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Lean Manufacturing Analysis: Using WAM and VALSAT to Reduce Waste in the Plastic Sack Finishing Process at PT Surya Plastindo

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Abstract. PT Surya Plastindo is a company that produces plastic sacks. The finishing workstation often encounters various issues, including an excessive number of defective printed products and production quantities consistently exceeding order specifications. This study aims to eliminate waste and implement improvements in the finishing workstation. The lean manufacturing method is suitable for reducing waste at PT Surya Plastindo. The waste elimination process begins with describing the production flow and calculating cycle times for each process, using Value Stream Mapping (VSM) to depict the current state. Subsequently, the Waste Assessment Model (WAM) is employed to weight and rank critical waste. The most critical wastes are further analyzed using value stream mapping tools, with the VALSAT tool selected to map the value flow during production. Finally, a five-why analysis is performed to recommend improvements. According to WAM's waste weighting calculations, defects (20.76%), motion (18.32%), and overproduction (17.54%) are identified as the most significant wastes. The analysis, combined with discussions with production heads and detailed mapping using VALSAT tools, resulted in three recommendations for improvement: the creation of daily production cards, checklists for printing machines, and plastic sack supports for the printing machines. The implementation of these improvements resulted in a reduction in delays and increased efficiency in plastic sack production.

Introduction

The current competitive environment in the manufacturing industry encourages businesses to maintain optimal performance. Companies need to ensure that key aspects such as pricing, quality, production capacity, human resource management, and sustainability are all properly managed. One of the strategies for achieving a competitive edge is by developing operational and production systems that add value. To achieve this, companies must eliminate activities or systems that are deemed unproductive or wasteful [1]. Lean manufacturing is an approach that effectively addresses waste elimination. It aims to create a zero-waste production system that focuses on delivering products based on customer demand [2]. Several methods and tools can be employed in lean manufacturing to support this objective. The company's lean manufacturing initiatives are designed to keep inventory levels efficient, minimize defect rates, and increase the variety of product types, ultimately enhancing overall company performance and the supply chain [3][4]. Manufacturing companies typically face seven types of waste: overproduction, waiting time, transportation, excessive processing, unnecessary inventory, unnecessary motion, and defects. Waste can occur at any stage of the production process. Generally, there are three types of activities in the industrial stream: value-added activities, necessary but non-value-added activities, and non-value-added activities [5].

PT Surya Plastindo, based in Gresik, specializes in producing plastic sacks. Its production process involves several stages, including the preparation of raw materials, extrusion processes, circular looms, finishing, packing, and shipping. However, in the finishing workstation, human involvement in performing the work increases the likelihood of waste, making this area particularly vulnerable to inefficiencies. In 2023, production data revealed a discrepancy between the number of plastic sacks produced and those delivered to customers. This indicated overproduction, with approximately 18,467 excess sacks being produced. Overproduction leads to excessive storage costs and reduces production efficiency. After brainstorming, it was determined that the finishing workstation was the main contributor to this issue, pointing to an imbalance between production orders and output. Other contributing factors included issues with machinery, labor, and material fulfillment.

Besides overproduction, PT Surya Plastindo also faced issues with defective products, particularly in the printing section. The company's standard allows for a maximum of 1% printing defects, but actual defect rates exceeded this limit. Missprints, where the printing on plastic sacks is blurred or uneven, accounted for a significant portion of defects. Any products that fail to meet specifications are discarded. The problems of overproduction and defects have led to increased operational costs, excessive inventory, and disruptions to the overall production process.

