstation to analyze their conditions.

4.2.4 Workstation Area in Current Conditions

This section will detail the initial conditions on the production floor that lead to waste. The development of an improvement plan will follow this identification process. As outlined in Table 5, the table includes images depicting the conditions in each area that may contribute to waste, descriptions of these conditions, their locations, and their impact on production activities.

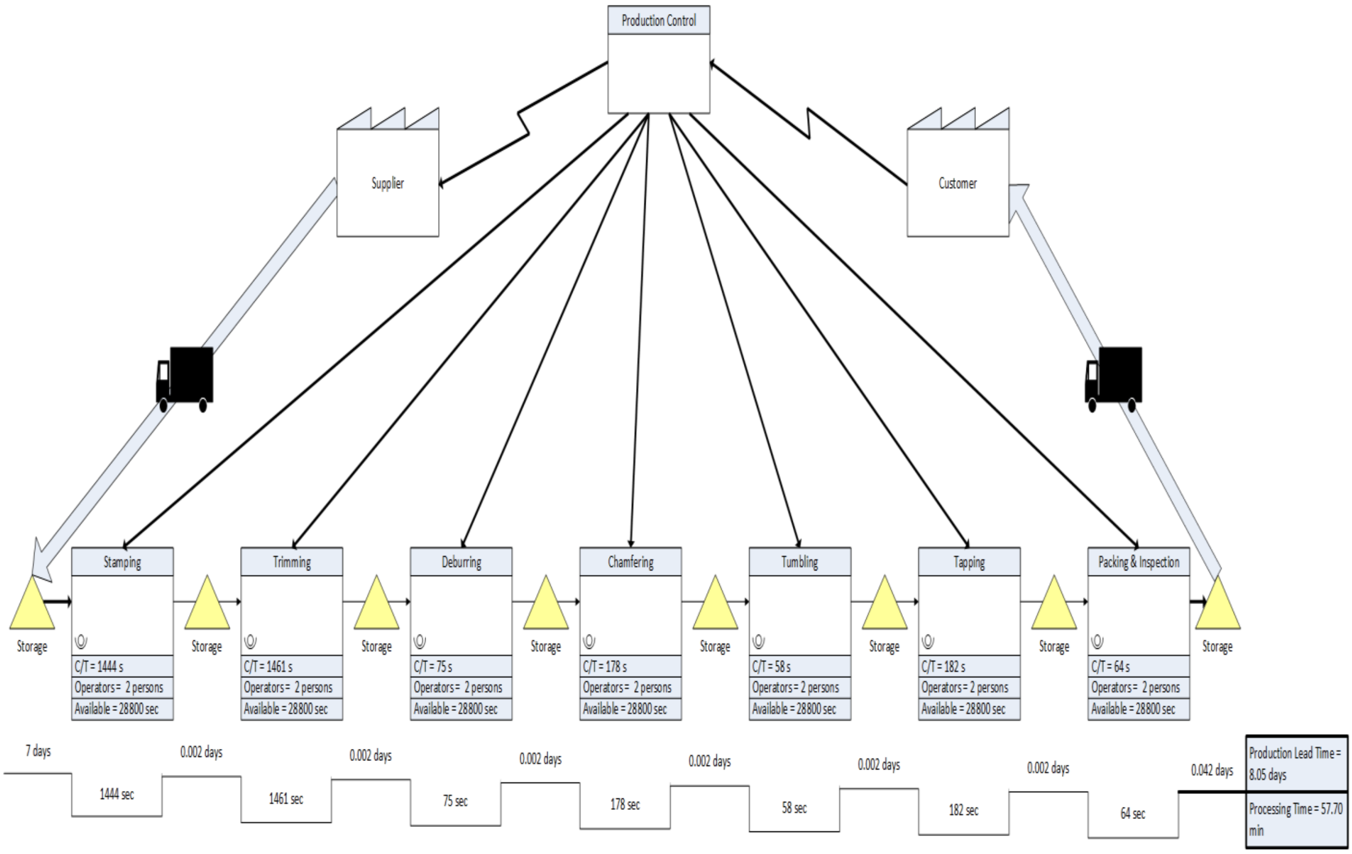


Figure 3. Current State Visual Stream Mapping

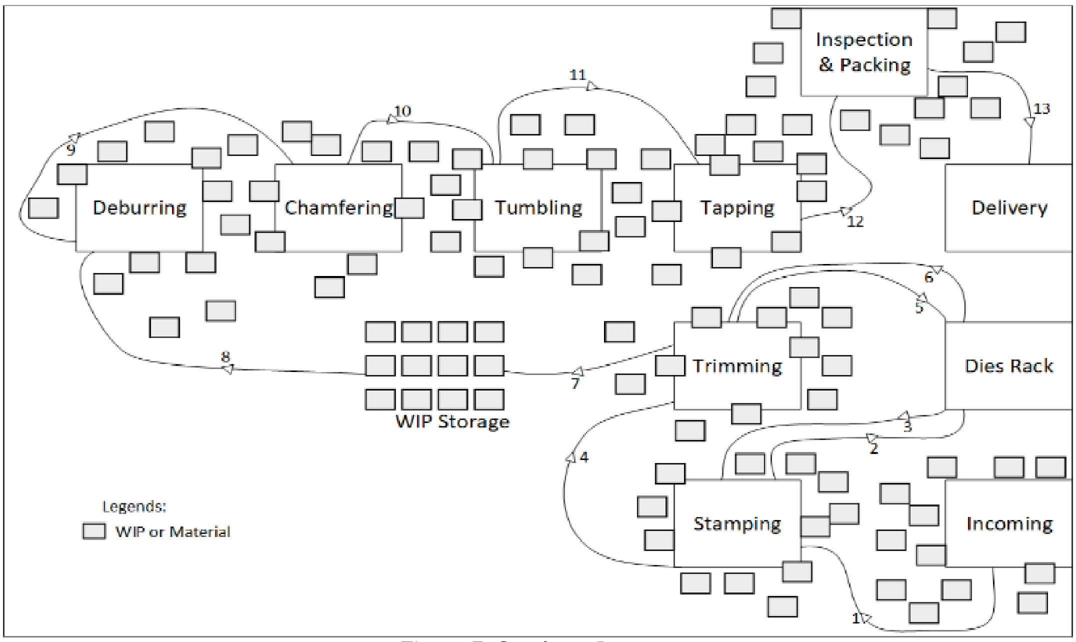


Figure 5. Spaghetti Diagram

Table 5. Workstation in Current Condition

No	Problem	Location	Impact
1	irregular arrangement of raw materials and no identification labels on each item.	Raw material storage	It causes the transfer of raw materials to take a long time due to the high search and pick-up time.
2	There are lots of WIP boxes and wooden pallets, messy plastic placement, and oil spills.	Stamping	It causes the transfer of WIP to the trimming station takes a long time due to high pick-up time.

No	Problem	Location	Impact
3	There are iron shelves, WIP boxes, and scrap boxes whose placement is messy and there are oil spills.	Trimming	it causes the transfer of WIP to deburring to take a long time due to high pick-up time.
4	There is a WIP trolley covering the machine blocking the transportation route.	Deburring	It causes the transfer of WIP to chamfering to take a long time due to high pick-up and searching time
5	There are stacks of WIP boxes blocking the transportation route	Chamfering	This causes delays when transferring WIP from chamfering to tumbling
6	There are piles of WIP boxes and wooden pallets blocking the transportation route	Tumbling	It causes delays when transferring WIP from tumbling to tapping
7	There are piles of WIP boxes and wooden pallets blocking the transportation route.	Tapping	It causes delays when transferring WIP from tapping to finished good storage.
8	Stacks of boxes of finished goods block the transportation route to the warehouse.	Inspection and Packing	The transfer of finished goods to the warehouse takes a long time due to high pick-up time.
9	There are no identification labels on each die and there is a lot of oil spilled on the rack.	Dies Rack	It takes a long time to take the die due to the high search and pick-up time

The main issue is transportation waste, which occurs because blocked paths between workstations force operators to navigate around obstacles, increasing transportation time. Although transportation waste is an NNVA activity, it contributes to longer production lead times and indicates an inefficient process. To improve efficiency, it's necessary to reduce transportation time by reorganizing workstations using 5S.

4.2.5 Fishbone Diagram

The next step is to create a fishbone diagram as seen in Figure 5. to identify the root causes of waste, which will help in developing an effective improvement plan. The fishbone diagram highlights the root causes of waiting and transportation waste.

