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Integration of lean and green manufacturing to speed up the automotive parts production process for sustainability orders from customers

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ABSTRACT

Fulfilling orders from the automotive industry customers is a necessity. Problems arising from product delivery to customers are due to production delays, decreased production yields, and environmental pollution caused by production waste. The production process often experiences wasted time producing four-wheeled vehicle spare parts and a high percentage of production defects. This research aims to reduce production process time, provide solutions to reduce waste, and balance production stock according to customer orders. This research uses the Lean Manufacturing (LM) approach with the Value Stream Mapping (VSM) method combined with the Green Manufacturing (GM) approach with the Just in Time (JIT) and Kanban methods. This research resulted in the production process time for four-wheeled vehicle spare parts decreasing from 11.0 days to 4.5 days, meaning a decrease of 159%. It affected production results, increasing from average monthly production of 42,917 pcs to 59,990 pcs, meaning an increase of 128%. Meanwhile, the shipment plan target has been achieved at 96% of the plan order. Meanwhile, Turn Over Inventory (TOI) results are under 30 days, so customer order continuity exists.

1. INTRODUCTION

After Covid 19 ends in 2021, the four-wheeled automotive industry will revive. Several countries in ASEAN have started thinking about new targets because customers of four-wheeled vehicles have started ordering. Indonesia is the largest car market in the ASEAN region due to its population of around 280 million people as of 2023. The automotive industry in Indonesia is snowballing and controls around a third of the total annual four-wheeled vehicle sales in ASEAN during 2023 (Fig. 1). Indonesia shows that the automotive industry is growing rapidly and rapidly. It indicates that the public's need for four-wheeled vehicles is increasing. Customer demand for four-wheeled vehicles will increase, impacting business in Indonesia's automotive manufacturing sector [1].

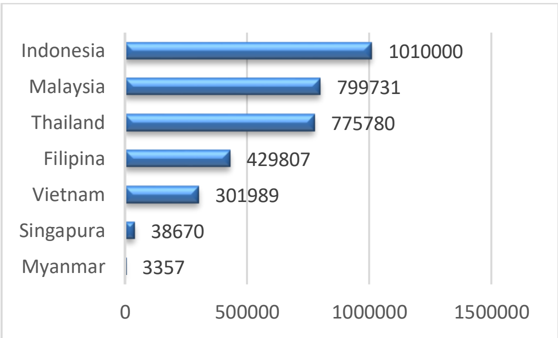

Fig. 1. Number of four-wheel sales in the ASEAN region

Indonesia has many automotive companies with foreign investment, such as Japan, Korea, China, and several European countries. Each company has its market share due to its superior products. Fluctuating demand and creating the best and highest quality products at competitive prices are challenges for the company [2]. Local and foreign customers want their goods to be delivered according to target. However, problems regarding automotive spare parts are sometimes sent late from the spare part manufacturing company to the four-wheeled company. It disrupts the delivery process from the four-wheeled industry to several customers [3].

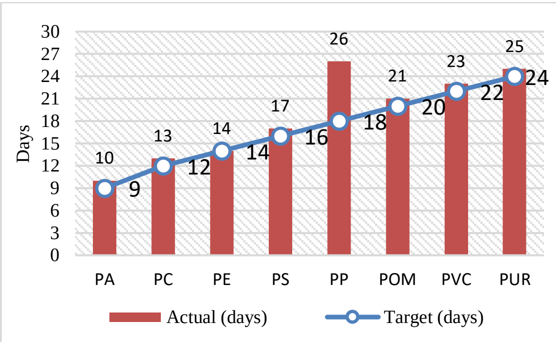

Fig. 2. Lead Time for delivery of spare parts to customers (Jul-Sep 2022)
Remarks: PA (polyamide), PC (polycarbonate), PE (polyethylene), PS (polystyrene), PP (polypropylene), POM (polyoxymethylene), PVC (polyvinyl chloride and), PUR (polyurethane)

The Part Protector type for Polypropylene (PP) spare parts has the longest lead time for delivery to customers, namely 26 days from the target of 18 days, meaning it is 8 days late (Fig. 2). Meanwhile, other types of parts are also several days late. However, the delays are still below those of the PP part type. In general, all spare parts experience delays at the spare part manufacturing company due to internal problems. One is the delivery lead time from building 1 of the assembly section to building 2 of the recipient warehouse, which will be sent to the assembly section. This results in wasted transportation from building 1 to building 2, around 25 km away. However, this research will discuss how to speed up the production of PP-type spare parts as an example of analyzing and conducting process time experiments in manufacturing automotive spare parts.

Another problem is that this automotive spare part manufacturing company does not yet have a production quantity control system. Every month, there is overproduction, which does not match the target orders from customers. The absence of flexible system applications is an important requirement to deal with this wasteful overproduction. The company has tried to negotiate with customers so that overproduction of these spare parts can be accepted. However, customers are very firm and do not accept overproduced spare parts. Spare parts that are dead stock burden the spare parts company. Apart from that, production defects at this company increase every year; data for 2022 reports that production defects are 6%, with a total of almost 10,000 defects every month. Production defects are accommodated in a production and non-production waste storage building. One way to prevent it from becoming a prolonged burden is to destroy the item by burning it.

This research focuses on reducing waste from all activities that do not add value. This research synergizes with companies that want environmentally friendly manufacturing and reduce environmental pollution or Green Manufacturing (GM). Environmental pollution has occurred due to burning production waste from production defects in each department. It is a hot issue for the company that must be addressed immediately to handle environmental pollution properly. The balance application system between spare part manufacturing companies and customers is not yet well connected [4]. Processing, receiving, storing, and delivering reports still use manual methods, namely, paper. The use of paper increases by 10% every year, making paper an industrial waste. The waste is destroyed by burning it through internal combustion. Waste of paper and spare parts is also a waste of inventory [5]. This burning activity is a problem for the surrounding environment, which will be polluted because the thick smoke pollutes the local environment.

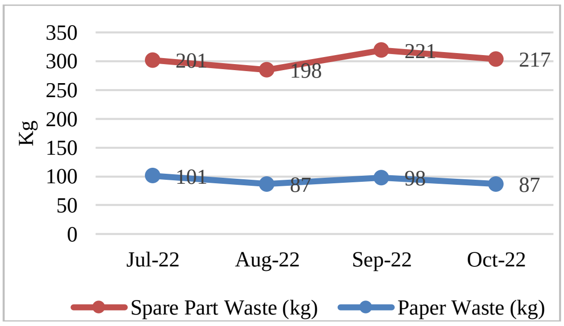

Fig. 3. Production waste incineration

The average amount of paper waste burned is 93 kg per month, and spare part waste burned is 209 kg per month (Fig. 3). In the production process in a company, some activities do not have added value or Non-Value-Added (NVA) or waste, which will result in the use of resources ranging from energy, human resources, and time, making the process inefficient [6].

The problem phenomenon that has occurred in spare part manufacturing companies is that several activities do not have added value or are wasteful. This waste is due to delays in sending spare parts to customers. This delivery delay was due to the extended production process time in the assembly section of building 1, which had to be sent to building 2 in the

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preparation warehouse section. This type of waste includes transportation waste, explained by the analysis of delivery delays for all kinds of automotive manufacturing spare parts (Fig. 2). The problem-solving approach uses the Lean Manufacturing (LM) approach using the Value Stream Mapping (VSM) method.

The company is also constrained by excess inventory stock for several spare parts in the finishing warehouse due to a lack of control from the PPIC department. Even though we have tried to offer spare parts again so that they can be accepted, the customer cannot fulfill this request. Meanwhile, the system for receiving, storing, and sending goods still uses manual methods. Every month, it produces quite a lot of paper waste. This results in activities that do not have added value or include waste. The company handles waste only by burning it, so the smoke from the burning results can pollute the surrounding environment. The approach to solving this problem is the Green Manufacturing (GM) approach with the Just in Time (JIT) method. By integrating the LM and GM approaches, a solution can be achieved to speed up the spare part production process and reduce environmental pollution, making the demand for fulfilling spare part orders from customers sustainable.

The new approach of this research is the continuity of fulfilling orders from customers using the LM approach to speed up the lead time of the spare part production process using the VSM method. The LM approach can be combined with the GM approach, JIT and Kanban methods. At the analysis stage, activities without added value use the Current State Mapping (CSM) and Future State Mapping (FSM) methods. Meanwhile, other LM approaches use the JIT and Kanban methods, where there is a balance between demand and delivery from the spare part manufacturing company to the customer. The results of this research are in the form of measuring GM's performance in reducing waste resulting from excessive stock inventory and reducing environmental pollution from destroyed waste. The Lean VSM approach combined with tools 4.0 is also used in the manufacturing industry's sustainability of supply chain distribution, especially in fulfilling wiring orders to customers in the automotive industry sector [7]. This research discusses the integration between the application of the LM and GM approaches to accelerate spare parts production in the automotive industry. The reason why it must be researched is that the application of LM to analyze any activities that are wasteful or non-value-added must be reduced in the production process, as well as the application of GM to analyze activities on excessive stock inventory so that it becomes production waste which will pollute the environment through burning for destruction finished product. This research aims to reduce production process time, provide solutions to reduce waste, and balance production stock according to customer orders. The main contribution of this research is to offer analytical solutions for reducing wasteful activities in the automotive spare part manufacturing process and balancing production stock according to customer orders. So that the production process for making spare parts can be accelerated and customer orders can be continued.

