



## Waste Analysis in Connection Clamp Production Process with Lean Manufacturing and Failure Mode Effect Analysis

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### Abstract

UD H and M Electric is a manufacturing company engaged in the production of medium voltage overhead line (SUTM) components, one of its products is the Connection Clamp. The purpose of this study is to determine the level of waste that occurs and provide suggestions for improvements to reduce waste. The research data used is questionnaire data with respondents who meet the qualifications and know the entire flow of the Connection Clamp production process, as well as waste data that occurs during the production process. To determine the level of waste that occurs and provide suggestions for improvements, the Waste Assessment Model, Process Activity Mapping, Fishone Diagram, and Failure Mode and Effect Analysis methods are used. In the Waste Assessment Model method, the top three critical levels of waste were obtained, namely waste defect of 19.55%, waste motion of 16.88%, waste transportation of 16.10%. In the Failure Mode and Effect Analysis, the Risk Priority Number (RPN) value was obtained from the top three wastes with each sub-waste, namely waste motion sub-waste lifting products manually with a score of 280, waste motion sub-waste rearranging before the process with a score of 240, waste transport, namely the distance of the work station is less than optimal with a score of 200, waste reject sub-waste cracked plates with a score of 168, waste Defect, namely imperfect layers with a score of 168.

## Introduction

UD H and M Electric is a company engaged in manufacturing, especially in the production of medium voltage overhead line components (SUTM), one of its products is the connection clamp which functions as a hook for the mvtric cable to the wire rope so that the cable does not loosen easily when exposed to wind or heat. The process flow for making clamp connections at UD H And M Electric begins with the process of raw materials, cutting, bending, punching, pressing, packing, and finishing.

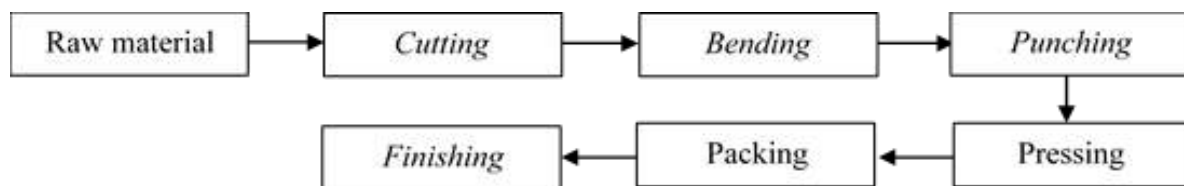


Figure 1. Connection Clamp Production Process Flow

In the connection clamp production process, the Value-Added (VA) value was 952.95 seconds, the Non-Value-Added-Activity (NNVA) was 5590.82 seconds, and the Non-Value-

Added (NVA) was 457.68 seconds. Waste still occurs on the production floor during the connection clamp production process. Among the most common wastes are waste defects due to cracked/broken plates during the bending process and imperfect coating; waste motion due to manual lifting and rearranging of the plates each time they are processed on the machine; waste transportation due to suboptimal workstation distances; waste waiting due to delays in finding material handling; waste inventory due to the accumulation of finished goods in the warehouse; waste overproduction due to excess production; and waste overprocessing due to rework.

Based on the problems encountered at UD H and M Electric, a structured analytical approach is required to identify and minimize this waste. Therefore, this study uses a combination of the Waste Assessment Model (WAM) and Failure Mode and Effect Analysis (FMEA) methods. The results obtained from previous research using the lean manufacturing method by (Firdaus and Wahyudin, 2023) states that the principle of lean manufacturing using the Value Stream Mapping (VSM) tool can reduce the duration of long production processes by reducing waste. Then, FMEA analysis was conducted to determine the highest RPN value against the influence of waste that occurs. Furthermore, research conducted by (Krisnanti & Garside, 2022) combined the WAM and FMEA methods. The WAM method can determine critical waste types, while the FMEA method results from brainstorming with company owners to determine the RPN value (Cardiel-Ortega & Baeza-Serrato, 2023; Gomaa, 2025; Baharun & Hasanah, 2023; Samimi, 2025). From several research results, the Waste Assessment Model method can measure waste levels to determine general waste improvements. Failure Mode and Effect Analysis (FMEA) focuses more on root causes and risks in detail. By combining these two methods, it can produce improvement proposals that can be clearly prioritized. In addition to these two combinations, this study also uses the systematic layout planning (SLP) method to provide optimal factory layout proposals (Mansur et al., 2021; Gao et al., 2023; Rodriguez & Oliveira, 2022). The combination of these three methods is expected to provide a comprehensive understanding of the state of the production process and the possibility of improvement, especially in the manufacturing sector, particularly in the manufacture of components for medium voltage overhead lines (SUTM)

### **Lean manufacturing**

Lean manufacturing is applied to increase production efficiency by identifying, analyzing, measuring, and providing solutions for continuous improvement to reduce waste that can be detrimental to the company (Hartanti et al., 2022). Lean manufacturing is a production philosophy that focuses on reducing the use of all available resources (including time) across all company activities (Kurnia, 2023). There are two approaches to implementing Lean Manufacturing. First, identifying every type of waste in the production process and eliminating waste that directly impacts the process. Second, accelerating the production flow to save time (Putro & Nursyamsiah, 2024; Taher & Bashar, 2024; Ciliberto et al., 2021; Rahardjo et al., 2021; Hemalatha et al., 2021).

### **Waste**

Waste encompasses all non-value-adding activities in the production process across the value stream (Pratiwi et al., 2020; Macedo et al., 2025; Dara et al., 2025; Dancer et al., 2024). Liker (2019) in (Sampeallo & Hasiara, 2024) states that by recognizing various types of waste, companies can design strategies to reduce or even eliminate them. This will help companies maximize resource utilization and increase customer value. According to Gasperz (2007) in (Suradi, 2022), generally identifies "seven types of waste" that arise in production systems: overproduction, waiting time, transportation, excessive storage, movement, inventory, and defective products.

## **Big Picture Mapping**

Big Picture Mapping is a tool used to visualize the entire system and value flow that occurs within a company. It maps processes at the highest level, encompassing broad processes but with a low level of detail (Nelfiyanti et al., 2023). In depicting Big Picture Mapping, the initial stage is to explain how physical flows and information flows occur. By depicting material flows, it is possible to understand how materials move during a project or production process. Meanwhile, information flows are depicted to understand how the production process takes place (Salsabila & Rochmoeljati, 2021). According to Androdion in Khunaifi (2022), to map material flows and information flows, there are five stages to implementing Big Picture Mapping. The first is: 1) Customer Requirements: Describes consumer need; 2) Information Flow: Describes the flow of information from consumers to suppliers; 3) Physical Flows: Describes the physical flow of the production process; 4) Linking Physical and Information Flows: Draws arrows to connect an information flow and a physical flow; 5) Complete Map: Complete the information flow and physical flow diagrams by adding the lead time and value-added time for all processes below the flowchart.