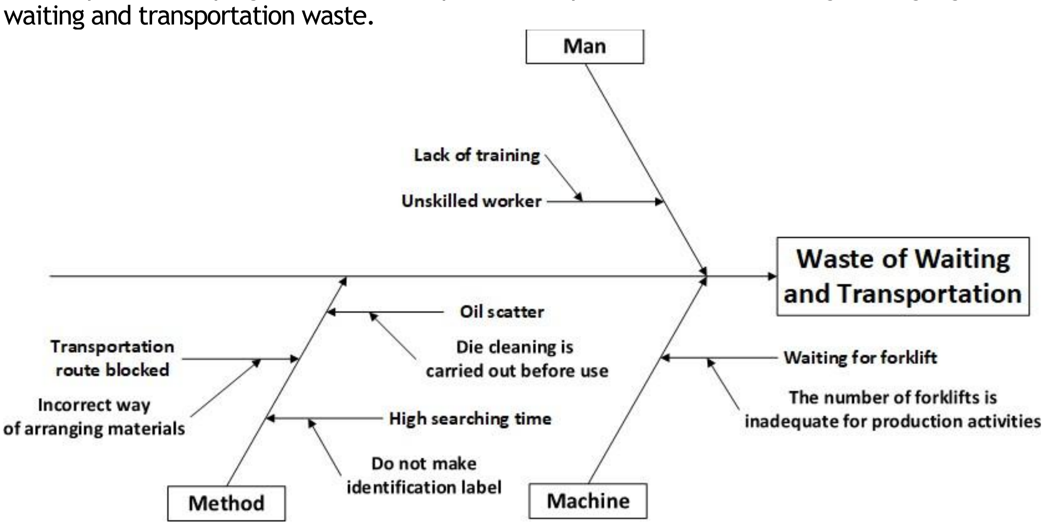


Figure 5. Fishbone Diagram

Figure 6 explains that:

1. Man: Waste is caused by insufficient operator skills, leading to incorrect work, poor cleanliness, and a lack of material labels. It is due to inadequate training and unclear work instructions.
2. Machine: Waste occurs from waiting for forklifts, which is caused by having too few forklifts for the high demand in production, resulting in operators having to share them.
3. Method: Waste is caused by spilt oil around workstations because dies are cleaned before use instead of after, leading to spills during transport. High search times result from missing identification labels on materials and dies. Additionally, transportation routes are blocked because operators do not properly arrange materials, causing some to spill outside workstation areas.

4.3 Improvement Plan

This section will explain strategic planning to reduce waste that occurs in the production process. This effort is made so that all efforts to reduce waste can be carried out effectively at the plan implementation stage, and production lead time can be reduced, as in Table 6.

Table 6. Improvement Plan

Activity	Location	Action	Improvement
Waiting for the forklift	Stamping, Trimming	Eliminate	Provide hand lift machine
Clean the remaining oil on the die	Stamping, Trimming	Eliminate	Change the work instruction to always clean die after used it
Moving raw materials to the stamping station	Stamping	Reduction	5S method to make the workstation neat and does not block the transport route
Move WIP to the trimming machine	Trimming		
Move WIP to the WIP storage.	Trimming		
Move WIP to the deburring station.	Deburring		
Move WIP to the chamfering station.	Chamfering		
Move WIP to the tumbling station.	Tumbling		
Move WIP to the tapping station.	Tapping		
Move WIP to packing & Inspection	Inspection		
Move finished goods to storage.	Inspection		
Moving the die from the rack to the workstation	Stamping, Trimming		

4.4 Implementation Plan

In the implementation phase, the primary focus of the improvement process is on applying the 5S method and proposing new material handling equipment, such as a hand lift machine, to enhance the effectiveness of each activity on the production line, thereby reducing production lead time. The details of the 5S implementation can be seen in Table 7.