2. RELATED WORK

Regarding terminology, LM is an approach to system efficiency that reduces waste. Companies must identify Value Added (VA) product activities and eliminate NVA activities to reduce production lead times [8]. LM can be used for an internal service approach where all information can be ensured to be conveyed to consumers directly and quickly so that consumers receive effective service to increase customer satisfaction [9], [10]. Lean is to improve quality, increase productivity, increase the ability to gain profits, and increase market competitiveness [11]. Many manufacturing organizations use lean tools and techniques to identify and eliminate waste through continuous improvement [12]. Other research also uses the LM approach with VSM, namely identifying waste during the cement packaging to estimate increasing process cycle efficiency.

GM continues to experience development with five perspectives that concern the manufacturing industry, including work safety, production waste, income, production costs, and solid material residues [13], [14]. Environmentally friendly products can increase social trust for employees, customers, and the surrounding community, but they are thought to hurt the economy by using environmentally friendly input materials [15]. The literature review of this research, which is related to the gap between the research and other research, can be seen in Table 1.

LM and GM can produce benefits and influences in various organizational areas simultaneously or sequentially [16]. Integration of LM and GM [17], [18], [19] makes improvements to LM that affect GM in reducing waste and preserving the environment. Consumer satisfaction can be achieved by creating quality, service, and customer satisfaction value [20]. The key to gaining customer loyalty is to provide value to the customer [21].

3. RESEARCH METHODS

This research method includes an exploratory, descriptive design where this research describes the problem and the causes of the problem and finds solutions related to solving the problem. The data that has been collected provides information and data as material for solving the problem. This type of research includes a mixture of quantitative and qualitative. It is included in the quantitative type because there are data

Table 1. Literature review

No	Author	Tools	Remarks
1	Ikatrinasari *et al.* [18]	Sustainability Value and Stream Mapping (SVSM)	Elimination of NVA and decrease energy use in the electronic component industry
2	Purba *et al.* [3]	VSM, Kanban, Pareto diagram	The sustainability of order picking is one of the supply chain processes that play a role in warehouse operations to meet customer needs.
3	Choudhary *et al.* [22]	Green Integrated Value Stream Mapping (GIVSM)	Improving sustainability performance in packaging manufacturing SME
4	Prasad *et al.* [23]	VSM, 5S, Kanban, and Pokayoke	Applying a lean manufacturing approach to the textile industry and analyzing non-value-added activities
5	Kurnia *et al.* [19]	FGD, VSM, and Kaizen	Reduce the recruitment process's LT and paper waste in pro audio manufacturing.
6	Kihel *et al.* [7]	LVSM, and tools 4.0	Optimization of continuous distribution supply chain using lean value stream mapping tools 4.0: on automotive wiring industry
7	Kuncorosidi *et al.* [24]	Fishbone diagram, and LVSM	Reducing wasteful activities in the hospital service sector in inpatient outpatient units
8	Abdullah *et al.* [25]	SGRL	Evaluate SME performance and understand the combined impact of Smart Green Resilient Lean (SGRL) manufacturing on SME performance.
9	Fiorello *et al.* [26]	LM, GM and 6 Sigma	Increasing sustainable performance, especially the environmental impact, to achieve company targets is very important to operational performance.
10	Zhu *et al.* [27]	Matrix-Based Cross-Impact Multiplication Applied to Classification (MICMAC) and Interpretative Structural Model (ISM)	Application of the LM and GM approaches by identifying Fragility Factors in the Manufacturing Industry
11	Jaqin *et al.* [28]	Lean, VSM, Pareto diagram, and Fishbone diagram	Reducing waste time in the plastic injection manufacturing process in the automotive industry
12	Kurnia *et al.* [2]	Lean, VSM, A3, and Kaizen	Combination of Lean Thinking and A3 Problem-Solving Methods to Reduce the Cost of Purchasing Cleaning Agents in the Paint Industry in Indonesia
13	Elemure *et al.* [29]	M and GM	Integration of Lean Green and Sustainability approaches in the manufacturing Industry seen from a future perspective
14	This research	FGD, VSM, JIT and E-Kanban	Reduce production process time, provide solutions to reduce waste, and balance production stock according to customer orders in the Automotive Industry.

The form of numbers obtained during data collection before and after improvement. Meanwhile, the qualitative type is obtained from Focus Group Discussion (FGD) activities to determine themes, causes, and corrective actions [30].

Data collection uses two types: primary data with observation techniques and secondary data with the production stock report data documentation. The population used as the object of this research is located in the Karawang industrial area, with the main product being spare parts for the automotive industry. Meanwhile, the limitation of this research is that it only focuses on the production process and monthly inventory results at the company. The research stage begins with the problem phenomenon in its decline. These steps can be explained in Fig. 4.

The research begins with a problem phenomenon and then determines the research objectives. The next step is to identify conditions before improvement in the form of any activities in the spare part production process. Determining activities before this improvement was carried out using the FGD and LM (CSM) method. An odd number of internal and external experts will attend the FGD. Once it is known that there are wastes, the next step is to take corrective action in the production process using the LM approach in the form of the JIT and Kanban methods.

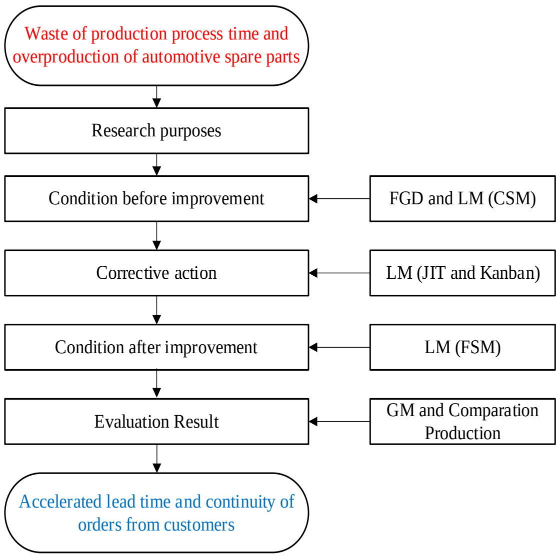

Fig. 4. Research stages

Efficiency calculations:

$$Eff(\%) = \frac{Actual\ Production}{Production\ Plan} x\ 100\% \quad (1)$$

Calculation of production defects:

$$Defect\ (\%) = \frac{Defect\ (pcs)}{Defect\ (pcs)+Production\ (pcs)} \quad (2)$$

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Kanban calculation:

$$Quantity\ Order(Day/Pcs) = \frac{Quantity\ Order\ (month)}{Working\ Days/month} \quad (3)$$

$$Draft\ Lot\ Size\ (lot) = \frac{Total\ Quantity\ Order}{andory\ Frequency} \quad (4)$$

$$Loading\ Time\ (second) = Quantity\ Order\ x\ Cycle\ Time \quad (5)$$

$$Free\ time\ (minute) = Work\ time/shift - \frac{Total\ loading\ time}{60} \quad (6)$$

JIT calculations:

$$Safety\ Stock\ (pcs) = Stock\ WIP + Production\ Planning - Shipment\ Plan \quad (7)$$

Then, if improvements have been made, it is necessary to re-analyze the spare part manufacturing process activities with LM (FSM). The final step is to evaluate the results of improvements by measuring performance and whether all activities follow GM, which can preserve the environment. Integrating LM and GM in this research is appropriate for speeding up the production process time by eliminating non-value-added activities such as shipping waste, excessive waste of WIP stock on certain items, and environmental pollution through waste destruction. Therefore, implementing LM in VSM, JIT, and E-Kanban, as well as GM, can simultaneously increase the supply of sustainable orders.

4. RESULTS AND DISCUSSION

At this stage, the results of processing the data and information obtained during the research were obtained empirically and objectively. The data obtained includes primary data and secondary data. Apart from that, by conducted direct observations in the field, documented production reports, and conducted interviews with the Automotive Indonesia company in the Karawang industrial area, West Java. In this research, several data related to data or activities were collected to reduce the time wasted in making four-wheeled vehicle spare parts.

4.1. Production layout

In this section, we will discuss the production layout for making spare parts from various types of plastic injection for the needs of four-wheeled vehicle spare parts. In general, the manufacture of these spare parts is almost the same, but there are differences in the process flow based on the type of material used. The layout for making four-wheeled vehicle spare parts can be seen in Fig. 5.

The overall production layout for making four-wheeled vehicle spare parts consists of two buildings: Building 1 and Building 2. Several main processes start from the supplier being received by the company, and then there is an inspection activity. If the material is in good, it will be stored as a stock of materials in the warehouse. The next production process is line injection, and then the plastic product is placed in a steam room for product conditioning before the assembly process. After that, it is transferred to Building 2 for the assembly and Final Inspection process until the finished product is stored in the warehouse in preparation for sending to customers. The spare parts production process at each stage will be supplied to each production stage process following the production flow.

4.2. Volume or production amount

The type of product usually produced by the company is making spare parts for four-wheeled vehicles. This research will be carried out on processes using PP resin because this type of PP material has the most complete process, and lots of waste is found. The part that will be used as a research sample is the part protector with part number 7263-XX.