## **Value stream Analysis Tools (VALSAT)**

Value Stream Analysis Tools, also known as VALSAT is a tool developed by Hines and Rich to help understand current value streams and support improvements by focusing on existing waste. Some of the tools used in VALSAT are Process Activity Mapping, Supply Chain Response Matrix, and Quality Filter Mapping, as mentioned (Rahman et al., 2024; Suparno et al., 2021; Jatmiko & Safirin, 2025; Pical et al., 2025). This method is carried out to obtain the right tool in identifying potential waste in the project.

## **Process Activity Mapping (PAM)**

Process Activity Mapping gives a clear picture of how things move physically and how information flows, along with the time needed for each task, the distance traveled, and how much product is stored at each step of making things. It's easier to spot activities because they are grouped into five main categories: operation (O), transportation (T), inspection (I), delay (D), and storage (S). Activities are also sorted based on whether they add value (VA), are not valuable but still needed (NNVA), or don't add any value (NVA) (Maulana et al., 2023; Dancer et al., 2024). This method is commonly used to find out how much time is spent and where improvements can be made in the movement of products and information from the factory to the supply chain. The Process Activity Mapping process has five steps, namely (Syaproni, 2024): 1) Process flow; 2) Waste identification; 3) Process flow can be considered by rearranging it in a more efficient sequence; 4) Weighing more efficient flow patterns, involving layouts in different streams; 5) Everything considered is done at each stage, whether it is really necessary, and what would happen if wasteful activities were eliminated.

## **Waste Assessment Model (WAM)**

The Waste Assessment Model is a tool designed to simplify the identification of waste problems, enabling the recognition and elimination of waste. It highlights the relationships among seven types of waste: overproduction, waiting, transportation, excess processing, inventory, motion, and defects. The Waste Assessment Model (WAM) comprises the Waste Relationship Matrix (WRM) and the Waste Assessment Questionnaire (WAQ) (Afriandi & Saifuddin, 2023; Irawan & Fitriani, 2024; Hidayatullah & Widjajati, 2024). The data processing is divided into three stages: 1) Calculating the interrelationships between each type of waste was done using a questionnaire and a weighting system or score developed by Rawabdeh and Daonil (Naziihah et al., 2022). The interrelationships were determined through discussions with the company and the distribution of questionnaires using the weighting

criteria from Rawabdeh (2005) (Hidayati, 2021). The interrelationship scores between wastes were then converted into symbols: A = 17-20 (Absolutely Necessary), E = 13-16 (Especially Important), I = 9-12 (Important), O = 5-8 (Ordinary Closeness), and U = 1-4 (Unimportant). 2) After obtaining the weighted interrelationships between wastes in the table, the Waste Relationship Matrix (WRM) stage was continued by converting the total weights of the Seven Waste Relationships and using them as input into the Waste Relationship Matrix. This was then formatted into a Waste Relationship Matrix (WRM). The matrix between wastes, the symbol F indicates "From" and T means "To." To make the matrix easier to understand, a simplification was made by converting letters into numbers or percentages with the reference A = 10, E = 8, I = 6, O = 4, U = 2, and X = 0; 3) The waste weighting results from the Waste Relationship Matrix were used for the initial assessment stage of the Waste Assessment Questionnaire. The questionnaire consists of 68 questions, each with three answer choices weighted at 1, 0.5, or 0. These questions were classified into four categories: Man, Material, Machine, and Method.

### **Failure mode and Effect Analysis (FMEA)**

Failure Mode and Effect Analysis (FMEA) is a structured process used to find and prevent problems in production processes. FMEA helps analyze the causes of waste that should be prioritized for process improvement. Failure modes include design defects, conditions that go outside set specifications, or changes in the product that could affect its function. Overall, this study highlights the importance of identifying and managing waste in production processes to improve efficiency, reduce costs, and enhance product quality. The approaches and tools discussed provide a comprehensive framework to achieve these goals (Rahman et al., 2024). FMEA is a tool used in risk management. It helps identify potential failures in processes, products, or services. The most commonly used methods in risk management are qualitative and descriptive. FMEA is considered a semi-quantitative method. Many studies that use this technique prioritize risks based on the Risk Priority Number (RPN), which is calculated by multiplying three risk factors: Severity (S), Occurrence (O), and Detection (D) (Alriwanda et al., 2024).

### **Methods**

This research was conducted at UD H and M Electric located in Ngemplak Lor Hamlet, RT. 06/RW. 02, Kramat, Wonokasian, Wonoayu District, Sidoarjo Regency, East Java. The research was carried out in February 2025 and continued until sufficient data were obtained to support the analysis.

This study focuses on the Connection Clamp production process, which is one of the company's flagship products and has a high production volume. The purpose of this research is to identify and measure the level of waste occurring in the production process and to provide improvement recommendations aimed at reducing waste and increasing production efficiency.

Several analytical methods were employed in this study. The Waste Assessment Model (WAM) was used to assess and quantify the level of waste present in each production activity. Big Picture Mapping was applied to illustrate the overall production flow from raw materials to finished products, while Process Activity Mapping (PAM) was used to classify activities into value-added, non-value-added, and necessary but non-value-added activities. Furthermore, Failure Mode and Effects Analysis (FMEA) was utilized to identify potential failure modes and prioritize improvement actions based on the level of risk associated with each problem.

