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Optimizing Lean Manufacturing for Timely Product Completion in Project Manufacturing Company: A Case Study

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Abstract

In this modern era, companies are eager to provide quality products and services at affordable prices and pay attention to production timelines. This study aims to implement lean manufacturing principles to overcome challenges such as delays in product completion and improve production efficiency in a single company, PT. X that produces tanks. Using Lean principles, Value Stream Mapping (VSM) and Value Stream Tools (VALSAT) analysis, it was found that the most common types of waste were Waiting (20%), Defective Parts (18%), and Excess Processing (15%). Process Activity Mapping (PAM) identified areas for improvement, especially in reducing transportation time (Necessary Non-Value Adding Activity (NNVA)) (3%). This research highlights the positive impact of lean manufacturing on production efficiency and customer satisfaction. Future research projections include exploring automation technologies, integrating Industry 4.0, environmental monitoring, and employee development.

1. Introduction

Increasingly intense industry competition encourages companies to provide a high-quality product at an economical price and a scheduled production time. Where quality is crucial in supporting business continuity [1]. In dealing with the iron triangle of time, cost, and quality, the increased competition significantly affects the efficiency and completion rate of the project. However, in realization, there are several inefficiencies due to competition that affect production time or schedule, such as cost overruns and delays, client dissatisfaction, and fragmented industry structure [2 - 4]. The changing economy and how companies ensure quality affect production costs and output. To reduce delays and ensure high production quality, companies need systems and work cultures that incentivize workers. Ensuring production in the industry is completed on time and to the satisfaction of all parties requires understanding how competition, efficiency, and quality are interconnected.

Lean manufacturing systematically manages and improves processes to simplify processes, maximize efficiency, and eliminate waste [5]. With a focus on emphasizing continuous improvement and the involvement of all workers in problem-solving. Where this successfully reduces costs and fosters an ethos of innovation and collective effort [6]. By implementing lean manufacturing, companies can improve communication between departments, strengthen integrity through promoting transparency and accountability, improve product quality with standardized operations, and strengthen supply chain capacity by optimizing inventory control and reducing lead times. The application focuses on creating customer value and reducing waste [7]. It is characterized by principles derived from the Toyota Production System (TPS), such as just-in-time (JIT) production, continuous improvement, visual management, and respect for people. These principles have proven effective in increasing productivity, reducing costs, and improving quality in manufacturing and service organizations [8 - 9]. So, amid intense industry competition, the application of lean manufacturing is essential to maintain competitiveness at the global level [10].

The core of lean production is the capability to work in synergy to produce a quality system to produce finished goods and products that meet consumer demand [11]. Where lean manufacturing is derived from TPS by using JIT methods, cellular manufacturing, total production maintenance, and reducing the number of machine setups to reduce waste [12 - 14]. Through comparing TPS with the mass production concept, it was found that lean concepts are required on the production floor and supply floor [15]. By using this concept, companies can build a more productive framework to retain half of the inventory, reduce defects, increase product variety, and continuously evolve to perform more effectively and efficiently [16].

In reducing wastage, improving efficiency, and optimizing processes, it is essential to categorize activities in industrial flows. Waste can be categorized into three [17], namely value-added, necessary but non-value-added (type I wastage), and non-value-added wastage (type II wastage). Waste uses resources but does not produce value [3], [18]. There are seven types of waste identified by Taiichi Ohno, the head of Toyota, namely overproduction, waiting time, transportation, overprocessing, unnecessary investment, and defects [15], which can occur and be found anywhere and often unnoticed [19]. This initiated the development of the lean thinking concept, which includes five fundamental principles, including determining value from the customer's perspective, identifying and streamlining the value stream until the product reaches the customer, implementing a pull system that delivers value on demand, increasing customer satisfaction by focusing on quality and making continuous improvements to minimize costs and ensure on-time delivery [20 - 21].

The VALSAT method attempts to improve efficiency and reduce waste in the production process by focusing on value-related steps that directly add value to the final product [22]. With VSM, companies can visualize and analyze each stage of the production process, from raw materials to product delivery. This allows companies to identify and reduce waste, simplify activities, and improve overall operational efficiency [23]. Completing tank production projects efficiently and on time to meet demand, maintain smooth operations, and maintain market competitiveness.

PT X is a manufacturing company that produces process tanks and runs a make-to-order (MTO) system. The production process in this company starts with raw materials, followed by cutting, machining, forming of raw materials and assembly. In its endeavour to produce good products, reduce production costs, and provide on-time delivery during production activities, it requires improvement in several stages of its operations. This is because some process areas exhibit waste, such as over-processing. Thus, this research aims to apply VSM and VALSAT to overcome these problems and improve production efficiency at PT X.

2. Methodology

This research follows a systematic four-stage methodology to implement lean manufacturing principles in a tank manufacturing company. A flowchart (Figure 1) can illustrate these stages for better visualization.
The details of each stage are as follows:

Stage 1: Problem Identification.