Table 7. Implementation Plan

Location	Sort	Set	Shine	Standardize	Sustain
Raw Material Storage	Place raw materials that will be used soon at the front and those for later at the back, which helps operators find and retrieve items more easily.	Ensure materials are placed within designated areas and do not obstruct transport routes. Add labels to each material to reduce search time. This organization speeds up the transfer of raw materials to the stamping station.	Clean both incoming materials and the storage area to remove dust and dirt.	Create work instructions for the incoming material station to ensure immediate inspection and labeling of materials, maintain cleanliness, and arrange materials by their processing order, keeping them within boundaries.	Train operators to consistently apply the 5S method and use check sheets to ensure ongoing adherence to 5S practices.
Stamping	Remove unnecessary items such as WIP boxes and wooden pallets to reduce the time spent searching for materials.	Place WIP boxes in their designated spots and label them to eliminate searching and speed up the transfer to the trimming station.	Clean up oil spills around the machine and stamping area to prevent slipping, which otherwise slows down WIP transport.	Develop work instructions for proper placement of goods, labeling WIP boxes, keeping the stamping station clean, and cleaning dies before shelving.	Train operators on the 5S method and use check sheets to ensure consistent application of 5S practices.
Trimming	Remove unnecessary	Move the scrap box to the back	Clean up oil spills and iron scraps to	Create work instructions for	Train operators on 5S practices

Location	Sort	Set	Shine	Standardize	Sustain
	items, such as the iron racks and wooden pallets, and place the WIP box in its designated spot.	of the machine to clear the transport route, place the shelf next to the machine, and organize WIP boxes with identification labels for processed and unprocessed materials.	improve safety and prevent delays.	proper item placement, labeling WIP boxes, maintaining cleanliness, and cleaning dies before shelving.	and use a checklist to ensure ongoing adherence to the 5S method.
Deburring	Move the trolley away from the deburring area so it doesn't obstruct the machine.	A wooden pallet near the machine should be used to hold large stacks of WIP boxes instead of the trolley.	Clean the deburring station to remove any scrap from the floor.	Create work instructions to ensure items are placed correctly and the deburring station remains clean.	Train operators to consistently follow 5S practices and use a checklist to ensure ongoing adherence to 5S.
Chamfering	Move the WIP boxes to the side of the machine to clear the transportation route.	Label each WIP box and place unprocessed materials on the left side of the machine and processed materials on the right side.	Clean the chamfering station of scrap and dust.	Create work instructions for item placement, ensure the transportation route is clear, and keep the chamfering station clean.	Train operators to consistently apply 5S practices and use a checklist to ensure ongoing adherence to the 5S method.
Tumbling	Move the WIP boxes and pallets from the transportation route.	Place pallets beside the machine and label each WIP box station.	Clean the tumbling station area of scrap and dust.	Create work instructions to define item placement, ensure no blockage of the transportation route, and keep the tumbling station clean.	Train operators to consistently apply 5S and use a 5S checklist to ensure ongoing adherence.
Tapping	Move the WIP boxes to the side of the machine, so the transportation route is not blocked by stack of WIP box.	Label each WIP box and place unprocessed materials on the left side of the machine and processed materials on the right side.	Clean the area of tumbling station from scrap and dust.	Create work instruction regulate each item's placement, the placement of WIP box, ensure that there must be no items blocking the transportation route, and keep the tumbling station clean from scrap and dust.	Train the operator to get used to do 5S and making check sheet of 5S method to maintain the operator always doing 5S.
Inspection & Packing	Move the WIP boxes out of the transportation route to clear it.	Label each WIP box and organize them so uninspected materials are on the left side of the table and inspected materials are on the right side.	Clean the inspection and packing station to remove dust and plastic wrap.	Create work instructions to manage item placement, ensure no items block the transportation route, and clean the inspection and packing area.	Train operators to consistently apply 5S and use a checklist to ensure adherence to the 5S method.
Dies Rack	Move the WIP box	Add labels to	Clean oil spills	Ensure each die	Train operators to

Location	Sort	Set	Shine	Standardize	Sustain
	from the dies rack.	each die and organize them by usage frequency. For instance, the most used die, AAI-001, is placed in the top right corner for easy access.	around the shelves to prevent slipping, making it faster to retrieve dies.	has a label, arrange frequently used dies at the front of the rack, and keep the rack clean.	consistently apply 5S and use a checklist to ensure adherence to the 5S method.