To solve a problem in a study, systematic steps are needed. The steps used to solve the problem in this study include the following:

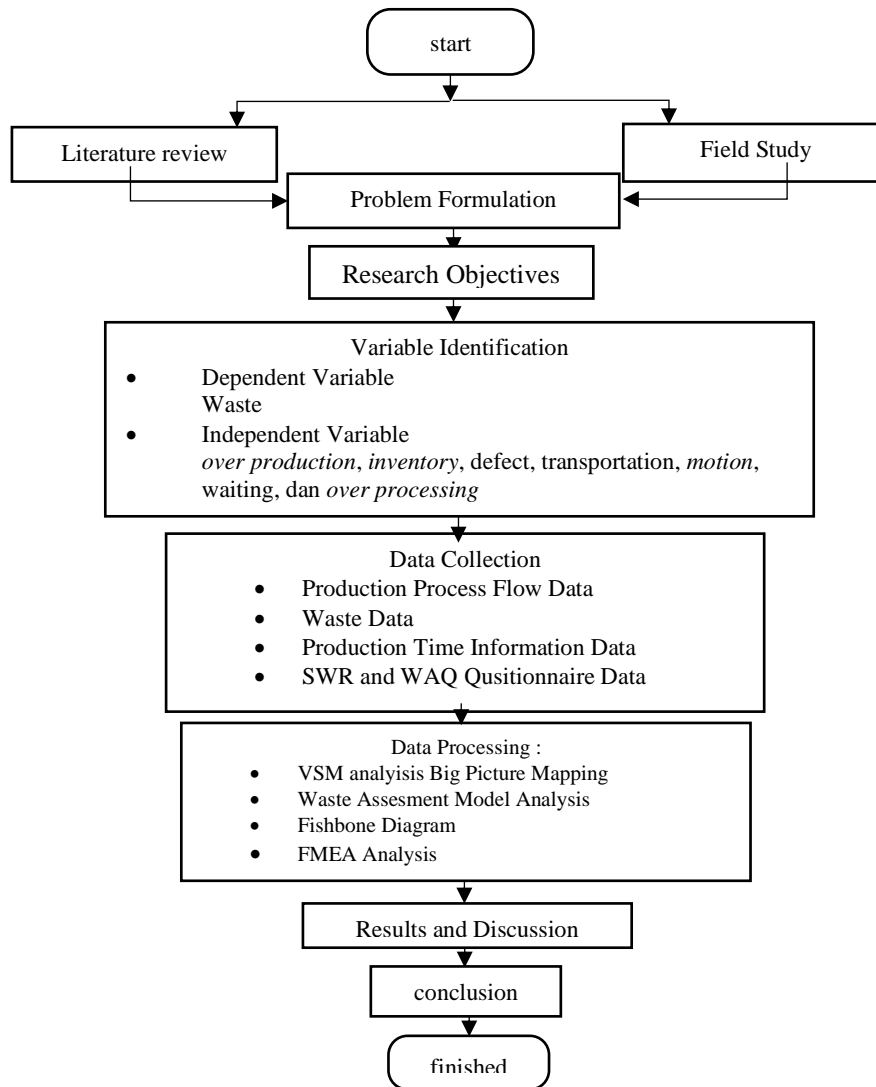


Figure 2. Research Steps

### Literature Study

A literature study is conducted to find literature or guidelines for problem solving. This study then provides knowledge to help understand the problem and support the methods used.

### Field Study

A field study involves direct and detailed on-site observations, reflecting the company's internal situation, to identify the problem. After identifying the field conditions, the research problem is formulated, focusing on the level of waste occurring in the connection clamp production process at UD H and M Electric, its root causes, and proposed improvements to minimize waste).

### Research Objective

The goal of this final project is to find and look into the waste and why it happens in the process of making connection clamps at UD H and M Electric. We will use the Waste Assessment Model and Failure Mode Effect Analysis to do this. The project also wants to suggest better ways to reduce the waste.

### Variable Identification

The dependent variable in this study is the level of waste in the Connection Clamp production process at UD H and M Electric. Waste reduction is defined as the reduction of non-value-

adding activities and the reduction of total process time on the production line. This variable is measured quantitatively using the following indicators: 1) Total production time in one production cycle in seconds; 2) Duration of VA, NVA, and NNVA activities based on Process Activity Mapping; 3) Percentage of non-value-adding activities eliminated; 4) Percentage of total time efficiency before and after improvements.

The independent variables include seven types of waste in the lean manufacturing concept, operationalized into measurable indicators based on direct observation in the production area, as shown in the table below.

### ***Defects***

This category includes waste because it can extend lead times and increase operational costs. The defects that occur in the company include cracked plates and imperfect plate coatings.

### ***Motion***

Motion includes operator movements that do not add value, manual lifting, and rearranging WIP products.

### ***Transportation***

Transportation refers to the duration and distance of material movement between workstations.

### ***Waiting***

Waiting is considered waste because it doesn't add value to the product. Wasteful waiting involves searching for a trolley when sending WIP products from the cutting to bending process.

### ***Inventory***

Excess inventory of finished products is considered waste because it reduces storage space and consumes capital. Durable products don't eliminate waste if the quantity exceeds actual needs.

### ***Overproduction***

This is considered waste and occurs when a company produces more products than needed. This waste occurs in labor, inventory, and transportation costs. Even if the goods are durable and don't deteriorate during storage, in the Lean Manufacturing concept, they are considered waste because they increase storage costs and hold up working capital.

### ***Overprocessing***

This activity is considered waste due to excessive processing in producing a product. One reason for this inefficient process is defects, which require reprocessing.

These indicators serve as a reference in filling out the Waste Assessment Questionnaire, weighting the Waste Relationship Matrix, and determining Severity, Occurrence, and Detection in the Failure Mode and Effect Analysis.

### **Data Collection**

At this stage, the researcher collects data and information needed by the company to solve the problem. The data collection phase was conducted through direct observation and interviews. The data required for this study include production process flow data, waste data, production time information, and SWR and WAQ questionnaire data.

## Data Processing

At this stage, research results are obtained, which are then discussed using theoretical foundations related to the research method, along with suggestions for improvement.

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From the data processing, conclusions will be drawn from the study, which will determine the critical level of waste in the connection clamp production process at UD H and M Electric and the root causes of this waste. These alternative improvements will also be identified for developing the connection clamp production process at UD H and M Electric

## Results and Discussion

### Data Collection

The collected data relates to the Connection Clamp production process at UD H and M Electric. The collected data includes a general overview of the company, the connection clamp products used as research objects, the connection clamp production layout, the sequence of the connection clamp production process from raw materials to storage, observation data from the production process used to create a big picture mapping, and respondents' answers to questions from the waste assessment model (WAM) questionnaire.