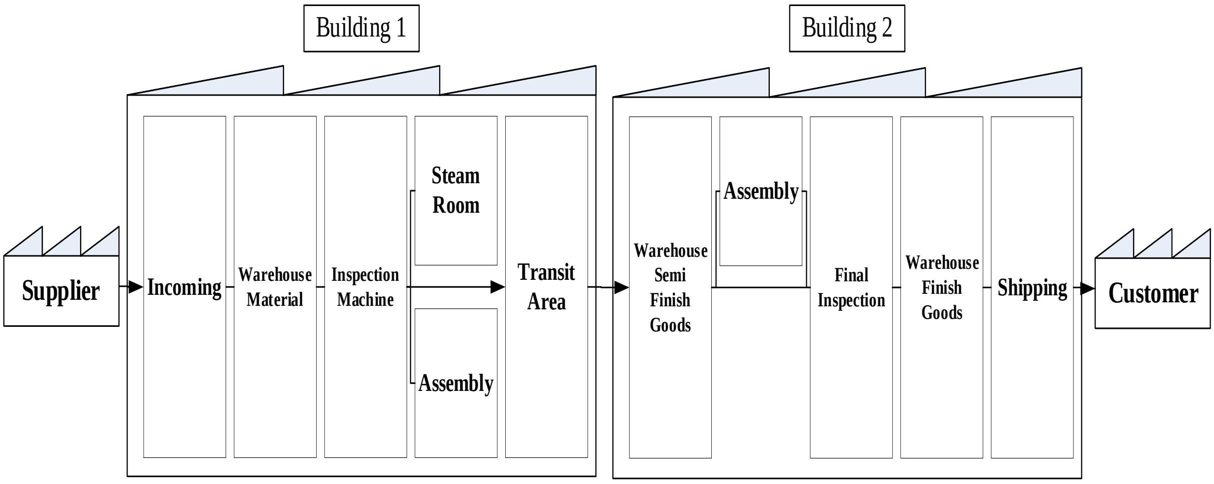

Fig. 5. Four-wheeled motorized vehicle production process (before improvement)

The production results for 1 year in 2022 with PP family items can be explained by the volume or number of output of four-wheeled vehicle spare parts, the most dominant being the PP125 item (Fig. 6). This production volume is determined based on customer requests that the PPIC department has received The customer demand data used is demand during 2022 with a total production of 513,200 pcs. This PP125 type is a plastic injection part for body cover accessories for four-wheeled vehicles. Therefore, this PP125-type part will be used as research material to reduce the production time for making four-wheeled vehicle spare parts. Products that become dominant in production must remain within inventory stock control to fulfill customer orders [31]. The production results of PP125-type spare parts before repairs for 6 months can be seen in Fig. 7.

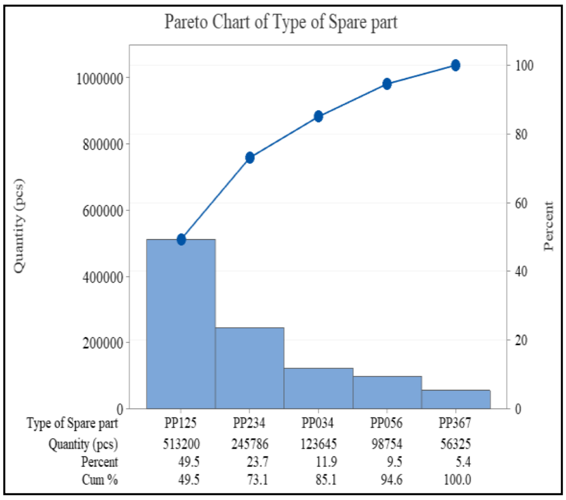

Fig. 6. Pareto Diagram of spare part production items
Remarks: PP (polypropylene)

The simulated monthly or average efficiency calculations can use the formula (1):

$$Eff(\%) = \frac{42917}{55000} x\ 100\% = 78\%$$

Based on the calculations above, for six months as research data before improvement, it has been explained that the average efficiency results were 78% or 42917 pcs produced by the spare parts manufacturing process in Buildings 1 and 2. It is far below the company's target, an efficiency target of 85% monthly. The results of this achievement are still far from the production target of 55,000 pcs/month. Good achievements from manufacturing companies can be seen in efficiency every month. Continuous improvement is needed if they have not reached the efficiency target [32]. Meanwhile, production defects for 6 months from July 2022 to December 2022 can be seen in Table 2.

Table 2. PP125 production defects Jul-Dec 2022

Parameter	Actual production (pcs)	Production defect (pcs)	Percentage defect (%)
Ave	42917	2681	6%
Jul-22	44000	2457	5%
Aug-22	46000	2420	5%
Sep-22	44500	2701	6%
Oct-22	41200	2653	6%
Nov-22	39000	2860	7%
Dec-22	42800	2995	7%

To find out the percentage of production defects each month or on average, can use formula (2):

$$Defect\ (\%) = \frac{2681}{2681+42917)} x\ 100\% = 6\%$$

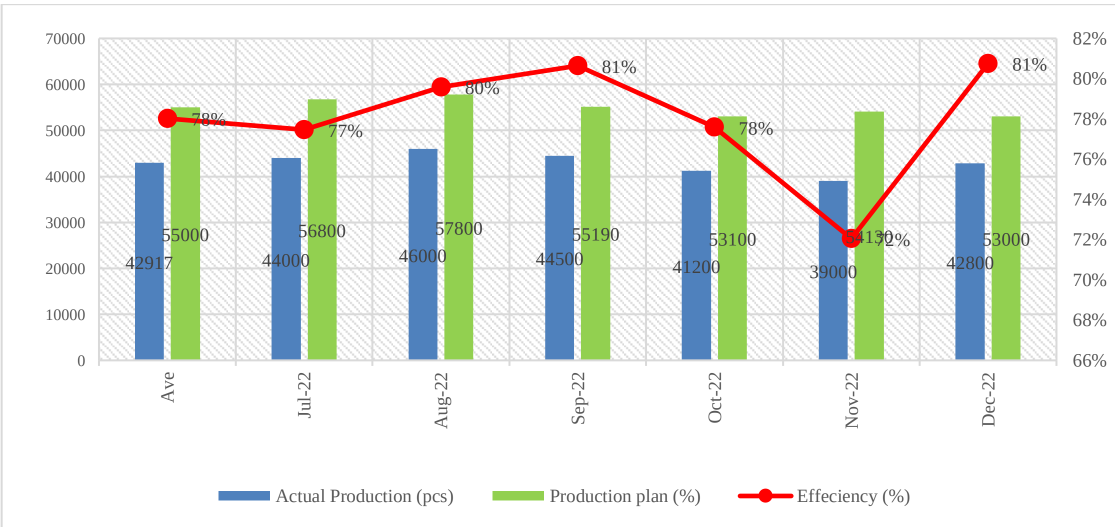

Fig. 7. Production of PP125-type plastic parts before improvement

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Table 3. WIP inventory turnover data at each process stage before improvement

Parameter (day)	WIP turnover inventory Jul-Dec 2022					
	Jul	**Ags**	**Sep**	**Okt**	**Nov**	**Des**
Raw Material	13	12	15	11	17	13
Semi Finish	10	12	12	7	11	4
Finish Goods	11	15	21	17	21	30
Total	34	39	48	35	49	47
Target	30	30	30	30	30	30
Waste WIP	4	9	18	5	19	17
Achievement (%)	113%	130%	160%	97%	163%	157%
Average (%)	137%					

The average production defect from July 22 to December 22 resulted in 6% defects, so this is the company's cost in terms of waste of production defects. So far, the company has incurred losses from production defects that cannot be reworked every month because customers cannot accept product defects. Customers do not receive products produced from products improved by suppliers to maintain the quality of the products produced. Therefore, the company took action to destroy production defects by burning them to eliminate defective products so that other competitors could not imitate them. It results in environmental pollution every month; the company burns almost 10,000 defective products, including 2681 defective product items, PP125 per month.

Environmental pollution in the form of smoke, which can produce carbon monoxide emissions, can damage the air and make it unhealthy due to burning production defects. The company tries to reduce environmental pollution with the environmentally friendly Green Manufacturing (GM) method, namely reducing the number of production defects produced by each part of production.

4.3. Material flow

The flow of material after inventory is carried out during 2022 experiences problems with the imbalance of processed material. There is still a lot of information in the flow of material and stagnation or accumulation of WIP parts at several points, which results in a long lead time (L/T) process. This information and stagnation can be categorized as waste because much time will be wasted, resulting in a long process and high stocks of Finished Goods (FG) and WIP (Table 3).

The stock of finished goods, semi-finished goods, and raw materials in July - December 2022 is still above standard. The company has a standard for a total stock of 30 days per month. Inventory turnover data in days in 2022 is 137%, which is above the standard limit of 100%. Inventory is included in the seven waste categories, which indicate overproduction in the assembly and final inspection sections.

4.4. Focus group discussion (FGD)

This FGD method was carried out to gather several experts in industrial engineering and management, both internally and externally (Table 4). The task of this FGD is to determine company problems, identify NVA activities, determine the leading causes, plan corrective actions, and calculate sustainable company targets for orders from all customers. In this way, it is hoped that companies can reduce waste, reduce environmental pollution, and increase company profits yearly.

Table 4. Member of FGD expert

Expert	Age (years)	Experiences (year)	Skill	Remark
1	39	17	PPIC	Internal
2	53	25	LM-GM	Internal
3	46	19	VSM	Internal
4	51	22	QA-Production	Internal
5	43	15	TQM	External

4.5. Current state mapping (CSM)

In this section, the data processing results will be discussed by measuring process time before improvement using a CSM diagram (Fig. 8). The results of measuring time before improvement are in the form of a CSM diagram related to the results of Lead Time (L/T) of 2.5 days and Process Time (P/T) of 7.5 days, so the total production process time in 1 lot = 3656 pcs for 11 days. The calculation of L/T and P/T resulting from the start-to-finish process is calculated based on all parts of Building 1 and Building 2.

4.6. Waste Identification

In this section, we will discuss the results of data processing in the form of waste identification consisting of Value Added (VA), Non-Value-Added (NVA), and Non-Value-Added Necessary (NNVA). The grouping of waste types based on process flow and waste categories can be seen in Table 5.

