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Implementing Lean Manufacturing Using Value Stream Mapping for Automotive Maintenance Efficiency

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Abstract. Transportation is very vital to society these days as it provides mobility and maintains economic growth. In January 2022, Indonesia was Southeast Asia's largest auto market. PT Blue Bird Tbk., one of the largest car rental and transportation companies in Indonesia, faced very critical problems involving workshop efficiency and customer satisfaction. This study will optimize the car repair process via the implementation of Lean Manufacturing principles with the Digital Value Stream Mapping (DVSM) technique. Identification of waste was conducted via Waste Assessment Model (WAM) and a directed questionnaire, wherein the three major types of waste were overproduction (21.07%), defects (16.89%), and waiting (16.65%). For these, two VALSAT tools—Process Activity Mapping and Supply Chain Response Matrix—were employed. Simulation using Arena software was performed to validate the proposed improvements. Upon implementation, the lead time for car repair decreased from 12.887 seconds to 12.203 seconds, a decrease of 5.3%. The research indicates that lean tools can be effectively applied in car maintenance services, particularly in developing countries, to increase operating efficiency and service performance.

Keywords: value stream mapping, lead time, lean manufacturing, VALSAT, automotive service, repair optimization, lean service improvement

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1. Introduction

Transportation plays a strategic role in enhancing public well-being and driving the economic development of a country [1]. Investment in transportation infrastructure has multiplier effects on labor mobility, product distribution, and overall industrial productivity [2,3]. In the case of Southeast Asia, Indonesia has seen considerable development of the automotive and transportation services sectors, e.g., rising vehicle sales and growing car rental enterprises [4,5].

PT Blue Bird Tbk, which is one of Indonesia's largest players in the transport service industry, offers several services such as taxis, buses, and car rental [6]. However, company statistics in 2023 indicated that 69% of customer complaints were about cars, and 40% of these were particularly linked to workshop performance [7]. 224 minutes on average is less than customers' expectations of getting the job done within 180 minutes. This repair time difference and service overload reflect inefficiencies that have a detrimental impact on customer satisfaction [7].

At the international level, lean manufacturing in automotive services has been proven beneficial in identifying and reducing non-value-added activities through scientifically sound approaches such as Value Stream Mapping (VSM) [8]. However, research on the application of lean methods to vehicle maintenance services, especially in developing countries, is limited. The existing literature has mainly focused on large-scale industrial sectors, whereas lean interventions in the environments of automotive services are less researched.

This study attempts to bridge that gap in knowledge by investigating the means through which Lean principles can be applied to improve the efficiency of motor vehicle repair services, particularly in the application of VSM. This study is not only relevant to the Indonesian automotive service sector but also contributes to the broader debate on lean service efficiency improvement in the developing world where there are such constraints in resources and customer needs.

2. Literature Review

Value Stream Mapping (VSM) method, consisting of three major phases, was utilized in a case study of the iron and steel industry in South Africa as a management tool to spot, visualize, and assess industrial waste [8]. The first phase deals with data gathering and verification on waste generation and flow. Waste identification, fraction mapping, and horizontal and vertical performance analysis are included in the second phase. The final step is the mapping of both current and future states. By the end of the first year of implementation, waste had been reduced by 28%, while the cost of waste disposal dropped by 45%, surpassing the initial 5% annual waste reduction target [9]. VSM primarily endeavors to map the general flow of material and information, and most benefits are grounded in specific organizational objectives. They are enhanced customer satisfaction, reduced service cycle times, cost saving, increased profitability, improved service quality, competitive advantage, and the design of more efficient and effective processes [9].

Lean thinking emphasizes process streamlining and effective improvement, extensively applied in manufacturing and service sectors to attain organizational goals. Fundamentally, a lean system relies on some key principles: creating value from a customer's perspective, value stream mapping of all products or services, elimination of wastages in all operations of the stream, use of a pull system, and constant improvement (Vincent Gaspersz, 2007). All these principles combined go towards reducing inefficiencies and enhancing overall organizational efficiency.

