

Improving Process Cycle Efficiency in SNI-Certified Tire Testing Through Lean Manufacturing and Value Stream Mapping Approach

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Abstract: This study aims to improve the efficiency of the tire testing process at PT XYZ through the application of the Lean Manufacturing approach using the Value Stream Mapping (VSM) method. A quantitative descriptive approach with a case study was employed. Data were collected through direct observation, interviews, and documentation of the tire testing process. The current state mapping revealed the presence of non-value-added activities that led to time and resource waste. After implementing improvements using the future state map, the efficiency of the testing process increased by 38%. These findings indicate that VSM is effective in identifying and eliminating waste, thereby enhancing process efficiency. This research provides practical contributions to testing laboratories and supports the achievement of SDG 9 by improving the quality of testing infrastructure.

Keywords: Lean Manufacturing, Value Stream Mapping, Process Efficiency, Tire Testing, SDG 9

1. Introduction

Sustainability has become a central theme in the development of global industries, including the automotive sector. In this context, improving process efficiency, reducing waste, and enhancing product safety are critical factors that not only contribute to industrial competitiveness but also support the achievement of Sustainable Development Goals (SDGs), particularly SDG 9, which promotes resilient infrastructure, sustainable industrialization, and innovation (UNIDO, 2022).

Despite rapid technological advancements in the automotive industry such as the widespread adoption of electric vehicles and the integration of digital and autonomous technologies tires remain a critical component that directly influences safety, fuel efficiency, and driving comfort. Studies have shown that poor tire conditions increase accident risks by up to 30%, while incorrect tire pressure can lead to 2–4% higher fuel consumption (Sari & Nugroho, 2022).

In Indonesia, tire certification is governed by the Indonesian National Standard (SNI), which mandates rigorous testing for safety and performance parameters such as endurance, grip, heat resistance, and wear. These processes play an essential role in maintaining product quality, consumer safety, and national industrial competitiveness (Rahmawati et al., 2023).

PT XYZ is a nationally accredited institution engaged in testing and certification services, with specialized facilities for tire testing. However, between 2023 and 2024, the company experienced a noticeable decline in service demand, largely due to extended testing lead times. An internal customer satisfaction survey revealed that prolonged testing durations have negatively impacted client trust and production timelines, resulting in reduced service uptake.

To address these challenges, this study proposes the implementation of Lean Manufacturing supported by the Value Stream Mapping (VSM) method. Lean Manufacturing is a systematic approach that aims to eliminate non-value-added activities (waste), improve process flow, and maximize value for customers (Womack & Jones, 2003). VSM, a core tool in lean practices, enables organizations to visualize and analyze their processes, identify

inefficiencies, and design future-state improvements (Rother & Shook, 2003).

Previous empirical studies have demonstrated the effectiveness of VSM in reducing process time and enhancing operational performance. For example, Jacob and Joseph (2014) reported that applying VSM in a tire manufacturing context reduced throughput time and increased workflow efficiency. Similarly, Yuliana et al. (2020) confirmed the relevance of VSM in laboratory testing environments, showing significant improvements in turnaround time and service quality.

Accordingly, this research seeks to evaluate the current tire testing process at PT XYZ, identify process waste, and propose structured improvements using VSM. The findings are expected to contribute practical insights for PT XYZ and offer a replicable model for other testing laboratories aiming to enhance efficiency and align with sustainability goals.

2. Literature Review

2.1 Lean Manufacturing and Value Stream Mapping (VSM)

Lean Manufacturing is a managerial approach that focuses on operational efficiency by reducing non-value-added activities and improving process flow to maximize customer value. Originating from the Toyota Production System, Lean emphasizes delivering the highest value with the least waste (Womack & Jones, 2003). In recent years, Lean has been widely adopted not only in manufacturing sectors but also in service and laboratory environments to enhance service performance.

A core tool in Lean is Value Stream Mapping (VSM), a visual technique used to map material and information flows throughout the process. VSM helps identify bottlenecks, inefficiencies, and redundant steps, allowing organizations to redesign workflows strategically (Rother & Shook, 2003). Jacob and Joseph (2014) applied VSM in the tire manufacturing industry and successfully reduced cycle time and improved process throughput. Similarly, Tito et al. (2023), in their review of 42 studies, concluded that VSM is effective across various industries including automotive, food, textile, and laboratory services.