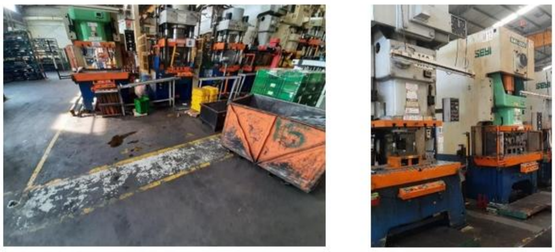
Implementing the 5S method in the production of calliper brackets will affect the total process time and production lead time. In addition, the implementation process can also affect the condition of each workstation. Figure 7 provides more details about the environmental conditions before and after the implementation of 5S at the workstation.

Before **After**

Figure 7a. Raw Material Storage

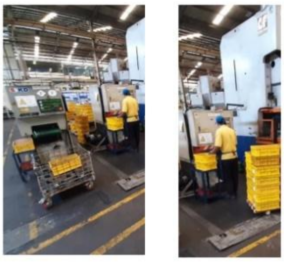
Before **After**

Figure 7b. Stamping



Before After

Figure 7c. Trimming



Before After

Figure 7d. Deburring

Before After

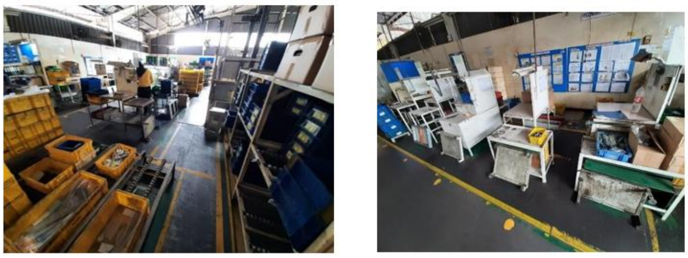
Figure 7e. Chamfering

Before After

Figure 7f. Tumbling

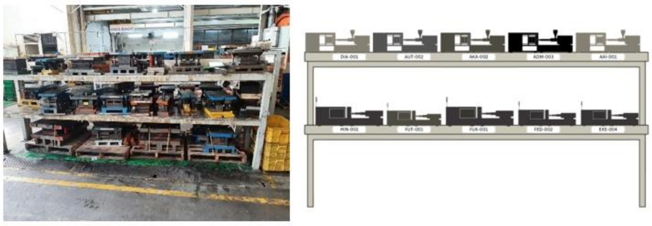
Before After

Figure 7g. Tapping



Before After

Figure 7h. Inspection & Packing



Before After

Figure 7i. Dies Rack

Figure 8 shows the addition of a hand lift machine for moving dies. It helps eliminate the need to wait for a forklift to transport dies between the rack and the stamping and trimming stations, thus reducing production lead time. Hand lift machines were chosen because there are few forklifts available, and they are heavily used in production. Hand lifts are much cheaper than forklifts, costing about IDR 45,000,000 each compared to IDR 250,000,000 for a forklift.

Figure 8. Proposed Hand Lift Machine

4.5 Implementation Result

Applying the 5S method and proposing new material handling equipment such as hand lift machines impacts production lead time and processing time. This section will discuss additional impacts, such as changes in production numbers and sales losses

Figure 9 shows that the future state value stream mapping has seen several changes; namely, the time used for each station has decreased due to the successful improvement process to make the calliper bracket production activities more efficient. VSM shows a reduction in production lead time from 8.05 days to 5.53 days, a time reduction of 31.30%. Changes also occurred in the processing time from 57.70 minutes to 25.03 minutes, reducing processing time by 56.62%. A significant reason for decreased production lead time is that it is influenced by reduced storage time for raw materials in warehouses and the delivery process. The time used for storage, previously 7 days, has become 5 days, while the delivery time has gone from 1 day to 0.5 days.

Figure 10 displays time spent in each activity category: VA, NNVA, and NVA. The graph features two bar graphs in blue and orange, where blue indicates time before improvement, and orange indicates time after. The VA category saw no change, remaining at 1032 seconds. However, NNVA time decreased from 1170 seconds to 270 seconds, a reduction of 76.9%. The NVA category also saw a notable decrease from 1240 seconds to 200 seconds, a reduction of 83.9%. This data suggests that the 5S method reduces waste and process time in calliper bracket production.

