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| RESEARCH ARTICLE

Application of Lean Manufacturing in Aluminum Cable Ladder Manufacturing Companies: Case Study at PT. Indra Saputra Triassic

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| ABSTRACT
After the Covid-19 pandemic, the manufacturing industry was faced with the challenge of continuing to create the highest quality products at the lowest possible cost and in the shortest possible time. PT also experiences this. Trias Indra Saputra is a manufacturer of Aluminum Cable Ladder located in Kabupaten Tangerang, Indonesia. Lean manufacturing is one method that can be used to identify and reduce waste in the production process. The existence of waste in the production process can lead to increased cost and processing time for a product. Value Stream Mapping (VSM), as an approach in Lean Manufacturing, can be used to find problems in the flow of products and information. Identification of waste begins with describing the current state of VSM and then analyzing the waste into 7 categories. After obtaining the waste category, continue conducting a Root Cause Analysis before designing and taking action to improve the process. By implementing Lean manufacturing PT. Trias Indra Saputra can reduce production time by 52%, Man Power by 70%, and production cost by 34% with the same quality even better than before.

| KEYWORDS

Lean Manufacturing, Value Stream Mapping, 7 waste, Root Couse Analysis

| ARTICLE INFORMATION

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1. Introduction

PT. Trias Indra Saputra is a company that manufactures Aluminum Cable Ladder as a support for cables in various electrical projects in Indonesia. This company is located in Tangerang Regency, Indonesia, and runs its business using the project-based business model method, namely carrying out the production process based on the order needed for a project won. After going through the Covid-19 pandemic, manufacturing-based and project-based industries face increasing challenges in line with economic pressures and increasingly competitive market competition. To be competitive, companies must create the highest quality products at the lowest possible cost and in the shortest possible time.

To adapt to competitive conditions in the market, PT. Trias Indra Saputra seeks to evaluate the production process to reduce production costs and time. The company has never analyzed costs and production time in the aluminium cable ladder manufacturing process. Companies are looking for the right analytical methods to reduce costs and production time. By reducing costs and production time, the company hopes to compete in obtaining projects without sacrificing customer satisfaction, quality, delivery time, and profits.

Lean manufacturing is a corporate strategy to eliminate waste which can increase production costs and time, thereby increasing the value of a product or service (Elbert, 2018). In addition to reducing waste in processes, lean manufacturing practices and principles aim to satisfy customers and improve operational performance (Tortorella et al., 2017). There are two categories in the poor manufacturing method, namely identifying all waste in the production process and eliminating the most significant and direct impact waste. The second method focuses on making the production process more streamlined to reduce costs and production processes (Deshkar et al., 2017). This paper will use the two ways above to get the optimal price and production process.

1.1 Theoretical Basis

Lean manufacturing is an optimal method for producing goods by eliminating waste or waste (Wilson, 2010). Lean manufacturing is an approach that can be used to improve the waste that occurs in companies so that production time can be reduced. 5 Lean principles must be considered, namely specify the value, identify value stream, flow, pulled, and perfection (Hines and Taylor, 2000). Value Stream Mapping, or VSM, is a method of mapping production flows. Information flows to produce one product or one product family, not only in each work area but at the total production level and identifies activities that include value-added and non-value-added (Rother and Shock, 2003). VSM classifies the activities in the production process into value-added and non-value-added actions so that it can be identified which activities can provide added value and which do not provide added value, which can then be taken steps to eliminate the existing waste.

Seven types of waste are commonly found in industry, namely (Oppenheim, 2011):

1. Overproduction: produce more than the needs of internal and external customers, or produce faster or earlier than the time required by internal and external customers.
2. Waiting time: the delay that appears through the people waiting for machines, equipment, raw materials, supplies, and maintenance/maintenance (maintenance).
3. Transportation: moving materials or people over long distances from one process to the next can result in increased material handling time.
4. Overprocessing: includes additional processes or work activities that are unnecessary or inefficient.
5. Over-inventory: inventories hide problems and cause additional handling activities that should not be needed.
6. Motions: any movement of people or machines that do not add value to the goods and services delivered to customers but only increase costs and time.
7. Product defects: scrap, rework, customer returns, customer dissatisfaction.