Given these challenges, this study aims to eliminate waste and implement improvements at the finishing workstation using a lean manufacturing approach. Waste elimination starts with monitoring value-added activities, necessary but non-value-added activities, and non-value-added activities. The Waste Assessment Model (WAM) questionnaire helps to simplify this process by identifying and ranking the highest levels of waste. The Value Stream Mapping (VSM) tool is then used to visualize the current, future, and ideal state of the production process [6]. A study conducted on lean implementation in a box printing company in Malang using WAM and VSM methods demonstrated several benefits, including productivity gains through the reduction of non-value-added activities [7]. The benefits obtained include increasing productivity by reducing non-value-added numbers from the box printing process due to the proposed improvements implemented. A similar lean analysis applied to medical device production companies led to a 10% increase in output, with production rising from 292,768 pieces to 321,333 pieces [8]. Based on the successes of these previous studies, this research applies lean manufacturing, specifically using WAM and VSM methods, to PT Surya Plastindo's production processes.

Research Methodology

Field studies were conducted by observing all workstations at PT Surya Plastindo, with a specific focus on the finishing workstation. This section was chosen for detailed investigation since numerous tasks performed by humans increase the potential for waste. The research began in February and concluded in July 2024.

Data Collection

At this stage, data were collected through company observations, focusing on production activities and production times. The production activity data encompassed information about material flow and operator tasks carried out at the finishing workstation. In the production of plastic sacks, the finishing workstation required precise production time data for processes such as cutting, printing, and packing. Production times were measured for one plastic sack pallet at each process stage, with five observations taken for each process. This time data was later used for value stream mapping.

To ensure the accuracy of the production time data, rigorous testing was performed, including data adequacy and uniformity tests. Upper and lower control limits were applied to establish data uniformity, with a confidence level of 95% and a significance level of 5%, emphasizing the reliability of the research.

Value Stream Mapping (VSM)

VSM is a lean manufacturing tool used to visualize and analyze production processes. The VSM process involves two stages: mapping the current state and mapping the future state. VSM was used to examine production processes, identify areas for improvement, reduce lead times, minimize inventory, and compare performance before and after the implementation of improvement recommendations. VSM also helps to pinpoint activities that do not add value and reduce unnecessary waste [9][10].

Waste Assessment Model (WAM)

WAM analysis evaluates the relationship between different types of waste and their associated weights. The first step involves analyzing seven types of waste through interviews and questionnaires completed by the production head. The Waste Relationship Matrix (WRM) was then created to examine how one type of waste influences another. A scale from very weak to very strong was used to assess these relationships, and a questionnaire was developed to determine how frequently certain types of waste occurred. The WRM questionnaire consists of 31 relationships between types of waste I that influence kinds of waste j. The results of the WRM matrix percentage are used as input to determine critical waste at the Waste Assessment Questionnaire (WAQ) stage. Next, waste is weighted based on activities frequently occurring on the production floor, using the WAQ algorithm and questionnaire [11]. The head of production will fill in both questionnaires. Each question is given a weight value, namely, the answer "yes" is 1, "medium" is 0.5, and "no" is 0. The waste types were symbolized by letters: defects (D), transportation (T), unnecessary movement (M), unnecessary inventory (I), overproduction (O), waiting (W), and improper processing (P).

Value Stream Analysis Tools (VALSAT)

VALSAT is used to map value flow during production, with a focus on value-added activities [12][13]. The correlation between waste and each mapping tool is categorized as low (L), medium (M), or high (H). The score for each tool is determined by multiplying the percentage of waste by a correlation value (L= 1, M= 3, H= 9). The waste weights from WAM were multiplied by the corresponding mapping tool weights. Three tools with the highest correlation scores were selected for further analysis.

Process Activity Mapping (PAM) is one of the first VALSAT tools chosen for detailed mapping or further waste analysis. This tool aims to provide an explanation of the production process flow for each production process. The tool categorizes each stage into several categories, including operations, inspection, transportation, storage, and delays. These activities are then categorized into types of activities, namely value-added activities, necessary but non-value-added activities, and non-value-added.

The second tool for detailed mapping is the Supply Chain Response Matrix (SCRM). SCRM aims to show the distribution channel's relationship between inventory and waiting time. This makes it possible to identify changes in inventory during distribution time in each area of the supply chain. This change is based on the percentage of days of physical stock. Days physical stock is the daily average of the time the material is in the order fulfillment system.

