Lean Manufacturing Approach to Increase Packaging Efficiency

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Abstract. The company upon which this paper is based engages in flexible packaging production, especially pharmaceutical products with guaranteed quality, trusted by consumers. Its production process includes printing, laminating, and assembling processes. Production activities are done manually and automatically using machines, so various types of waste are often found in these processes, making the level of plant efficiency nonoptimal. This study aims to identify wastes occurring in the production process, especially the production of pollycelonium with three colour variants as the highest demand product, by applying lean manufacturing concepts. The Current Value Stream Mapping (CVSM) used to map the production process shows the amount of Value Added Time of 107.676 minutes, Non-Value Added Time of 311.450 minutes due to engine displacement and setup, and total lead time of 455.724 minutes with a 23.627% Cycle Efficiency. Transportation in the factory creates the largest waste with a distance of 340 meters. Further analysis using the fault tree analysis method and 5W+1H method results in a layout proposal and minimization of machine setup time activity projected with Future Value Stream Mapping (FVSM) to increase to percentage cycle efficiency 14.05% and decreasing process lead time of 169.939 minutes.
Keywords. Waste, Lean Manufacturing, Value Stream Mapping, Non-Value Added

INTRODUCTION

Industries in Indonesia have been improving lately, which delivers them to a competition on a global scale, hence encouraging many companies to keep improving and increasing the effectiveness and efficiency of their businesses. In their cause for improvements in productivity, companies must know which events can add value, reduce waste, and reduce the lead time [1].

The company upon which this paper is actively based engages in the production of flexible packaging. The company was founded in 1976, and for their high precision and material quality, they gained trust from customers and received support for their development until today. Currently, the company operates on an area of 18,527 square meters while employing 500 employees. The company's growth has been a success so far, but that does not state that the company is in the perfect situation, and there are still many problems that need attention so they can always keep their position upfront.

In general, the company faced problems such as a nonoptimal plant efficiency rate caused by waste in the company and activities that don't add value. There are six types of products in the company, but from these products, pollycelonium became the main focus of this research as its demand is the highest compared to the others.

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Objectives

The production process of flexible packaging goes through three steps: printing, laminating and assembling. The prepared material will be printed with a printing machine in the printing step according to the printing design. Before moving to the following step, inspection and examination are done by machine to check whether the results are appropriate according to the design. The laminating step is the procedure of coating or layering. According to the product category, this step also uses machines so that the printed material can be laminated on the inside and outside. The next step is assembling (Stitching) or cutting *work-in-process* materials to their specific dimensions according to the customer's orders.

One way to identify waste is to use the lean approach. The lean approach focuses on efficiency without reducing process effectivity, including increased operations with value-added, reduction of waste, and fulfilling customer needs [2]. With the lean approach, this study aims to identify waste occurring in the production process, especially the production of pollycelonium with three colour variants as the product of highest demand, by applying lean manufacturing concepts.

LITERATURE REVIEW

Lean Manufacturing

Lean manufacturing includes every activity in the facility that happens until the producer receives cash. The main focus in lean manufacturing is to reduce the timeline by eliminating wastes with no value-added. Waste can be reduced by conducting production at the correct quantity, correct time, and location. Continuous improvement is then implemented gradually and done continuously. Identification of probable wastes in the entire process needs to be done to maintain a lean condition [3].

Seven Waste Concept

The seven wastes are waste in the manufacturing or service process, including transportation, inventory, motion, waiting, overprocessing, overproduction, and defects. Further explanations of the seven wastes are described as follows: (a) Waste of Transportation – includes unnecessary movement or transport of goods. (b) Waste of Inventory – includes overstocking of inventory goods. (c) Waste of Motion – time and energy that are used for motions that give no added value. (d) Waste of Waiting – includes waiting for activities on automatic machines. (e) Waste of Overproduction – producing goods are exceeding the amount of demand. (f) Waste of Overprocessing – includes all added processes unnecessary for the product. (g) Waste of Defects – includes reworking, with no added value [4].

Value Stream Mapping

Tools are used for mapping value streams because all activities (value-added and non-value-added) are currently essential to bring the product through the necessary main flow to be introduced [2]. It is drawn as (a) Product design from its concept until release in the market. (b) Product flow from the material to shipment to the customers. (c) The flow of information is required to trigger and support itself. It is described that the higher benefit of waste elimination is realized mainly by looking at the big picture of the value stream to optimize the process as a whole.