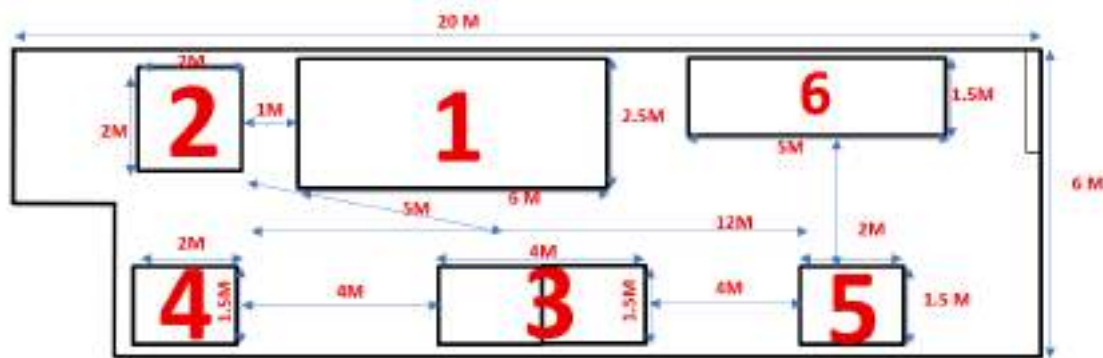


Figure 3. Production Layout

A production layout is the arrangement of factory facilities to simplify and expedite the production process, ensuring effectiveness and efficiency. UD H and M Electric's production layout consists of several work stations, including: 1) Raw Materials Storage; 2) Cutting Process; 3) Bending Process; 4) Punching Process; 5) Pressing Process; 6) Packaging.

Table 1. Connection Clamp Production Process Data Information

Part of	Work Station	Activity	Time (seconds)	Type of activity					Category VA/ NVA/ NNVA
				O	T	I	S	D	
Plat	Raw Material Warehouse	Arrival of raw materials	1778.00						NNVA
Body Clamp	Cutting	initial machine settings	487.50						NNVA
		plate retrieval	3.69					NNVA	
		cutting process	1.39					VA	
		Looking for a Trolley	60.67					NVA	
		arranging plates	1.56					NNVA	
	Bending	initial machine settings	494.27					NNVA	

		plate retrieval	10.86						NNVA	
		arranging plates	2.54						NNVA	
		benchmarking	2.30						VA	
		arranging plates	2.33						NNVA	
	Punching	initial machine settings	490.61						NNVA	
		plate retrieval	8.51						NNVA	
		arranging plates on the machine table	2.37						NVA	
		Punching	2.68						VA	
		arranging plates	2.47						NNVA	
	Pressing	initial machine settings	276.93						NNVA	
		plate retrieval	19.75						NNVA	
		arranging plates	2.76						NVA	
		Pressing	2.89						VA	
		arranging plates	2.29						NNVA	
		send to packing process	7.43						NNVA	
Pengait Pengunci	Cutting	initial machine settings	485.93						NNVA	
		plate retrieval	3.75						NNVA	
		Cutting	1.05						VA	
		Looking for a Trolley	55.49						NVA	
		arranging plates	1.53						NNVA	
	Bending	initial machine settings	486.92						NNVA	
		plat taking	11.46						NNVA	
		arranging plates on the machine table	1.34						NVA	
		bending process	2.75						VA	
		arranging plates	2.01						NNVA	
	Punching	initial machine settings	319.49						NNVA	
		plate retrieval	8.58						NNVA	
		menyusun plat pada meja mesin	2.11						NVA	
		punching process	3.04						VA	
		arranging plates	2.21						NNVA	
		Sending goods to the packing process	8.69						NNVA	
	Body Clamp dan Pengait Pengunci	Packing	assembling plates	182.14						VA
			Sending products to the warehouse	300.00						NNVA
Finishing		Inspeksi	181.21						NNVA	
		Rework	330						NVA	
		assembly	22.84						VA	
		Packing	732						VA	
Transporting sacks to storage		9.59						NNVA		
Storage	Storage	183.22						NNVA		

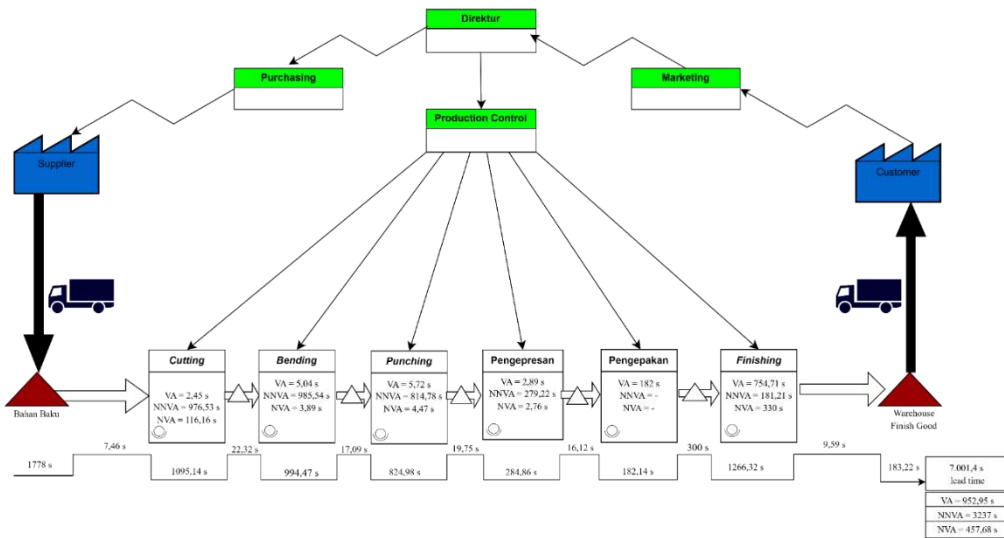


Figure 4. Initial Big Picture Mapping

The time calculation is as follows:

Total production time (lead time)

= 7,001 seconds = 116 minutes 41 seconds

Based on Figure 4.11, the big picture mapping shows the total production time or lead time for the connection clamp production is 7,001 seconds, or 116 minutes 41 seconds, and the value-added time is 953 seconds, or 15 minutes 47 seconds.

Table 2. Process Recapitulation

PAM Tools Recapitulation			
Work	Amount	Time (Seconds)	Percentage
Operation	31	6129,67	87.5%
Transportation	11	392,32	5.7%
Delay	2	116,16	1.7%
Storage	1	181,21	2.6%
Inspection	1	183,22	2.6%
Total	46	7001,4	100.0%

Based on the table, the recapitulation of PAM tools is obtained, classified based on the type of work, namely Operation with 31 jobs with a time of 6,129.67 seconds, Transportation with 11 jobs with a time of 392.32 seconds, Delay with 2 jobs with a time of 116.16 seconds, Storage with 1 job with a time of 181.21 seconds, and Inspection with 1 job with a time of 183.22 seconds.