The VSM diagram consists of the current state VSM which describes the initial conditions of a process, and the future state VSM which describes the process after improvement (Voehl et al., 2014). Pareto charts help identify the critical areas that cause the most problems. The Pareto principle states that 80% of issues are created by 20% of causes, so the root cause of this problem can be investigated through Root Cause Analysis (RCA). RCA is one of the tools used to find the underlying causes of problems (Barsalou, 2015). Jing (2008) explains that five methods are often used in RCA, namely is/is not comparative analysis, five why methods, fishbone diagrams, cause and effect matrix, and root cause trees. In this study, fishbone diagrams and five why methods were used. A fishbone diagram, often called a fishbone diagram, is an excellent analytical tool for investigating the causes of problems in large numbers. The 5 why method is a structured method with repeated why questions to understand the grounds of the pain.

2. Research Method

Research methods are structured as a basis for conducting research. The first step is identifying waste in the production process, which can lead to increased costs and production time. In this step, the method used is value stream mapping (VSM). VSM can describe the production process flow, which shows every value-added (VA) and non-value-added (NVA) activity that adds to the cost, processing time, and other time needed to deliver the product to the customer. VSM is used to find problems in the flow of products and information based on data collected through worker interviews and observations in the production process. The data collected is the production process, the number of operators, and cycle time.

Current state VSM is used to analyze products comprehensively and information flows to find waste in each process. Waste is classified into seven types: over-production, delay, transportation, processes, inventories, motions, and defective products.

The second step is to find the root causes of the waste using a fishbone diagram and designing remedial activities to eliminate or reduce this waste using the five why method.

The next step is to implement the proposed fix. The final stage of this research method is to compare and analyze the current state of the VSM and the proposed state of the VSM and conclude.

3. Results and Discussion

3.1 Creating Current State VSM

Current State VSM illustrates the production process that takes place within the company, including the flow of information and materials. Current state VSM is needed as the first step in identifying waste that occurs in the Aluminum Cable Ladder production process at PT Trias Indra Saputra. The VSM current state image can be seen in Figure 1.

3.2 Analisa Current State VSM

VSM Current State Analysis

After describing the current state of VSM, the mapping will be used to identify waste and opportunities for streamlining processes along the value stream. Previously, activities would be grouped into value-added (VA) and nonvalue added (NVA). The grouping of these activities can be seen in Table 1.

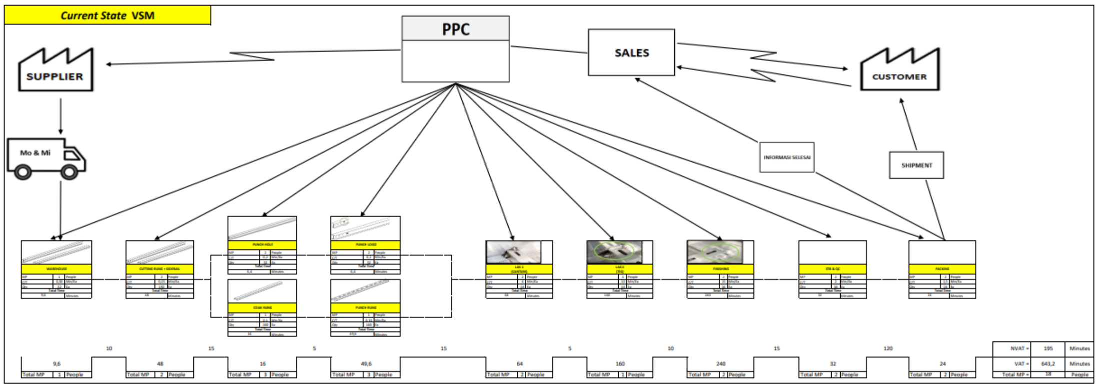


Figure 1. Current State VSM

Table 1. Value-added (VA), nonvalue added (NVA) activities, along with the number of Man Power

