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Integration of Lean Manufacturing and Promodel Simulation on Repair Production Process Flow of Polysilane Bottle Printing Using VSM, WAM, VALSAT, And RCA Methods: Case Study Packaging Manufacturing Company

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ABSTRACT
In the production process, waste is found, which causes a decrease in the efficiency and effectiveness of the production process. The obstacle faced is not achieving the monthly production target from the target set by the company. This study aims to minimize waste or activities that do not provide added value by visualizing the ProModel simulation. The first step of the research is to identify the production process and waste using Operation Process Chart (OPC), Value Stream Mapping (VSM), and Waste Assessment Model (WAM). Based on WAM, it is known that there are 3 critical wastes, namely Transportation 13.5%, motion 13.01%, and waiting for 10.7%. Next is waste mapping with Value Stream Analysis Tools (VALSAT) using Process Activity Mapping (PAM). Based on PAM, it is known that there are 9 Value Added (VA) operations for 210 seconds and 4 Necessary but Non-Value Added (NNVA) transportation activities for 194 seconds. Then the root cause analysis was carried out using the 5 Whys Root Cause Analysis (RCA) and analysis of the design recommendations for improvement using the RCA 5W 1H tool. Based on the 5W 1H tool, it is known that there are 2 recommended improvement activities. That is by combining the machining process and changing the layout of the machine to eliminate waste. The last is the simulation of the repair results using the Promodel software. Based on the Promodel simulation with a runtime of 1440 minutes, it is known that 2,621 pcs of polysilane finish good bottles exit.

Keywords: Lean Manufacturing; Value Stream Mapping (VSM); Waste Assessment Model (WAM); Value Stream Analysis Tools (VALSAT); Root Cause Analysis (RCA); Promodel Simulation

INTRODUCTION
The manufacturing industry in general cannot be separated from the role of the packaging industry. Based on data (IPF) Indonesia Packaging Federation, the country's packaging industry's performance is projected to grow 6% in 2021 from last year's realization of Rp 98.8 trillion. Judging from the material, the packaging in circulation consists of 44% flexible packaging, 14% rigid plastic packaging, and 28% paperboard packaging.

During the Covid-19 pandemic, the domestic packaging industry experienced a significant increase in demand. Especially the plastic bottle packaging industry. This company is a manufacturing company engaged in manufacturing plastic bottle packaging intended for industry/products (pharmaceuticals, drugs, herbs, cosmetics, oil, food & beverages). The need for primary packaging is urgently needed, and the demand for increasing production results will increase, which requires a company to increase the output and efficiency of its operations.

Meeting the efficiency of production operations activities supports the smooth operation of a company. The problem that often occurs in the company's operations is that there is still a lot of waste in the production process. To meet the efficiency of suitable operating activities, you must understand the movement of tools and machines, waiting for processes, and the process flow of the devices used.

To increase the engine output by planning and efficiency at the time of production so that profits can be achieved as expected as needed to ensure the continuity and development of the company's organization.

For this reason, this research was carried out to achieve the production target. The following is the data on the achievement of the Polysilane Bottle Printing Production Process results.

TABLE 1: Achievement of 2021 Polysilane Bottle Printing Production Results

No	Production Target Printing Polysilane Bottle 2021			
	Month, year	Target Planning	Actual	Time Planning
1	January, 2021	55.200 pcs	54.000 pcs	1.200 pcs
2	February, 2021	56.500 pcs	54.500 pcs	2000 pcs
3	March, 2021	55.800 pcs	55.140 pcs	660 pcs
Total		166.300 pcs	163.640 pcs	3.860 pcs

Based on table 1 shows that the target of the Polysilane Bottle Printing Production Process from January 2021 to March 2021 has never reached the 100% planning target. So, from these problems, this research is expected to be able to achieve the production target to improve work efficiency and productivity.

Lean Manufacturing is a continuous effort to eliminate waste that occurs in an industrial company and increase the added value of products (goods and services) to provide value to customers (customer value), according to Gasperz [1-7]. Implementing the Lean Manufacturing system is where this system focuses on identifying and eliminating all forms of waste. Satao et al., [5-11].

To pursue excellence. Adrianto & Kholil [11-17] say that Lean is an approach to identifying and eliminating waste or non-value-added activities through continuous improvement by flowing products and information using a pull system from customers. In addition, this approach can reduce unnecessary inventory regarding the production process, save costs, reduce defects so that quality increases, reduce production lead times, and reduce waste.

