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Strategy for Defect Reduction and Operational Efficiency in the Production Process of Metal Products for Transformers at PT. Gemilang Jaya Prima Perkasa

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ABSTRACT

This study aims to minimize defects and increase production time efficiency in the manufacture of transformer tanks to support the sustainability and competitiveness of the metal industry. Problems faced include process waste, late delivery, and production results that do not reach the target, which impacts quality and customer satisfaction. The method used is descriptive qualitative through field observations with analysis of Current State Value Stream Mapping, Fishbone Diagram, Value Stream Analysis Tools, and Future State Value Stream Mapping. The study focused on the welding, assembly, NDT test, finishing, and quality control processes for the 2023–2024 period which have high levels of waste and product defects, to formulate proposals for improving the production process.

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INTRODUCTION

The development of the manufacturing industry requires companies to improve quality, efficiency, and operational sustainability to remain competitive. The transformer fabrication industry faces challenges such as process waste, high defect rates, late deliveries, and missed production targets, all of which impact costs, product quality, and customer satisfaction.

Transformer tanks, as vital components, require a precise fabrication process, from cutting to quality control. However, the risk of welding defects such as porosity, pinholes, undercuts, cracks, and spatter remain common, potentially leading to leaks and rework.

During the 2023–2024 period, PT. Gemilang Jaya Prima Perkasa experienced problems such as slow production flow, imbalanced workload, high waiting times, and fluctuations in production output. These conditions indicate the need for a comprehensive evaluation and improvement of the production system to increase efficiency and quality.

LITERATURE REVIEW

Lean Manufacturing

Lean manufacturing is a philosophy of continuous improvement. Lean manufacturing is a management philosophy and operational approach that focuses on waste reduction without sacrificing productivity. This concept emphasizes efficiency, high quality, and responsiveness to customer needs by maximizing value and minimizing all forms of waste in the production process.

Total Quality Management

Total quality management is a managerial approach that focuses on improving the quality of products and services through the participation of all members of the organization. TQM emphasizes the importance of involving all employees in the continuous improvement process, with the goal of meeting or exceeding customer expectations. One key component of total quality management is the use of statistical tools and techniques to measure and analyze performance.

Value Stream Mapping

Value Stream Mapping (VSM) is a visual and analytical tool used to map, analyze, and design the flow of materials and information required to produce a product or service from start to finish. VSM serves as a "roadmap" that shows each step in the production process, from raw materials to the product itself, reaching the consumer. After the hypothesis section, if your study is quantitative, please provide a contextual framework here, or your mind map, if qualitative.

Welding Defects

Welding is the process of joining two metals, primarily steel, to create a machine structure by melting them. In the welding process, problems often arise, such as weld defects caused by errors during welding. To detect damage in cracks without damaging the material during the testing process, can be done using non-destructive testing (NDT) methods.