Quality Filter Mapping (QFM) is the third tool for detailed mapping. These tools are used to inspect a product's quality. QFM distinguishes three types of defects: physical product defects, service defects, and internal defects within the company. Five-why analysis is a structured approach that repeatedly asks "why" questions to understand the causes of problems and produce effective corrective actions to reduce incidents or prevent accidents from happening again [14].

Results and Discussion

Current State Value Stream Mapping

Based on the description of the current state value stream mapping, the total production time for one pallet of plastic sacks at the finishing workstation is 34,054.80 seconds, with 31,543.42 seconds dedicated to value-added activities and 2,511.38 seconds for non-value-added activities. This significant figure indicates that, overall, the production flow at PT Surya Plastindo's finishing workstation has been running efficiently, in line with the direction of the head of production. However, the production output remains inconsistent with the PPIC’s production plan or master production schedule. The number of sacks ordered differs from the number processed. In addition to overproduction, the finishing workstation at PT Surya Plastindo still faces issues with defective sacks. Figure 1 illustrates the complete production process of PT Surya Plastindo’s finishing workstation.

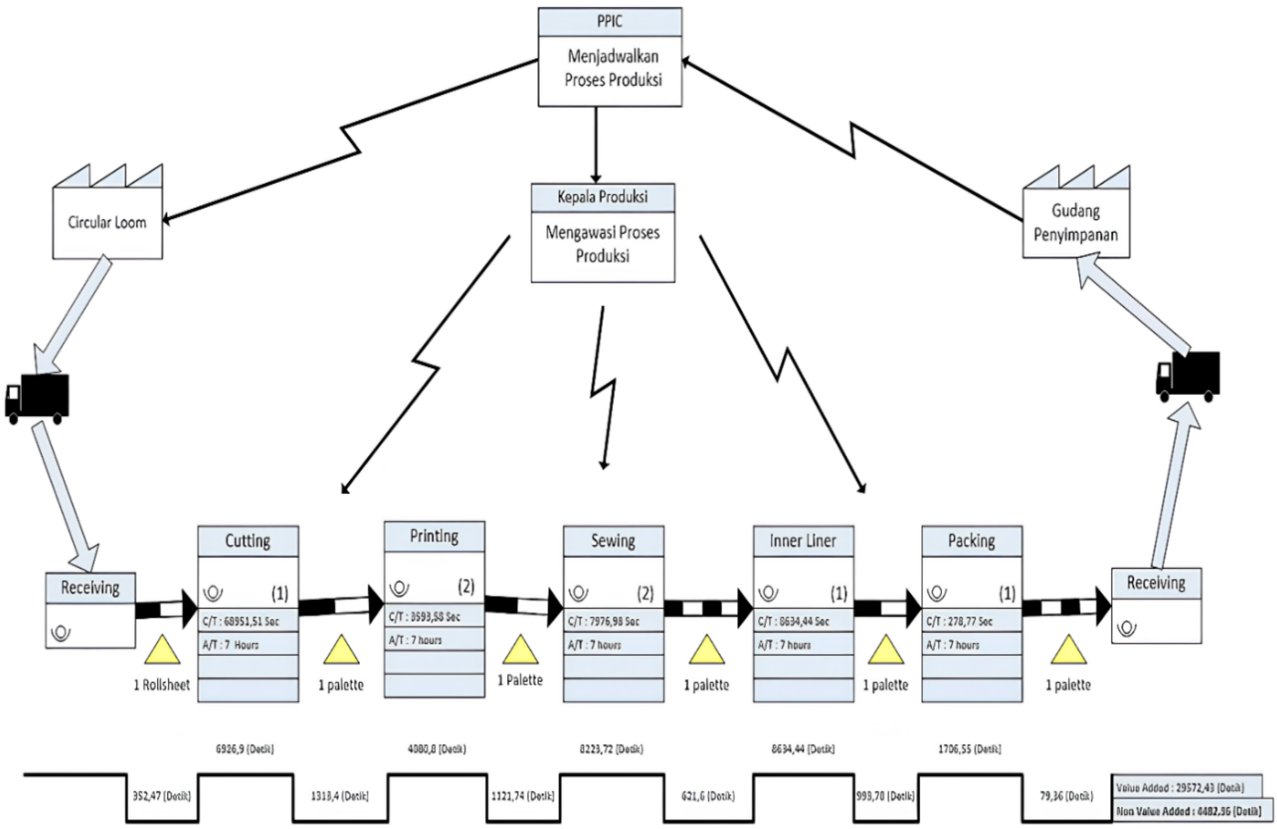

Fig.1. Current State Value Mapping

Waste Identification

WAM's waste identification focuses on identifying issues at finishing workstations. The identification was carried out through interviews with company experts, using two types of questionnaires: the Seven Waste Relationship Questionnaires to compile the WRM and the WAQ.

Waste Relationship Matrix (WRM)

The WRM is used to determine the weight or severity of one type of waste's influence on the emergence of other wastes. The results of the WRM are shown in Table 1.

Table 1. WRM Value

F/T	O	I	D	M	T	P	W	Score	%
O	10	6	8	8	8	0	6	46	15.23
I	6	10	8	8	8	0	0	40	13.25
D	8	8	10	10	8	0	8	52	17.22
M	0	10	10	10	0	10	8	48	15.89
T	8	2	2	6	10	0	4	32	10.6
P	10	6	10	8	0	10	8	52	17.22
W	8	6	8	0	0	0	10	32	10.6
Score	50	48	56	50	34	20	44	302	
%	16.56	15.89	18.54	16.56	11.26	6.62	14.57		