The results of the improvements obtained will be simulated using a simulation promodel. With simulation, system experimentation can reduce the risk of confusing existing structures with unprofitable changes. Charles et al., [17-24].

In the book Simulation Using Promodel Simulation, according to Bowden, R [16], it is defined as a way to reproduce the conditions of a situation by using a model for learning, testing, or training. Meanwhile, according to Harrel [16], ProModel is a simulation software designed to model systems with processes. It provides periodic reporting options and statistics that are processed by a period which can provide a complete picture of system activity during the entire simulation while the benefits of doing this simulation are:

(1) Able to detect bottlenecks that occur in the production process and can be directly eliminated.
(2) Able to develop an efficient production process.
(3) Reducing the required lead-time.
(4) Improve resource utilization.
(5) Reducing the accumulation of inventory.

During the simulation process, animations of ongoing activities can be observed, and the results will be displayed in the form of tables or graphs that make them easier to analyze. The advantage of using simulation is that it can avoid the use of expensive costs, does not take a long time, and does not interfere with the system. To find out the simulation of the waste reduction process flow and maintain consistency, efficiency, and engine output results by the target.

RESEARCH METHODOLOGY

The data processing and data analysis method describes the procedures for processing and analyzing data according to the approach taken. Because this research uses a qualitative method, the data processing method is carried out by describing the data in several stages, including through the stages: (VSM) Value Stream Mapping, Waste Assessment Method (WAM), and using VALSAT Tools, concluded by using Root Cause Analysis (RCA).

Future State Value Stream Mapping (FSVSM), and the last is visualization using ProModel Simulation of each stage that has been done.

Stage 1: Value Stream Mapping (VSM)
VSM is a method of mapping related to product flow and information flow from suppliers, producers, and consumers in one complete picture covering all processes in a system.

Creating a Current State Map vsm, namely, understanding the current condition of the production process, identifying the processes that occur from the arrival of materials to finished products, making pictures of material process steps, process information flow, and communication relationships that occur in it. Then fill in the operation box (data box) at each processing station.

Stage 2: Waste Assessment Method (WAM)
At this stage, it will identify and measure waste by using a questionnaire by the Waste Assessment Model (WAM) method.

After knowing the waste description obtained from the Waste Assessment Method (WAM) questionnaire, waste identification will be carried out using VALSAT. The following is the identification of waste using the tools in the Value Stream Analysis Tools (VALSAT):

(a) Overproduction
The steps to minimize this waste are as follows:
1. Calculate the daily production data from January 2021 to April 2021.
2. Create a graph that illustrates the relationship between the total planned production and the actual total production results from January 2021 to April 2021.

(b) Excessive Inventory
One of the tools that can minimize excessive inventory wastage is to use the Supply Chain Response Matrix with the following steps:
1. Calculating the total lead time data on the production process of printing Polysilane bottles.
2. Calculating cumulative inventory in the production process of printing Polysilane bottles.
3. Create a graph that illustrates the relationship between inventory and total lead time to find out and evaluate the level of increase and decrease in stock and the length of lead time in each area of the supply chain of the Polysilane bottle printing production process.
4. Waiting time, excessive transportation, inappropriate processing, and unnecessary motion One of the tools in VALSAT that can identify these four types of waste is Process Activity Mapping by:
   a. The first step is to directly observe how the existing production process produces Polysilane bottle printing and record the activities that occur, the distance traveled, the time required, and the labor involved.
   b. The results of these observations need to be grouped into 5 activity groups, namely (1) operations, (2) transportation, (3) inspections, (4) waiting, and (5) storage.
   c. The 5 groups of activities are depicted using diagram symbols
   d. The last step is the analysis of the existing types of activities. Calculating the proportion of non-value-added activities compared to value-added activities is necessary.
   e. Defect
   The steps to be able to identify this waste are as follows:
      i. Create a table that contains a comparison between the number of production, good production, and defects.
      ii. Calculate the percentage of defects that occur

Stage 3: Root Cause Analysis (RCA)
From the results of the identification of waste obtained using the Waste Assessment Method (WAM) & Value Stream Analysis Tools (VALSAT) it can be concluded using Root Cause Analysis (RCA), that waste that has a significant effect and makes a table of the relationship between the production process and the waste. From the linkage table, the causal factor data is analyzed using a fishbone diagram, and then the essential factors are described through five whys

Stage 4: Future State Value Stream Mapping (FSVSM)
After making CSVSM, Current conditions describe previous conditions, and of course, where there are Current conditions, Future conditions must also be made to see the difference between Current conditions, namely Initial conditions and conditions after many improvements have been made.