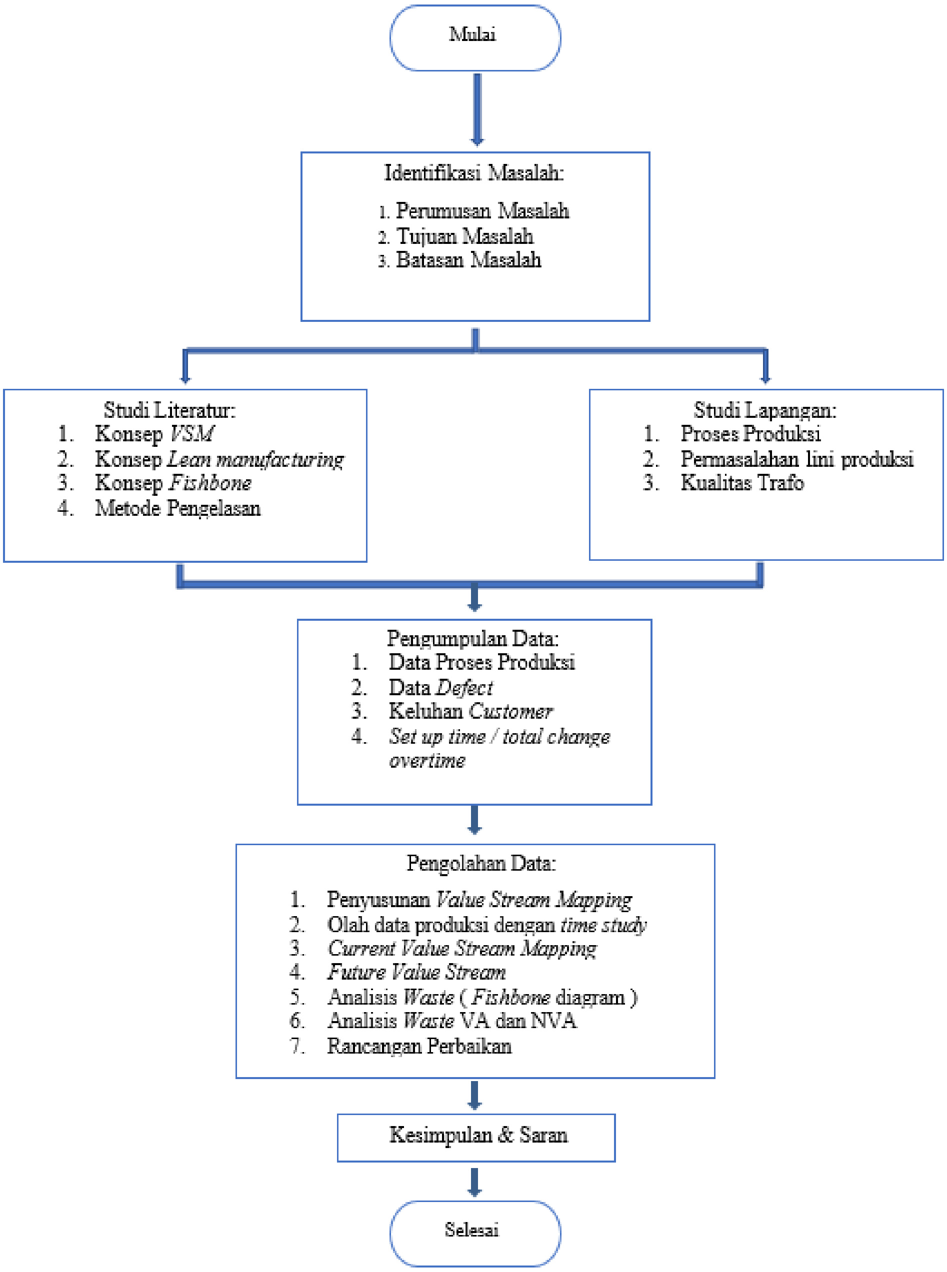

Figure 1. Research Flow

METHODOLOGY

This research applies a mixed method. A mixed methods research design is a procedure for collecting, analyzing, and combining quantitative and qualitative methods in one study. The main topic of discussion in this research is the transformer tank production process, due to defects occurring in the transformer tank and the inefficiency of the production process resulting in many complaints from consumers which led to rework.

Population and Sample

Population: All transformer products (transformer tanks) produced by PT. Gemilang Jaya Prima Perkasa during the 2023–2024 period.

Sample: The stages of the production process that have the most significant contribution to the occurrence of defects and operational inefficiencies:

1. Welding Process
2. Assembly Process

These two processes were chosen because:

- Shows relatively high levels of rework and product defect rates.
- Has a direct impact on production lead time, product quality, and operational efficiency.

Research Object

The object of this research is the transformer tank production process at PT. Gemilang Jaya Prima Perkasa which includes the entire series of fabrication activities, from material receipt to finished product delivery. The research focused on three product variants, namely 50 KVA, 100 KVA, and 160 KVA transformer tanks. The selection of these three variants was based on the similarity of the production process flow, significant volume and demand during the 2023–2024 period, as well as the existence of similar waste problems in the welding, assembly, NDT test, finishing, and quality control stages and the many defects that occurred.