Table 3. Activity Classification

No	Activity	Frequency	Percentage	Time (seconds)	Percentage
1	Value Added Activity	10	22%	953,95	14%
2	Non Value Added Activity	8	17%	458,68	7%
3	Necessary but Non Value Added Activity	28	61%	5591,82	80%
	Total	46	100%	7001,45	100%

The table above shows that the total time needed to make the Connection Clamp is 7001.45 seconds, and there are 46 steps in the process. Out of these, 10 steps add value (14%), 8 steps don't add value but are still needed (7%), and 28 steps don't add value but are necessary (80%). These findings show that some non-value-added activities should be removed, and others that are necessary but don't add value should be cut down..

Although the results of the Process Activity Mapping show that operational activities dominate production time, accounting for 87.5% of the total cycle, this does not necessarily indicate high process efficiency. From a lean manufacturing perspective, not all operational activities directly support the creation of added value for customers. Observation findings indicate that some activities categorized as operational include support activities such as setting up machines, adjusting process parameters, and reorganizing materials before processing, which, from a conceptual perspective, are considered non-value-added activities, or essential but not value-added activities.

This finding is reinforced by the classification of activities based on value-added, which shows that only 14% of total production time is value-added (VA) activities, while the majority of time is dominated by essential but non-value-added (NNVA) activities (80% and non-value-added (NVA) activities (around 7%). Thus, the dominance of operational time reflects structural inefficiencies in the production process, not simply a sign of high productivity.

### Data Processing

In the calculation using the waste assessment model method, each respondent's answer is recorded and a correlation score is calculated for each question. The next step is to design a Waste Relationship Matrix Value. The correlation score between wastes can be converted into letter symbols as follows:

A (Absolute) (Score range 17-20) = Very strong relationship

E (Essential) (Score range 13-16) = Important relationship

I (Important) (Score range 9-12) = Moderately important relationship

O (Occasional) (Score range 5-8) = So-so relationship

U (Unnecessary) (Score range 1-4) = Unimportant

These are then mapped to the rows and columns of the Waste Relationship Matrix Value, as shown below:

Table 4. WRM Questionnaire Results

F/T	O	I	D	M	T	P	W
O	A	O	I	I	E	X	O
I	O	A	I	I	E	X	X
D	I	O	A	E	A	X	I
M	X	U	O	A	X	E	A
T	U	E	O	I	A	X	A
P	U	U	I	I	X	A	I
W	O	O	U	X	X	X	A

After converting the letters in the waste relationship matrix value, the next step is to convert these values by translating the letter symbols in the waste relationship matrix into numerical weights based on the previously established provisions mentioned in point four. The resulting numerical conversion will then be used to calculate the waste weighting. The conversion of the letter symbols in the Waste Matrix Value into numerical weights is presented as follows:

Table 5. Results of Waste Relationship Matrix Value Conversion

F/T	O	I	D	M	T	P	W	Score	%
O	10	4	6	6	8	0	4	38	15.70
I	4	10	6	6	8	0	0	34	14.05
D	6	4	10	8	10	0	6	44	18.18
M	0	2	4	10	0	8	10	34	14.05
T	2	8	4	6	10	0	10	40	16.53
P	2	2	6	6	0	10	6	32	13.22
W	4	4	2	0	0	0	10	20	8.26
Score	28	34	38	42	36	18	46	242	100
%	11.57	14.05	15.70	17.36	14.88	7.44	19.01	100	

Based on the table above, the Form Defect (D) row has the highest score and percentage, at 18.18%. This indicates that if a defect occurs, it will significantly impact the emergence of other waste. Meanwhile, in the matrix column, To Waiting (W) has the highest score and percentage, at 19.01%. This indicates that To Waiting waste is the most influenced by other waste.

Based on the Waste Assessment Questionnaire (WAQ) algorithm. The Waste Assessment Questionnaire (WAQ) is a questionnaire-based assessment instrument used to identify and allocate the types of waste that occur in the production line. This questionnaire consists of 68 varied questions, where respondents are asked to check (✓) one of three answer options: Yes, Moderate, or No, according to the condition that best describes the situation.

Table 6. WAQ Question Grouping

No	Question Type	Number of Questions
1	From Overproduction	3
2	From Inventory	6
3	From Defect	8
4	From Motion	11
5	From Transportation	4
6	From Process	7
7	From Waiting	8
8	To Defect	4
9	To Motion	9
10	To Transportation	3
11	To Waiting	5
	Total	68

From the calculations using the WAQ method, the following results were obtained.:

Table 7. Final results of the Waste Assessment Questionnaire calculation

	O	I	D	M	T	P	W
Score (Yj)	0.31	0.29208	0.29478	0.29809	0.28196	0.30883	0.3863
Score (Pj)	0.018	0.020	0.029	0.024	0.025	0.010	0.016
Final Result (Yj Final)	0.00556	0.00577	0.00842	0.00727	0.00693	0.00304	0.00607
Final Result (%)	12.92	13.39	19.55	16.88	16.10	7.06	14.10
Ranking	6	5	1	2	3	7	4

Based on the summary of the WAQ calculation results shown in the table above, we know the order of waste types in the Connection Clamp production process at UD H and M Electric, from highest to lowest, is as follows: Defect is ranked first with a final value of 0.00842 or 19.55%, followed by motion of 0.00727 (16.88%), transportation of 0.00693 (16.10%), waiting of 0.00607 (14.10%) inventory of 0.00577 (13.39%), overproduction of 0.00556 (12.92%), overprocessing of 0.00304 (7.06%). This shows that Defect, Motion, and Transportation are the top three types of waste, with Defect being the biggest issue in the production process. The next step in improving the Connection Clamp production process will involve the problems identified from the cause-and-effect diagram (fishbone diagram) and will be covered in the Failure Mode and Effect Analysis (FMEA) study. From observations of Severity, Occurrence, and Detection, we will gather data to calculate the Risk Priority Number. This number helps us decide which waste type should be fixed first and suggests improvements for the most significant waste issues. Below are the results of the FMEA calculations.