Waste Assessment Model (WAM) was brought forth to make the identification and elimination of waste possible. WAM addresses seven types of waste—Overproduction, Processing, Inventory, Transportation, Defects, Waiting, and Motion. A Waste Assessment Questionnaire consisting of 68 pertinent items is utilized to detect and quantify waste that occurs along the production line [10]. Under such a paradigm, a value stream has been defined as a sequence of distinctive activities in the supply chain required to design, order, and deliver a given product or service [11]. Value Stream Mapping (VSM), including Current State Mapping and Future State Mapping, is a visual tool to map and analyze such processes. Seven supporting tools by Peter Hines and Nick Rich (1997) complement the analysis in graphing the collective structure of the value stream.

Simulation software is utilized to manipulate and process the data needed to facilitate the improvement of VSM effectiveness and minimize the risk of errors. Computer-based VSM simulates various control systems, such as push and pull, to facilitate improved value flow efficiency. The ultimate objective is not merely the elimination of waste but the provision of products and services to customers in the shortest possible time and minimum cost. A comparative illustration of digital and conventional VSM processes is shown in Figure 1 [12].

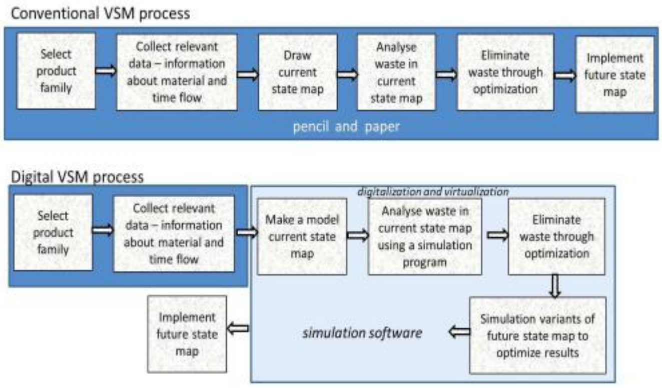

Figure 1. Conventional VSM vs Digital VSM

The application of lean manufacturing in the food industry, specifically in the fisheries sector, has proven to identify non-value-added activities that account for 37.7% of the process time, including excessive inventory, unnecessary motion, and bottlenecks in the filleting process [13]. Similarly, in the small-scale heating business, lean implementation has resulted in dramatic improvement, such as reducing waiting time from 17.5 to 11 days, value-added time from 3412 to 2415 seconds, and takt time from 250 to 192 seconds [14]. Apart from this, SVSM implementation successfully eliminated non-value-added time from six major workstations, resulting in a 4% productivity gain and 95% performance rate. This also resulted in cycle time improvement to 451 for small units and 466 for large units [15].

All these results point to the success of lean methods in waste elimination and efficiency enhancement in a wide range of industries. In the wake of this evidence, the research at hand aims to apply Lean and Value Stream Mapping principles to further improve the car workshop repair process within the maintenance department. Computer simulation will be utilized to validate the feasibility and effectiveness of proposed improvements, with the same lean principles applied to optimize the vehicle repair process and improve overall service delivery.

3. Methods

The research framework (Figure 2) is founded on lean manufacturing theory, which is a strategic method of developing a lean industry through elimination or minimization of waste emanating from the production process [16]. The method is designed to enhance efficiency in production, increase productivity, and improve the delivery of customer services.

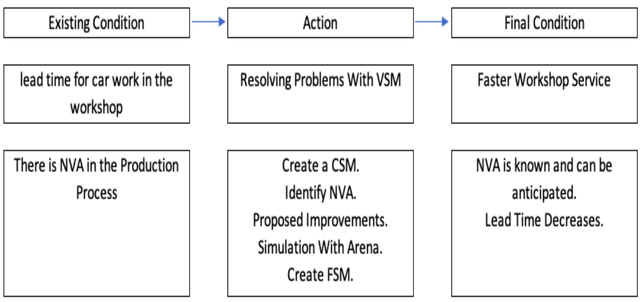

Figure 2. Research Framework

This research employs the Value Stream Mapping (VSM) approach to minimize non-value-added processes in the car repair process. By analyzing inefficiencies in the process, there is an improvement to counteract waste and enhance overall service performance. VSM is a strategic and diagnostic tool employed in enabling visualization of current operations as well as creating more efficient future operations.