The dominant production process time for making PP125-type spare parts is 4.0 days in the Assembly production process and 2.0 days in the Final Inspection (FI) category in the information waste and stagnation categories. Waste categories without added value need to be improved in processing time because it will affect efficiency [33]. Activities in the Assembling and Final Inspection sections are determined by the FGD members during the meeting, including details of activities that do not have added value that must be corrected immediately. Six identified activities do not

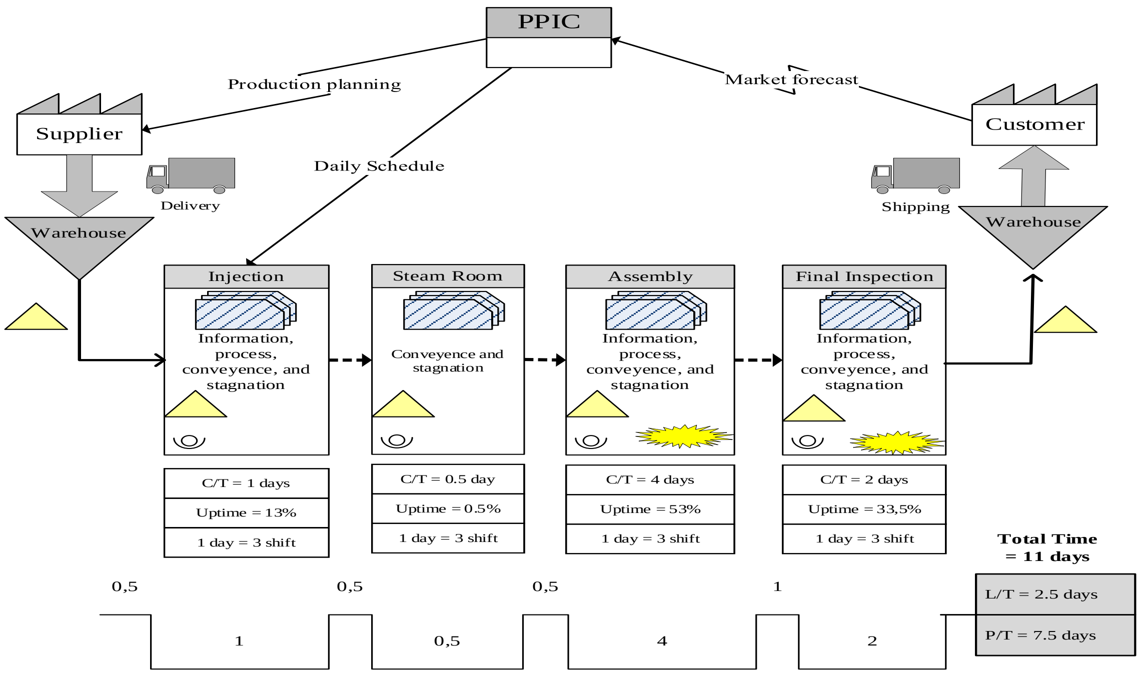

Fig. 8. Current state mapping

Table 5. Identification of parts manufacturing waste before improvement

Activity	Injection (day)	Steam room (day)	Assembly (day)	Final inspection (day)
Information	0.040		0.500	0.500
Process	0.230		0.500	0.040
Conveyance	0.230	0.250	1.000	0.460
Stagnation	0.500	0.250	2.000	1.000
Total	1.000	0.500	4.000	2.000

Table 6. Classification of spare parts manufacturing waste

Process	Activity	Activity identification	Time (day)	Waste classification		
				VA	NVA	NNVA
Assembly	Information	Information from other departments was provided late	0.500		√	
	Process	There are 2x assembly processes	2.000		√	
	Conveyance	Transportation from Building 1 to Building 2	0.500			√
	Stagnation	Waiting for confirmation from customers and suppliers	1.000		√	
Final Inspection	Information	Information from previous sections is often late	0.500		√	
	Process	The production process involves manual input of materials and products	1.000		√	
	Conveyance	FI location is in Building 2	0.500			√
	Stagnation	Waiting for confirmation from customers and suppliers			√	
		Total	6.000		5.000	1.000

Remarks: VA (value added), NVA (non-value added), and NNVA (necessary non-value added)

have added value, with a total NVA of 1.5 days and NNVA of 4.0 days (Table 6). Identifying activities without added value must be immediately addressed to improve them [34]. It is to reduce waste of production process time and can increase the amount of production for making four-wheeled vehicle spare parts.

4.7. Corrective action

After the improvement plan has been carried out, this section will discuss the results of the improvements, which concentrate on reducing waste from non-value-added activities that have been carried out.

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a. Information

The problem that has arisen so far in terms of information is that information from the previous section is often late in the Proxpro system, which only provides manual input modules for incoming goods, processed goods, inventory corrections, and stock taking. The information produced includes stock conditions, stock mutations/cards, transaction recapitulation, and the Cost of Goods Sold (Fig. 9).

Fig. 9. Inventory proxpro system

The old system still uses manual input for both production and defects. The admin staff for each section will manually input the information into the Proxpro application. Meanwhile, the corrective action is using a new system using a complete Kanban system consisting of electronic modules for incoming goods, storage, returns, material processing, stock in the warehouse, reprocessing, returns, stock taking, and results. The new system's results will be more effective than the old system because this new system uses a barcode system for input, stock requests, and product release, as well as creating the latest stock cards following automatic production scheduling. The new system uses E-kanban, stock stability, and production results can be seen in Fig. 10.

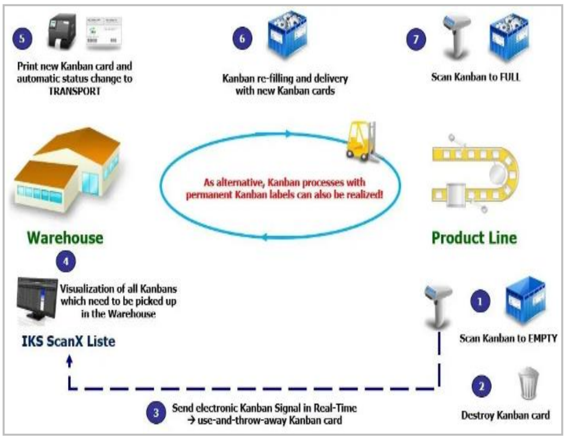

Fig. 10. E-Kanban system

Table 7. Kanban calculation assembling department

Kanban calculation						
Line Name	Assembly		Pulling Time		40	2400
Month	August	2023	Efficiency (%)		90%	
Working Day	22		Conveyance Time		5	300
Work Time (minute) /shift	420	25200	KPI Dandory allocation (Policy Management) -- %		10%	
Total Shift	3					
Dandory Allocation (times)	42	2520	Machine Cycle Time			
Dandory Time (minute)	20	1200	Post 1	Post 2	Post 3	Post 4
Dandory Frequency (times)	2.1		√	√	√	√
Draft Lot Size (pcs)	1465		Post 5	Post 6	Post 7	Post 8
Loading Time/Day	997	59826.8				
Free time (minute)	-577.113	-34626.8				

No	Part Number	Part name	Quantity Order /Month (pcs)	Quantity Order/ Day (pcs)	Quantity/ Kanban (pcs/kb)	Draft Lotsize (Kb)		Lot Size (pcs)	Cycle Time (second)	Loading Time/ Day (second)	Loading Time/ Lot (second)	Accumulation (second)
1	PP125-PN84		11509	523	30	48.8	49	1470	19.95	10436	29327	10437
2	PP125-PN82		12863	585	32	45.8	46	1472	16.5	9647	24288	20084
3	PP125-PN53		14217	646	20	73.3	74	1480	18.5	11955	27380	32039
4	PP125-PN63		29111	1323	12	122.1	123	1476	21	27787	30996	59827
	Total		67700	3077	94					59827	111991	

The Kanban system is used both e-Kanban and manually with information boards in whiteboards and layer displays for information on production results, defects, and stock. Every production or warehouse admin can input all goods movement transaction activities processes. Every employee has access to monitoring and evaluation following the authorized access provided by the company. The implementation of E-Kanban has provided value-added activities so that the production process runs smoothly, product confirmation of OK and NG status can be quickly known, and the difference in stock-taking results is <1%. One example of Kanban Calculation can be seen in Table 7.

The company's internal data processing obtained from PPIC, the need for Kanban cards during August 2023 for family-type PP125 items resulted in 94 Kanban cards. Meanwhile, for initial calculations of order quantity, draft lot size, loading time, and free time, can use simulation formulas (3), (4), (5), and (6):

$$Quantity\ Order = \frac{11590}{22} = 523 \text{ day/pcs}$$

$$Draft\ Lot\ Size\ (lot) = \frac{3077}{2.1} = 1465$$

$$Loading\ Time\ (secound) = 524\ x\ 19.95 = 10436$$

$$Free\ time\ (minute) = 420 - \frac{59827}{60} = -577.113$$

From these calculations, it is found that PP 125PN84 requires 1465 kanban cards. A PPIC needs this calculation to reference the production department to produce according to the monthly production plan. PP125 items have 4 types in spare part production, so in determining Kanban cards, they cannot be separated because they are already part of the PP125 product family group (Fig. 11).

b. Process

The problem with process parameters is that the production process involves manual input of materials and products, so goods movement transactions take a long time. Then, when inventory also requires accuracy from the inventory member who does it, this has the potential for calculation errors. Therefore, the new E-kanban system is equipped with a Product Inventory system in the form of a Radio Frequency Identification (RFID) system. One example of implementing an RFID system is using system barcodes during goods transactions and monitoring the stock of goods through System Application and Processing (SAP), which is included in Enterprise Resource Planning (ERP). The presence of RFID cannot be separated from access control security, which functions to connect the access network from an area to a documented report on the computer. The role of RFID in a company can provide benefits, including identification based on RFID tags, automatic access to certain areas or information, suitable identification and authentication speed, high level of security or privacy, monitoring or tracking, and wide scalability [35].

c. Conveyance

The machine settings are closely related to the previous program, which was processed in Building 1, so the next process is waiting for confirmation from the previous process, which can be seen in Figure 4. After improvement, re-layout the Assembly and Final Inspection areas into 1 Building to sustain the production process (Fig. 12).