Table 1. Operationalization of variables

No	Variables	Indicator	Method
1	**Production process**	- Transformer tank production process flow - Cycle time for each process - Value Added (VA) and Non-Value Added (NVA) activities	Cycle time $= \frac{Total\ Waktu\ Produksi}{Jumlah\ Unit\ Produksi}$ $\%VA = \frac{Waktu\ Value\ Added}{Total\ Lead\ Time} \times 100\%$
2	*Defect*	- Type of welding defect (pinhole, porosity, undercut, spatter, crack) - Number and frequency of defects - Results of visual inspection and NDT	$\%\ Defect = \frac{Jumlah\ produk\ cacat}{Total\ produksi} \times 100\%$ $\%\ DPPM = \frac{Jumlah\ Defffect}{Total\ unit\ produksi} \times 1{,}000{,}000$
3	**Operational Efficiency**	- Comparison of VA and NVA time - Reduction of reject products - Improvement of production process methods	$\%\ NVA = \frac{Waktu\ Value\ Added}{Total\ Lead\ Time} \times 100\%$

RESEARCH RESULT

Based on the Pareto diagram of transformer defect types, leakage defects are the largest contributor to total production defects, which indicates that problems with joint tightness and welding process quality are still dominant issues in transformer tank manufacturing. In addition, cumulatively, leakage defects, spatter, and dimensional errors contribute more than 70% of all defects, so that these three types of defects can be classified as critical defects and are set as top priorities in quality improvement programs.

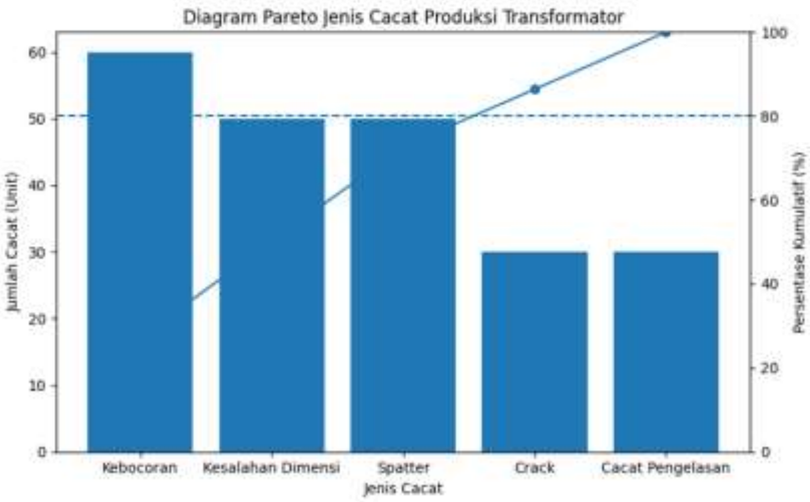

Figure 2, Pareto diagram for defects in transformer tanks

This section allows you to outline your research findings in an academic manner. You should not include figures related to your statistical tests here; instead, you should explain those figures. You should structure your discussion with academic support for your study and a clear explanation relevant to the specific field you are investigating.

DPPM Calculation

- Leak = $\frac{60}{945}$x 1000000 = 63492 DPPM
- Spatter =$\frac{50}{945}$x 1000000 = 52910 DPPM
- Dimension = $\frac{50}{945}$x 1000000 = 52910 DPPM
- Welding = $\frac{30}{945}$x 1000000 = 31746 DPPM
- Crack = $\frac{30}{945}$x 1000000 = 31746 DPPM

Based on the results of converting DPPM to sigma level, the production process is at the 3–3.35 sigma level, which indicates that there is still significant opportunity for improvement in reducing the level of production defects.

Transformer Tank Production Cycle Time

Table 2. Cycle time results data

No	Process	Time (Seconds)
1	*Assembly Cover*	630
2	*Assembly Body*	720
3	*Welding*	1008
	Total	2358 Seconds