2.2 The Seven Types of Waste

The concept of the seven types of waste was introduced by Taiichi Ohno (1988) and forms the foundation of Lean philosophy. These wastes include:

1. Overproduction,
2. Waiting,
3. Transportation,
4. Overprocessing,
5. Inventory,
6. Motion, and
7. Defects.

These types of waste often remain hidden in daily routines, especially in administrative and testing activities. In laboratory environments, repeated manual data entry, multi-layered documentation, and delayed verifications can represent forms of overprocessing and motion. Sari and Nugroho (2022) observed that waiting and motion were the most dominant types of waste in automotive testing laboratories in Indonesia. VSM enables systematic identification and elimination of such waste through process redesign.

2.3 Tire Testing and Its Relevance to Sustainability

Tires are critical components in any vehicle, as they are the only part in contact with the road surface. Their functions include bearing loads, enabling movement, ensuring stability, and affecting fuel efficiency. Thus, tire testing is crucial to ensure safety and performance standards. In Indonesia, tire certification is regulated by the Indonesian National Standard (SNI), which includes tests for grip, heat resistance, wear, and durability.

Gokilakrishnan et al. (2023) demonstrated that the implementation of Lean Six Sigma in tire manufacturing significantly improved process capability (Cpk) from 0.94 to 2.66 and reduced process variation. Such results show the relevance of integrating Lean tools into the tire industry for quality and efficiency improvements.

Tire testing also supports the achievement of Sustainable Development Goal 9 (SDG 9), which emphasizes resilient infrastructure, sustainable industrialization, and innovation (UNIDO, 2022). Efficient and accurate testing contributes to national industrial competitiveness and accelerates the certification of safe and sustainable products.

2.4 Lean Implementation in Automotive and Laboratory Environments

Numerous studies confirm the success of Lean implementation across sectors. Aripin et al. (2025) highlighted that sustainable Lean success requires not only tools, but also effective leadership, technological integration, and a collaborative work culture. Rifqi et al. (2021) found that the DMAIC (Define–Measure–Analyze–Improve–Control) framework under Lean significantly improved process flow and delivered tangible financial benefits in manufacturing.

In laboratory contexts, Lean applications though less common show great potential. Yuliana et al. (2020) applied VSM in a calibration laboratory and achieved up to 40% reduction in service lead time. This finding is highly relevant to tire testing labs such as PT XYZ, where lengthy test cycles have been identified as a key customer complaint.

Based on these foundations, the present study seeks to address the efficiency gap in tire testing operations by applying Lean principles and VSM, which have been empirically proven to enhance performance and support sustainable industrial operations.

In this study, the conceptual framework is used to explain the process of evaluating the provision of tire testing units. The conceptual framework is illustrated in the figure below.

Condition 	<ol style="list-style-type: none"> 1. Decline in demand for tire testing services 2. Numerous customer complaints related to testing lead time
Input 	<ol style="list-style-type: none"> 1. Human resources 2. Testing machines 3. Tire product samples
Process 	<ol style="list-style-type: none"> 1. Mapping the current condition (<i>current state</i>) 2. Analyzing the types of waste 3. Mapping the future condition (<i>future state</i>) 4. Identifying waste and proposing improvements
Output	<ol style="list-style-type: none"> 1. Increased productivity of the tire testing process

Figure 1. Conceptual Framework

3. Research Methodology

3.1 Research Design

This study employed a **descriptive quantitative approach** using a **case study method** at PT XYZ's tire testing laboratory. The purpose of this research design is to describe the actual conditions of the tire testing process and evaluate the impact of Lean Manufacturing implementation using Value Stream Mapping (VSM) on process efficiency. This design has been effectively used in similar studies to identify time-related waste and performance gaps in manufacturing and testing environments (Damanik et al., 2020).