Improvements such as a closer layout of assembly

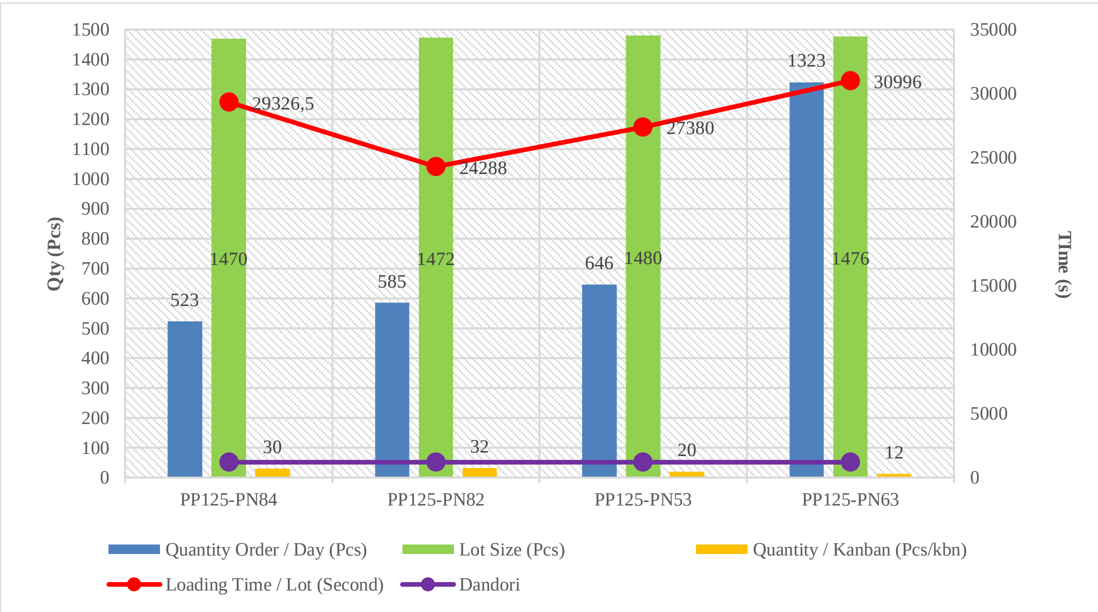

Fig. 11. Production quantity chart assembling in August 2023

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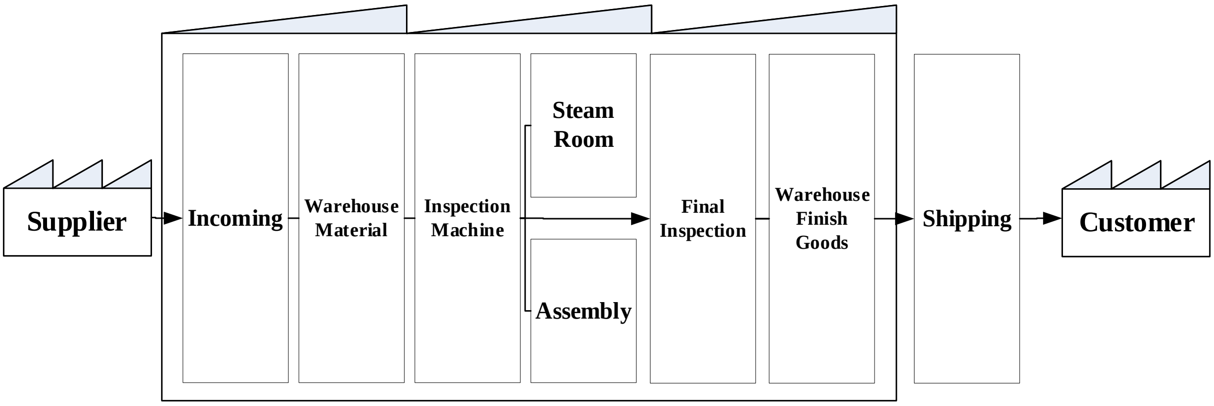

Fig. 12. Production re-layout after improvement

Table 8. Balancing production with JIT

End Jul-23	**Production Plan Aug-23**		**End Aug-23**			
A (Stock WIP)	**B (Prod. planning)**	**C (Delivery)**	**D (Safety stock)**	**Target stock**	**Achievement**	**Target safety stock (%)**
Stock Warehouse 3530	Prod. Packing 67100	Ship. Plan 66800	3830	3340	115%	5%
Stock Packing 3363	Prod. FI 67400	Prod. Packing 67100	Packing 3663	3355	109%	5%
Stock FI 3289	Prod. Assembling 67700	Prod. FI 67400	FI 3589	3370	106%	5%
Stock Assembling 3435	Prod. Injection 68100	Prod. Assembling 67700	Assembling 3835	3385	113%	5%
Stock Injection 3528	Preparation 68200	Prod. Injection 68100	Injection 3628	3405	107%	5%
Stock Preparation 5458	Spare Part WH 68400	Preparation 68200	Preparation 5658	6820	83%	10%
Stock WH Spare Part 6876	From Supplier 68500	WH Spare Part 68400	WH Spare Part 6976	6840	102%	10%
29479			31179			

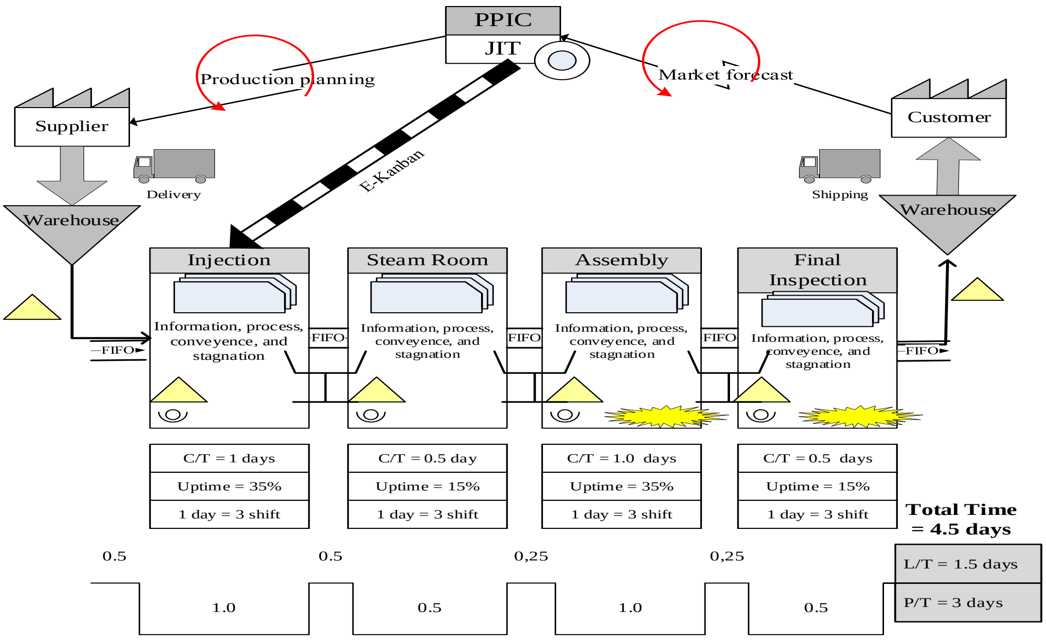

Fig. 13. Future State Mapping

and final inspection production areas and a continuous production process can reduce lead time and make process time more efficient and effective. Machine relaying must be done to effectively move goods, thereby reducing waste [36].

d. Stagnation

Waiting time in the production process is wasted because production planning related to production cards has not been prepared by PPIC, and PPIC has to balance the production of each part. Therefore, this research applies the JIT method, where the results can be evaluated in real-time every week (Table 8). The implementation of JIT in the production section. Simulations for calculating safety stock in the assembling section can use formula (7):

$$Safety\ Stock\ (pcs) = 3435 + 68100 - 67700 = 3835$$

The safety stock for assembly parts in August 2023 is 3835 pcs

4.8. Analysis of future state mapping

After all improvement activities, the results of measuring the processing time for making four-wheeled vehicle spare parts have been carried out. The results of measuring the production process time for 1 lot, namely 3656 pcs (Fig. 13). The results of time measurements before improvement are in the form of an FSM diagram related to the Lead Time (L/T) results of 1.5 days and Process Time (P/T) of 3 days, so the total production process time in 1 lot = 3,656 pcs is 4.5 days. The L/T and P/T results from the start to the end are calculated based on all production process activities after re-layout into one production building [37]. Implementing VSM to reduce time waste by measuring Cycle Time (C/T) for each product will increase production efficiency in the manufacturing industry [38].

4.9. Analysis of waste identification

Waste is identified in two ways: inventory waste and process time (P/T) waste. The WIP inventory turnover data is for six months after the improvement (Table 9). The improvements have reduced inventory turnover or prevented overproduction due to the monthly average achievement of 96%. The company has set an inventory turnover target of 30 days for the maximum movement of materials and products.

After improvement, there are several categories of waste in the Assembling and Final Inspection (FI) sections, namely information, process, conveyance, and stagnation. Improvements have been made to both sections, and the dominant waste categories are information and stagnation conditions. Activities that do not add value to the production process need to be eliminated with efforts to maximize forms of improvement [39].