METHODS

The flowchart of the research methodology can be seen in Figure 1. In the beginning, starting with problem identification, the topic chosen and the aim of the research. The study for this research continued with a literature review and field study. After the literature study, the research continues with the data collection and data calculation such as time study [5][6], worked mapping, data analysis with Value Stream Mapping (VSM), value added analysis, and waste analysis. The research ended with a conclusion and suggestion. The research methodology shown in figure 1.

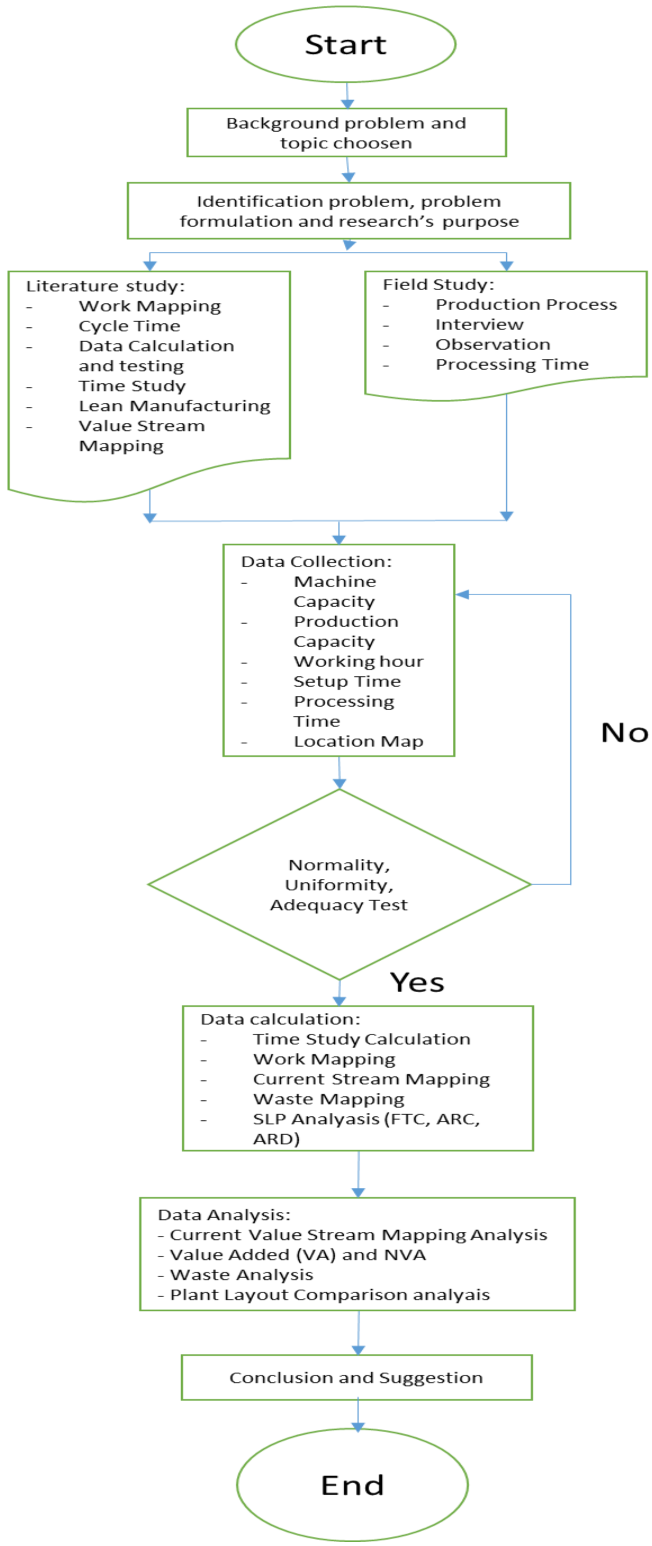

Figure 1. Flowchart of Research Methodology

DATA COLLECTION

Time data of every activity (activities 1-12) in the production process are collected by manual observation. The production process of flexible packages is done 30 times. Note that activities 3, 5, 8, and 11 are not subject to manual observation due to machine operation in the production process.

RESULTS AND DISCUSSION

Numerical Results

Before using the measured time data, the data has to go through tests such as the normality test, distribution test, and the data adequacy test to ensure that the data is normal, uniform, adequate, and valid for this study. The confidence level is set at 95% and the accuracy level at 5% because observers allow the mean of test results to deviate 5% from the actual average. The certainty of the data can be trusted by 95% because the data is obtained manually without advanced technology. Calculations of the standard time are based on the collected data, which is the cycle time that has passed the normality test, distribution test, and data adequacy test. Calculations of the cycle time for each activity are shown in Table 1.