3.2 Variables and Operational Definitions

The variables in this study and their operational definitions are as follows:

Table 1. Operational Definitions and Indicators of Research Variables

Variable	Definition	Operational Indicators
Lean Manufacturing	A systematic approach to eliminate waste and improve value	Application of lean principles, waste identification, process improvement actions
Value Stream Mapping (VSM)	A visual tool to map process and information flow	Current state map, future state map, identification of VA and NVA activities
Process Efficiency	The level of effectiveness in the testing process	Cycle time, number of non-value-added activities, output per time unit
Cycle Time	Total time required to complete one full testing process	Lead time, waiting time, effective process time
Test Quality	Accuracy and consistency of testing results	Number of re-tests, compliance with SNI standards, result validity

3.3 Population and Sample

The **population** in this study consists of all tire testing processes conducted at PT XYZ between January and June 2025. The **sample** was selected using **purposive sampling**, focusing on high-volume tire tests with the longest cycle times. This technique is chosen to target processes with the highest potential for waste, as recommended in previous lean studies (Arum, 2017).

3.4 Data Collection Methods

Data were collected using multiple techniques to ensure accuracy and triangulation, including:

1. **Direct observation** of the tire testing workflow
2. **Structured interviews** with laboratory technicians and operational managers
3. **Documentation** review such as testing time logs, historical performance data, and internal reports
4. **VSM mapping** to develop both current state and future state process diagrams

3.5 Data Analysis Procedures

The data analysis followed the structured steps below:

1. **Mapping the Current State** using VSM to identify non-value-added activities
2. **Calculating Process Cycle Efficiency (PCE)** as:

$$PCE = \frac{\text{Value-Added Time}}{\text{Total Cycle Time}} \times 100\%$$

3. **Identifying Waste** using the 5 Why method to determine root causes

4. **Designing the Future State Map** based on the 5W1H approach to propose improvements
5. **Comparative Analysis** of the process before and after the lean implementation, focusing on cycle time reduction, waste elimination, and efficiency improvement
6. **Visualization** of results using process charts, tables, and VSM diagrams

4. Results and Discussion

4.1 Current State Process Mapping

Initial data collection and process observation at PT XYZ's tire testing laboratory revealed that the total cycle time for tire testing, from sample reception to final report submission, was 7,864 minutes. Of this total, only 234 minutes were categorized as value-added activities (VA), while the remaining 7,630 minutes consisted of non-value-added (NVA) activities, such as waiting, manual recording, data transfer, and approvals.

These findings were visualized in a current state map, which clearly showed excessive time spent on repetitive administrative tasks and non-automated reporting processes. The calculated Process Cycle Efficiency (PCE) before improvement was only 2.97%.

This is consistent with Sari & Nugroho (2022), who identified similar waste patterns especially *waiting* and *motion* in automotive laboratory environments.

4.2 Process Activity Mapping and Waste Identification

Detailed process activity mapping (PAM) was conducted, confirming that most activities were either non-value-added or necessary but inefficient. For example:

1. Inputting customer and sample data was done manually twice.
2. Tire mounting used conventional tools, consuming excessive time and effort.
3. Testing results were recorded on paper, then re-entered into Excel, and then formatted again in Word for final reports.

The types of waste identified were categorized according to Ohno's (1988) seven wastes, with the most prominent being:

1. **Overprocessing** (due to redundant data handling),
2. **Motion** (manual tire handling),
3. **Waiting** (delayed report approval and dispatch).

4.3 Root Cause Analysis and Improvements

Using the 5 Why method (Serrat, 2009), root causes were identified:

1. Lack of integrated data tools
2. No digital form automation
3. No tire changer tool
4. Delayed management response in final verification

To address these, the company implemented four key improvements:

1. Integrated database system using Microsoft List
2. Acquisition of tire changer machine
3. Automation of reporting via Excel formulas
4. Internal policy mandating report submission within 1x24 hours

These improvements were visualized in a future state map, and waste was significantly reduced.

4.4 Process Efficiency After Improvements

Post-improvement measurements showed a reduction in total process time to 4,824 minutes, with value-added time remaining at 234 minutes. This resulted in a new PCE of 4.85%, and a time saving of 3,040 minutes, or 38.6% improvement in overall efficiency.