The initial stage involved clearly defining the problem or issue at hand. It was essential to identify the scope, objectives, and limitations of the problem to ensure a focused and efficient approach. At this stage, fundamental questions were formulated to guide the subsequent stages. This research conducted a literature study on lean manufacturing, VALSAT, VSM, and on-time project delivery.

Stage 2: Data Collection and Processing

This research involves one company, PT X, as a sample. In this stage, the value stream analysis tool is used to discuss project delays. Initially, the current conditions at PT X were mapped, followed by the application of VSM to describe the model by outlining the current state of the production process and the sequence of making working drawings, cutting, assembling, and identifying waste. The next step was to create a Big Mapping Picture Current State Map, which included collecting the necessary data from the industrial process, identifying production achievements, and determining the key stages in the production process. Then, the production process activities were analyzed using the seven-waste approach through the VALSAT tool. After that, the questionnaire results were weighted to identify areas for improvement and prioritize actions for waste elimination.

Stage 3: Analysis

The problem was analyzed, and suggestions were given to implement lean manufacturing methods in the company. VSM was used as a tool to describe the system as a whole and the value stream within it. This tool also identified where wastage occurred and determined the relationship between information and material flow. In performing VSM, the process was followed from beginning to end and measured at each stage. For example, during process monitoring, we recorded the resources used, the amount of resource usage each time, and other relevant information. The VSM process provided an overview of the system to determine the differences that occurred after the improvement stage, based on the VALSAT analysis results, including PAM, Product Variety Funnel (PVF), Supply Chain Response Matrix (SCRM), Quality Filter Mapping (QFM), Demand Amplification Mapping (DAM), and Decision Point Analysis (DPA). Three factors were selected based on their significant impact on waste in the tank manufacturing process. Furthermore, activities considered to be of no value were eliminated or minimized. This mapping provided a complete picture of the process time to identify value-added and non-value-added activities.

Stage 4: Conclusion and Future Works

In the final stage, the findings from the analysis were synthesized to conclude the problem. This involved interpreting the results in the context of the original problem and objectives identified in Stage 1. Based on these conclusions, actionable suggestions or recommendations were made. These included strategies to mitigate the problem, steps for further research, or potential policy changes. The aim was to provide practical and well-informed solutions to address the identified problems effectively.

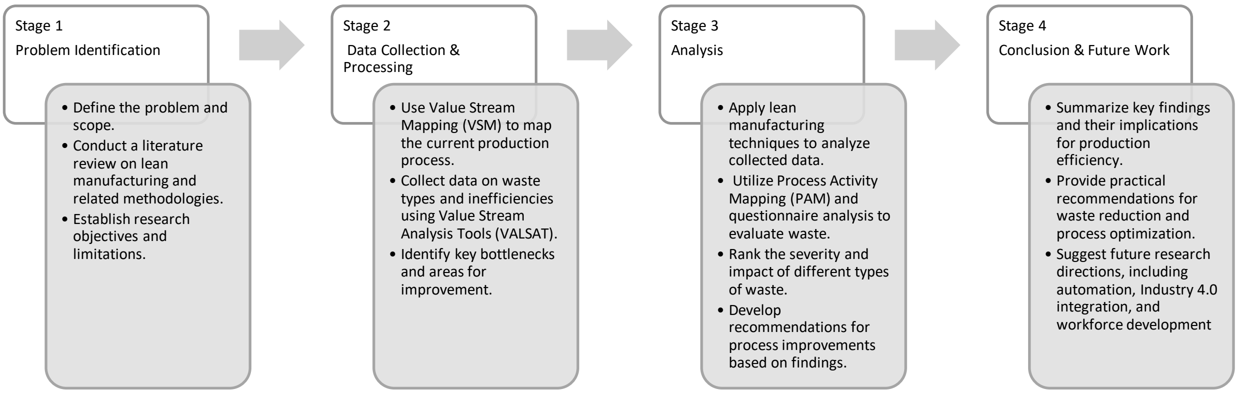

Fig. 1 *Flow chart of a systematic four-stage methodology*

3. Result and Discussion

3.1 Supply Chain and Production

PT. X provides Make-to-order (MTO), which means the tank is manufactured after the customer requests it, with production time depending on the design or size of the tank. The tank manufacturing process starts from receiving material in the warehouse, cutting, conveying to the machining process, rolling, and making components. After completing these processes, it goes into the assembly process and delivery to the customer. The sequence of the tank manufacturing process until it is delivered to the customer is illustrated in Figure 2. MTO ensures that tank production meets the customer's desired specifications so that the company prioritizes production based on the urgency of orders, complexity, and required specifications. This method allocates resources efficiently, ensuring that raw materials, labour, and machinery are effectively scheduled to meet production schedules without high inventory costs [24]. MTO also provides flexibility in scheduling production, which allows for adjustments in the production order based on fluctuations in demand and customer deadlines [19].