Set Up Time and Production Time Data

Table 3. Setup and production time data

No.	Process	Product Lot (Pcs)	Cycle time (Sec)	Set Up Time (min)	QC time (min)	Material Change time (min)	Production Time (Min)	Total time/item (Min)	Ave Item/day	Total Production Time (hr)	Total Change Over Time /Day (hr)	LoadingTotal Time (hr)
		a	b	c	d	e	= (axb)/60	= ((axb)/60)+c+d+e	f	(prod Time x Ave item per day) / 60	= ((c+d+e)xf)/60	(Total Prod Time + Total Changeovertime)
1	*Assembly cover*	50	630	2	2	1	525	530	40	350	3.3	353.3
2	*Assembly Body*	50	720	5	3	1	600	726	35	350	5.2	355.2
3	*Full Welding*	50	1008	8	5	1	840	854	25	350	5.8	355.8

In Table 3 the process *Full welding* have value *NVA* the highest is 14 minutes, *Assembly body* have value *NVA* which is moderate with a value of 9 minutes and *NVA* the lowest is in the process *assembly cover*. So, the author will make the process *full welding* as *"Pilot Project"* and process *assembly body* as a supporter, because the two processes are interrelated and can be improved.

Map Current State Value Stream Mapping

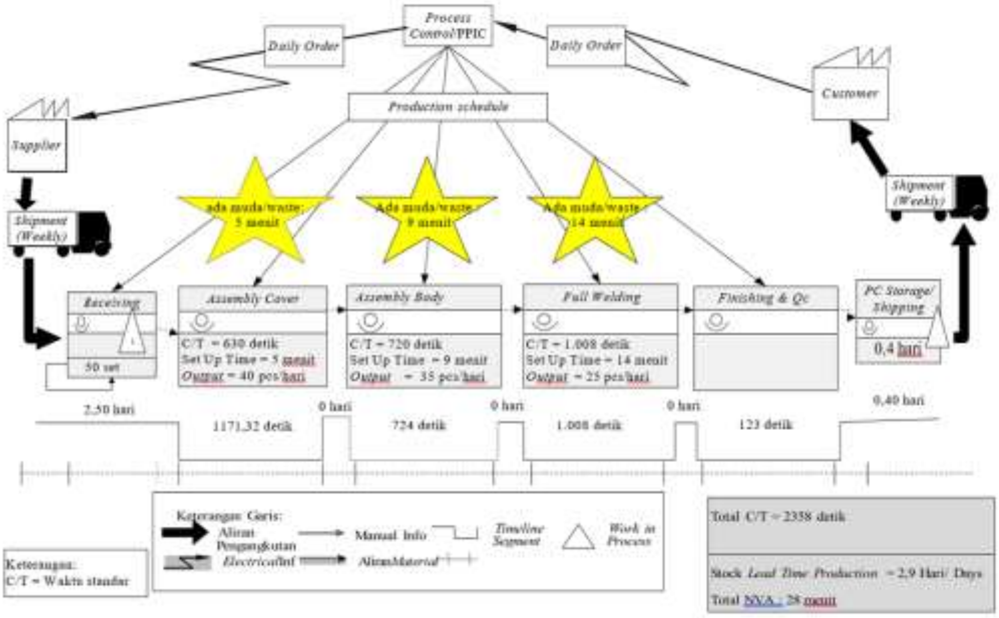

Figure 3. Map Current State Value Stream Mapping

The results of Current State Value Stream Mapping show that the main waste in the transformer tank production process comes from:

1. High non-value added time in the full welding process
2. Low output due to bottlenecks in the welding process
3. The high potential for defects triggers rework and increases processing time.

Therefore, the full welding process is set as the main priority for improvement in the Future State Value Stream Mapping design to increase productivity and reduce product defect rates.

Value Added and Non-Value Added

At this point, the author will analyze the continuation of the Current State Value Stream Mapping, carried out after mapping the actual conditions of the production process has been compiled, with the aim of identifying and evaluating activities that do not provide added value.

