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Waste Reduction with Lean Manufacturing on the Garment Production Line of PT XYZ

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Abstract

This company is engaged in garment manufacturing, producing various types of clothing. One of the products produced is polo shirts with a make-to-order (MTO) production system. From the results of observations that have been made, it is known that there is much waste that occurs on the production line. The waste that occurs is product defects, transportation, and waiting waste. Based on these problems, research was conducted using lean manufacturing to increase production and reduce waste using Value Stream Mapping (VSM), Value Stream Analysis Tools (VALSAT), fishbone diagrams, and 5 Why's is Analysis to identify the production process flow from start to finish. The production process is completed, and the root cause of waste is. Based on the results, the lead time value was 346.50 minutes on the current value stream map, NVA activity was 54.17 minutes, NNVA activity was 32.10 minutes, and defects were 5%. Proposed improvements to be implemented in the company to reduce waste are by providing suggestions for maintenance activities, warning signs, additions, and utilization of work facilities. Carrying out the proposed improvements that have been given can result in a reduction in the total lead time of 13.78 minutes, an increase in process cycle efficiency of 1.65%, and a reduction in the defect rate of 1% from a value of 5% to 4% based on the results of future value stream mapping.

Keywords
Waste, Lean Manufacturing, VSM, VALSAT

1. Introduction
A company operating in the garment industry located in North Jakarta. The products produced are t-shirts and polo shirts, with the company's production system being make-to-order (MTO). The production process begins with preparing the raw materials, which is then continued with the patterning process/making clothing patterns. Then, it cuts the fabric according to the size requested by the consumer. After cutting, the sewing process is carried out, followed by making holes or buttoning in the product and marking the buttons that will be attached. On the clothes, the inspection process is carried out to ensure that the clothes produced are of good quality. If the quality of the product is said to be good, then the clothes will go through the rubbing stage first before reaching the consumer. The product will go through the pack using a poly bag and end with cardboard packaging; the finished goods will be stored in the finished product storage area.

By carrying out the production process effectively, waste will be reduced to provide added value to the product. In the production process, activities with no added value and waste lead to higher use of energy and human resources and inefficient production (Shou et al., 2020). Currently, the production process in companies can, of course, still be improved in terms of efficiency by reducing the possibility of defects, waiting, and inefficiencies when moving goods (Muhammad and Yadrifil, 2018). One use that can reduce waste on the production line is lean manufacturing. The principles used in the use of lean manufacturing are Value Stream Mapping (VSM) and Value Stream Analysis Tools (VALSAT) because they can identify the efficiency of the production process flow from start to finish and can increase efficiency in the production process by reducing unnecessary activities and by decreased lead time (Haekal J, 2022). Apart from that, the waste is identified by analyzing the root causes using a fishbone diagram and 5 why's analysis. Implementing lean manufacturing and waste analysis is hoped to reduce waste that occurs and increase process cycle efficiency (PCE) by providing suggestions that can increase profits for the company (Maysuda et al., 2021).

2. Literature Review
This study aims to increase the efficiency of the garment production process by implementing lean manufacturing methods, lean manufacturing Lean manufacturing refers to management techniques and strategies to increase

production or manufacturing efficiency to reduce waste and increase product value to be useful for consumers. It focuses on activities to identify and eliminate forms of waste, such as reducing costs, improving quality, flexibility, and others. Through the use of Value Stream Mapping (VSM) is a technique for visualizing activity processes in the form of a flowchart, which is helpful for mapping activities that provide added value in realizing a lean process (Salomon et al. 2020). Value Stream Analysis Tools (VALSAT) is a tool to identify each waste in more detail (Nihlah and Immawan, 2018). Fishbone diagrams and 5 why's analysis are used to analyze the root causes and consequences of waste that often occurs in this research. Pay attention to the main factors that are the source of the waste, including man, machine, material, method, and environment (environment), and to understand the cause of this problem by asking why questions repeatedly, this research identified waste in the polo shirt production process. Proposed improvements include maintenance activities, warning signs, additional work facilities, and utilization of work facilities. Implementation of proposed improvements can increase process cycle efficiency. The results of this research can provide added value for companies in increasing the efficiency of the garment production process.