Table 8. Calculation of Risk Priority Number (RPN)

Failure mode (waste)	Potential Failure	Cause of Failure	Effect of Failure	Severity	Occurance	Detection	RPN
Defect	Cracked plate	material is too brittle, bending machine pressure is unstable and there is no lubrication	rejected product / cannot be used	7	6	4	168
	Imperfect layers	there is rust or dirt during coating	corrosion potential	6	5	4	120
Motion	lifting products manually	Limited material handling	Risk of injury to workers and operators experiencing fatigue	7	10	4	280
	Rearrange before process	Products arrive in random condition and there is no SOP for WIP placement	Lead time will be longer	6	10	4	240
Transportation	Work station distance is less than optimal	factory layout does not place the machine sequence according to the process flow.	lead times increase and distances between work stations become longer.	5	10	4	200

Priority improvements and proposed improvements can be seen in the table below:

Table 9. Recommendations for Improvement

Waste	Subwaste	RPN	Prioritas	Recommendations for Improvement
Motion	lifting products manually	280	1	provide material handling that meets the needs of the production process flowi
Motion	Rearrange before process	240	2	provide a container for laying the plates and create an SOP for laying them
Transportation	Work station distance is less than optimal	200	3	Redesign the layout according to the production process flow
Defect	Cracked plate	168	4	Select quality materials, control bending machine pressure, and apply lubrication before bending..
Defect	Lapisan tidak sempurna	120	5	place WIP properly

Based on identification using FMEA, there are problems in the transportation sector due to less than optimal production layout. After conducting research using the systematic layout planning (SLP) method by analyzing using the Activity Relationship Chart (ARC) and Activity Relationship Diagram (ARD), the suggestions that researchers can provide as a solution to minimize transportation time are as follows.:

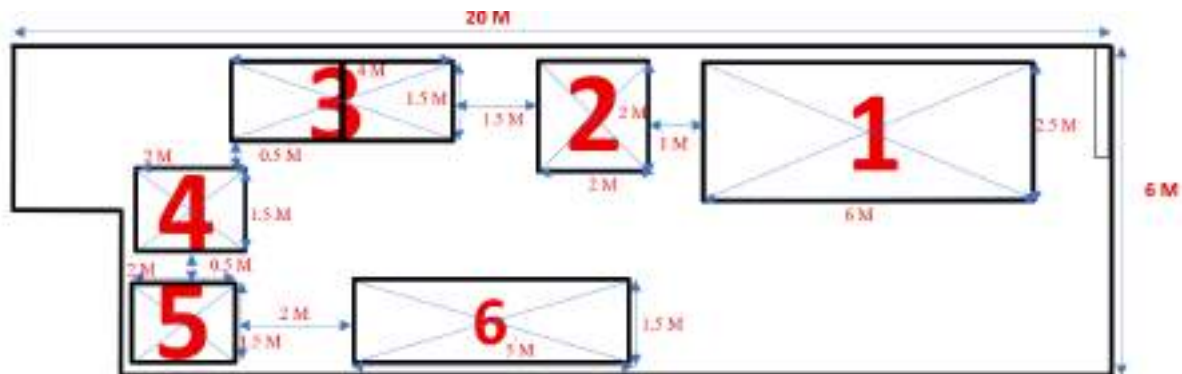


Figure 5. Proposed Layout of UD H and M Electric Connection Clamp Production

After obtaining the calculation of the time after repair, the next stage is to compare the initial time with the time after repair as follows.:

Table 10. Comparison of Time Before and After Repair

No	Activity	Frequency Before Repair	Time Before Repair	Frequency After Repair	Time After Repair
1	Value Added Activity	10	953,95	10	952,95

No	Activity	Frequency Before Repair	Time Before Repair	Frequency After Repair	Time After Repair
2	Non Value Added Activity	8	458,68	0	0
3	Necessary but Non Value Added Activity	28	5591,82	28	5547,37
	Total	46	7001,45	38	6500,30

Based on the table above, it can be seen that the total frequency before the repair was 46 activities, after the repair, the frequency was reduced to 38 activities. The total time required before the repair was 7001.45 seconds, and after the repair, the time required was 6500.30 seconds.

Table 11. Percentage Efficiency After Repair

No	Activity	Time Before Repair	Time After Repair	Percentage of Improvement (%)
1	Value Added Activity	953,95	952,95	0%
2	Non Value Added Activity	458,68	0	100%
3	Necessary but Non Value Added Activity	5591,82	5547,37	1%
	Total	7001,45	6500,30	7%

Based on the table above, it can be seen that Value-Added Activities have an improvement percentage of 0%, Non-Value-Added Activities have an improvement percentage of 100%, Necessary but Non-Value-Added Activities have an improvement percentage of 1%, and the total improvement time has a percentage of 7%. Although the efficiency increase achieved is only 7%, this result is still considered significant in the context of the manufacturing industry. This is because a 7% reduction per cycle will have a significant cumulative impact on daily and monthly production capacity. Therefore, the big picture mapping proposed from this research is as follows.