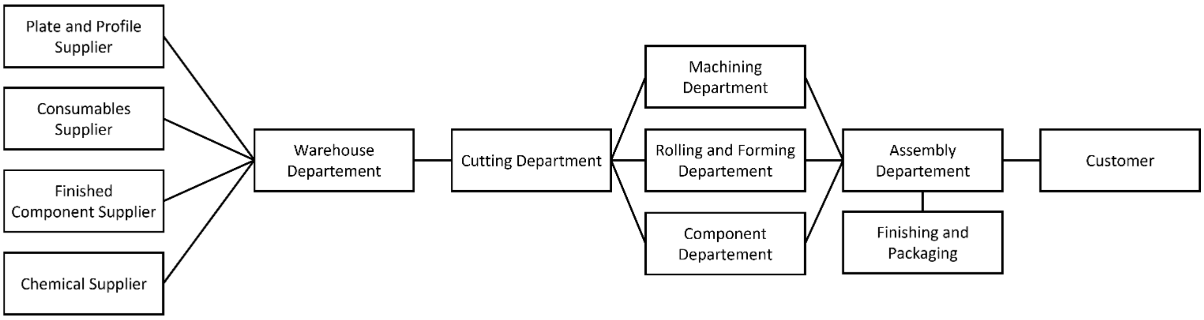

Fig. 2 *Scheme of production stages*

3.2 VSM Current State

VSM is a production flow map of a company that considers two types of flows in PT. X: information and physical. Information flow relates to several divisions that cause communication processes such as customers, marketing, estimation, and drawings. Meanwhile, the physical flow is related to the tank production process, as described in Table 1. By analyzing both flows, VSM helps identify inefficiencies and opportunities for improvement in the overall production system [25 - 26].

Table 1 *Information flow of PT. X tank production output*

Department	QTY (People)	Number of Operators	Takt Time (Hours)
Cutting			
Laser Cutting	2	4	24
Shearing	2	2	8
Sawing	3	2	12
Machining			
Turning	2	2	16
Milling	1	1	12
Drilling	3	3	8
Rolling and forming			
Rolling	2	2	8
Pressing	3	2	20
Components			
Fitting	2	2	33
Welding	2	4	17
Assembling			
Fitting	3	3	200
Welding	3	6	130
Finishing and packaging			
Finishing and Packing Process	4	8	160
Total			648

Therefore, Table 2 presents detailed lead time information to illustrate more details on the processing time affecting efficiency in tank production at PT. X. This table systematically represents each stage in the production flow, providing insight into potential points that can be optimized to accelerate product completion and improve overall performance. VSM involves the processes of cutting, manufacturing, parts making, assembly, finishing, and packing as presented in Figure 3. Each process has a specific processing time and requires a certain number of operators. Therefore, the time value for each process is determined by its average processing time.

Table 2 *Lead time information flow on PT. X tank production*

Process	Lead Time (Hours)	Note
Preparation		
Designing	40	
Material Procurement	80	
Warehouse		
Inventory to Cutting Department	8	
Cutting		
Laser Cutting	13	
Shearing	8.5	
Sawing	2	
Machining		
Turning	11	
Milling	8	
Drilling	6	
Rolling and forming		
Rolling	4	
Pressing	12	
Components		
Fitting	22	
Welding	16	
Assembling		
Fitting	176	
Welding	120	
Finishing and packaging		
Finishing and Packaging Process	120	
Total	646.5	