3. Methods

Research conducted in North Jakarta. This research has three main stages: the initial or preliminary stage, the data collection process, data processing, analysis, and drawing conclusions. The initial stage begins with conducting field studies and literature studies by making direct observations at the company, identifying and formulating problems, and determining the objectives, benefits, and limitations of the problem. Then, the data collection stage involves collecting primary and secondary data. Primary data was obtained through direct observation of the company and interviews. In contrast, secondary data was obtained through information indirectly provided by the company, such as company profiles and company historical data. At the data processing stage, lean manufacturing principles are used to reduce waste in the production process.

Data processing begins with testing the production process time, obtained through direct observation accompanied by adequacy tests, normality tests and uniformity tests to state that the data during the production process is said to be sufficient and regular so that data calculations can be continued. Then, carry out data calculations to get cycle time, average time, and standard time to know the standard time required when carrying out the polo shirt production process (Ahmed et al., 2018). After that, current Value Stream Mapping (VSM) was created to determine the efficiency of the flow of the polo shirt production process. Next is calculating value-added, non-value added and process cycle efficiency (PCE) (Patil et al., 2021). Then, carry out an analysis of the causes of waste using VALSAT, fishbone diagrams and 5 why's analysis to find out the root causes and continue with the application of lean manufacturing principles by implementing the proposals made so that they can be applied to companies and can observe changes that occur in the production system. After implementing the proposal, proceed with creating future value stream mapping to determine the efficiency of the production process flow after implementing the proposed improvements and comparing the Process Cycle Efficiency (PCE) value to measure how effectively a process is running, one of the metrics is used in the current condition and future (Gebeyehu et al., 2022). The final stage is to conclude from the research results obtained.

4. Data Collection

The data used is related to lean manufacturing. By collecting production process time by carrying out 10 observations. The production time can be seen in Table 1.

Table 1. Production Process Time

No.	Production Time (Minutes)									
	Prepare Raw Material	Patterning	Cutting	Sewing	Buttoning	Inspection	Ironing	Polybag Packaging	Cardboard	Transfer of Finished Good
1	7.0	32	5.9	94	64	36	62	26	7.2	6.3
2	7.1	32	5.4	90	72	33	66	28	7.3	6.5
3	7.6	32	5.6	92	70	34	63	24	7.5	6.7
4	7.5	32	5.8	96	68	32	65	28	7.4	6.2
5	7.7	32	5.5	90	70	35	67	25	7.5	6.4
6	7.3	32	5.3	92	74	34	66	27	7.4	6.3
7	7.1	32	5.7	96	68	36	61	24	7.6	6.8
8	7.4	32	5.9	90	72	33	64	26	7.3	6.7
9	7.5	32	5.6	92	76	37	63	25	7.8	6.4
10	7.2	32	5.5	94	70	35	68	23	7.7	6.8

Continued by carrying out a data adequacy test, it was found that the results of the adequacy test were said to be sufficient because the value of N' < the value of N (10). Next, the normality test was tested and it was found that the data was normal because the significance value was >0.100. Uniformity test, carrying out a uniformity test, it is found that the data is said to be uniform because the process activity does not exceed the upper control limit (UCL) and lower control limit (LCL). Followed by calculating cycle time, normal time and standard time by determining the adjustment factor and allowance factor, the results of the data that has been calculated can be seen in Table 2.

Table 2. Recapitulation Results of Production Process Time Data

Activity	Cycle Time (Minutes)	Adjustment Factor	Normality Time (Minutes)	Slack Factor (%)	Standard Time
Prepare Raw Material	7.3	0.05	7.67	27.5	9.78
Patterning	32	0.12	35.84	20	43.01
Cutting	5.6	0.07	5.99	26	7.55
Sewing	92.6	0.09	100.93	28.5	129.7
Buttoning	70.4	0.17	82.37	24	102.14
Inspection	34.5	0.21	41.75	22.5	51.14
Ironing	64.5	0.18	76.11	19	90.57
Polybag Packaging	25.6	0.14	29.18	16.5	33.99
Cardboard Packaging	7.5	0.11	8.33	18	9.83
Transfer of Finished Goods	6.5	-0.02	6.37	52.5	9.71

Based on the results of Table 2, the total cycle time is 346.50 minutes, followed by calculating the normal time for each production activity using the Westinghouse adjustment factor to get the normal time, the total normal time is 394.54 minutes. Standard time calculations are carried out after calculating normal time in the production process, to maintain process productivity, allowances are made when calculating standard time to reduce worker boredom or tension, standard time calculation is obtained of 487.42 minutes.