Table 4. Value Added and Non-Value Added

No.	Process	Total Production Time (hr)	Total ChangeOvertime /Day (hr)	LoadingTotal Time (hr)	VA	Non-VA	VA	Non-VA
		(Prod TimeXave item/day)/60	= (c+d+e)/60	(To Prod Time + Tot. Change over time)				
1	*Assembly Cover*	3.50	3.50	6.80	3.50	3.30	51.47%	48.53%
2	*Assembly Body*	3.50	5.20	8.70	3.50	5.20	40.23%	59.77%
3	*Full Welding*	3.50	5.80	9.30	3.50	5.80	37.63%	62.37%

Based on Table 4, it can be seen that the Full Welding process has the highest Non-Value-Added percentage of 62.37%, which indicates a significant waste of time in the process. Meanwhile, the Assembly Body process has an NVA of 59.77%, and the Assembly Cover process has the lowest NVA of 48.53%. How to calculate VA and NVA:

a. Cover Assembly Process

Total Production Time VA = 3.50 hours
Total Change Over Time NVA = 3.30 hours
Loading Total Time = 6.80 hours
VA: = (3.50 / 6.80) × 100%
= 0.5147 × 100%
= 51.47%

NVA: = (3.30 / 6.80) × 100%
= 0.4853 × 100%
= 48.53%

b. Body Assembly Process

Total Production Time VA = 3.50 hours
Total Change Over Time NVA Non-VA = 5.20 hours
Loading Total Time = 8.70 hours
VA: = (3.50 / 8.70) × 100%
= 0.4023 × 100%
= 40.23
NVA: = (5.20 / 8.70) × 100%
= 0.5977 × 100%
= 59.77%

c. Full Welding Process

Total Production Time VA = 3.50 hours
Total Change Over Time NVA = 5.80 hours
Total Loading Time = 9.30 hours
VA: = (3.50 / 9.30) × 100%
= 0.3763 × 100%
= 37.63%
NVA: = (5.80 / 9.30) × 100%
= 0.6237 × 100%
= 62.37%

Fishbone Diagram

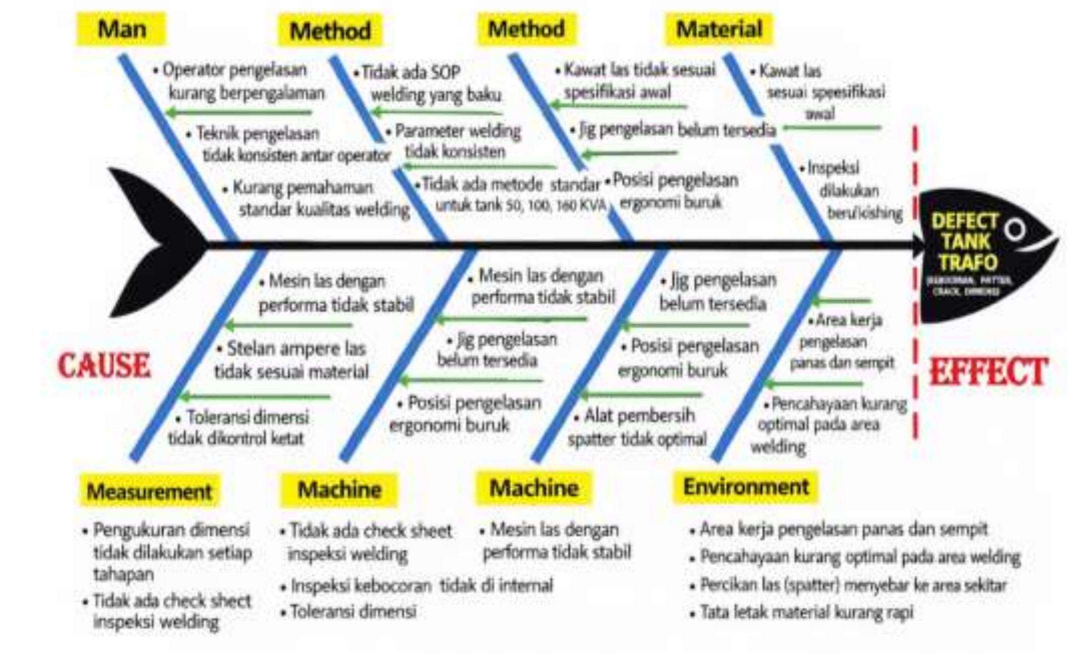

Figure 4. Fishbone Diagram

Table 5. Factors causing defects

No	Factor	Reason
1	Man	• Welding operators have varying levels of experience. • Welding techniques are inconsistent between operators
2	Method	• There is no specific welding method for each type of transformer tank (50 kVA, 100 kVA, and 160 kVA) • Welding parameters such as welding current and speed are not standardized.
3	Machine	• Ampere settings do not always match material specifications • The welding machine has unstable performance
4	Material	• Welding wire does not always conform to the initial specifications. • The plate surface is not completely clean from dirt or oil.
5	Measurement	• Dimensional measurements are not performed at every stage of the process. • Absence of welding inspection check sheet
6	Environment	• Lighting is less than optimal • Welding spatter spreads to the surrounding area