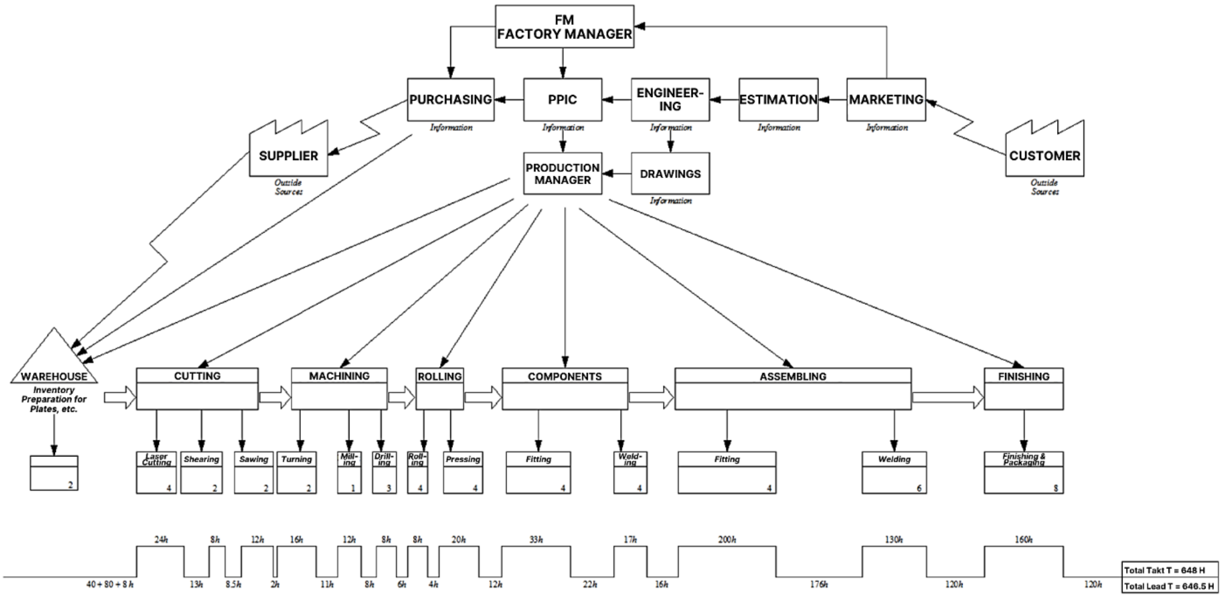

Fig. 3 *Current state mapping of the production process of PT. X*

3.3 Questionnaire of Wastage

A questionnaire was conducted to collect data on wastage among the seven categories. The questionnaires were filled out by people knowledgeable about the field conditions. As shown in Table 3, the frequency of the seven types of wastage is assessed [27]. From the data, it was found that the three highest wastes (as bolded in Table 3) were waiting (20%), defective products (18%), and redundant processes (15%), which are further presented in Figure 4. These findings are backed by previous studies, which provide clear explanations and evidence to support them:

1. **Waiting (20%)** – Delays occur mainly due to inefficient material procurement and slow department communication. [2] found that excessive waiting in MTO environments is often due to raw materials' unavailability and delays in engineering approvals. Additionally, [7] highlighted that a lack of real-time inventory monitoring can extend lead times and disrupt production schedules.
2. **Defective Products (18%)** – Defective parts are primarily due to inadequate machine maintenance and handling errors during assembly. [9] identified that quality control gaps and insufficient operator training are primary contributors to defects in lean manufacturing environments. Furthermore, [5] emphasized that implementing Ishikawa's quality control tools can help reduce defects by identifying recurring causes.
3. **Redundant Processes (15%)** – Over-processing is commonly observed in the assembly and polishing stages, where rework is needed to meet customer specifications. Studies by [28] confirm that excessive processing in lean manufacturing results from inefficient workflow standardization and poor initial quality control.

Table 3 *Recapitulation of questionnaire results*

Type of Waste	Q1	Q2	Q3	Q4	Q5	Total	%	Ranking
Transportation	8	4	4	5	2	23	14.5	4
Waiting	**5**	**9**	**8**	**4**	**6**	**32**	**20**	**1**
Overproduction	0	2	5	8	0	15	9.5	7
Defective Parts	**6**	**6**	**8**	**4**	**3**	**27**	**18**	**2**
Inventory	2	8	5	3	1	19	12	5
Movement	3	3	4	6	2	18	11	6
Excessive Processing	**7**	**5**	**6**	**5**	**1**	**24**	**15**	**3**

Note: Q1-Q5: Questions on the questionnaire

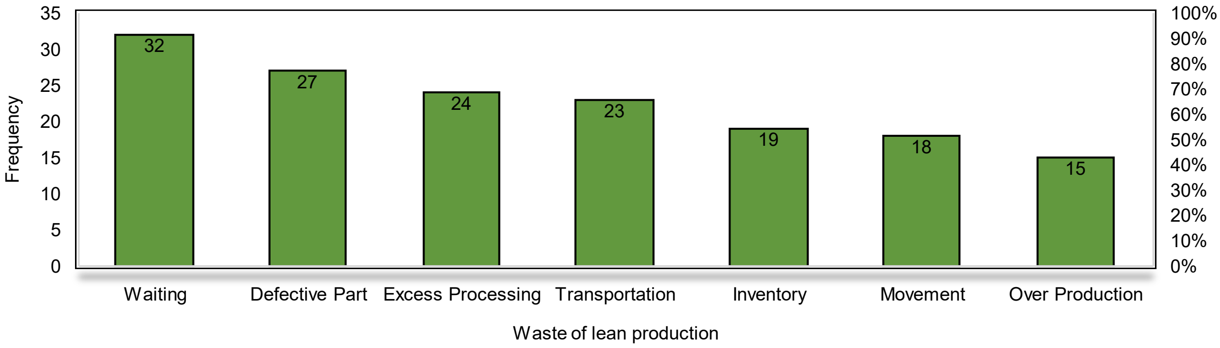

Fig. 4 *Pareto diagram of seven waste*

3.4 Value Stream Mapping Tools (VALSAT)

The assessment results from the waste identification become the primary data for selecting relevant tools using the VALSAT approach. The average value is multiplied by the weight value in the VALSAT matrix, and the graph of the VALSAT matrix conversion results is shown in Table 4. From the VALSAT conversion results, the dominant tools for identifying waste are PAM (39%), SCRM (21%), and DAM (12%), as presented in Figure 5. These tools were chosen based on their effectiveness in addressing the identified waste areas, ensuring targeted and efficient waste reduction strategies [27], [29].