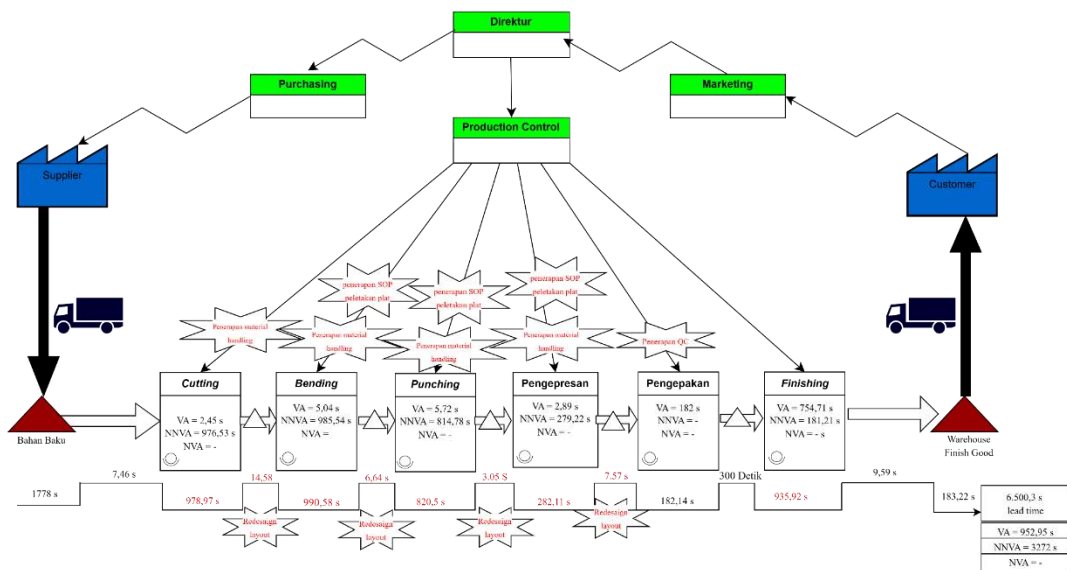


Figure 6. Big Picture Mapping Improvement

## Conclusion

The level of waste in the connection clamp production process at UD H and M Electric from the results of the Waste Assessment Model obtained the top 3 levels of waste, namely waste Defect of 91.55%, Waste motion of 16.88%, waste transportation of 16.10%. Recommendations for improvement given In the waste motion subwaste, lifting the product manually with an RPN score of 280 with recommendations for improvement, namely providing material handling that is in accordance with the needs of the production process flow. In the waste motion subwaste, rearranging before the process with an RPN score of 240 with recommendations for improvement providing a container for placing plates and creating SOPs for placement. In waste transportation, namely the distance of work stations is less than optimal with an RPN score of 200 with recommendations for improvement redesigning the layout according to the production process flow so that production is shorter. In the waste defects subwaste, the plate is cracked with an RPN score of 168 with recommendations for improvement in selecting quality materials, controlling bending machine pressure, and applying lubrication before bending. In the waste defect, namely an imperfect layer with an RPN score of 120 with recommendations for improvement placing WIP properly to avoid dirt and conducting quality control before the plating process. So that the production process time of the Connection Clamp was obtained which was initially 7001.4 seconds to 6500.3 seconds. Suggestions for further research include adding the Fuzzy-FMEA method to reduce subjectivity and increase the accuracy of the results.

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## References

- Afriandi, F., & Saifuddin, J. A. (2023). Penerapan Lean Manufacturing Menggunakan Metode Waste Assessment Model (WAM) Untuk Mengurangi Waste Pada Lini Produksi Steel Structure. *Jurnal Teknik Mesin, Industri, Elektro dan Informatika*, 2(4), 62-75. <https://doi.org/10.55606/jtmei.v2i4.2930>
- Aliwanda, Saputra, E., & Ahsyar, T. K. (2024). Analisa Manajemen Resiko Keamanan Sistem Informasi Baznas Kampar dengan Metode Failure Mode And Effect Analysis ( FMEA ). *Jurnal Penerapan Sistem Informasi (Komputer & Manajemen)*, 5(3), 1225–1232.
- Baharun, H., & Hasanah, R. (2023). Quality Improvement in Increasing Public Trust Using the Failure Mode and Effect Analysis (FMEA) Method. *Tarbawi: Jurnal Keilmuan Manajemen Pendidikan*, 9(01), 59-68. <https://doi.org/10.32678/tarbawi.v9i01.7982>
- Cardiel-Ortega, J. J., & Baeza-Serrato, R. (2023). Failure mode and effect analysis with a Fuzzy Logic approach. *Systems*, 11(7), 348.
- Ciliberto, C., Szopik-Decpczyńska, K., Tarczyńska-Luniewska, M., Ruggieri, A., & Ioppolo, G. (2021). Enabling the Circular Economy transition: A sustainable lean manufacturing recipe for Industry 4.0. *Business Strategy and the Environment*, 30(7), 3255-3272. <https://doi.org/10.1002/bse.2801>
- Dancer, W. T., Chopra, H., & Duong, A. (2024). The Value of Non-Value Activities. *Journal of Accounting & Finance* (2158-3625), 24(5). <https://doi.org/10.33423/jaf.v24i5.7364>

- Dara, H. M., Adamu, M., Ingle, P. V., Raut, A., & Ibrahim, Y. E. (2025). An MCDM Approach to Lean Tool Implementation for Minimizing Non-Value-Added Activities in the Precast Industry. *Infrastructures*, 10(3), 55. <https://doi.org/10.3390/infrastructures10030055>
- Firdaus, R. Z., Wahyudin, W., & Zani, R. (2023). Penerapan Konsep Lean Manufacturing untuk Meminimasi Waste pada PT Anugerah Damai Mandiri (ADM) Applying Lean Manufacturing Concepts to Minimize Waste in PT Anugerah Damai Mandiri (ADM). *Journal of Integrated System (JIS)*, 6(1), 21–31. <https://doi.org/10.28932/jis.v6i1.5632>
- Gao, G., Feng, Y., Zhang, Z., Wang, S., & Yang, Z. (2023). Integrating SLP with simulation to design and evaluate facility layout for industrial head lettuce production. *Annals of operations research*, 321(1), 209-240. <https://doi.org/10.1007/s10479-022-04893-z>
- Gomaa, A. H. (2025). Enhancing Failure Mode and Effects Analysis with Industry 4.0 (FMEA 4.0): A Comprehensive Review and Strategic Framework. *International Journal of Darshan Institute of Engineering Research and Emerging Technologies*, 14(2), 1-12. <https://doi.org/10.32692/IJDI-ERET/14.2.2025.2501>
- Hartanti, L. P. S., Mulyono, J., & Mayang, V. (2022). Penerapan Fmea Dan Fuzzy Fmea Dalam Penilaian Risiko Lean Waste Di Industri Manufaktur. *JST (Jurnal Sains Dan Teknologi)*, 11(2), 293–304. <https://doi.org/10.23887/jstundiksha.v11i2.50552>
- Hemalatha, C., Sankaranarayanan, K., & Durairaj, N. (2021). Lean and agile manufacturing for work-in-process (WIP) control. *Materials Today: Proceedings*, 46, 10334-10338. <https://doi.org/10.1016/j.matpr.2020.12.473>
- Hidayati, A. N. N., & Nurhidayat, A. E. (2021). Analisis Penyebab Kecacatan Produksi Permen Yupi Dengan FTA, Fuzzy-FMEA dan WAM. *J. Optimasi Tek. Ind*, 3(02), 70-75.
- Hidayatullah, M. A., & Widjajati, E. P. (2024). Lean Manufacturing Analysis Using Waste Assessment Model (WAM) and Root Cause Analysis (RCA) Methods. *Rekayasa*, 17(2), 240-249. <https://doi.org/10.21107/rekayasa.v17i2.25657>
- Irawan, Y. B., & Fitriani, K. (2024). Waste Assessment Model (WAM): How Does the Company Assess the Waste?. *Jurnal Sains & Teknologi Lingkungan*, 16(2), 54-68. <https://doi.org/10.20885/jstl.vol16.iss2.art4>
- Jatmiko, L. V. P., & Safirin, M. T. (2025). Waste Reduction in the Sickle Production Process Using the VALSAT Method and Value Stream Mapping. *Golden Ratio of Data in Summary*, 5(2), 08-15. <https://doi.org/10.52970/grdis.v5i2.936>
- Khunaifi, A., Rangga Primadasa, & Sugoro Bhakti Sutono. (2022). Implementasi Lean Manufacturing untuk Meminimasi Pemborosan (Waste) Menggunakan Metode Value Stream Mapping di PT. Pura Barutama. *Jurnal Rekayasa Industri (JRI)*, 4(2), 87–93. <https://doi.org/10.37631/jri.v4i2.560>
- Kurnia, I. (2023). Basic Lean Manufacturing, 2023. In *Bahan Ajar Basic Lean Manufacturing, 2023*. [https://repository.unkris.ac.id/id/eprint/536/1/Bahan\\_Ajar\\_Lean\\_Manufacturing.pdf](https://repository.unkris.ac.id/id/eprint/536/1/Bahan_Ajar_Lean_Manufacturing.pdf)
- Macedo, H., Tomaz, L., Guimarães, L., Cerqueira-Pinto, L., Sá, J. C., & Dinis-Carvalho, J. (2025). Development of a Classification Model for Value-Added and Non-Value-Added Operations in Retail Logistics: Insights from a Supermarket Case Study. *Sustainability*, 17(7), 3177. <https://doi.org/10.3390/su17073177>