Table 9. WIP Inventory turnover data after improvement

Parameters (day)	WIP turnover inventory 2023					
	Jul	**Ags**	**Sep**	**Okt**	**Nov**	**Des**
Raw Material	7	8	7	6	5	5
Semi Finish	5	4	4	5	3	4
Finish Goods	18	17	19	18	21	16
Total	30	29	30	29	29	25
Target	30	30	30	30	30	30
Achievement (%)	100%	97%	100%	97%	97%	83%
Average (%)	96%					

The production process time for making PP125-type spare parts after re-layout by combining the Assembly area is 1,000, and FI is 0.500 days (Table 10). The total processing time for making spare parts in the Assembling and FI sections is 1,500 days. However, this differs from the results before repairs, namely 6.0 days compared to the previous process in the Assembly

Table 10. Identification of waste from making spare parts after improvement

Activity	Injection (day)	Steam room (day)	Assembly (day)	Final inspection (day)
Information	0.500	0.100	0.895	0.457
Process	0.240	0.000	0.001	0.000
Conveyance	0.120	0.100	0.004	0.001
Stagnation	0.240	0.300	0.096	0.056
Total	1.000	0.500	1.000	0.500

Table 11. Comparison of research results

Type of activity	Current state map		Future state map		Ratio
	Time (days)	%	Time (days)	%	(%)
P/T Injection	1.0		1.0		
P/T Steam Room	0.5		0.5		
P/T Assembly	4.0	87.3	1.0	66.7	60.0
P/T Final Inspection	2.0		0.5		
Total P/T	7.5		3.0		
L/T	2.5	22.7	1.5	33.3	40.0
Grand Total	11.0	100.0	4.5	100.0	59.0

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and FI processes in different buildings. It has significantly reduced processing time and improved the production process time for spare parts in the assembling and FI sections by 400%.

4.10. Evaluation

Evaluation of research results is by comparing the results before improvement with the results after improvement. In comparing the research results of both CSM and FSM results in ratio, there is a reduction in L/T time by 40.0% and P/T time by 60.0%. There is a reduction in production process time for making four-wheeled vehicle spare parts, which amounted to 59.0% (Table 11). Implementing SVSM can reduce waiting time by 15% from the current time of 1,742 and save energy consumption by 43,695 kWh. Implementing SVSM will effectively sustain company operations in the future [18].

Comparison of waste categories in the Assembling and Final Inspection sections in manufacturing four-wheeled vehicle spare parts occurs in information waste and stagnation categories. It is explained that the total P/T before improvement was 7.5 days, and after improvement was 3.0 days (Fig. 14). It resulted in a decrease in P/T of 135%. Combining the Assembling and FI sections in one building effectively reduces P/T and can increase production efficiency.

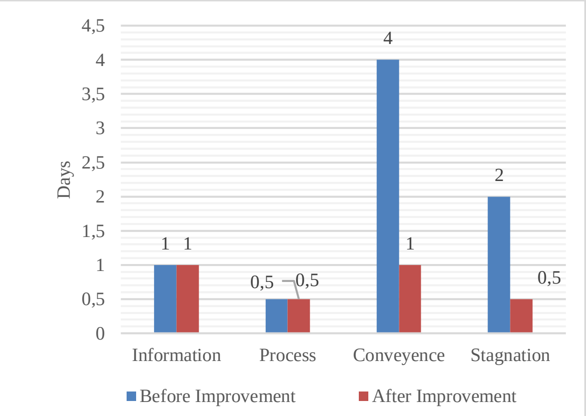

Fig. 14. Comparison of waste categories in the assembling and FI sections

The efficiency value after improvement increased to 90% or 59990 pcs on average per month. The production efficiency after the improvement increased by 12% from the data before the improvement (Fig. 15). Meanwhile, the production target after the layout changed, with the new target increasing by 13,000 pcs to 67003 pcs every month. Therefore, the results obtained from monthly production reach 90.00%. Other research has applied LM combined with GM and the Kanban system to reduce material overstock by up to 90.0% so that line balancing for each part can be controlled and increase productivity [40]. Meanwhile, production defects after improvement can be seen in Table 12.

Table 12. PP125 production defects after improvement

Parameter	Actual production (pcs)	Production defect (pcs)	Percentage defects (%)
Ave	59990	384	0.6%
Jul-23	62040	512	0.8%
Aug-23	60400	432	0.7%
Sep-23	62300	342	0.5%
Oct-23	57680	351	0.6%
Nov-23	57600	298	0.5%
Dec-23	59920	367	0.6%

For companies implementing the Kanban system, each container or pallet only has one Kanban, and the Kanban must always be in its section. The amount (quantity) in the container must be the same as the amount stated on the Kanban. The Kanban post contains Kanban whose parts are processed when production begins in downstream processes. Transport Kanban is placed at the transport Kanban post to signal the upstream process for sending the part. Production Kanban is placed in the production Kanban post in the order in which parts are used. Production from upstream to downstream processes is carried out sequentially at Kanban posts [41].

E-Kanban manages all goods movements, and all data is entered by the operators of each section so that all production supervisors can see the movement of goods and goods balances in the e-Kanban application. The operator's work is very effective because the e-Kanban system assists in taking the materials needed to complete the product. If any label is blocked, it cannot be scanned and, therefore, cannot be moved to another stage until it is unblocked [8]. Every year, customers send forecasting orders to the company to be fulfilled with an initial agreement of 95% (Fig. 16).

Management provides space for parameters for improvement activities to be included in the KPIs of each department. One example of a KPI that has existed in the production department for several decades has been the responsibility of all personnel in the production department. The average production increases every year along with improvements in production layout, implementation of E-Kanban and JIT (Table 13). Acceleration of spare parts production in the production section cannot be separated from collaboration between the PPIC section, production, and other parties that support productivity. Therefore, all activities that add value to the company are made into company targets in the form of KPIs, which management will review every year. KPI is a reference for management in reporting company targets in the core program, where employees will be held accountable every year for the results of their reporting [42].

4.11. Managerial implications

With this research, companies can take advantage of the improvements that have been implemented so that they can improve their current production system to be even better. In theory, the implications of this research can be used as a reference by other researchers regarding the application of LM, which combines the VSM method with the Kanban system in the automotive industry, especially in manufacturing plastic injection spare parts for four-wheeled vehicles. Meanwhile, the practical implications of this research can increase knowledge for industrial practitioners in terms of solutions to reduce time waste in the production process of making four-wheeled vehicle spare parts.

Table 13. KPI production department

Core Program	Unit	Target	2022 Actual	2023 Plan	2023 Actual	2024 Plan	2024 Actual to June
Cycle Time (C/T)	days	100%	7.5	3.0	3.0	3.0	3.0
Production Lead Time (L/T)	days	67%	2.5	1.5	1.5	1.0	1.3
Line efficiency	%	101	78	90	90	92	91
Takt Time	second	100	35	22	20	20	21
Average Production	pcs	103	42917	62000	59990	62000	61000
Defect	%	95	6.0	6.0	6.0	5.7	5.8

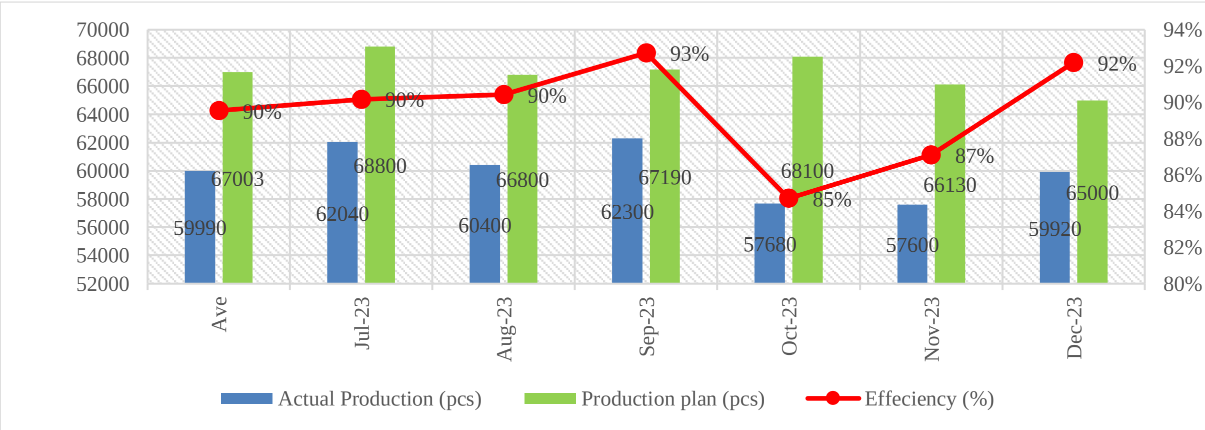

Fig. 15. Production of PP125-type plastic parts after improvement

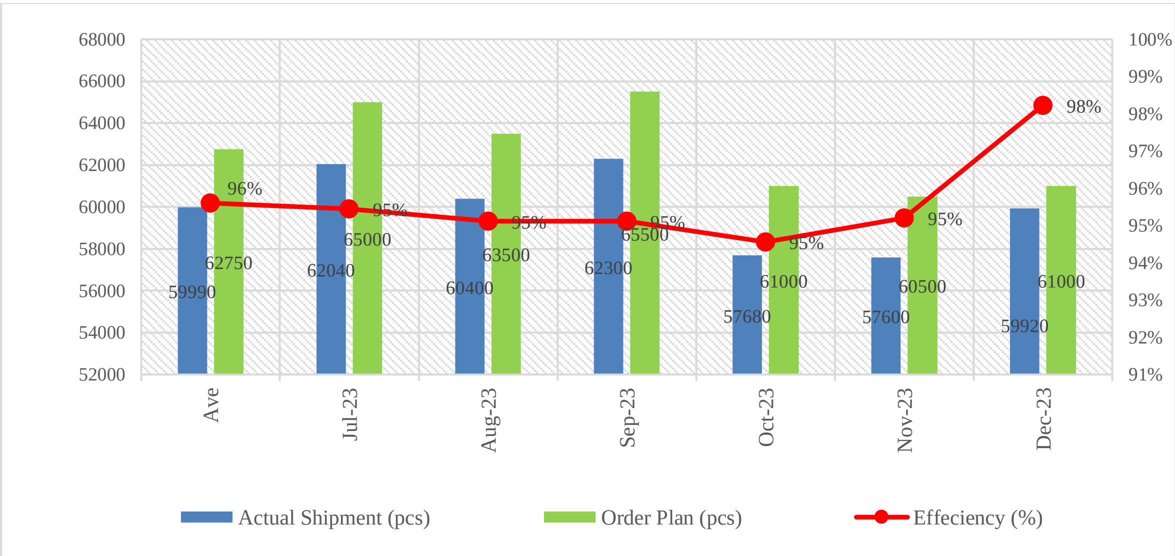

Fig. 16. Product delivery to customers

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Other research has integrated LM with GM, which resulted in a reduction in LT using the VSM method, reduced material waste, saved energy, production processes, and environmental issues, with an average decrease of 15% [18]. Implementing LM and GM reduced employee recruitment LT from 17.9 days to 16.4 days or 8.37%. There was also a decrease in paper waste from 191.6 kg/month to 0 kg/month. The integration of LM and GM can synergize to reduce LT and paper waste in the manufacturing industry [43].