Figure 11 compares processing times in seconds before and after improvements at various production stages. In the stamping stage, time decreased from 1444 seconds to 474 seconds, a reduction of 67.2%. The trimming stage saw a 64.7% reduction, from 1461 seconds to 516 seconds. The deburring stage's time dropped by 13.3%, from 75 seconds to 65 seconds. In chamfering, time decreased by 2.8%, from 178 seconds to 173 seconds. Tumbling's time reduced by 8.6%, from 58 seconds to 53 seconds. Tapping saw a 2.7% decrease, from 182 seconds to 177 seconds. Finally, the inspection and packing stage showed a 31.3% reduction, from 64 seconds to 44 seconds. Overall, the most significant improvements were in the stamping and trimming stages, with over a 60% reduction in time, while other stages like deburring, chamfering, tumbling, and tapping also showed meaningful time reductions, enhancing overall production efficiency.

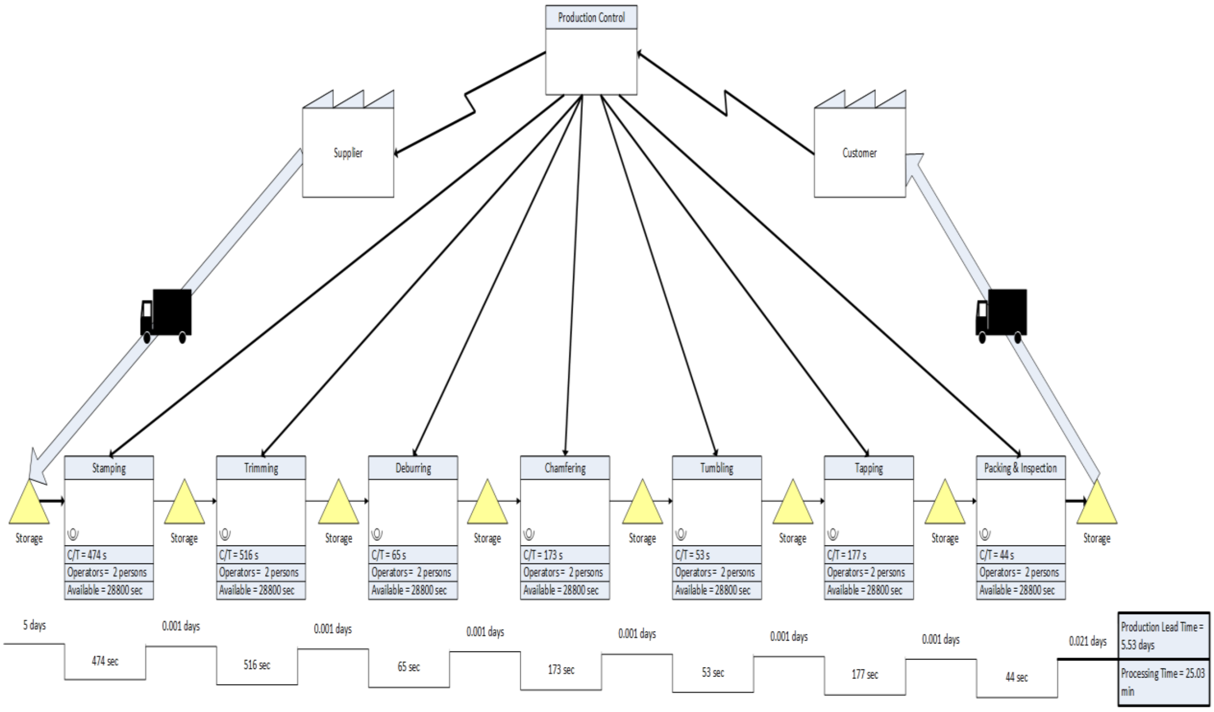


Figure 9. Future State Visual Stream Mapping

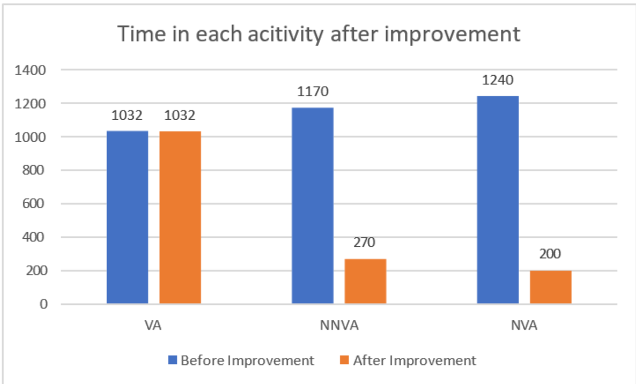


Figure 10. Time in each activity after improvement

Figure 12 compares sales loss data between conditions before and after improvement. The sales loss data used as a comparison in conditions before improvement is the average sales loss data for four months, namely from January to April, while the data used in conditions after improvement is sales loss data in May. The data for conditions before improvement shows a sales loss of IDR 1,579,787,500, while the sales loss in conditions after improvement is IDR 111,150,000. Sales loss decreased by IDR 1,468,637,500 or 92.96%.

The improvements had a positive effect on calliper bracket production. The 5S method was applied to reduce NNVA activities and eliminate NVA activities. This included reducing transportation waste and eliminating waiting time for forklifts. The 5S method improved material arrangement at workstations, ensuring a cleaner workspace and preventing blockages. It also led to updating work instructions to clean dies after use, which keeps the workstation and die rack free of oil spills.