As illustrated in the research process (Figure 3), the research begins with field observation and a comprehensive literature review. These are followed by problem definition, and respective data collection. The next is to develop the Current State Mapping for analyzing the current state. This leads to a Future State Mapping being developed and implemented. Finally, the outcomes are tracked in order to conclude and establish whether the recommended improvements were effective.

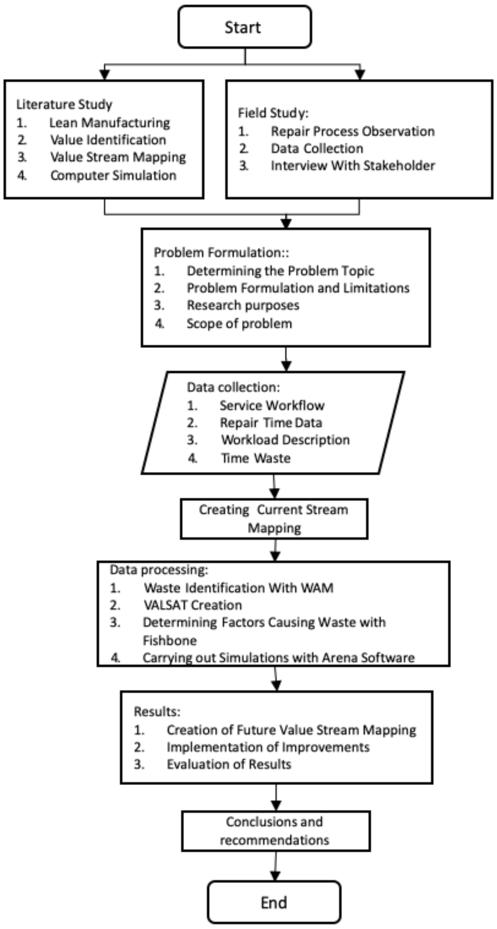

Figure 3. Research Flow

The study employs a lean manufacturing paradigm (Figure 2), which operates to improve performance and customer satisfaction by minimizing waste in service operations [16]. The fundamental methodology is founded upon Value Stream Mapping (VSM), which is utilized to identify, examine, and remove non-value-added (NVA) activities in repairing cars.

3.1. Research Design and Flow

The research process has a formalized flow as indicated by Figure 3. It encompasses field observation, expert interviews, issuance of validated questionnaires, and computer simulation. It has qualitative and quantitative components to be rigor and triangulated.

3.2. Data Collection and Sampling

The data were gathered from two main sources:

- **Direct observation** of PT Blue Bird Tbk's automobile repair workshop.
- **Professional questionnaire** with **the Waste Assessment Questionnaire (WAQ) having 68 items of the Waste Assessment Model (WAM)** [19,22].

The participants were 10 employees of the workshop having at least 3 years of experience. The participants were selected using purposive sampling with domain-specific experience in repair activities.

3.3. Questionnaire Validation

WAQ was formulated based on existing lean literature and translated into Bahasa Indonesia. The content validity was verified by three independent lean practitioners, and construct validity was established through item-total correlation. **Cronbach's alpha** was calculated to verify reliability, and the resulting value of 0.86 showed high internal consistency.

3.4. Data Analysis and Tool Selection

After calculating waste type weights through WAQ, two analysis tools were selected using the **VALSAT** method [23]:

- **Process Activity Mapping (PAM**) to examine time distributions for value-added and non-value-added activities.
- **Supply Chain Response Matrix (SCRM**) to analyze lead time, stock flow, and responsiveness of processes along the repair service chain.

These tools were chosen due to their relevance to waste types discovered, according to guidelines proposed by Hines and Rich (1997) and supported by findings in similar service industry studies [13,14].

3.5. Simulation and Assumptions

Simulation modeling was done using **Arena** Software, founded on the following parameters:

- Replication time: 12 hours of service time per day.
- Entity arrival rate: scaled based on historical average (10–15 cars per day).
- Queue behavior: **FIFO (first-in-first-out)** with resource constraints based on actual mechanic number and station repairs.