Stage 5: ProModel Simulation
Create a promodel simulation with an overview of the Future State Value Stream Mapping (FSVSM) process flow. The working stages of the ProModel simulation process are as follows: According to Harrell (2011) to model a system, ProModel has provided several steps of elements that have been adjusted for the procedure. These essential elements include:

(1) Location in ProModel represents a fixed area where entities undergo processing, waiting, storage, decision making, or other activities.

(2) Entities
Everything that is processed in the system is called an entity. Entities can be products, raw materials, semi-finished goods, or even people.

(3) Arrivals
Arrivals define how entities enter the system. The number of entities arriving at a time is called the batch size. Each entity's arrival rate is called the frequency, the total number of arriving batches is called the occurrences, and when the arrival pattern first starts is called the first time.

(4) Processing
determine the route traversed by each entity and the operations experienced at each location. The process describes what the entity experiences from the first time it enters the system until it leaves the system. This element will consist of two parts, namely the process window and the routing window.

(5) Resources
perform certain operations in the performance of a system. In ProModel, objects used as resources will move according to our wishes, for example, operators, forklifts, transportation equipment for material handling, etc.

(6) Path network
determine the direction and path taken by a resource or entity when moving from one location to another. This network path is a must if you want to use moving resources or entities.

RESULT AND DISCUSSION

From several data processing methods carried out by the authors in the previous chapter, the results and discussion of WAM are as follows:

(1) Waste Analysis

- Condition Mapping Using Current State Value Flow Mapping (CSVSM) is a description of the production process within the company, which includes the flow of information and materials. After describing the current state map, the mapping will be used as a reference to identify waste that occurs along the value stream. CSVSM is known that the percentage value-added time is 484.23 seconds divided by the total production time of 321.23 seconds. Then obtained a 50.1% percentage of value-added time in CSVSM.

- Waste Analysis Based on Waste Assessment Model (WAM) Based on the WAM method, the results of the waste in the polysilane bottle printing production process can be seen in Table 2

TABLE 2: Identification of Waste Based on WAM

Rank	Waste	Final Percentage
1	Motion	13,1%
2	Waiting	10,7%
3	Transportation	13,5%
4	Process	9,8%
5	Overproduction	9,6%
6	Defect	9%
7	Inventory	7%

Based on Table 2, it is known that the first order of waste in the polysilane bottle printing production process is motion waste with a percentage of 13.5%, followed by waiting waste of 13.1%, and the third-order is transportation waste with a percentage of 10.7%. Next, sequentially, are waste transportation, defect, overproduction, and inventory with a percentage of 9.8%, 9.6%, 9%, and 7%, respectively. So, it can be concluded that the critical waste in the production process of printing polysilane bottles based on WAM results are motion, process, and waiting.

- Waste Analysis Based on Value Stream Analysis Tools (VALSAT) Based on the VALSAT method, the most effective tool value used is Process Activity Mapping (PAM), with a total value of 432.70. The waste analysis results in the production process of printing polysilane bottles using the PAM tool can be seen in the Table.

TABLE 3: Identification of Waste Based on PAM

No.	Activity Details	Time(s)	VA / NVA/NNVA
1	Moving Plain/blank Bottles	5	NNVA
2	Transferring the bottle of printing 1 to the printing machine 2	10	NNVA
3	Transferring the bottle of printing 2 to the printing machine 3	300	NNVA
4	Transferring the bottle of printing 3 to the container container Box	6	NNVA

In table 3 there are 4 Necessary but Non-Value Added (NNVA) activities due to the material transfer process. It can be concluded that critical waste in moving bottles from printing 2 to printing machine 3 (waste motion & transportation) with a time of 300 seconds and a percentage of 93% of the total NNVA for 326 seconds.

• Root Cause Analysis
This method is used after mapping the activities that cause waste and are non-value-added. This method is used to find out what causes waste in an activity or process. The nature of this method is to identify activities that have the potential for waste and identify the causes from the beginning to the end of these activities.