Table 1 shows that the value from the "process" (P) line has the highest score and percentage, namely 17.22%. This percentage suggests that if a waste occurs in the process, it will significantly influence the emergence of other types of waste. Meanwhile, in the matrix column, the "defect" (D) value also shows the highest score and percentage at 18.54%. This indicates that other types of waste have the greatest influence on the emergence of defect waste.

Waste Assessment Questionnaire (WAQ)

The WAQ is used to determine how frequently one type of waste affects the occurrence of other waste in the production system, with the final result being the Yj value. Below are the WAQ results from PT Surya Plastindo's finishing workstation.

Table 2. WAQ Calculation

Information	O	I	D	M	T	P	W
Yj	3.6122	3.3306	3.377	3.6164	3.136	5.2857	3.7281
Pj	252.18	210.52	319.28	263.15	119.29	114.03	154.38
Yj Final	910.94	701.15	1,078.2	951.64	374.1	602.73	575.54
The final result [%]	17.537	13.498	20.758	18.321	7.2022	11.604	11.08
Rank	3	4	1	2	7	5	6

The assessment results show the ranking of dominant wastes that strongly influence others. This study focused on analyzing the three largest wastes: defect waste, which accounted for 20.76% of the total; motion waste, which accounted for 18.32%; and overproduction waste, which accounted for 17.54%. These three wastes significantly influence one another.

Identify Causes of Waste with VALSAT

The next step uses the WAM analysis results' percentage weights to determine the appropriate VALSAT tool. VALSAT is an approach that calculates waste weights and selects an instrument using a matrix. The results of this process are shown in Table 3.

Table 3. VALSAT Calculation

Waste	Weight	PAM	SCRM	PVF	QFM	DAM	DPA	PS
Overproduction	17.54	17.54	52.61	0.00	17.54	52.61	52.61	0.00
Waiting	11.08	99.72	99.72	11.08	0.00	33.24	33.24	0.00
Excessive Transportation	7.20	64.82	0.00	0.00	0.00	0.00	0.00	7.20
Innappropiate Processing	11.60	104.43	0.00	34.81	11.60	0.00	11.60	0.00
Unneccessary Inventory	13.50	40.49	121.48	40.49	0.00	0.00	13.50	0.00
Unneccessary Motion	18.32	18.32	18.32	0.00	0.00	0.00	0.00	0.00
Defect	20.76	20.76	0.00	0.00	186.82	0.00	0.00	0.00
Total		366.08	292.14	86.39	215.96	85.85	110.95	7.20
Ranking		1	2	5	3	6	4	7