Table 1. Cycle time of each activity

Activity	Cycle Time (in minutes)
1	17.54
2	98.43
3	30.00
4	5.82
5	30.00
6	8.01
7	59.73
8	25.00
9	10.96
10	25.00
11	20.00
12	2.62

Operators may do anomalies during the collection of time data. For example, when operators were doing their tasks too quickly as if in a rush or when operators find technical difficulties working, i.e. caused by a poor working environment. Those factors may influence the speed of work, and so when anomalies were found, observers must know and consider the length in which it can happen. Usually, adjustments are symbolized by (p). When operators work faster than usual, then the value of p is greater than 1 (p>1); when slower than usual, then the value of p is less than 1 (p<1). When operators work in the normal condition, then the value of p is equal to 1 (p=1). After determining the adjustment factor of each activity, the normal time of the activities can be obtained by multiplying the cycle time of each activity with ith adjustment factor. After obtaining the normal time of each activity, calculations to determine the standard time of the process can be done by multiplying the normal time of each activity by its allowance factor, determined beforehand. The standard time of each activity in the production process is shown in Table 2.

Table 2. Standard time of each activity in the production process

Activity	Normal Time (in minutes)	Allowance (%)	Standard Time (in minutes)
1	11.24	50	16.865
2	95.48	55	147.995
3	30.00	39	41.700
4	2.79	52	4.244

Activity	Normal Time (in minutes)	Allowance (%)	Standard Time (in minutes)
5	25.00	39	34.750
6	3.85	52	5.846
7	60.33	53	92.306
8	30.00	39	41.700
9	5.26	52	7.996
10	28.00	30	36.400
11	20.40	19	24.276
12	1.37	27	1.746

Graphical Results

Value stream mapping is used to understand the process happening in the information and physical flow of the production system. The time data that has been tested and processed is used to create the Current State Value Stream Mapping. The Current State Value Stream Mapping is shown in Figure 2.