5. Results and Discussion

After getting the cycle time results, determining the adjustment factor, normal time, allowance factor, and standard time, continue by mapping the current value stream using the calculated cycle time. Next, analyze the causes of waste using a fishbone diagram and continue with the 5 Why's analysis to find out the root causes of waste.

5.1 Process Mapping of the Production Process Using Current Value Stream Mapping

Creating current Value Stream Mapping (VSM), with help provides a visual representation of the essential steps and related information for each level so that the process can be understood and according to carried out more efficiently, it is required. The current value stream mapping can be seen in Figure 1.

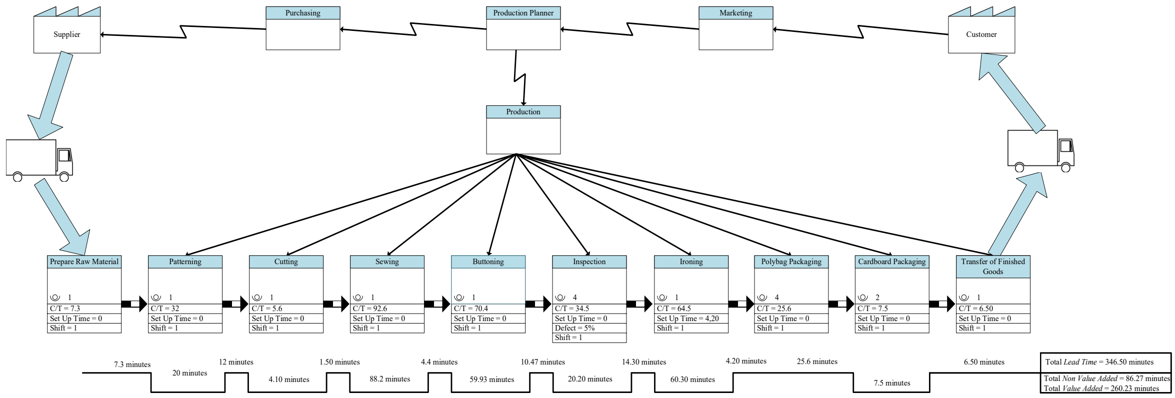

Figure 1. Current Value Stream Mapping

Based on the creation of the current value stream mapping, it is known that the total lead time is 346.50 minutes, the total non-value added is 86.27 minutes, and the total value added is 260.23 minutes. For defects that occur, there is a defect rate of 5% when carrying out the inspection. The defect rate described represents the result of the entire production process. Then, weighting is carried out using the Value Stream Analysis Tools (VALSAT) method. Next, analyze the waste that occurs and determine the use of analysis tools that will be used in this research.

5.2 Waste Analysis

At the waste analysis stage, waste weighting will be carried out using direct observation and discussion with the company to identify various types of waste in each production process activity.

Table 3. Waste Weighting Results

No.	Waste	Score
1	Inventory	1
2	Transportation	3
3	Defect	4
4	Motion	1
5	Overproduction	1
6	Over-processing	0
7	Waiting	2

Based on the weighting results determined for each waste, there are three types of top waste: defect waste, transportation and waiting. Next, the weight of each waste can be multiplied by the waste multiplier factor in the mapping tool in that column to determine waste analysis using the VALSAT method (Rimawan et al., 2018).