Table 4 *VALSAT matrix conversion results*

Waste	Score	PAM	SCRM	PVF	QMF	DAM	DPA	PS
Transportation	23	207						23
Waiting	32	288	288	32		96	96	
Overproduction	15	15	45		15	45	45	
Defective Parts	27	27			243			
Inventory	19	57	19	57		144	57	19
Movement	18	162	162					
Excessive Processing	24	216		72	24			
Total		972	514	161	282	285	198	42
%		39%	21%	7%	11%	12%	8%	2%
Ranking		1	2	6	4	3	5	7

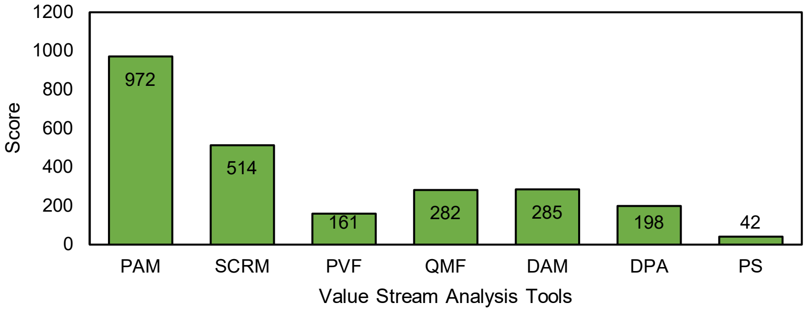

Fig. 5 *The VALSAT conversion results*

3.5 Identification of Waste with Process Activity Mapping (PAM)

Process Activity Mapping (PAM) requires direct observation of distance, time, and labor activities. The results are summarized in a table that categorizes activities into five primary types: operations, transportation, inspection, delays, and storage. A description of each process in a VSM, which illustrates the flow and nature of information coming from each process [30], inclusion of the number of operators or workers involved in tank production, and development of a graphical representation depicting the VA and NVA time components at the base of the VSM [31]. Since value-added activities are operations, value-added activities (VA) can be derived, including those from operations. Meanwhile, transportation and storage are classified as non-value-added but necessary activities (NNVA), while delays are categorized as non-value-added activities (NVA). The proportion of PAM is presented in Table 5 outlines the distribution of each type of activity. Table 6 presents a more detailed breakdown of the amount and proportion of time for each activity, providing further insight into how time and resources are allocated across different activities. Both tables highlight critical areas of potential improvement and optimization.

Table 5 *PAM current state*

Activities	Machine/ Tool	Distance (Meters)	Time (Hours)	QTY (People)	Activities					VA/NVA/ NNVA
					O	T	I	S	D	
Material delivery from warehouse to cutting department	Forklift	100	8	1		✓				NNVA
Cutting top cone and ball front plates	Laser cutting machine		24	4	✓					VA
Cutting shell plates	Shearing machine		8	2	✓					VA
Cutting round bars	Sawing machine		12	2	✓					VA
Dimensional inspection of cuts			3	1			✓			VA
Transfer to machining department	Forklift	20	2	1		✓				NNVA
Turning of cut materials	Lathe machine		16	2	✓					VA
Flange forming	Milling machine		12	1	✓					VA
Flange drilling	Drilling machine		8	3	✓					VA
Transfer to forming department	Forklift	50	2	1		✓				NNVA
Rolling process	Rolling machine		8	2	✓					VA
Pressing process	Pressing machine		20	2	✓					VA
Transfer to components department	Forklift	20	2	1		✓				NNVA
Fitting process	Welding machine		33	2	✓					VA
Welding process	Welding machine		17	4	✓					VA
Material cooling process			4	1					✓	NVA
Final component inspection			3	1			✓			VA
Transfer to assembling department	Forklift	50	2	1		✓				NNVA
Fitting process	Welding machine		200	3	✓					VA
Welding process	Welding machine		130	6	✓					VA
Transfer to finishing area	Forklift	20	2	1		✓				NNVA
Polishing	Grinding machine		100	2	✓					VA
Accessory installation	Screws, packaging, etc.		8	2	✓					VA
Hydrotesting			24	1	✓					VA
Overall inspection			24	1			✓			VA
Packing process			8	2	✓					VA
Transfer of tanks to shipping warehouse	Forklift		3	1				✓		NNVA

Note: One working day for 8 h

Table 6 *Number and time proportion of each activity*

Activity	QTY (People)	Time (Hours)	Percentage (%)	VA	NNVA	NVA
Operation	16	628	92	628		
Transportation	6	18	3		6	
Inspection	3	30	4	30		
Storage	1	3	0.4		3	
Delay	1	4	0.6			4
Total	27	683	100	658	9	4

Table 5 shows that all activities in the tank manufacturing process are classified into five categories: Operation, Transportation, Inspection, Storage, and Delay. There are 27 activities in total, 16 of which belong to the Operations category, 6 in Transportation, 3 in Inspection, and one each in the Storage and Delay categories. Moreover, Table 5 also categorizes these activities based on their added value, namely Value-Added (VA), Necessary Non-Value-Added (NNVA), and Non-Value-Added (NVA) activities. This grouping has been proven to facilitate the evaluation of production efficiency and follows previous research findings. Value-added (VA) activities comprise 92% of the process, consisting of core operations such as cutting, machining, welding, and assembly.