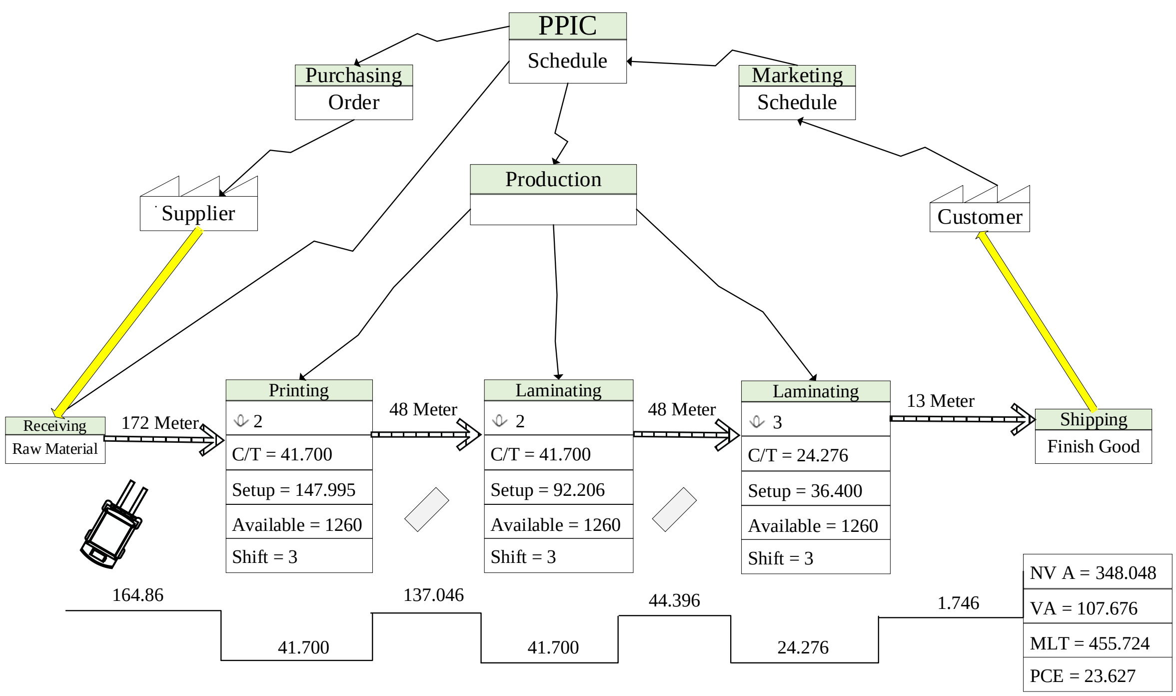

Figure 2. Current State Value Stream Mapping

According to the Current State Value Stream Mapping, there are 107.676 minutes of value-added time, 348.048 non-value-added time caused by waste, and 455.724 minutes of manufacturing lead time identified in the production of flexible packaging, with a cycle efficiency percentage of 23.627%. Further analysis was conducted by Process Activity Mapping (PAM) to know the proportion of each value-added time, non-value-added time, and necessary non-value-added time. Process activity mapping is also used to identify waste occurring in the value stream map and optimize the process to increase effectivity and efficiency by creating a more simple design. The result of process activity mapping shows the proportion of the production process activity in Figure 3.

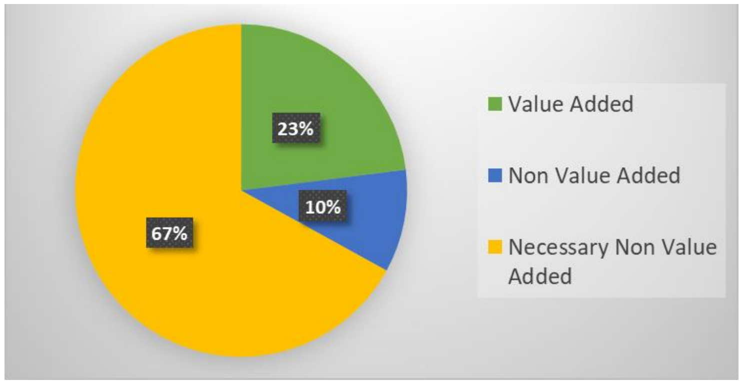

Figure 3. Proportion of the production process activity

Based on the proportion of the production activities, 23% of the activities in the production process bring added value, and 67% of the activities do not bring added value. Out of the twelve activities in the production process, six activities are operations, five activities are transportations, and one activity is categorized as inspection. In the next step, a waste analysis will identify waste found in the production process of pollycelonium at the company. The waste analysis is done based on the seven waste concepts: overproduction, overprocessing, waiting, transportation, motion, defects, and inventory. This concept will be implemented for every activity by reviewing the activities on-site directly [7]. Results of the waste analysis are then shown in Table 3.

Table 3. Waste analysis for 12 activites.

Activity		Waste	Description of Waste
1	Materials are transported from the warehouse to the printing area	Transportation	These transportations are considered relatively slow due to the 172-meter distance between the warehouse and the printing area, and the probability of using a forklift.
2	Printing machine set up according to the designated design	Waiting	Waiting time of machine setup, i.e. placing materials, attaching cylinders, pouring ink, etc.
		Motion	A lot of excessive motions during setup, i.e. move and hold.
3	Printing process to create a design	Overproduction	The printing process may cause overproduction.
4	Processed materials are transported to the inspection area	Transportation	Transportation is done by the operator using a trolley for 12 meters to move work-in-process from the printing area to the inspection area to be tested.
5	Waiting for the inspection process to finish	Waiting	The inspection process is done automatically by machine, so finishing this process is required before moving to the next process.
6	Inspected materials are transported to the laminating area.	Transportation	Transportation by the operator using a hand truck for 36 meters to the laminating area. Problem is found in long-distance caused by

Activity		Waste	Description of Waste
			path passing through the printing area again.
7	Laminating machine setup process according to product type	Waiting	Waiting time of machine setup, i.e. placing work in process, managing machine settings, etc.
		Motion	A lot of excessive motion during setup, i.e. move and position.
8	Laminating process for the inner and outer layer	-	No waste identified
9	Laminated materials are transported to the assembling area	Transportation	Transportation by the operator using a hand truck for 48 meters to the assembling area. Problem is found in long-distance caused by a path through the outside of the plant.
10	Assembling machine setup process according to set sizes	Waiting	The machine setup process, i.e. managing cutting settings according to customer demand.
11	Assembling process or cutting of product according to customer demand	-	No waste identified
12	Slit products are transported to the finished goods warehouse	Motion	Transportation to the finished goods warehouse is done manually. Motion waste is considered compared to transportation waste due to short-distance transport without the use of tools.