Implementing LM and GM in the manufacturing industry reduces waste in important indicators such as defective products (20%) or late delivery rates (60%). His research has succeeded in reducing 13% and 30%, respectively, after validation, thus confirming the effectiveness of Kanban, JIT, and Standard work as a tool to increase efficiency [44].

In practice, this research has implemented the LM approach using the VSM method and running Just in Time manufacturing by implementing the e-Kanban system. The improvement stage uses the JIT and E-Kanban methods. It is hoped that this research can contribute to all research groups. Apart from that, the results of this research are expected to reduce environmental pollution by controlling stock inventory and eliminating the destruction of defects by burning waste. Simultaneous implementation of the lean and environmentally friendly paradigm has a synergistic effect in increasing operational efficiency and environmental performance [22].

The results of this research improvement have provided benefits for the company in fulfilling orders from customers and reducing environmental pollution in the area around the company. This research includes a body of knowledge on design and engineering systems because, in this research, there is a re-layout process so that changes to the work system can reduce the wastage of production process time, and the processing time becomes more effective and efficient.

4.12. Limitations of this research

In its implementation, this research has several limitations. This research is still far from perfect; therefore, it is important to develop this research into further research. Limitations in terms of data sources, such as in terms of calculating production costs the company has incurred. This research has not been analyzed by calculating production costs before and after improvement. Human resources or employee power has not been considered because, during the research period, there was no determination of the number of employees who would be installed.

The object of this research was only carried out in one work area, namely in the production process of making four-wheeled vehicle spare parts for MPV models, so the improvements that had been implemented were only focused on this work area. Since most of the processes for making four-wheeled vehicle parts are almost identical, similar problems will likely arise in other work environments. The implementation of JIT and E-Kanban is only to fulfill customer needs and a strategy for balancing the production process for each section, especially in the Assembling and Final Inspect sections. The application of JIT is still limited to the need for spare parts from suppliers because the stock of production spare parts in the warehouse can still be controlled by the company's internal department, namely the PPIC department. This research has value in increasing the production of plastic injection-type automotive spare parts by speeding up processing time and reducing inventory stock differences, thereby ensuring continuity of orders from customers and reducing environmental pollution.

5. CONCLUSION

This research has found problems that have resulted in a waste of processing time in the Assembling and Final Inspection sections. This research has produced the right solution for reducing the production process time for four-wheeled vehicle spare parts, including making the re-layout of the Assembly and Final Inspection production areas closer and more sustainable, using the Kanban system, both e-Kanban and manual Kanban, and implementing the JIT method. To control the production balancing of each part and fulfill orders from customers. The results of measuring the production process time for 1 lot of four-wheeled vehicle spare parts decreased from 11.0 days to 4.5 days, meaning a decrease of 159%. It affected production results, increasing from average monthly production of 42,917 pcs to 59,990 pcs, meaning an increase of 128%.

Meanwhile, the shipment plan target has been achieved at 96% of the customers' expected order plan. It is hoped that orders from customers will continue every month. Future research can be expanded by converting the results of improvements into financial aspects so that management can see how much cost savings the company receives by reducing waste, implementing E-Kanban and JIT.

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REFERENCES

[1] I. Zulkarnaen, H. Kurnia, B. Saing, A. Apriyani, and A. Nuryono, 'Reduced painting defects in the 4-wheeled vehicle industry on product type H-1 using the lean six sigma-

DMAIC approach', *J. Sist. dan Manaj. Ind.*, vol. 7, no. 2, pp. 179–192, Dec. 2023, doi: 10.30656/jsmi.v7i2.7512.

[2] H. Kurnia, S. Suhendra, H. Manurung, and K. B. Juliantoro, 'Implementation of Lean Service Approaches to Improve Customer Satisfaction and Sustainability of Health Equipment Procurement Process at Hospitals', *Qual. Innov. Prosper.*, vol. 27, no. 3, pp. 1–17, Dec. 2023, doi: 10.12776/qip.v27i3.1875.

[3] H. H. Purba, Mukhlisin, and S. Aisyah, 'Productivity improvement picking order by appropriate method, value stream mapping analysis, and storage design: A case study in automotive part center', *Manag. Prod. Eng. Rev.*, vol. 9, no. 1, pp. 71–81, 2018, doi: 10.24425/119402.

[4] M. Iranmanesh, S. Zailani, S. S. Hyun, M. H. Ali, and K. Kim, 'Impact of Lean Manufacturing Practices on Firms' Sustainable Performance: Lean Culture as a Moderator', *Sustainability*, vol. 11, no. 4, p. 1112, Feb. 2019, doi: 10.3390/su11041112.

[5] C. P. Carvalho, D. S. Carvalho, and M. B. Silva, 'Value stream mapping as a lean manufacturing tool: A new account approach for cost saving in a textile company', *Int. J. Prod. Manag. Eng.*, vol. 7, no. 1, p. 1, Jan. 2019, doi: 10.4995/ijpme.2019.8607.

[6] F. Pomalia, I. Iftadi, and R. D. Astuti, 'Waste analysis of fuselage assembly in panelization group of the 117th NC212i aircraft', *J. Sist. dan Manaj. Ind.*, vol. 4, no. 1 SE-Research Article, pp. 61–71, Jul. 2020, doi: 10.30656/jsmi.v4i1.2187.

[7] Y. El Kihel, A. El Kihel, and S. Embarki, 'Optimization of the Sustainable Distribution Supply Chain Using the Lean Value Stream Mapping 4.0 Tool: A Case Study of the Automotive Wiring Industry', *Processes*, vol. 10, no. 9, p. 1671, Aug. 2022, doi: 10.3390/pr10091671.

[8] B. Martins *et al.*, 'Implementation of a Pull System – A Case Study of a Polymeric Production System for the Automotive Industry', *Manag. Syst. Prod. Eng.*, vol. 29, no. 4, pp. 253–259, Dec. 2021, doi: 10.2478/mspe-2021-0031.

[9] G. Narayanamurthy, A. Gurumurthy, and A. A. Lankayil, 'Experience of implementing lean thinking in an Indian healthcare institution', *Int. J. Lean Six Sigma*, vol. 12, no. 1, pp. 23–60, Feb. 2021, doi: 10.1108/IJLSS-10-2016-0062.

[10] K. S and B. K. M, 'Implementation of lean tools and techniques in an ethical papers production industry', *J. Sist. dan Manaj. Ind.*, vol. 5, no. 2, pp. 63–73, Nov. 2021, doi: 10.30656/jsmi.v5i2.3611.

[11] Ganjar Sidik Gandara, Riko Muri, and Humiras Hardi Purba, 'Increase Service Selling of Formaldehyde Products By Implementing Quality Function Deployment (QFD)', *J. Appl. Res. Ind. Eng.*, vol. 6, no. 3, pp. 219–231, 2019, doi: 10.22105/jarie.2019.192932.1095.

[12] M. M. Narke and C. T. Jayadeva, 'Value Stream Mapping: Effective Lean Tool for SMEs', *Mater. Today Proc.*, vol. 24, no. 2, pp. 1263–1272, 2020, doi: 10.1016/j.matpr.2020.04.441.

[13] E. Amrina and R. Andryan, 'Assessing Wastes in Rubber Production Using Lean Manufacturing: A Case Study', in *2019 IEEE 6th International Conference on Industrial Engineering and Applications (ICIEA)*, IEEE, Apr. 2019, pp. 328–332. doi: 10.1109/IEA.2019.8714925.

[14] F. Abu, H. Gholami, M. Z. Mat Saman, N. Zakuan, and D. Streimikiene, 'The implementation of lean manufacturing in the furniture industry: A review and analysis on the motives, barriers, challenges, and the applications', *J. Clean. Prod.*, vol. 234, pp. 660–680, 2019, doi: 10.1016/j.jclepro.2019.06.279.

[15] G. N. T. Purnama and S. Hasibuan, 'Implementation of sustainable manufacturing in Indonesia paint industry based on triple bottom line', in *Proceedings of the International Conference on Industrial Engineering and Operations Management*, 2021, pp. 3923–3932, doi: 10.46254/AN11.20210708.

[16] R. Salvador, C. M. Piekarski, and A. C. de Francisco, 'Approach of the Two-way Influence Between Lean and Green Manufacturing and its Connection to Related Organisational Areas', *Int. J. Prod. Manag. Eng.*, vol. 5, no. 2, p. 73, Jul. 2017, doi: 10.4995/ijpme.2017.7013.