No	activity	VA (minute)	NVA (minute)	MP.VA (people)	MP.NVA (People)
1	Reception & Checking of Side Rail and Alm Rung Materials	9.6		1	
2	Transfer the Side Rail and Rung Alm materials to the Cut section.		10		1
3	Process of cutting two side rails and rungs	48		2	
4.1	Transfer Side Rail to punch hole process for side rail		15		1
4.2	Transfer Rung to Process coak rung				
5.1	Side rail punch hole process	16		3	
5.2	The Coak Rung Process				
6.1	Side Rail transfer process to Side Rail logo punch		5		1
6.2	Process of transferring rung to Punch Rung				
7.1	Side Rail Logo Punch Process	49.6		3	
7.2	Punch rung process				
8.1	Side Rail Transfer to Welding Process		15		1
8.2	Transfer Rung to Welding Process				
9	Welding Process 1 (Ballet)	64		2	
10	Transfer Cable Ladder to Welding Process 2		5		2
11	Welding Process 2 (TIG)	160		1	
12	Transfer Cable Ladder to the Finishing process		10		1
13	Finishing Process	240		2	
14	Cable Ladder Transfer Process to the STB area		15		2
15	STB and QC processes	32		2	
16	The process is waiting for the packing process		120		0
17	packing process	24		2	
		584	**195**	**18**	**9**

3.3 Waste Identification
Identification of waste during the process at PT. Triassic Indra Saputra is as follows.

D.1 Overproduction
With the current VSM analysis, no excess production waste was found in PT's aluminum cable ladder production process. Trias Indra Saputra because this company implements a pull system.

D.2 waiting time
The waiting time waste identified in the manufacture of aluminum cable ladder at PT. Trias Indra Saputra is waiting for the packing process. Based on Table 1, the waiting time is 120 minutes.

D.3. Transportation
The total waste of transportation time from transferring materials, WIP, and products are 75 minutes with a total of 9 people.

D.4 Overprocessing
Based on the analysis of the current state of VSM, several excess processes were obtained in the side rail cutting process, the side rail logo punch process, the welding process, and the finishing process. The total time required is 358.4 minutes, with 8 MPs.

D.5 Excess inventory (over inventory)
With the analysis of the current state of VSM, no excess inventory waste was found in the aluminum cable ladder production process at PT. Trias Indra Saputra because this company implements a pull system.

D6 Unnecessary motion (motion)
No unnecessary movements were identified during the VSM current state analysis.

D7 Product defects
No defects were identified during the VSM current state analysis.

3.4 Analysis of the causes of the emergence of waste
Based on the analysis of the current state of VSM, we found time wasted waiting for the packing process, which was identified in the manufacture of aluminum cable ladders at PT. Triassic Indra Saputra of 120 minutes. Transportation waste of 75 minutes was obtained from the combined approach of transferring material, WIP, and finished product. Waste of several excess processes in the side rail cutting process, the side rail logo punch process, the welding process, and the finishing process with a total time of 358.4 minutes with a full MP of 8 people.

Next, a Root Cause Analysis (RCA) will be carried out for each waste generated using a fishbone diagram and the five why method—starting from excess process waste, which can be seen in Figure 2 and Table 2, waiting waste in Figure 3 and Table 3 and transportation waste in Figure 4 and Table 4.