Table 6. *Root cause analysis*5W+1H

Factor	What	Why	Where	When	Who	How
MAN	Welding	Defective welding results (porosity, uneven bead, cracks)	Operators have non-uniform welding techniques and do not follow standards.	Full Welding Process (joint radiator to body tank)	During the welding process	Welding operator
	Leakage	Many leak points in the welded joints	The welding results are not perfectly penetrated and are not tight enough.	Radiator connection to body tank	After the welding process (during the soap test / leak test)	Welding operator
MATERIAL	Welding	Poor weld joint quality	Welding wire does not meet specifications and surface material is dirty	Body and cover welding area	Before and during welding	Operator & QC
	Dimensions	Product dimension mismatch	Plate thickness variations	Body Assembly and	During the assembl	Assembly operators

			and accessory placement errors	Cover Assembly Process	y process	
MACHINE	Welding	Excessive spatter and unstable weld results	Welding machine and ampere settings are unstable	Welding machine in the Full Welding process	During the welding process	Operator & Maintenance
	Crack	Cracks in radiator welds	Lack of precision welding jigs	Radiator welding process	During the welding process	Welding operator
METHOD	Welding	Variation in welding quality	Absence of SOP and standard welding parameters	The entire Full Welding process	During the production process	Operator & Supervisor
	Dimensions	Accessory installation error	There is no dimensional inspection procedure in each process.	Body Assembly Process	During the assembly process	Operator & QC

Measurement	Defect detected late	Defective products pass to the next process	Inspection is only done at the end of the process	Final Quality Control	After finishing	QC
ENVIRONMENT	Welding	Spatter spreads and the weld results are not neat.	Lighting and work area conditions are less than optimal	Welding area	During the welding process	Operator

Table 7, Improvement plan

No	Process	Current State of the Problem	Types of Waste	Root Cause (Fishbone)	Improvement Plan (Future State)
1	*Welding*	High welding defects (pin holes, porosity, undercuts, spatter)	*Defect, Rework*	Welder skills are uneven,	WPS standardization & welding current parameters- Training and
2	*Welding*	High rework time due to leaking welds	*Waiting, Overprocessing*	No initial inspection	Initial visual inspection & leak test after welding
4	*Assembly*	Component installation error	*Defect*	There is no standard visual work	Creating visual work instructions, labeling and component position standards
5	*Quality Control*	Inspection is done at the end of the process	*Defect*	*Quality control*reactive	*Quality checkpoint*in every process

Creating Future State Mapping

From the current state data, the stock lead time was 2.5 days, the total C/T was 2358 seconds, and the setup time was 15 minutes. The total changeover time, which is an NVA activity, was reduced from 3.5 hours to 2 hours for the cover assembly process and from 5.2 hours to 4 hours for the body assembly process, and the welding process also decreased from 5.8 hours to 4.2 hours.