The order of the VALSAT mapping tools in Table 3 is as follows: 482.389 for PAM (Process Activity Mapping), 292.14 for SCRM (Supply Chain Response Matrix), and 215.96 for QFM (Quality Filter Mapping). The VALSAT calculations focus on the three tools with the highest scores to address waste. Therefore, researchers chose PAM, SCRM, and QFM tools to eliminate waste at PT Surya Plastindo's finishing workstations.

Process Activity Mapping (PAM)

Process Activity Mapping is a VALSAT tool that thoroughly maps all activities to minimize waste. The following table summarizes the results and percentages of PAM based on Process Activity Mapping.

Table 4. PAM Calculation

Activity	Activity Total	Time [Minutes]	Time [Minutes]	%
Operation	16	29,628.762	493.8127	0.870032
Transport	17	1,959.492	32.6582	0.057539
Inspect	1	106.944	1.7824	0.00314
Storage	0	0	0	0
Delay	9	2,359.602	39.3267	0.06928838
Total	43	34,054.8	567.58	100%

According to the table above, there are nine delay activities totaling 2,359.60 seconds at the finishing workstation. These delays occur because operators repeatedly check the number of plastic sacks produced in one pallet, which halts the production process. This repeated checking is necessary because operators need to know how many sacks the consumers ordered, whereas they currently only follow daily production targets. It is essential to track production targets, actual output, and the number of sacks in a single pallet. The existing delay activities must be minimized immediately, as they do not add value to the production process at the finishing workstation.

Supply Chain Response Matrix (SCRM)

Based on data from PT Surya Plastindo for the period of February 2024, an SCRM was created for the plastic sack production process with the following stages:

1. The raw material storage area (finished goods from the circular loom) operates with an average waiting time of 3 hours or 0.125 days for materials received from the output of the circular loom process. Efficiency is evident from the average amount of raw materials received, which is 120,000 items per day, and the average amount of raw materials processed or ordered, which is 96,750 items per day. This results in a one-day physical storage for raw materials. The physical stock is determined by dividing the raw materials received by the raw materials used.
2. The process of making plastic sacks is rapid, requiring a total of 34,054.80 seconds (0.394 days) in the work-in-process area of the finishing workstation. With 120,000 incoming raw materials daily, the system maintains a high average production output of 107,689 items, leading to a physical goods stock of 0.897 days. The days of physical stock are calculated by dividing the average production output by the average raw materials used.
3. In the finished product storage area (finished goods finishing), the average waiting time for delivery or withdrawal to the next process is 1 hour, which is equivalent to 0.041 days. The average number of deliveries is 96,750 pieces per day, while the incoming finished products are 107,689 pieces per day, leading to a physical stock of 1.113 days. The days of physical stock are calculated by dividing the average amount of plywood sent by the average production output.

The following table tabulates lead time and inventory calculations based on the data obtained.

Table 5. SCRM Calculation

No	Activity Total	Days Physical Stock	Time [Minutes]	%
1	Raw Material Storage Area (F/G Circular loom)	1	0.125	0.125
2	Production Process Area (WIP Workstation Finishing)	0.897	0.394	0.519
3	Finished Product Storage Area (F/G Finishing Workstation)	1.113	0.041	0.56
	Total			3.57

Table 5 shows that in the production series of the finishing workstation, the largest days of physical stock occur in the finished product area, with a stock of 1.113 days. This occurs because the number of plastic sacks produced exceeds the number of plastic sacks ordered by consumers. As a result, the packing process may become more optimal, leading to an accumulation of finished products, commonly referred to as overproduction.

Quality Filter Mapping (QFM)

At PT Surya Plastindo's finishing workstation, the standard for product quality defects is set at a maximum of 1% of total production. Based on actual reject/defect data from January to June 2023, the highest reject rate occurs in the printing process due to misprints, with an average reject rate of 1.22%. Therefore, misprint waste becomes a priority for identifying improvement recommendations. Below is detailed rejection rate percentage data for misprints.