The cause of waste is then reanalyzed using the fault tree analysis to comprehend further the waste occurring in every activity. Fault tree analysis aids in finding solutions by mapping the cause-and-effect anatomy around the problem, similar to a mind map but with more structure [8].

After the cause of waste is identified [9], it is then summarized, and proposed improvements can be given according to the problem that occurs using the 5W+1H method. Hence, from each identified waste, a proposal for improvement for the most dominant waste, which is the waste of transportation caused by the length of transport in the facility, continued by the waste of waiting, during machine setup activities of printing, laminating or assembling processes.

Proposed Improvements

Based on the analysis, the proposed improvements for the problem in this study are as follows.

a. New layout design proposal: After discussions with the plant officials, a new layout design shows the most interest in improving the production process because the current layout is considered defective. A poor layout causes the excessive duration of transportation. This condition may be due to the lower factory efficiency in the non-value-added activities of the production. So, a new layout that is planned according to the production process and the designed system must be proposed. Then, an Activity Relationship Diagram (ARD) analysis is done by designing improvements on the current layout according to the process flow, and six departments require improvements. According to the ARD, the proposed layout design is then created and continued by quantitative design using from to chart. Output is created as a block plan of the new layout. The activity relationship diagram of the proposed layout is shown in Figure 4. The block plan and the proposed new layout are illustrated in Figures 5 and 6, respectively.