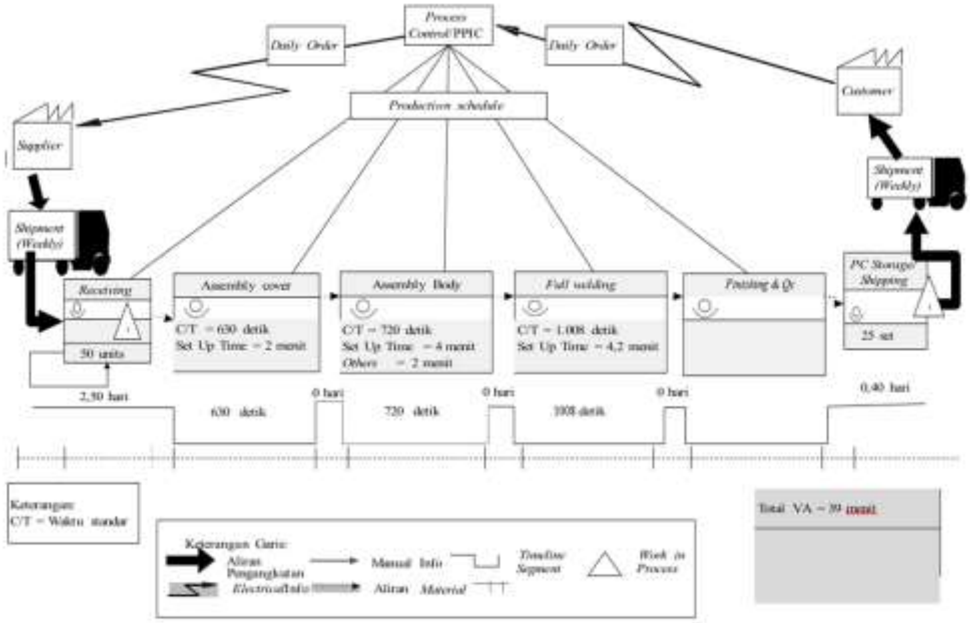

Figure 5. Creating Future State Mapping

DISCUSSION

This study aims to identify waste and analyze the causes of inefficiency in the transformer production process, as well as to design future state value stream mapping as a strategy to improve operational efficiency at PT. Gemilang Jaya Prima Perkasa. Based on the results of field observations, current state value stream mapping, and analysis using fishbone diagrams and waste analysis, it was found that the transformer tank production process is still dominated by non-value-added activities, especially at the welding, assembly, and quality control stages.

These findings indicate that the main problems stem not only from technical aspects of production, but also from workflow management, team allocation, operational standards, and quality control systems. These conditions directly impact production times, high product defect rates, and delays in meeting production targets.

Managerial Implications

Managerial Implications The results of this study provide several important managerial implications for the management of PT. Gemilang Jaya Prima Perkasa, including:

a. Management needs to make lean manufacturing a sustainable work culture, not just a short-term improvement project, with full support from the managerial level to production operators.

b. A policy of standardizing work processes is needed, especially in welding and quality inspection processes, to minimize process variation and reduce defect rates.
c. Management is advised to conduct periodic operator competency training and certification to improve the quality of work results and reduce rework.
d. The use of Future State VSM as an operational decision-making tool can help management in planning capacity, organizing production flow, and improving the timeliness of product delivery.

CONCLUSION AND RECOMMENDATION

This study aims to answer the problem formulation related to the challenges of the transformer production process, the types of waste that occur, and the optimal design of Future State Value Stream Mapping at PT. Gemilang Jaya Prima Perkasa. Based on the results of the Current State Value Stream Mapping mapping, waste analysis using Value Stream Analysis Tools and identification of root causes through Fishbone Diagram, several conclusions can be drawn as follows:

a. The main challenges in the transformer production process at PT. Gemilang Jaya Prima Perkasa include low process flow efficiency, high waiting time, imbalance in workload between processes, and high defect rates, especially in welding, assembly, NDT testing, finishing, and quality control. And business competition with competitors.
b. The dominant types of waste found in the transformer production process are waiting, defects, and rework. This waste is largely caused by a lack of standard work procedures and uneven operator skills.
c. The design of Future State Value Stream Mapping shows that the application of lean manufacturing principles can significantly reduce non-value-added activities.

ADVANCED RESEARCH

This study concludes that inefficiencies in the transformer production process at PT. Gemilang Jaya Prima Perkasa—particularly high waiting time, workload imbalance, and defect rates—are primarily driven by weak standardization and uneven operator competency, resulting in dominant wastes such as waiting, defects, and rework. The proposed Future State Value Stream Mapping confirms that implementing lean manufacturing principles can significantly reduce non-value-added activities and improve operational performance. Therefore, the company should strengthen standard work systems, enhance workforce skills, and institutionalize continuous improvement to achieve sustainable competitiveness.

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