The simulation was validated by comparison of output metrics to historical repair time data (mean repair time: 224 minutes).

3.6. Mapping and Evaluation

Two types of VSM maps were produced:

- **Current State VSM:** illustrating the baseline process flow and wastes identified.
- **Future State VSM:** redesigned based on improvement proposals and simulation results.

Following simulation, performance metrics such as lead time, process time, and service capacity were benchmarked against those in previous literature [8,14,15].

4. Results and Discussion

4.1. Value Stream Mapping Analysis

Value Stream Mapping (VSM) has been utilized in a bid to visualize the existing state of the car repair process (Figure 4). The mapping revealed the presence of redundant activities, delays, and too much idle time in some stages. There were some non-value-added (NVA) activities that resulted in wastage of time and resources.

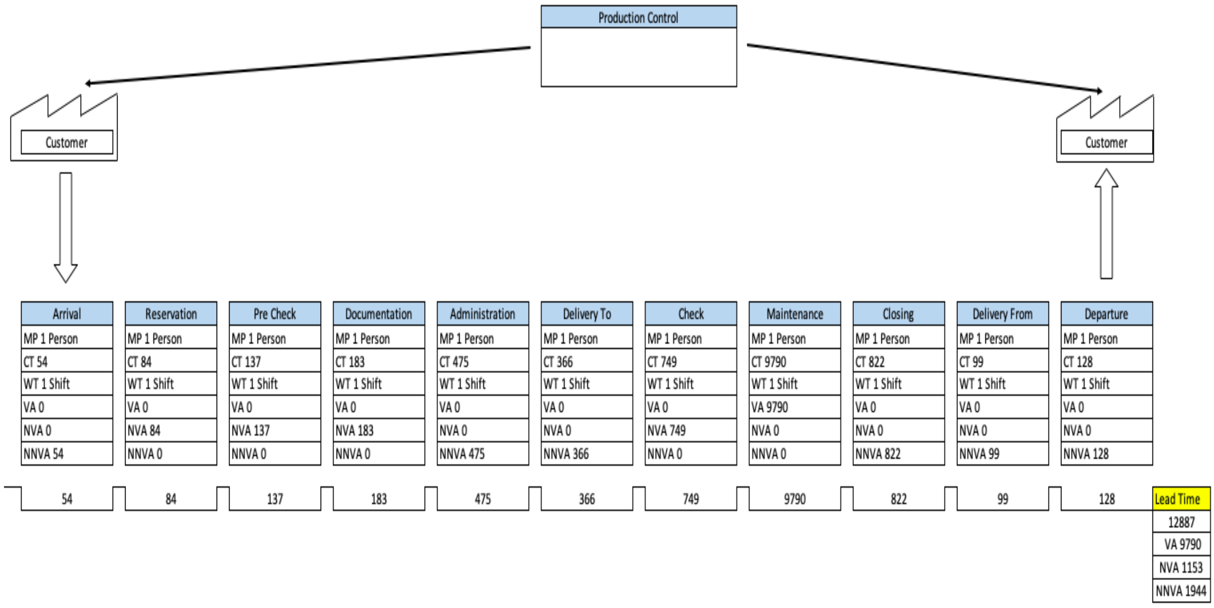

Figure 4. Current State Value Stream Mapping

4.2. Waste Assessment and Prioritization

With the assistance of the Waste Assessment Model (WAM), waste categories were separated and ranked. The most dominant categories of waste have been determined to be overproduction (21.07%), defect (16.89%), and waiting (16.65%) from the Waste Relationship Matrix (WRM) (Table 1) and Waste Assessment Questionnaire (WAQ) (Table 2).