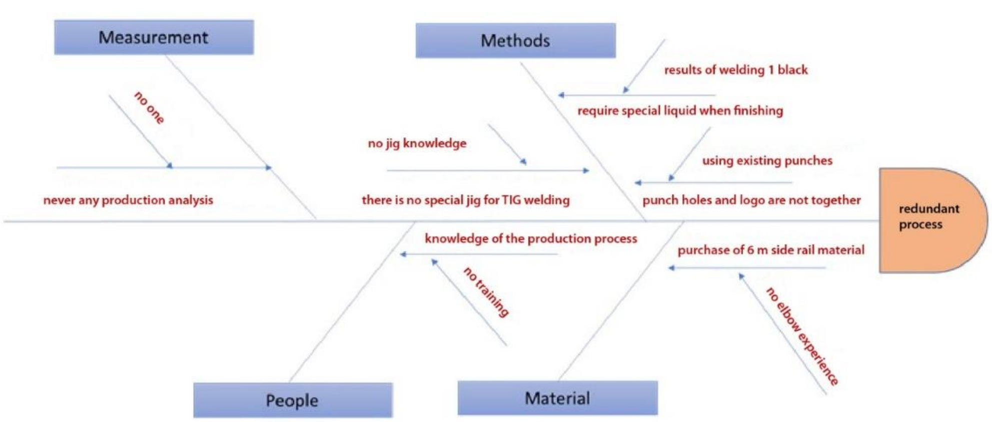


Figure 2 Fishbone diagram of excess process waste

Table 2.5 WHY analysis of excess process waste

Potential causes of Process Overload	WHY 1	WHY 2	WHY 3	WHY 4	WHY 5
Punch holes and logos don't go together	Using a punch that has a hole and a separate logo	No fuss	Need to modify the punch hole and logo	The project deadline is tight.	There is no information about the project
There is no special jig for TIG welding	No knowledge of TIG welding JIG	Never had training on JIG			
Requires special liquid when finishing	Results of welding 1 black	No Jigs	No knowledge of TIG welding JIG	Never had training on JIG	
Purchase of 6 m side rail material	Material is not elbow	Never communicated with the supplier	Never info to purchasing if the material is not elbow	Can be overcome by production	
There has never been an analysis of the production process	No one	No knowledge of production process analysis	No training		

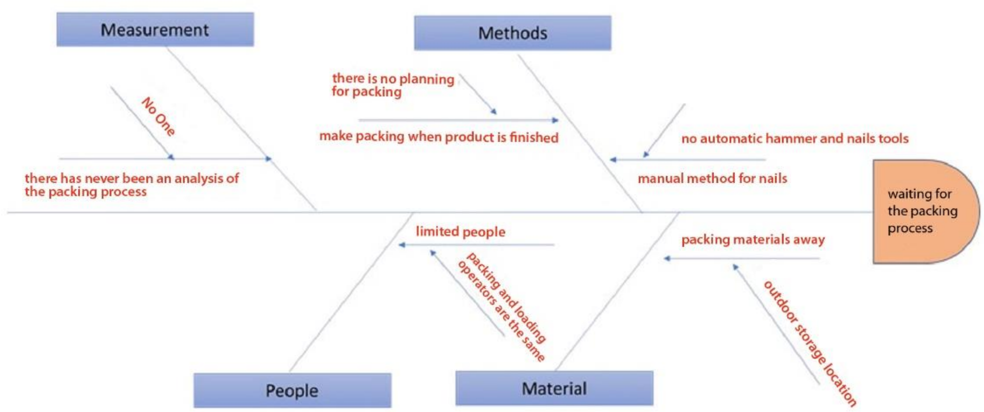


Figure 3. Fishbone Diagram of Waste Waiting For The Packing Process

Table 3. 5WHY Analysis Of Excess Process Waste

Potential causes Waiting for the Packing Process	WHY 1	WHY 2	WHY 3	WHY 4	WHY 5
Distant Packing Materials	Storage outside the factory	For easy access to suppliers	Size 3 meters long	Vendor availability is only 3 meters	
Manual method for nailing process	Does not have an automatic nail tool	Not filed	Don't know	There has never been any packing training	
Make packing when the product is finished	There is no planning for packing	Habit	There is no training about packing planning		
There is no packing process analysis	No one	Nothing to do analysis	There is no analysis training		