Table 6. QFM Calculation

Period	Number of Miss Prints	Percentage [%]
January	36,500	1.30
February	34,500	1.60
March	45,500	1.30
April	18,000	0.80
May	43,000	1.40
June	18,500	0.80

The data above shows that the actual total rejection rate exceeds the set standard, with the highest percentage reaching 1.6%. There are two machines used in the printing process, and both contribute equally to the occurrence of misprints. Misprints are caused by operator negligence in monitoring machine component performance and improper placement of plastic sacks into the printing machine.

Five-Why Analysis and Recommendations for Improvement

After detailed mapping with the VALSAT tool, the next step involves conducting a Five-Why analysis. The proposed improvements focus on addressing the three types of waste analyzed using three detailed mapping tools: Process Activity Mapping (PAM), Supply Chain Response Matrix (SCRM), and Quality Filter Mapping (QFM). The analysis and recommendations for improvement are as follows:

1. Reducing Overproduction Waste

   Overproduction can lead to significant losses for the company, including unnecessary storage and production costs, while also disrupting the production process at the finishing workstation. To address this issue, a daily production card is recommended. This card, based on the PPIC's production target for each customer order, provides a clear production plan. The production team will create a daily production card, including job/order number, completion time allocation, production targets, and actual production output. The responsible operator at each workstation will attach this card to each production pallet.

2. Reducing Defect Waste Caused by Machine Components

   One of the key recommendations to prevent misprints due to machine or material issues is implementing a checklist. Operators must follow specific procedures to inspect and adjust machine components, ensuring that plastic sacks meet production specifications. Since PT Surya Plastindo has not yet implemented this tool, the checklist is crucial to ensure that employees properly utilize machine settings.

3. Reducing Defect Waste Caused by Incorrect Bag Positioning on the Machine

   The next improvement recommendation focuses on the printing machine's support system for plastic sacks. Unlike the checklist, the printing machine support tool is designed to prevent misprints caused by human error, particularly due to the incorrect positioning of plastic sacks in the printing machine. This recommendation was inspired by a similar support tool developed by another company in the Sidoarjo area. Implementing this support tool can help reduce human-caused misprints [15]. The following diagram illustrates a plastic sack support tool for the printing machine.

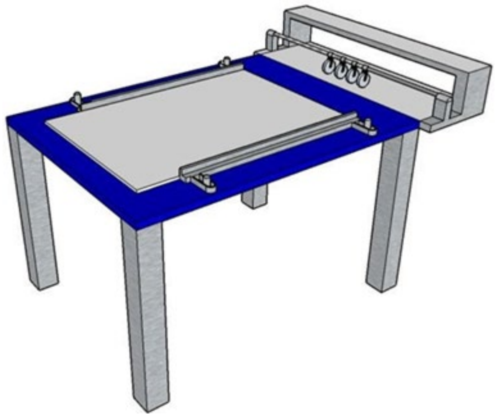

Fig.2. Overview of Printing machine's Sack Support

Creating Future State Mapping

Based on the proposed improvement recommendations, the following is the Future State Value Stream Mapping (FSVSM) for implementing these recommendations in each stage of the production process.