Table 4. VALSAT Calculation Results

Waste	Mapping Tools						
	Process Activity Mapping	Supply Chain Response Matrix	Production Variety Funnel	Quality Filter Mapping	Demand Amplification Matrix	Decision Point Analysis	Physical Structure
Inventory	1	3	0	1	3	3	0
Transportation	9	27	9	0	27	9	3
Defect	36	0	0	0	0	0	4
Motion	9	0	3	1	0	1	0
Overproduction	1	0	0	9	0	0	0
Over processing	0	0	0	0	0	0	0
Waiting	18	2	0	0	0	0	0

Total	74	32	12	11	30	13	7
Rank	1	2	5	6	3	4	7

Table 4 shows that the tool that got the highest total was Process Activity Mapping (PAM), with a total of 74, and got the first score. Based on VALSAT calculations, the highest ranking was obtained in the mapping activity process. Second ranking on the supply chain response matrix and third ranking on the demand amplification matrix. The analysis continues by analyzing the root causes of waste using the Activity Mapping process. In the mapping activity process, there are 5 categories, namely operations (O), transportation (T), inspection (I), delays (D), and storage (S). Next, record each activity to determine the added value generated during the process.

Table 5. Process Activity Mapping

No.	Description	Tools	Time (Minutes)	Symbol					Information
				O	T	I	D	S	
		Prepare Raw Material							
1	Transferring raw materials to the fabric cutting area		7.3		X				NVA
		Patterning							
2	Measuring fabric	Gauge	11	X					NVA
3	Make clothes patterns using paper		20	X					VA
4	Provide the pattern results to the fabric cutting table		1.0		X				NVA
		Cutting							
5	Mark the cut		1.50	X					NVA
6	Cutting Fabric	Band knife and Rotary cutter	4.10	X					VA
		Sewing							
7	Waiting for the fabric cutting results		3.10				X		NVA
8	Sewing fabric	Sewing Machine	88.2	X					VA
9	Sending sewing results to the hole table		1.3		X				NVA
		Buttoning							
10	Gives the button sign	Sewing Chalk	9.47				X		NVA
11	Holes in clothes	Buttonhole Machine	28.90	X					VA
12	Adding buttons		31.03	X					VA
13	Send the buttoning results to the inspection table		1.0		X				NVA
		Inspection							
14	Inspect stitching and fabric		20.2			X			VA
15	Clean stitch marks		2.20				X		NVA
16	Gives a sticker that has passed the inspection		10			X			NNVA
17	Provide inspection results to the scrubbing table		2.10		X				NVA
		Ironing							
18	Wait for the iron to reach optimal temperature		4.20				X		NVA
19	Ironing	Iron	60.30	X					VA
		Polybag Packaging							
20	Waiting for the transportation process from the ironing table to polybag packaging		3.50		X				NVA
21	Put the clothes in a polybag		22.10	X					NNVA
		Cardboard Packaging							
22	Put the clothes that have been packed in polybags into cardboard boxes		7.50		X				VA
		Transfer of Finished Goods							
23	Transferring finished goods to the finished goods warehouse	Trolley	6.50					X	NVA
	Total			9	7	2	4	1	

Next, an analysis of the results of the activity mapping process was carried out based on the categories of activities carried out and added value.

Table 6. Results of Process Activity Mapping Analysis

Activity	Amount	Time (minutes)	Percentage (%)
Operations	9	267.13	77.09
Transportation	7	23.70	6.84
Inspection	2	30.20	8.72
Delay	4	18.97	5.47
Storage	1	6.50	1.88
Total	23	346.50	100

Based on the results of the process activity mapping analysis that has been carried out, it was found that there are eighteen activities divided by category, namely nine operation activities with a total production process time of 267.13 minutes, seven transportation activities with a total time of 23.70 minutes, two activities inspection with a total time of 30.20 minutes, four delay activities with a total time of 18.97 minutes and one storage activity with a total time of 6.50 minutes with a total of 23 processes with a time of 346.50 minutes.

Table 7. Analysis of Process Activity Mapping on Added Value

Activity	Amount	Time (minutes)	Percentage (%)
Value Added Activity	8	260.23	75.10
Non-Value Added Activity	13	54.17	15.63
Necessary Non-Value Added Activity	2	32.10	9.26
Total	23	346.50	100

Based on Table 7, the Value Added and total lead time values are obtained for calculating process cycle efficiency in current value stream mapping. The PCE calculation was carried out by comparing the value added value with the total lead time, so a PCE value of 75.10% was obtained. The company still has waste in the production process, so it is necessary to analyze the leading causes of waste with a fishbone diagram and continue making 5 whys to understand the cause of this problem by asking why questions repeatedly. To identify the leading cause of this problem, field observations were carried out in conjunction with questions and answers from various sources to look at it from different points of view and find the factors causing waste, making a fishbone diagram.