[7] In explaining the importance of maximizing VA activities to improve overall manufacturing performance, activities that are necessary but do not add value (NNVA) account for 3% of the process, especially those involving transportation and handling of materials between departments. Although these activities do not directly add value to the product, they are crucial to ensure production flow. Efficient transportation contributes to production delays, and strategic layout planning helps reduce unnecessary movement [8]. Non-value-added (NVA) activities, although minimal at 0.6%, include unnecessary delays and storage, which can hinder efficiency. According to [9], lean manufacturing strives to eliminate these activities through process optimization, ensuring a smoother and more efficient production workflow. The balance of VA, NNVA, and NVA activities in the MTO process at PT. X aligns with industry benchmarks, as outlined in [10], and emphasizes that lean principles should minimize NVA and NNVA while ensuring optimal VA allocation [20].

3.6 Identification of Waste with Five Whys

To improve production efficiency, a comprehensive analysis was conducted to identify critical areas of wastage. This was conducted by collecting data through various methods, including detailed interviews and questionnaires with personnel involved in the production cycle. In this section, the causes of waste, such as waiting, defective parts, and over-processing, were identified based on the results of the interviews and questionnaires, as shown in Figure 6. By determining these specific areas, targeted interventions can be developed to address and reduce these inefficiencies, thereby improving the production process. Based on the findings of prior research, targeted interventions have been developed to address wastage and inefficiencies:

1. Material Procurement Optimization – To reduce waiting times, real-time inventory tracking systems and automated procurement processes should be implemented. [23] found that integrating value stream mapping with inventory control reduces procurement delays by up to 30%.
2. Quality Control Enhancements – Defective parts can be minimized by implementing total productive maintenance (TPM) and regular operator training. [18] emphasized that a structured defect-prevention strategy significantly improves product quality in MTO manufacturing.
3. Process Standardization – Redundant processing can be mitigated by improving work instructions and establishing clear standard operating procedures (SOPs). [32] demonstrated that incorporating Industry 4.0 digital twins into process control significantly reduces unnecessary rework in lean systems.
4. Production Flow Optimization – The strategic reconfiguration of the factory layout and adoption of just-in-time (JIT) scheduling will enhance efficiency. [14] confirmed that linking lean principles with Industry 4.0 automation can improve production efficiency by 20-40%.

These targeted interventions align with lean manufacturing best practices, ensuring PT. X enhances efficiency, minimizes waste, and improves overall production output.

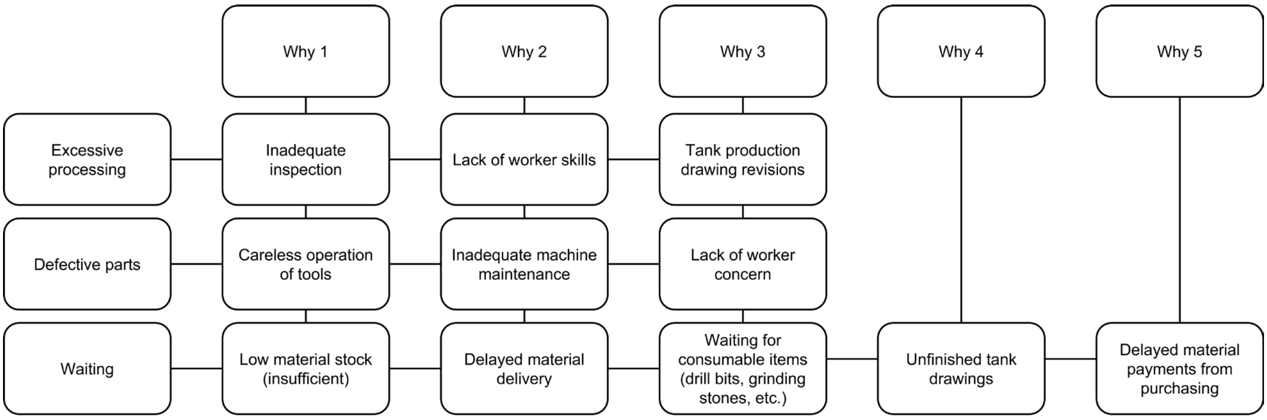

Fig. 6 *Identifying all waste with five whys*

3.7 Analysis of Seven Waste Identification

Based on the questionnaire results, seven wastes were distributed to parties directly related to tank production, with a maximum score of 10 (occurs frequently) and a minimum score of 0 (never occurs). The questionnaire revealed the top three wastes: waiting, defective parts, and over-processing. Waiting had a total score of 32 (20%). This is caused by delays in the material purchasing process in the purchasing department, which causes a halt in the subsequent production process. This became a big problem at PT X because the tank production process uses the MTO system.