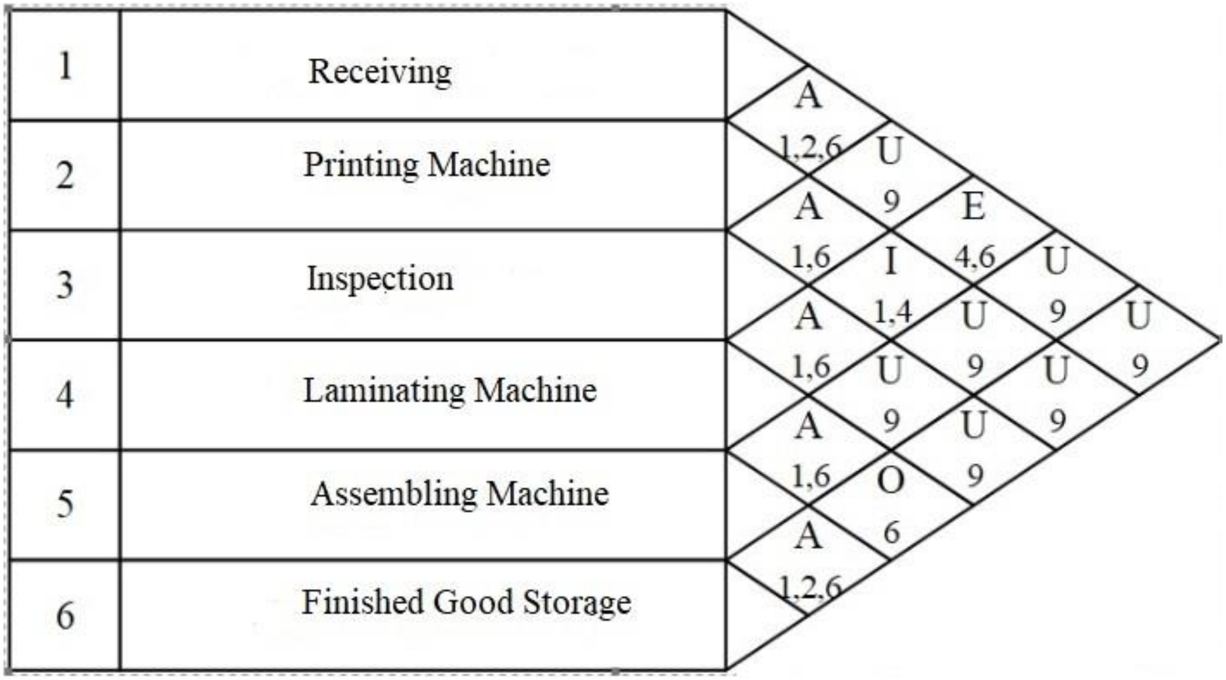

Figure 4. Activity Relationship Diagram (ARD) of the proposed layout

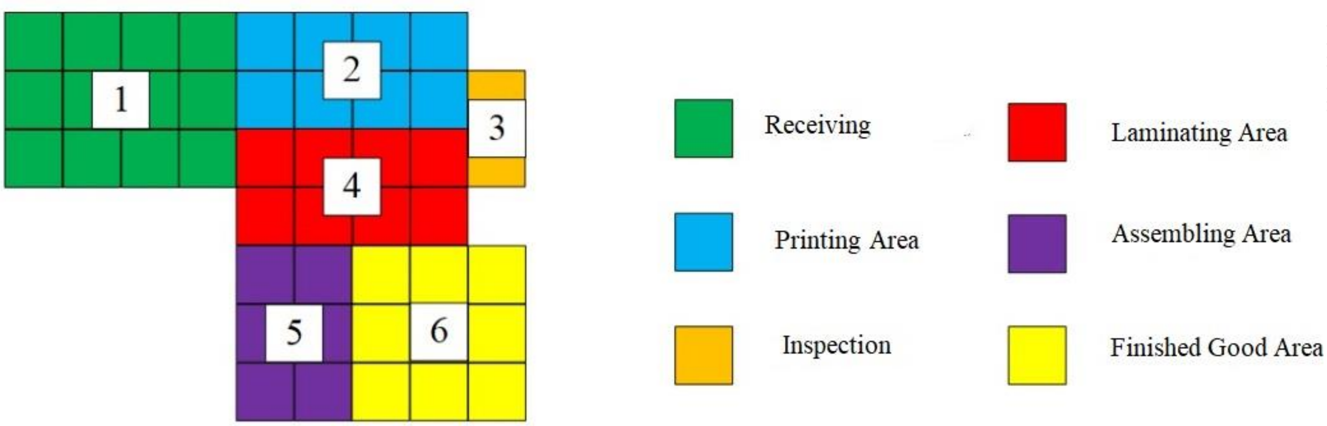

Figure 5. Block plan of the proposed layout

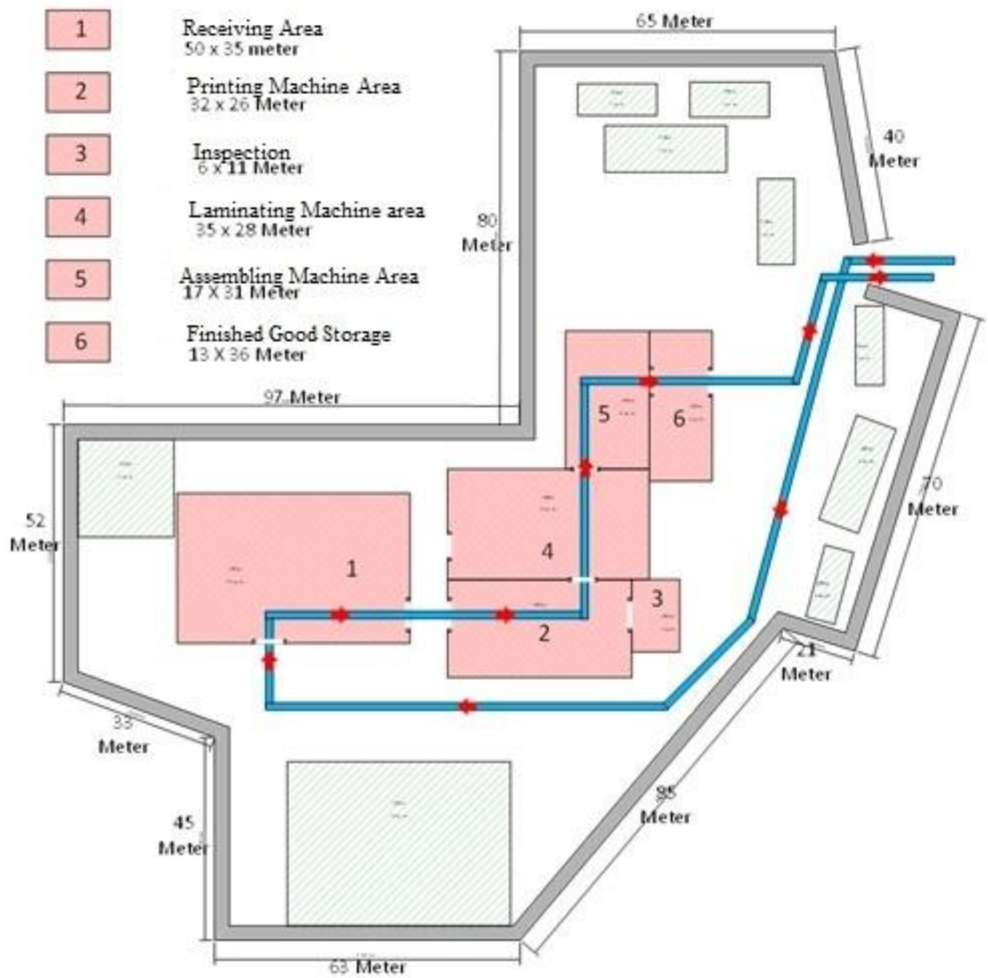

Figure 6. Proposed new layout

Based on the new proposed layout, new distances between facilities are achieved. The distance from the material warehouse to the printing area is 67 meters. The distance from the printing area to the inspection area is 29 meters. The distance from the inspection area to the laminating area is 30 meters. The distance from the laminating area to the assembling area is 39 meters, and the distance from the assembling area to the finished goods warehouse is 19 meters. The total distance of transport in the new layout is 184 meters, whereas the transport distance in the current layout is 340 meters. Supplementary to the new proposed layout, it is also suggested that transport and material handling is done using conveyor systems. Conveyor systems are used for conditions when transporting goods continuously from one position to another in a fixed path since the company produces flexible packagings in rolls, transportation of materials, work in process, and finished goods are all continuous and systematic, i.e. from printing to laminating areas, continuing to the assembling area, and repeating. Conveyor belts can be installed to transport material from the printing area to the laminating area, then the assembling area, and finally to the finished goods warehouse, covering 77 meters of distance between the four departments.

b. Minimize the setup time by optimizing activities using the Single-Minute Exchange of Die (SMED) method: This method reduces setup by classifying setups into two types: internal setup and external setup. Internal setup is done when machines are off; meanwhile, the external setup is done while machines are operating [10]. By implementing the SMED method, the duration of machine setup activities in the production process is expected to be minimized. Machine setup does not add value to the product, so the plant efficiency reduces as the machine setup happens during production while the machine is on. Before implementing setup time minimization using SMED, setup time for each machine (printing, laminating, and assembling) is required. The results of the proposed improvements are depicted in Table 4.