Table 1. Waste Relationship Matrix

F/T	W	P	T	M	D	I	O	Score	%
W	10	0	0	0	6	4	8	28	12%
P	8	10	0	8	8	4	8	46	19%
T	8	0	10	6	2	2	4	32	13%
M	10	8	0	10	2	2	0	32	13%
D	10	0	2	8	10	2	10	42	18%
I	0	0	2	2	2	10	4	20	8%
O	8	0	2	6	4	8	10	38	16%
Score	54	18	16	40	34	32	44	238	100,0%
%	23%	8%	7%	17%	14%	13%	18%	100%	

Table 2. Waste Assessment Questionnaire Result

	W	P	T	M	D	I	O
Score (Yj)	0,030	0,031	0,018	0,035	0,033	0,072	0,035
Pj Factor	267,86	146,68	89,78	225,12	251,68	112,56	296,00
Yj Final	8,16	4,62	1,62	7,87	8,28	8,13	10,33
Percentage	16,65%	9,43%	3,31%	16,06%	16,89%	16,59%	21,07%
Rank	3	6	7	5	2	4	1

These findings are consistent with Widiwati et al. [18] and Mulyana et al. [19], who identified waiting times and rework as the most important inefficiencies in service-based operations.

4.3. *VALSAT Analysis and Tool Selection*

VALSAT model was applied to identify the most suitable lean tools. From waste-weighting outputs, the top two-ranking tools were Process Activity Mapping (PAM) and Supply Chain Response Matrix (SCRM) (Figure 5).

Figure 5. VALSAT Tool Ranking

PAM analysis showed that value-added time consumed only 76% of the total time, and 24% of the time was utilized on NVA activities (Table 3). The result is in accordance with Zahraee et al. [14], who depicted the same in lean implementations.

Table 3. PAM Analysis Result

No.	Activity	Tools	Distance (Meter)	Time (Second)	Number Of Operator	Operation	Transportation	Inspection	Storage	Delay	VA	NVA	NNVA	Analysis
1	Customers enter the pool and head to the operating room	-	50	54	0					1			1	There is a distance of 50 meters from the car check area to the service room.
2	Operations Officer checks police number data and reservation code	EXCEL	0	84	1	1						1		There was a time wastage of about 84 seconds, from the ideal time of about 60 seconds.
3	Customer Officers check complaints	-	50	137	1			1				1		There is a distance of 50 meters from the service room to the car check area.
4	Customer returns to operating room with car checklist	BASTK	50	183	1			1				1		There is a distance of 50 meters from the car check area to the service room.
5	The Operations Officer makes a SIO for the Quality Control Officer who will take the car to the workshop.	SIO	0	475	1	1							1	There was a lead time of about 475 seconds, from an ideal time of about 300 seconds.
6	Quality Control Officer brings the unit to the workshop	-	180	366	1		1						1	There was a lead time of about 366 seconds, from an ideal time of about 300 seconds.
7	Workshop Officer Checks Repair Plan	BASTK	30	749	1			1				1		-
9	Workshop Officer Making Repairs	SYSTEM SAP	30	9790	2	1					1			There is a potential time delay in the information that the car will be repaired.
10	Workshop Officer Closes Maintenance Order	SYSTEM SAP	30	822	1	1							1	There is a time delay in the information that the car has been repaired.
10	Quality Control Officer takes the completed service unit to be given to the Customer.	-	180	99	1		1						1	There is a distance of 50 meters from the car check area to the service room.
11	Customer exit Pool	-	50	128	0					1			1	-
				12887		4	2	3	0	2	1	4	6	
						36%	18%	27%	0%	18%	9%	36%	55%	
						11171	465	1069	0	182	9790	1153	1944	
						87%	4%	8%	0%	1%	76%	9%	15%	

SCRM analysis revealed high holding times of materials in the system, especially in the process of parts supply and queues for repairs (Figure 6), which are indicative of poor inventory control and process slack.