- Mansur, M., Ahmarofi, A. A., & Gui, A. (2021). Designing the re-layout of the production floor using integrated systematic layout planning (SLP) and simulation methods. *International Journal of Industrial Management*, *10*, 151-159. <https://doi.org/10.15282/ijim.10.1.2021.6058>
- Maulana, M., Suhendar, E., & Prasasty, A. T. (2023). Penerapan Lean Management Untuk Meminimasi Waste Pada Lini Produksi CV. Mandiri Jaya Dengan Metode WAM Dan VALSAT. *Jurnal Optimasi Teknik Industri (JOTI)*, *5*(1), 1. <https://doi.org/10.30998/joti.v5i1.13747>
- Naziihah, A., Arifin, J., & Nugraha, B. (2022). Identifikasi Waste Menggunakan Waste Assessment Model (WAM) di Warehouse Raw Material PT. XYZ. *Jurnal Media Teknik Dan Sistem Industri*, *6*(1), 30–40. <https://doi.org/10.35194/jmtsi.v6i1.1599>
- Nelfiyanti, N., Saputra, D., & Puteri, R. A. M. (2023). Penerapan Value Stream Mapping Tools dalam Meminimasi Pemborosan Proses Packing Part Disc di line Servis. *JISI: Jurnal Integrasi Sistem Industri*, *10*(1), 9–18. <https://doi.org/10.24853/jisi.10.1.9-18>
- Pical, A. J., Irawati, D. Y., & Andrian, D. (2025). Lean Manufacturing Analysis: Using WAM and VALSAT to Reduce Waste in the Plastic Sack Finishing Process at PT Surya Plastindo. *Engineering Headway*, *18*, 153-162. <https://doi.org/10.4028/p-nKM8rh>
- Pratiwi, Y., Djanggu, N. H., & Anggela, P. (2020). Penerapan Lean Manufacturing Untuk Meminimasi Pemborosan (Waste) Dengan Menggunakan Metode Value Stream Mapping (Vsm) Pada Pt. X. *Jurnal Teknik Industri Universitas Tanjungpura*, *4*(2), 8–15. <https://jurnal.untan.ac.id/index.php/jtinUNTAN/article/view/42196>
- Putro, A. M. S., & Nursyamsiah, S. (2024). Analisis Implementasi Lean Manufacturing Dengan Metode 5s Pada Startup Manufaktur Di Indonesia. *8*(3), 1800–1817.
- Rahardjo, B., Wang, F. K., Yeh, R. H., & Chen, Y. P. (2023). Lean manufacturing in industry 4.0: a smart and sustainable manufacturing system. *Machines*, *11*(1), 72.
- Rahman, A. D., Marlyana, N., & Mas'idah, E. (2024). Penerapan Lean Manufacturing Untuk Meningkatkan Efisiensi Pada Proses Produksi Garmen Pt.Xyz. *Jurnal Ilmiah Sultan Agung*, 591–609.
- Rodriguez, A. R. S. C., & Oliveira, P. V. D. (2022). An extension of systematic layout planning by using fuzzy AHP and fuzzy VIKOR methods: a case study. *European Journal of Industrial Engineering*, *16*(1), 1-30. <https://doi.org/10.1504/EJIE.2022.119368>
- Salsabila, I. R., & Rochmoeljati, R. (2021). Analisis Penerapan Konsep Lean Manufacturing Pada Proses Produksi Stainless Steel Coil Untuk Mereduksi Pemborosan (Waste) Di Pt. Xyz. *Juminten : Jurnal Manajemen Industri Dan Teknologi*, *2*(2), 120–131. <https://doi.org/10.33005/juminten.v2i2.235>
- Samimi, A. (2025). Application of failure mode and effects analysis (FMEA) for risk management in hospital laboratories. *Medicinal, Psychological, and Health Research Journal (mphrj)*, *1*(5), 160-168. <https://doi.org/10.22034/mphrj.2025.532521.1021>
- Sampeallo, Y. G., & Hasiara, L. O. (2024). *Manajemen Produksi*. PT Media Penerbit Indonesia.
- Suparno, A., Kholil, M., & Hasan, S. B. H. (2021). Implementation of lean manufacturing and waste minimization to overcome delay in metering regulating system fabrication process using value stream mapping and VALSAT method approach (Case Study:

- Company YS). *International Journal of Advanced Technology in Mechanical, Mechatronics and Materials*, 2(1), 22-34. <https://doi.org/10.37869/ijatec.v2i1.41>
- Suradi. (2022). Sistem Produksi. In Marhamah (Ed.), *Cetakan Pertama, Yogyakarta; Graha Ilmu*, (Vol. 1, Issue January 2022). CV. Tohar Media.
- Syaproni, M. F., Suhendar, E., & Hartini, S. (2024). Analisis Penerapan Lean Warehouse Untuk Meminimasi Waste Pada Gudang PT. Artaprima Cipta Caturindo Dengan Metode Value Stream Mapping (VSM) dan Waste Assesment Model (WAM). *Jurnal Pemasaran Bisnis*, 6(4). <https://doi.org/10.55826/jtmit.v4i4.938>
- Taher, M. A., & Bashar, M. A. (2024). The impact of lean manufacturing concepts on industrial processes' efficiency and waste reduction. *International Journal of Progressive Research in Engineering Management and Science*, 4(6), 338-349.