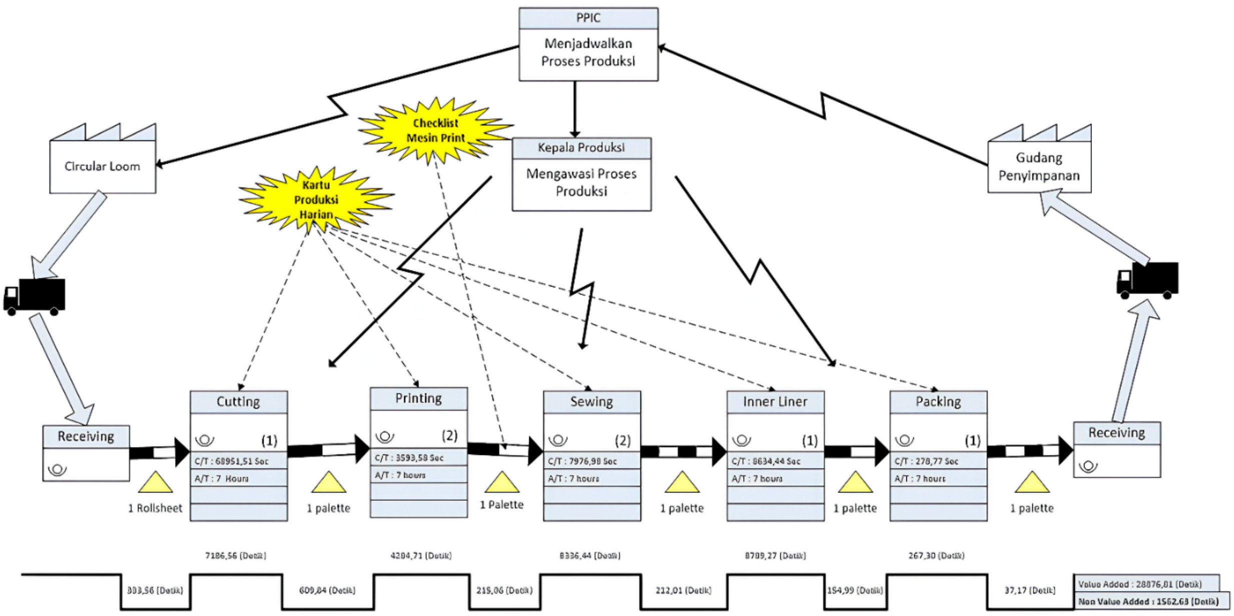

Fig.3. FSVSM Workstation Finishing

The FSVSM was created using an experimental production process involving a pallet containing 3,000 plastic sacks, with the implementation of daily production cards and checklists for the printing machines. The evaluation method used compares the process activity mapping results at the finishing workstation before and after improvements. Table 6 presents the conditions before and after these improvements, based on data from the production of a single pallet of plastic sacks at the finishing workstation.

Table 6. FSVSM calculation

Activity	Number of Activities		Time [Seconds]	
	Before	After	Before	After
Operation	16	26	29628.76	28645.1
Transport	17	15	1959.492	1484.49
Inspect	1	0	106.944	0
Storage	0	0	0	0
Delay	9	4	2359.602	297.37
Total	43	45	34054.8	30426.9

The implementation of the improvement recommendations successfully reduced non-value-added activities and significantly decreased delays. The delay was reduced from 39.33 minutes to just 4.96 minutes. Due to time constraints, the recommendations have yet to be analyzed periodically; however, the proposed improvements have streamlined the production process at PT Surya Plastindo's finishing workstation.

Conclusion

The waste weighting calculation using the WAM tool shows that the highest percentage of waste at PT Surya Plastindo's finishing workstation is defect waste, at 20.76%. To conduct a more detailed analysis of improvement recommendations, we focused on the three most significant types of waste—defect (20.76%), motion (18.32%), and overproduction (17.54%)—based on the issues identified. These three wastes were prioritized because of their relevance to field conditions and their mutual influence. Discussions with the head of production, along with detailed mapping using VALSAT tools and a five-why analysis, led to three key improvement recommendations. The first improvement involves creating daily production cards, which are placed on top of the plastic sack pallets by the operator. The second improvement is the introduction of a checklist specifically for the printing machine. This checklist allows operators to monitor the condition of machine components before starting the printing process. The third improvement is the creation of plastic sack supports for the printing machine, designed to reduce misprints caused by improper positioning of the sacks. The evaluation of these improvements showed a significant reduction in production delays at the finishing workstation, decreasing delay time from 39.33 minutes to 9.43 minutes, and increasing the efficiency of plastic sack production time to 60.46 minutes.

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