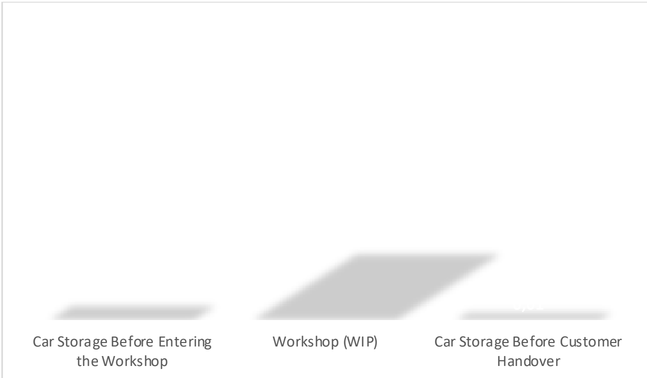

Figure 6. Days Physical Stock from

4.4 Simulation-Based Evaluation

Simulation through the use of Arena software (Figure 7) was done in an attempt to prove the proposed improvement options. It revealed bottlenecks in queue management and thus the proposed solutions of introducing service personnel and reorganizing physical layout of the workstations.

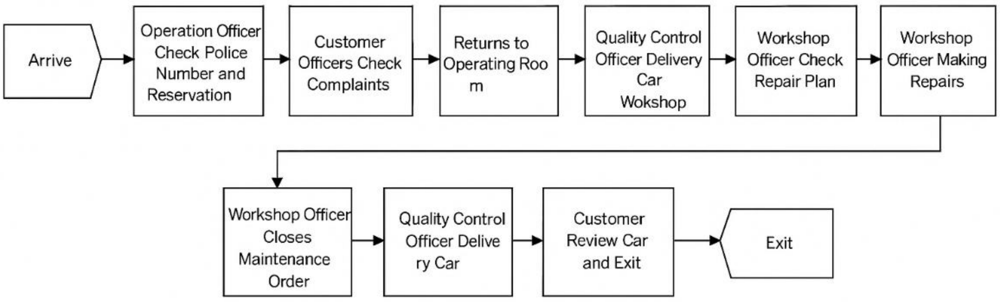

Figure 7. Simulation Using Arena Software

Findings such as these are consistent with Poswa et al. [15], who demonstrated that reconfiguring the workspace setup and modifying the personnel capacity reduced cycle time significantly for automotive service operations.

4.5. Implementation and Impact Evaluation

The Future State Value Stream Mapping (FSVSM), created in line with recommended improvements, demonstrates a balanced and smoothed workflow with reduced idle time (Figure 8).