Based on the fishbone diagram analysis, it is known that 5 root problems cause motion & transportation waste in the polysilane bottle printing production process, which are as follows:

(1) Method, in the process of printing polysilane bottles, transferring from machine 2 to machine 3 is still done manually, so it has additional time and energy.

(2) Humans, operators or selectors must carry out 2 work processes, namely moving products and controlling machines, to be less focused on the work process.

(3) Environment, setting the placement of the work process layout is not right so that the work process area becomes narrow, the risk of being mixed or mixed up.

(4) Material, there is a buildup of output in the process of machine 2, so there is a product delay that takes a long time to continue the advanced process.

(5) Machines, separate conveyor equipment with a long distance between machines, namely 5.4 meters.

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DISCUSSION

• Determination of Improvement Recommendations

At this stage the causes of waste based on the fishbone diagram are narrowed down the scope of the problem by using the RCA tool. Here is a table of suggestions using 5W and 1H:

TABLE 4: Tools 5W and 1H

<table>
<tr><th rowspan="2">Factor</th><th>WHAT</th><th>HOW</th><th>WHY</th><th>WHEN</th><th>WHERE</th><th>WHO</th></tr>
<tr><th>Issue</th><th>Response Plan</th><th>Cause</th><th>Time</th><th>Place</th><th>PIC</th></tr>
<tr><td>Machine</td><td>Separate conveyor equipment with a long distance between machines which is 5.4 meters</td><td rowspan="3">Creating an automation system by making conveyors connecting machines 2 and 3 as well as robots to move products from machine 2 to the conveyor</td><td rowspan="3">speed up the production process and product output are made into one process in line</td><td rowspan="3">-</td><td rowspan="3">Workshop Technical Support Engineering</td><td>Production Mgr.</td></tr>
<tr><td>Method</td><td>The process of printing polysilane bottles, the process of moving from machine 2 to machine 3 is still manual</td><td>Production Mgr.</td></tr>
<tr><td>Material</td><td>Buildup of product output in the process engine 2</td><td>Supply Chain Mgr.</td></tr>
<tr><td>Environ-ment</td><td>The position of setting the placement of the work process layout is not right</td><td>Layout changes. Machine area 2 and 3. The distance is adjustable.</td><td>So that the area is neatly organized and there is no accumulation of mix-up product risk</td><td>-</td><td>Production area of 2 and 3 machine polysilane bottle printing</td><td>Production Mgr.</td></tr>
<tr><td>Man</td><td>the operator or selector must carry out 2 work processes, namely machine control and product movement</td><td>Reduces manpower. Become a 1 man power focused on engine and conveyor settings</td><td>Elimite muda and man power</td><td></td><td></td><td>Hrd & Production Mgr.</td></tr>
</table>

• **Process Activity Mapping Recommendations (PAM)**
PAM recommendations indicate a change in activity after the proposed improvement is given. From the results of calculations using the lean manufacturing method to reduce NNVA in the polysilane bottle printing production process.

The following is PAM after proposing improvements to the addition of the conveyor length to adjust the distance for the printing machine 2 and printing machine 3 and the relay out area for the polysilane bottle printing machine production process:

TABLE 5: PAM Future Value Stream Mapping (FVSM)

No.	Process	Activity	Tools	Distance (m)	Activity					Time (s)	Frequency (s)	VA/NVA /NNVA	Man Power
					O	T	I	S	D				
1	Prepare	Preparing Plain/Blank Bottles for manual stacking	*Handlift*		1					10	10	NVA	1
		Moving Plain/blank Bottles	*Conveyor*	1,1		1				5	15	NNVA	1
2	Printing1	Automatic Printing Process (1) Purple and orange colors	*Yaodong*		1					47	62	VA	1
		Transferring the bottle of printing 1 to the printing machine 2	*Conveyor*	1,1		1				10	72	NNVA	1
3	Printing 2	Automatic Printing Process (2) Color Black and Green Move the yield bottle printing 2 to printing machine 3	*Yaodong and conveyor*	5,4	1	1				59	131	VA	1
4	Printing 3	Printing Process Automatic (3) black and blue color	*Lathe*		1					51	182	VA	1
		Move the yield bottle printing 3 to the container	*Conveyor*	1,1		1				6	188	NNVA	1
5	Inspection	Inspection of all Color Printing Results (QC Inspector Manual Inspection (Visual, Writing Editor, and Ink Strength))	manual duct tape		1					5	193	VA	1
6	Packing	Packing Boxdan Pallet	Manual		1					5	198	VA	1

Based on table 5, it is known that reducing 1 NNVA activity and combining printing 2 processes which have added the length of the conveyor according to the distance between the machines and the use of robots to speed up the transfer from the machine to the conveyor.