Additionally, adding hand lift equipment helped eliminate waiting for forklifts. Since PT PPE's forklift fleet was insufficient, operators had to wait to use them. Hand lifts were introduced to allow operators to move materials and dies without delays.

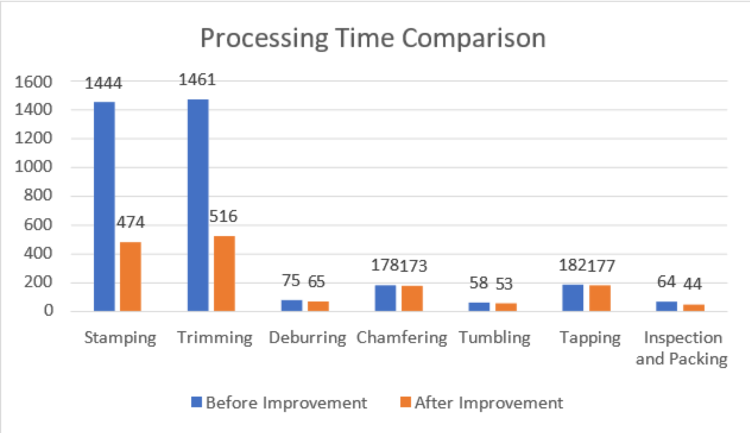


Figure 11. Processing Time Comparison

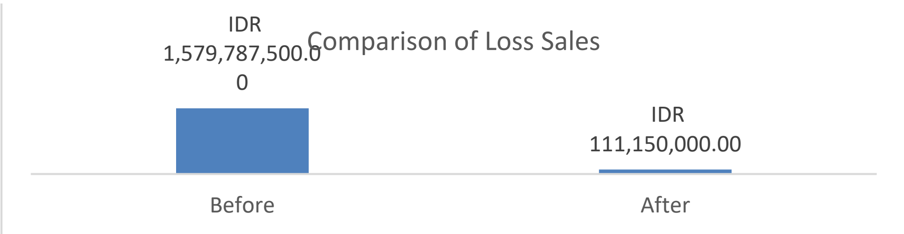


Figure 12. Comparison of Loss Sales Before and After Improvement

5. Conclusion

The conclusions are made based on the research objective, which answers the questions from the problem statement as follows:

1. Based on the problem identification process with VSM, PAM, spaghetti diagrams, and fishbone diagrams. It is known that the type of waste that occurs are waiting and transportation waste.
2. The way to reduce or eliminate waste in calliper bracket production is to use one of the lean manufacturing tools, namely 5S. Using 5S makes the environment of each workstation neat and clean to reduce search time, which is the cause of waiting, and reduces pick-up and transfer time, which is the cause of transportation. Also, hand lift machines were added to replace the role of forklifts, which are few but have a high intensity of use, thereby eliminating the activity of waiting for forklifts at stamping and trimming workstations. After making improvements to the calliper bracket production process, the cycle time has decreased from 57.70 minutes to 25.03 minutes or 56.62%, while the lead time has decreased from 8.05 days to 5.53 days or 31.30%. Sales losses can be reduced from IDR 1,936,100,000 to IDR 111,150,000 or 94.26%.

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