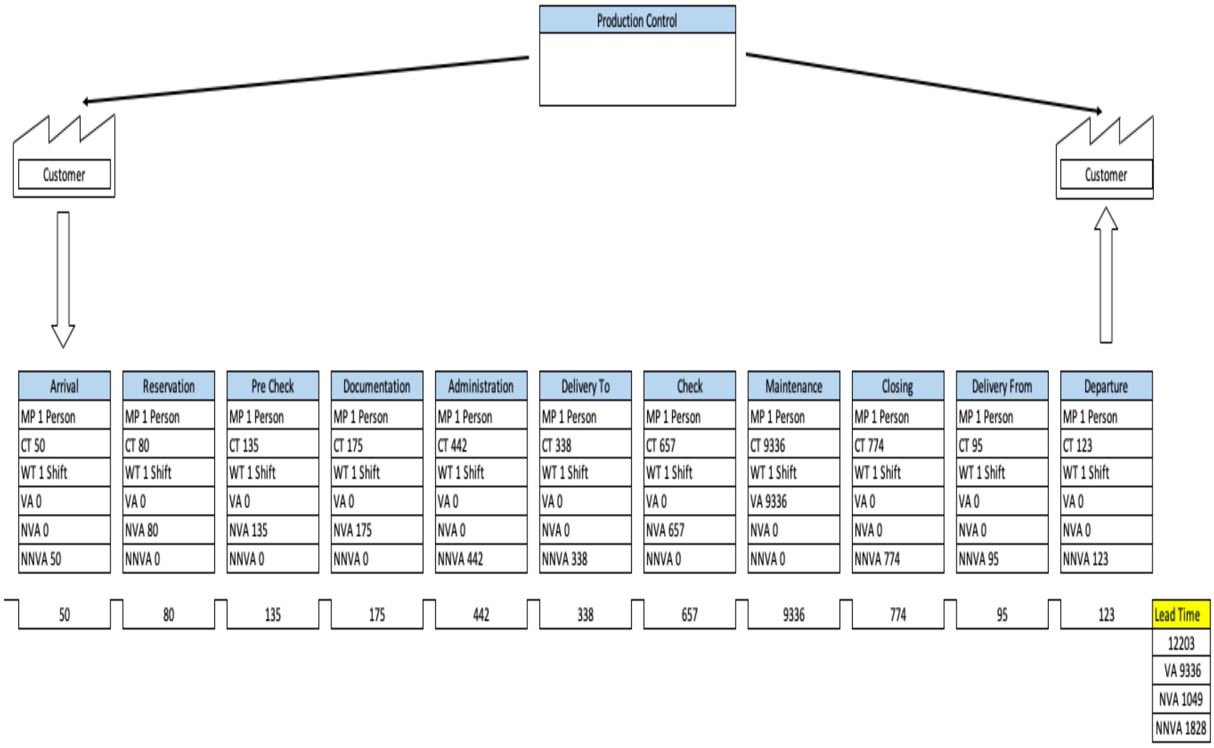

Figure 8. Future State Value Stream Mapping

Table 4. summarizes the comparison between the current and improved future states of the service process.

Metric	Current State	Future State	Improvement
Lead Time (seconds)	12.887	12.203	↓ 5.3%
Non-Value-Added Time (%)	24%	17%	↓ 7%
Cars Serviced per Day	10	12	↑ 20%

This result supports existing research [13,14] that has already established PAM and SCRM as effective in improving performance in small-scale or service-oriented environments. The radical lead time reduction and improved process flow particularly addressed the customer complaints issue of PT Blue Bird Tbk., enabling the company to handle greater workloads more effectively.

4.6. Critical Discussion and Generalization

The improvements achieved—particularly in NVA time and lead time reduction—demonstrate that lean manufacturing principles, and VSM specifically, can be applied effectively in service sectors in developing countries. While most of the literature deals with large-scale production or healthcare systems [12,20], this study contributes to the relatively limited literature on the application of lean in automotive service businesses.

Additionally, the generalizability of these improvements is also dependent on external factors such as workshop design, employee skill, and variability in service demand. Future studies could increase general applicability by either testing these findings in multiple workshop sites or comparing the results with regional or international standards.

5. Conclusion

The study revealed that activities in the car repair service process of PT Blue Bird Tbk. are categorized into three types: **Value-Added (VA), Non-Value-Added (NVA),** and **Necessary but Non-Value-Added (NNVA)**. Queueing, service delays, waiting for final inspection, and confirmation bottlenecks are the non-value-added activities. According to the Waste Assessment Model (WAM) and Waste Assessment Questionnaire (WAQ), the three most dominant wastes were **overproduction (21.07%), defect (16.89%),** and **waiting (16.65%).**

To counter such inefficiencies, some improvement strategies were implemented, which included an optimization of layout, better presentation of maintenance information, additional mechanic allocation, and an implementation of a high-level scheduling system. Thus, the total lead time reduced from **12.887 seconds to 12.203 seconds**, **which is by 5.3%.**

In addition to quantitative improvements, this study provides empirical findings for service industries seeking to adopt lean in low-resource settings. It demonstrates that targeted, low-cost interventions tied to value stream analysis and simulation can achieve incredible improvements in operating performance without requiring significant structural investment.

However, single-case study design may restrict generalizability. Subsequent research would have to validate the hypothesized model across different workshop settings, investigate digital integration with real-time data (e.g., Digital VSM), and utilize customer feedback to quantify enhanced perceived service quality.

Lastly, the research assists in broadening the application of Lean Manufacturing to the automobile maintenance service in emerging nations. The model and tools utilized may be applied to other services where efficiency, time, and speed in response are determining factors in competitiveness.

Author Contributions

Yusha Sinatrya initiated the study idea, directed data collection and analysis, and wrote the initial manuscript. Ardhianiswari Diah Ekawati oversaw research, agreed on the methodological framework, and revised critically. Both authors reviewed and approved the final manuscript.

Data Availability:

The datasets generated and/or analyzed during this study are available from the first author, Yusha Sinatrya, upon reasonable request.

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