Table 2. Comparison of Process Performance Before and After VSM Implementation

Indicator	Before	After	Improvement
Total Process Time (min)	7,864	4,824	↓ 3,040 minutes
Value-Added Time (min)	234	234	No change
Process Cycle Efficiency	2.97%	4.85%	↑ +1.88%
Lead Time for Report	2–3 days	≤ 24 hours	Faster and standardized

After implementing VSM-based improvements, the process cycle time was reduced from 7,864 minutes to 4,824 minutes, resulting in a time efficiency improvement of 3,040 minutes or approximately 38.6%. Moreover, the Process Cycle Efficiency (PCE) improved from 2.97% to 4.85%, indicating a significant reduction in non-value-added activities. This finding is strongly aligned with the results of Jacob & Joseph (2014), who found that VSM implementation in tire manufacturing led to a reduction in throughput time and improved overall workflow efficiency. Their study emphasized that visualizing the process through mapping exposed bottlenecks and duplicative steps that could be eliminated or simplified. Similarly, Mantiri et al. (2023) demonstrated that the application of Lean tools, especially VSM, in production processes led to efficiency gains of up to 30% in industrial environments by eliminating motion, waiting, and overprocessing. These same types of waste were prevalent in PT XYZ’s process prior to improvement. In addition, the study supports the conceptual model of Lean proposed by Womack & Jones (2003), which emphasizes continuous flow, waste elimination, and customer value. The implementation of digital tools such as Microsoft Excel automation and Microsoft List integration contributed to reducing overprocessing and manual motion both of which were prominent forms of waste before intervention. The results also resonate with Yuliana et al. (2020), who showed that applying VSM in calibration laboratories helped reduce lead time and improved service delivery. Like PT XYZ, their case involved reducing time spent on documentation and approvals by standardizing procedures and automating workflows.

Theoretically, this study confirms the relevance of Taiichi Ohno’s (1988) concept of the Seven Wastes (*muda*) in a non-manufacturing environment such as a testing laboratory. Although Lean principles originated in production settings, their applicability to service and laboratory operations is now well supported. Practically, this study offers concrete evidence that even minor process innovations such as automation of test data entry or updating internal reporting policies can yield major improvements in performance. The internal policy change requiring report approval within 24 hours was particularly effective in reducing waiting time. The results also contribute to SDG 9 (Industry, Innovation, and Infrastructure) by showing how targeted improvements in industrial testing infrastructure can strengthen national competitiveness and sustainability.

5. Conclusion & Recommendations

5.1 Conclusion

This study aimed to improve the efficiency of the tire testing process at PT XYZ’s laboratory through the application of Lean Manufacturing using the Value Stream Mapping (VSM) method. Based on the analysis and discussion, the following conclusions are drawn:

1. The current state of the tire testing process showed a high number of non-value-added activities especially in the form of overprocessing, motion, and waiting which contributed to long cycle times and low efficiency.
2. The implementation of VSM successfully mapped the entire process flow and identified major sources of waste. Improvements included the procurement of a tire changer machine, the development of an

integrated database system, the use of automated reporting tools, and a new internal policy requiring test report submission within 24 hours.

3. Process efficiency improved significantly, as demonstrated by the reduction in total process time from 7,864 minutes to 4,824 minutes and the increase in Process Cycle Efficiency (PCE) from 2.97% to 4.85%. These findings confirm that Lean and VSM are effective approaches when applied to laboratory testing environments.

5.2 Recommendations

Based on the research findings, the following recommendations are proposed:

1. Institutionalize Lean practices across operations

PT XYZ should integrate Lean principles into its overall quality management system and operational standard procedures, beyond just the tire testing division.

2. Expand digitalization of administrative processes

To further eliminate waste related to waiting and motion, it is recommended that the company broaden the use of digital systems and automation tools in data recording, reporting, and result management workflows.

3. Conduct regular monitoring and evaluations

Continuous evaluation of the tire testing process is necessary to ensure the long-term effectiveness of improvements and to detect and mitigate emerging inefficiencies.

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