Table 4. Machine setup time minimization

Printing Machine Setup		Time reduced after proposed improvements (in minutes)
Activities fixed	Changed activity 3, 6, 13, and 18 into an external activity and reduced required setup time	21.847
Activities paralleled	Aligned activity 3 with 7, and activity 13 with 17, to reduce required setup time	11.624
Laminating Machine Setup		
Activities fixed	Changed activity 3, 9, 13, and 14 into an external activity and reduced required setup time	15.992
Activities paralleled	Aligned activity 1 with 6, and activity 2 with 7, to reduce required setup time	6.841
Assembling Machine Setup		
Activities fixed	Reordered activity 2, 3, and 11 to reduce required setup time	4.170

After the proposed improvement, the amount of machine setup time reduced is obtained. Setup time for printing machines is reduced from 98.43 minutes to 64.959 minutes. Setup time for laminating machines is reduced from 59.73 minutes to 36.9 minutes. Lastly, the setup time for assembling machines is reduced from 25 minutes to 20.83 minutes. Setup times for machines before and after proposed improvements are summarized in Table 5.

Table 5. Setup time for machines before and after proposed improvements

Machine	Setup time before proposed improvement (in minutes)	Setup time after proposed improvement (in minutes)
Printing	98.430	64.959
Laminating	59.730	36.897
Assembling	25.000	20.830

Validation

Future Value Stream Mapping (FVSM) is mapping a company's condition in the future as an improvement proposal of the existing Current Value Stream Mapping (CVSM). Proposed improvements that are given for the company include the proposed improvement of the new layout by moving existing departments and placing them systematically close to each other. It also includes changing the existing material handling methods, such as trollies and hand trucks, to conveyor belts, especially from the printing department, to the laminating department, to the assembling department, and ending at the finished goods warehouse. The following proposed improvement includes minimizing machine setup time using the single-minute exchange of die method by changing machine setup activities as external activities and aligning some activities, making them parallel. The proposed improvements caused the plant cycle efficiency increase and reduced the total lead time significantly. The Future Value Stream Mapping is illustrated in Figure 7.