[17] M. Kholil, Hendri, B. Hanum, and R. Setiawan, 'Using 7 waste approach and VSM method to improve the efficiency of mackerel fish crackers production time at small medium enterprise (SME)', *Proc. Int. Conf. Ind. Eng. Oper. Manag.*, vol. 2018–March, pp. 2819–2826, 2018, doi: 10.46254/AN08.20180657.

[18] Z. F. Ikatrinasari, S. Hasibuan, and K. Kosasih, 'The Implementation Lean and Green Manufacturing through Sustainable Value Stream Mapping', *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 453, no. 1, p. 012004, Nov. 2018, doi: 10.1088/1757-899X/453/1/012004.

[19] H. Kurnia, I. Setiawan, and H. Hernadewita, 'Integration of Lean and Green Manufacturing to Reduce Waste in the Employee Recruitment Process in the Manufacturing Industry in

Indonesia', *J. Rekayasa Sist. Ind.*, vol. 11, no. 2, pp. 145–156, Oct. 2022, doi: 10.26593/jrsi.v11i2.5608.145-156.

[20] B. Al Kurdi, M. Alshurideh, and A. Alnaser, 'The impact of employee satisfaction on customer satisfaction: Theoretical and empirical underpinning', *Manag. Sci. Lett.*, vol. 10, no. 2, pp. 3561–3570, 2020, doi: 10.5267/j.msl.2020.6.038.

[21] S. Azarine and M. Yolanda, 'Effect of E-Service Quality and E-Trust on Customer E-Repurchase Intention and Customer E-Satisfaction as Intervening Variable (Case Study: Shopee Users) Shalsabilla', *J. Small Mediu. Enterp.*, vol. 1, no. 1, pp. 16–27, 2022, [Online]. Available: https://jsme.ppj.unp.ac.id/index.php/jsme/article/view/8.

[22] S. Choudhary, R. Nayak, M. Dora, N. Mishra, and A. Ghadge, 'An integrated lean and green approach for improving sustainability performance: a case study of a packaging manufacturing SME in the U.K.', *Prod. Plan. Control*, vol. 30, no. 5–6, pp. 353–368, Apr. 2019, doi: 10.1080/09537287.2018.1501811.

[23] M. Mohan Prasad, J. M. Dhiyaneswari, J. Ridzwanul Jamaan, S. Mythreyan, and S. M. Sutharsan, 'A framework for lean manufacturing implementation in Indian textile industry', *Mater. Today Proc.*, vol. 33, pp. 2986–2995, Jan. 2020, doi: 10.1016/j.matpr.2020.02.979.

[24] K. Kuncorosidi, R. Amelia, and D. W. Apriandi, 'Lean Hospital Simulation Using The Value Stream Mapping (VSM) Method', *J. Ris. Bisnis dan Manaj. Tirtayasa*, vol. 7, no. 2, pp. 48–63, 2023, [Online]. Available: https://jurnal.untirta.ac.id/index.php/JRBM/article/view/23239.

[25] A. Abdullah, S. Saraswat, and F. Talib, 'Impact of Smart, Green, Resilient, and Lean Manufacturing System on SMEs'Performance: A Data Envelopment Analysis (DEA) Approach', *Sustainability*, vol. 15, no. 2, p. 1379, Jan. 2023, doi: 10.3390/su15021379.

[26] M. Fiorello, B. Gladysz, D. Corti, M. Wybraniak-Kujawa, K. Ejsmont, and M. Sorlini, 'Towards a smart lean green production paradigm to improve operational performance', *J. Clean. Prod.*, vol. 413, no. 12, p. 137418, Aug. 2023, doi: 10.1016/j.jclepro.2023.137418.

[27] X. Zhu, Y. Liang, Y. Xiao, G. Xiao, and X. Deng, 'Identification of Key Brittleness Factors for the Lean–Green Manufacturing System in a Manufacturing Company in the Context of Industry 4.0, Based on the DEMATEL-ISM-MICMAC Method', *Processes*, vol. 11, no. 2, p. 499, Feb. 2023, doi: 10.3390/pr11020499.

[28] C. Jaqin, H. Kurnia, H. H. Purba, T. D. Molle, and S. Aisyah, 'Lean concept to reduce waste of process time in the plastic injection industry in Indonesia', *Niger. J. Technol. Dev.*, vol. 20, no. 2, pp. 73–82, Oct. 2023, doi: 10.4314/njtd.v20i2.1396.

[29] I. Elemure, H. N. Dhakal, M. Leseure, and J. Radulovic, 'Integration of Lean Green and Sustainability in Manufacturing: A Review on Current State and Future Perspectives', *Sustainability*, vol. 15, no. 13, p. 10261, Jun. 2023, doi: 10.3390/su151310261.

[30] I. A. Ningsih, D. Almasdy, and A. H. B. Adi, 'Evaluation and Development of Annual Drug Provides Planning at the Riau Islands Province Pharmaceutical Installation', *J. Optimasi Sist. Ind.*, vol. 18, no. 2, pp. 97–106, Oct. 2019, doi: 10.25077/josi.v18.n2.p97-106.2019.

[31] A. Yusuf and D. Soediantono, 'Supply chain management and recommendations for implementation in the defense industry: a literature review', *Int. J. Soc. Manag. Stud.*, vol. 3, no. 3, pp. 63–77, 2022, [Online]. Available: https://www.ijosmas.org/index.php/ijosmas/article/view/142.

[32] M. M. Uddin, 'Improving Product Quality and Production Yield in Wood Flooring Manufacturing Using Basic Quality Tools', *Int. J. Qual. Res.*, vol. 15, no. 1, pp. 155–170, Jan. 2021, doi: 10.24874/IJQR15.01-09.

[33] A. N. M. Rose, N. M. Z. N. Mohamed, F. F. Ab Rashid, M, H. M. Noor, and A. Mohd, 'Improving productivity through value stream mapping (VSM): A case study at electrical & electronic company', *J. Phys. Conf. Ser.*, vol. 1532, no. 1, p. 012005, Jun. 2020, doi: 10.1088/1742-6596/1532/1/012005.

[34] S. F. Fam, N. Ismail, H. Yanto, D. D. Prastyo, and B. P. Lau, 'Lean manufacturing and overall equipment efficiency (OEE) in paper manufacturing and paper products industry', *J. Adv. Manuf. Technol.*, vol. 12, no. 1, pp. 461–474, 2018, [Online]. Available: https://jamt.utem.edu.my/jamt/article/view/4305.

[35] A. Abugabah, N. Nizamuddin, and A. Abuqabbeh, 'A review of challenges and barriers implementing RFID technology in the Healthcare sector', *Procedia Comput. Sci.*, vol. 170, pp. 1003–1010, 2020, doi: 10.1016/j.procs.2020.03.094.

[36] K. Siregar, F. Ariani, and M. M. Tambunan, 'Reducing Waste in Spare Part Production Process with Lean Manufacturing Approach', *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 648, no.

1, p. 012016, Oct. 2019, doi: 10.1088/1757-899X/648/1/012016.

[37] H. Tannady, E. Gunawan, F. Nurprihatin, and F. Wilujeng, 'Process improvement to reduce waste in the biggest instant noodle manufacturing company in South East Asia', *J. Appl. Eng. Sci.*, vol. 17, no. 2, pp. 203–212, 2019, doi: 10.5937/jaes17-18951.

[38] W. A. Santosa and M. Sugarindra, 'Implementation of lean manufacturing to reduce waste in production line with value stream mapping approach and Kaizen in division sanding upright piano, case study in: PT. X', *MATEC Web Conf.*, vol. 154, p. 01095, Feb. 2018, doi: 10.1051/matecconf/201815401095.

[39] S. Zahoor and W. A. Kader, 'A Combined VSM and Kaizen Approach for Sustainable Continuous Process Improvement', *Int. J. Ind. Eng. Oper. Manag.*, vol. 1, no. 2, pp. 125–137, 2019, [Online]. Available: https://www.ieomsociety.org/journals/ijieom/vol-1-no-2-3.pdf.

[40] H. Rifqi, A. Zamma, S. Ben Souda, and M. Hansali, 'Lean Manufacturing Implementation through DMAIC Approach: A Case Study in the Automotive Industry', *Qual. Innov. Prosper.*, vol. 25, no. 2, pp. 54–77, Jul. 2021, doi: 10.12776/qip.v25i2.1576.

[41] B. Romeira, F. Cunha, and A. Moura, 'Development and Application of an e-Kanban System in the Automotive Industry', *Int. Conf. Ind. Eng. Oper. Manag.*, pp. 613–624, 2021, oi: 10.46254/NA06.20210101.

[42] J. Rodrigues, J. C. V. De Sá, L. P. Ferreira, F. J. G. Silva, and G. Santos, 'Lean Management "Quick-Wins": Results of Implementation. A Case Study', *Qual. Innov. Prosper.*, vol. 23, no. 3, pp. 3–21, Nov. 2019, doi: 10.12776/qip.v23i3.1291.

[43] H. Kurnia, I. Setiawan, and Hernadewita, 'Integration of Lean and Green Manufacturing to reduce Process Waste and Employee Recruitment Paper Waste in the Manufacturing Industry in Indonesia', *J. Rekayasa Sist. Ind.*, vol. 11, no. 2, pp. 145–156, 2022, doi: 10.26593/jrsi.v11i2.5608.

[44] L. Canales-Jeri, V. Rondinel-Oviedo, A. Flores-Perez, and M. Collao-Diaz, 'Lean model applying JIT, Kanban, and Standardized work to increase the productivity and management in a textile SME.', in *2022 The 3rd International Conference on Industrial Engineering and Industrial Management*, New York, NY, USA: ACM, Jan. 2022, pp. 79–84. doi: 10.1145/3524338.3524351.