Defective components reached a total score of 27 (18%). The cause of this waste is the movement of material from one process to another, which requires careful handling to avoid defects. Lack of machine maintenance also affects the occurrence of defects, such as the lack of table roller maintenance on the welding machine. Meanwhile, excess processing scored 24 points (15%) and occurred in several departments. Waste mainly occurs in the assembly department, such as repeated tank polishing due to its uneven surface. Thus, limited employee work skills can result in poor quality.

3.8 Root Cause Analysis

Interviews have been conducted with PT X's supervisors, foremen, and production managers regarding suggestions for reducing waste. The results obtained from the interviews can be grouped and sorted based on the highest improvement recommendations for each type of waste. It shows that the three most common recommendations are on waste waiting. In the first rank, there is a recommendation to pay for materials and consumables on time so the production process will not be disrupted due to the lack of raw materials. This is followed by a recommendation to make faster and more accurate drawings so that the assembly department can assemble the tank faster. For more details, the ranking for improvement recommendations to overcome waste can be seen in Table 7.

Table 7 *Ranking of improvement recommendations*

Type of Waste	Recommendation for Improvement	Ranking	Reason
Waiting	Faster and more accurate drawing creation.	2	Accelerating tank assembly in the assembling department.
	Timely payment for materials and consumables.	1	In this way, production processes are not hindered by material shortages.
	Conducting stocktaking.	3	Stock checks can provide input to purchasing for material purchases.
Defective parts	Routine machine maintenance.	5	Reducing material scratches during the production process.
	Providing employee training.	4	Skill training and accountability can reduce product defects.
Excessive processing	Creating inspection checklists.	6	Checklists can help improve inspector precision.

3.9 Value Stream Analysis with VSM

Problems in the tank production process at PT X can be identified using physical VSM and information flow methods. These problems can be in the form of delays in material arrival, as purchasing must know which materials to prioritize. Waste occurs because all departments must be stopped during this process. This should be evaluated every six months. The other problem is related to regular worker training, where skills upgrading training should be conducted. By improving skills, waste such as defective products can be avoided, and the production process is expected to become faster. Moreover, warehouse distance and the location of the material warehouse far from the workshop cause delays in material placement and a less organized schedule. Slow design creation also hampers the production process. Irregular machine maintenance also caused unexpected damage. Although the maintenance department has repaired damaged machines, it has yet to perform routine maintenance. The results of the proposed improvements obtained through interviews and brainstorming with relevant parties were used to map the future conditions, as shown in Figure 7.

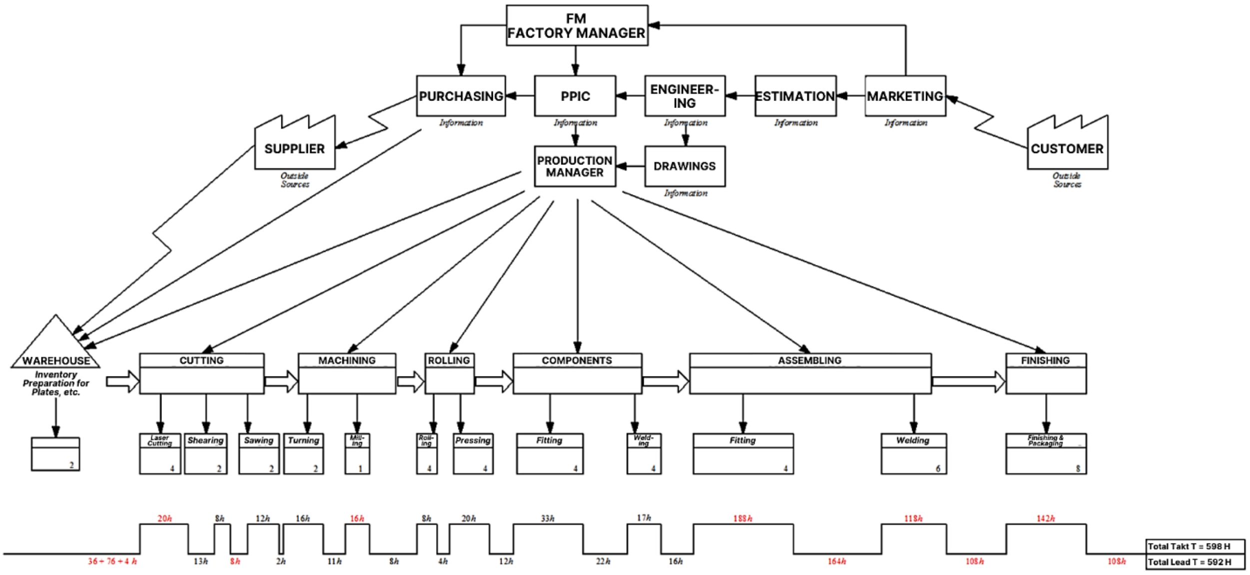

Fig. 7 *Future state mapping of production process of PT. X*

3.10 Process Activity Mapping (Future State)

Several industrial engineers often use PAM to plot all activities in detail to eliminate waste, inconsistency, and irrationality in the work area, improve performance efficiency through quality improvement, speed up processes, and reduce costs. PAM depicts the physical and information flow, time taken for each activity, travel distance, and inventory measurement at each production stage [32]. It can be divided into five groups: operation, transportation, inventory, inspection, and delay. Table 8 displays the activity mapping process with the proposed improvements in mind. The improved work is bolded in the table to highlight the more efficient steps in the future state. Table 9 shows the longest operating time is 59.4 hours or 94% of the total operating time. The next least time is the inspection activity (3.5%). The shortest time was storage (0.5%), which was completed on time. A value-added ratio of 98% was obtained.