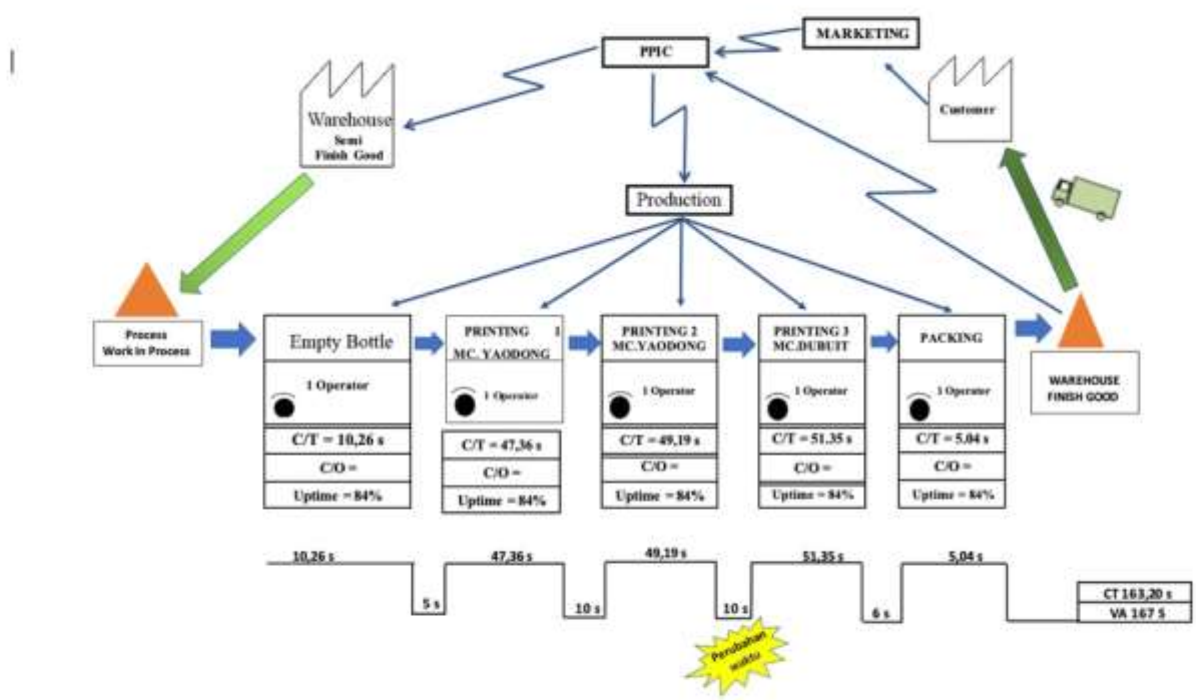
The following is a recapitulation of activities in the process before and after improvements to the polysilane bottle printing production process:

TABLE 6: Recap of Activities Before and After PAM Recommendations

No	Activity	After (s)	Before (s)
1	Preparing Plain/Blank Bottles for manual stacking	10	10
	move the Plain/blank Bottle	5	5
2	Automatic Printing Process (1) Purple and orange colors	47	47
	Transferring the bottle of printing 1 to the printing machine 2	10	10
3	Automatic Printing Process (2) Black and Green Warna	49	49
	Transferring the bottle of printing 2 to the printing machine 3	300	10
4	Process Printing Automatic (3) black and blue color	51	51
	Transferring the bottle of printing 3 to the container box	6	6
5	Inspection of all Color Printing Results (QC Inspector Manual Inspection (Visual, Writing Editor, and Ink Strength)	5	5
6	Packing Box dan Pallet	5	5
	Total	**488**	**198**

- **Future State Value Stream Mapping**

Based on Table 6 PAM recommendations, the future state value stream mapping can be described as follows:



- **Promodel Simulation Results**

Based on the simulation results on the polysilane bottle printing production process using Promodel software with a total runtime of 1 day for 1440 minutes or 24 hours 3 shifts with a bottleneck in the NNVA process, transferring the output of printing machine 2 to printing machine 3 for 10 seconds, the total product obtained in 1 working days are as follows:

Scoreboard

Name	Total Exits	Average Time In System (Min)	Average Time In O
Empty bottle	0.00	0.00	
BottlePrinting 1	0.00	0.00	
BottlePrinting 2	0.00	0.00	
Box	26.00	35.50	
BottleFinish	2,621.00	50.38	

FIGURE 1: ProModel simulation scoreboard of the polysilane bottle printing production process

Based on Figure 1, it is known that in 1 working day or 1440 minutes, 2,621 pcs of polysilane printing bottles can be produced. With a 1 working day production of 2,621 pcs, this is an indicator that production is more efficient and effective than the previous production target of 1,850 pcs.

Location Summary

In this simulation, the workload at each location is as follows from the largest to the smallest workload:

(1) Box WIP (92.61%)
(2) Printing Machine 1 (88.41%)
(3) Printing Machine 2 (76.81%)
(4) Printing Machine 3 (69.23%)
(5) Pallet Finish 1 (61.49%)
(6) Conveyor 1 (61.49%)
(7) Conveyor 2 (49.96%)
(8) Conveyor 3 (42.29%)
(9) Box Place (96.87%)

For the box's location utilisation with a value of 96.87%, WIP box operation is 63.59%, waiting for 0%, and the rest is idle at 91.26%. For details of the locations as a whole can be seen in the image below:

For a single cap location state or wherewith a capacity of 1 unit in 1 processing time, it is known that the waiting activity or waiting 0% only occurs at the enveloping location. The idle percentage at the box location is 3.13% as for the location state multi-cap or were with a capacity of more than 1 unit in 1 processing time such as in the mearing and casting processes. At the location of the WIP box process and printing machine 3, each has the same capacity, which is 2 units in 1 processing time. It is known after the printing production process. Polysilane bottles underwent a proposed improvement in the addition of conveyors and robots, full machine operation of 99.74% (2 units in 1 processing time) and partially filled by 93.29% (1 crew in 1 processing time).

CONCLUSION

Based on the results of research and discussion, the authors can draw the following conclusions:

(1) Analyzing and identifying waste in the production process of Polysilane Bottle Printing with WAM, VALSAT, and VSM methods. The results of waste identification based on WAM show that there are 3 critical wastes, namely Transportation 13.5%, motion 13.1%, and waiting for 10, 7%. The dominant waste is obtained, namely transportation waste, totaling 4 activities with a time of 321 seconds NOVA. Wastage of transportation (NNVA) in transferring products from printing machine 2 to printing machine 3 with a distance of 5.4 meters for 300 seconds with a percentage of 93%.

(2) Recommendations for improvement using the 5W 1H tool, it is known that there are 2 recommended improvement activities, namely modifying and combining the transfer of the product from the printing machine 2 to the printing machine 3 by using an in-line conveyor and a robot to place the results of the printing machine 2. and reducing excess manpower. from 2 to 1, manpower

(3) In conducting a promodel simulation on improving the production process flow in the screen-printing line through the WAM, VALSAT, VSM, and RCA methods at PT Jayatama Selaras, the author uses the Promodel software with a total runtime of 1 day for 1440 minutes or 24 hours 3 shifts with bottlenecks in the process. NNVA move output result

printing machine 2 to printing machine 3 for 10 seconds, the total product obtained in 1 working day.
With a 1 working day production of 2,621 pcs, this is an indicator that production is more efficient and effective than the previous production target of 1,850 pcs so that it can eliminate the time of the polysilane bottle printing production process in transferring bottles from machine 2 to 3 printing machines and reducing excess manpower, from 2 becomes 1 manpower.

SUGGESTION

Based on the results of the research and the conclusions that have been presented, the suggestions that the author can submit are as follows:

(1) There is further research by not only using one VALSAT tool. Of course, it will take more time and data than the research that has been done at this time.
(2) Further research takes into account the costs that may be related to the result of waste elimination that has been carried out in this research.
(3) Implementing the improvement results of Future State Value Stream Mapping based on Process Activity Mapping recommendations

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