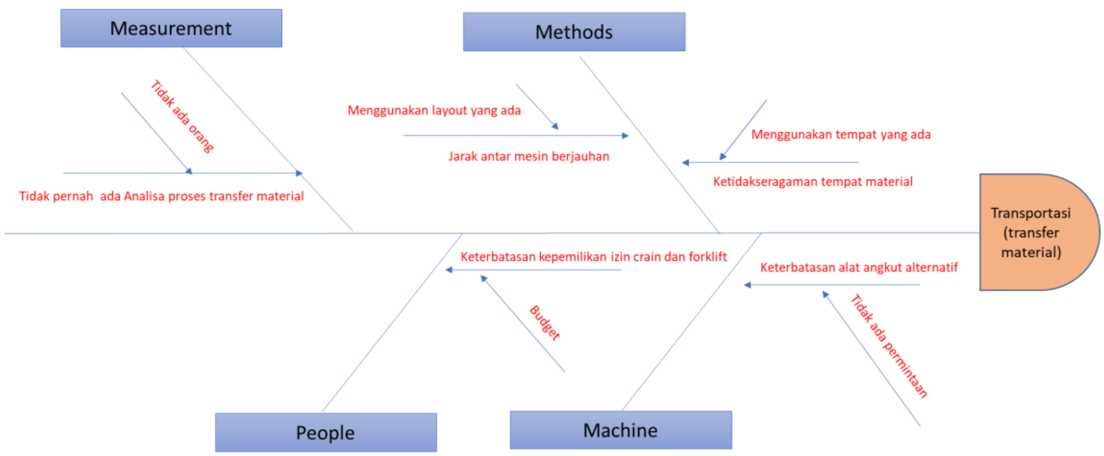


Figure 4 Fishbone diagram of transportation waste

Table 4. 5WHY analysis of transportation waste

Designing Improvement Activities

The fishbone and 5WHY methods are used to design improvement activities in the production process, along with the corrective actions that need to be carried out by PT. Triassic Indra Saputra:

F.1 Repair excess process waste

• Making punch holes and logos into one unit to reduce the side rail punch process. In addition, it is necessary to conduct a kick off meeting when there is a large project to avoid information not being conveyed to the production department.

• Making a jig for tig welding so the welding process becomes one. In addition, you can avoid black welding results by making a tig welding jig. This can reduce the finishing handling process that requires special fluids to remove black welds.

• Purchased 3-meter side rail material with good-quality elbows. This can be started by communicating it to suppliers and the desired quality standards.

• Conduct periodic analysis of production processes to evaluate existing processes.

• Conduct training activities on the production process, production process analysis, and knowledge of jig welding

F.2 Improved waste of time waiting for the packing process

• Planning the packing process by bringing the filling closer to the production process by placing pallets of goods to simplify and speed up the process.

• Provide automatic nailing equipment to speed up packing time and provide training on packing to employees.

• Conduct regular analysis of the packing process to evaluate the processes that are already running.

• Conducting training activities regarding the packing process, analysis of the filling process, and knowledge of packing planning.

F.3 Improvement of transportation waste

• Organizing alternative means of transportation, such as hand pallets and rolls, and conducting outreach and training that vehicle is important in the production process.

• Analyzing and standardizing storage areas and conducting outreach and training that storage is important in the production process.

• Evaluating layouts and getting closer to interconnected machines, as well as conducting outreach and training that layout layouts are important in the production process.

• Conducting priority scale analysis of employees who require transportation equipment permits so that they can meet the production process's needs and conducting socialization and training that transportation equipment permits are important in the production process.

• Conduct periodic analysis of material transfer processes to evaluate ongoing operations.

• Conduct training activities on the material transfer process and material transfer process analysis.

3.5 Implement the proposed fix.

Here are some examples of pictures regarding the improvements that PT has made. Triassic Indra Saputra:

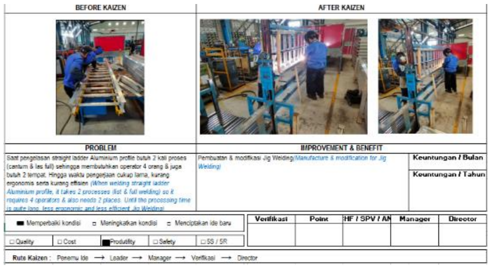


Figure 5. Welding Jig Making Figure 6. Merging holes and logo

Figure 5. Welding Jig Making Figure 6. Merging holes and logo

Figure 7. Improved finishing methods

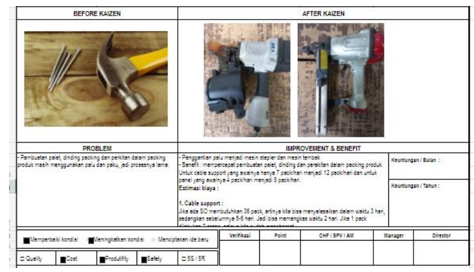
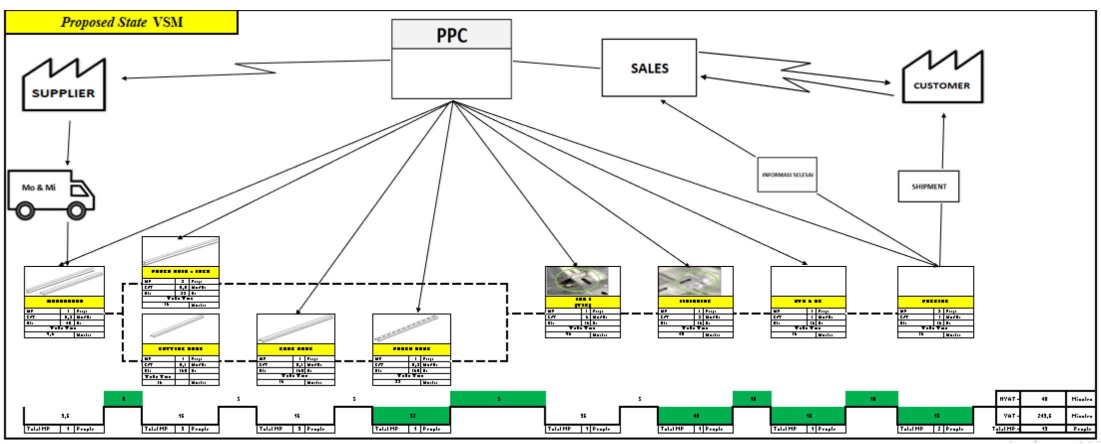


Figure 8. Procurement of automatic nailing tools

H Comparing and analyzing the current state of VSI and the proposed state of VSI

The following is the proposed state of VSM which has implemented the improvements as planned, which can be seen in Figure 9 and Table 5.



Gambar 9. Proposed State VSM

Table 5. Activities value added (VA) dan non-value added (NVA) from proposed state VSM

No	Activity	VA (minute)	NVA (Minute)	MP.VA	MP.NVA
1	Reception & Checking of Side Rail and Alm Rung Materials	9.6		1	
2.1	Transfer the Side Rail material to the Punch section		8		1
2.2	Transfer the Rung material to the Cutting Rung Section				
3.1	Punch hole process and Side Rail logo	16		3	
3.2	Process of cutting rungs				
4.1	waiting		5		1
4.2	Transfer rung to coak rung process				
5.1	waiting	16		1	
5.2	The Coak Rung Process				
6.1	waiting		5		1
6.2	Transfer Rung to Process Punch rung				

7.1	waiting	32		1	
7.2	Punch Rung Process				
8.1	Transfer Side rail to Welding process 1		5		1
8.2	Transfer Rung to Welding process 1				
11	Welding Process 1 (TIG)	96		1	
12	Transfer Cable Ladder to the Finishing process		5		1
13	Finishing Process	48		1	
14	Cable Ladder Transfer Process to the STB area		10		2
15	STB and QC processes	32		2	
16	The method of waiting for the packing schedule		100		0
17	packing process	16		2	
		256.6	**138**	**12**	**7**

Based on the comparative analysis data of the current state of VSM compared to the proposed form of VSM, the data obtained can be seen in Table 6.

Table 6. Comparison of Cycle Time, Amount of Man Power, and Production Costs

Parameter	Current VSM	Proposed VSM	Difference
VA	584 minutes	265.6 minutes	318.4 minutes
NVA	195 minutes	138 minutes	57 minutes
C/T	779 minutes	403.6 minutes	375.4 minutes
MP. VA	18 people	12 people	6 people
MP. NVA	Nine people	Seven people	Two persons
Total MPs	27 people	19 people	8 people
Cost of Production of 16 Cable Ladders	Rp 5.750.156	Rp 1.946.813	Rp 3.803.344
Cost 1 Cable Ladder	Rp 359.385	Rp 121.676	Rp 237.709

4. Conclusion

From the analysis comparing the current state VSI and the proposed state VSI, several wastes were obtained, namely excess process waste in the side rail cutting process, the side rail logo punch process, the welding process and the finishing process. Wasted waiting time in the packing process and wasted transportation time from the material, WIP and product transfer processes. After carrying out a root cause analysis and making improvements, we get an improvement in the production time of 52%, the number of people needed is 70%, and production costs are 34%. This proves that by implementing Lean Manufacturing PT. Trias Indra Saputra can reduce production time and costs.

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Conflicts of Interest: The authors declare no conflict of interest.

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