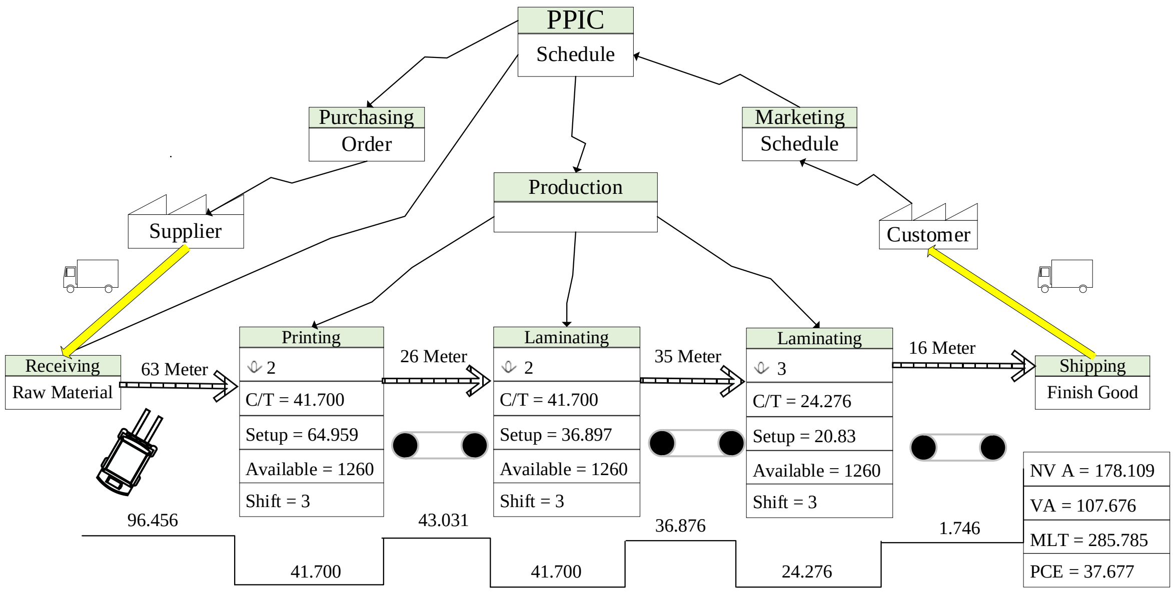

Figure 7. Future value stream mapping

According to the future state value stream mapping, there are 107.676 minutes of value-added time, 178.109 minutes of non-value-added time after implementing proposed improvements, and 285.785 minutes of manufacturing lead time identified in the production of flexible packaging, with an increased cycle efficiency percentage of 37.677%. After implementing the new proposed layout, the current value stream mapping changed in material handling. Minimizing machine setup time, the total Process Cycle Efficiency (PCE) increased by 14.05%. The total manufacturing lead time was reduced from 455.724 minutes to 285.785 minutes, a difference of 169.939 minutes, and the transport distance was reduced by 194 meters. A comparison of the CVSM and FVSM is shown in Table 6.

Table 6. Comparison of CVSM and FVSM

Description	CVSM	FVSM	Difference
Process Cycle Efficiency (%)	23.627	37.677	14.050
Total Lead Time (in minutes)	455.724	285.785	169.939
Total Transport Distance (in meters)	380	186	194

CONCLUSION

The largest source of waste found in the flexible packaging production process at the case company is the waste of transportation and waiting. The results of mapping the current condition of the plant according to the current value stream mapping show the amount of manufacturing lead time of 455.724 minutes with a cycle efficiency percentage of 23.627%. According to the result of process activity mapping, It is discovered that there are 107.676 minutes of activities with added value, 311.450 minutes of activities with no added value, and 36.598

minutes of necessary activities with no added value. The cause analysis results using the fault tree analysis and 5W+1H method show that waste and non-value-added excessive duration of material transport causes activities. This condition is caused by far distances between departments and machine setup activities that require minimization to increase efficiency. According to the identified cause, proposed layout improvements by proposing a new layout design with production departments close to each other and proposing the use of conveyor belts for material handling at production departments, and so a new total distance of 186 meters, and production transport time of 18.6 minutes is achieved. Then, improvements are also made by minimizing machine setup activity time using the single-minute exchange of die method on printing, laminating, and assembling machines. Time differences of 33.47 minutes on printing machines, 22.83 minutes on laminating machines, and 4.17 minutes on assembling machines are achieved. This research can be summarized according to the future value stream mapping with the manufacturing lead time of 285.785 minutes, and an increase of cycle efficiency percentage of 14.05 minutes is achieved.

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