Table 8 *PAM future state*

Activities	Machine/ Tool	Distance (Meters)	Time (Hours)	QTY (People)	Activities					VA/NVA/ NNVA
					O	T	I	S	D	
Material delivery from warehouse to cutting department	**Forklift**	**50**	**6**	**1**		✓				**NNVA**
Cutting top cone & ballfront plates	Laser cutting machine		24	4	✓					VA
Cutting shell plates	Shearing machine		8	2	✓					VA
Cutting round bars	Sawing machine		12	2	✓					VA
Dimensional inspection of cuts			3	1			✓			VA
Transfer to machining department	**Forklift**	**20**	**1.5**	**1**		✓				**NNVA**
Turning of cut materials	Lathe machine		16	2	✓					VA
Flange forming	Milling machine		12	1	✓					VA
Transfer to forming department	**Forklift**	**50**	**1.5**	**1**		✓				**NNVA**
Rolling process	Rolling machine		8	2	✓					VA
Pressing process	Pressing machine		20	2	✓					VA
Transfer to components department	**Forklift**	**20**	**1.5**	**1**		✓				**NNVA**
Fitting process	Welding machine		33	2	✓					VA
Welding process	Welding machine		17	4	✓					VA
Final component inspection			3	1			✓			VA
Transfer to assembling department	Forklift	50	2	1		✓				NNVA
Fitting process	**Welding machine**		**188**	**3**	✓					**VA**
Welding process	**Welding machine**		**118**	**6**	✓					**VA**
Transfer to finishing area	**Forklift**	**20**	**1.5**	**1**		✓				**NNVA**
Polishing	Grinding machine		100	2	✓					VA
Accessory installation	**Screws, packaging, etc.**		**6**	**2**	✓					**VA**
Hydrotesting			24	1	✓					VA
Overall inspection			**16**	**1**			✓			**VA**
Packing process			8	2	✓					VA
Transfer of tanks to shipping warehouse	Forklift		3	1				✓		NNVA

Table 9 *Number and time proportion of each activity after improvement*

Activity	QTY (People)	Time (Hours)	Percentage (%)	VA	NNVA	NVA
Operation	15	594	94	594		
Transportation	6	14	2		14	
Inspection	3	22	3.5	30		
Storage	1	3	0.5		3	
Delay						
Total	25	633	100	624	17	0

4. Conclusion

The findings show that the production system mapping at PT. X implements a make-to-order system that designs and manufactures tanks according to customer requirements. The system consists of information and physical flow with a lead time of 646.5 hours and a value-added ratio of 96%. Research revealed that the most common types of waste were waiting (20%), defective parts (18%), and over-processing (15%). The results of interviews and questionnaires indicated that sourcing materials on time can reduce waste, maintaining machines can reduce defective parts, and careful inspection can reduce overprocessing. Interviews and brainstorming with relevant parties after the proposed improvements imply that the reduction in delay time achieves a value-added ratio of 98%, and there is no delay, indicating improved operational efficiency. This study focuses specifically on the manufacture of tanks at PT. X, which may limit the generalizability of the findings to other types of manufacturing processes or industries.

Future research should explore the effectiveness of lean implementation policies on productivity and company development in different manufacturing contexts. Additionally, further studies should focus on incorporating automation technologies to enhance process efficiency, integrating Industry 4.0 to improve data-driven decision-making and production optimization, implementing environmental monitoring to ensure sustainable manufacturing practices, and developing employee skillsets to facilitate adaptability to new technologies and methodologies. This broader approach could provide deeper insights into the impact of lean practices across various sectors and contribute to more comprehensive strategies for operational improvement and long-term growth.

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Conflict of Interest

The authors state that there is no conflict of interest in this article.

Author Contribution

The authors confirm their contribution to the paper as follows: ***study conception and design:*** *Rini Oktavera, Dimas Aditya Yudistira;* ***data collection:*** *Dimas Aditya Yudistira, IGA Sri Deviyanti;* ***analysis and interpretation of results:*** *Dimas Aditya Yudistira, IGA Sri Deviyanti, Moch Ainul Fais;* ***draft manuscript preparation:*** *Rini Oktavera, Dimas Aditya Yudistira, IGA Sri Deviyanti, Moch Ainul Fais. All authors reviewed the results and approved the final version of the manuscript.*

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