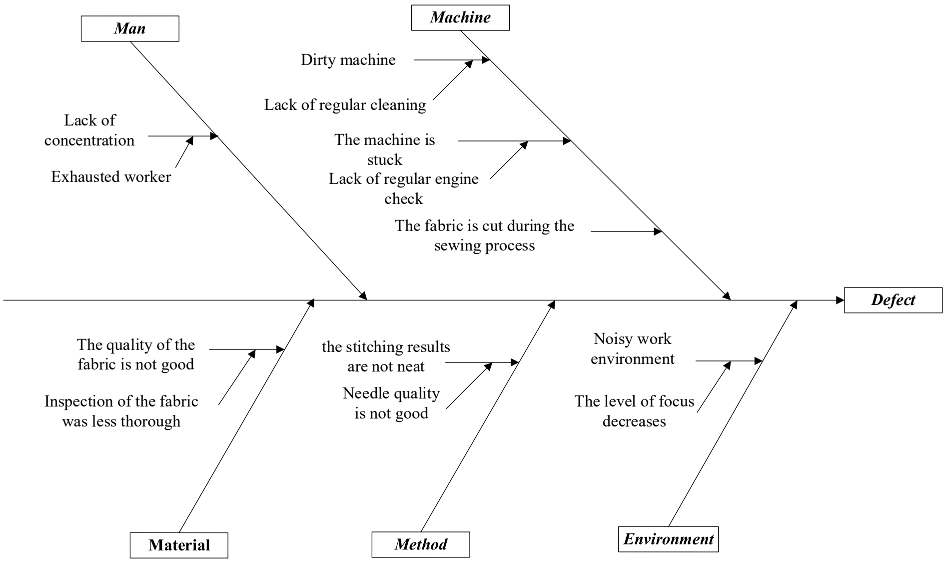

Figure 2. Fishbone Waste Defect Diagram

After making a fishbone diagram, proceed with making a 5 why's analysis to find out the root causes of waste defects. The 5 why's analysis can be seen in Table 8.

Table 8. 5 Why's Analysis Waste Defect

Factor	Why 1	Why 2	Why 3	Why 4	Why 5
Man	Workers lack concentration	Workers are tired when working	Work continuously	Limited rest time	The time interval for consumer requests is very short
Machine	Dirty sewing machine	Machine cleaning is not carried out regularly	Not having a regular cleaning schedule	There is no rule to clean the work desk after use	-

Factor	Why 1	Why 2	Why 3	Why 4	Why 5
	The sewing machine is jammed	Lack of regular engine checks	Does not have a routine check and maintenance schedule	There is no worker responsible for checking the machine	-
	The fabric is cut during the sewing process	Scissors cannot reach small parts of the seam	The scissors are too big	Using large scissors is thought to speed up the sewing process.	There are no claw thread scissors available on the sewing table
Material	There is poor quality fabric	Checking raw materials is not checked thoroughly	-	-	-
Method	The stitching results are not neat	The quality of the needle is not good	Do not check the needle before using it	-	-
Environment	Noisy work environment	A room that cannot reduce sound	-	-	-

Based on fishbone diagram and 5 why's analysis, it is known that the factor causing waste defects is workers' lack of concentration due to worker fatigue. This occurs because human error can occur because the distance between consumer requests is very short. A lack of regular cleaning causes machines to become dirty because there are no rules for cleaning the work table after use. Machine stalling is also a factor in defects due to lack of regular cleaning; this occurs because no workers are responsible for checking the machine. The fabric is cut during the sewing process due to the size of the scissors being too large to reach small parts; this happens because there are no thread-claw scissors available on the sewing table. Some raw materials are of poor quality because the fabric inspection is not thorough enough. This occurs because the inspection of the raw materials was not carried out thoroughly. The stitching could be more neat because the quality of the needle could be better, which causes the product to experience defects due to not checking the needle before use. A noisy work environment can reduce workers' focus levels because the room cannot reduce sound.

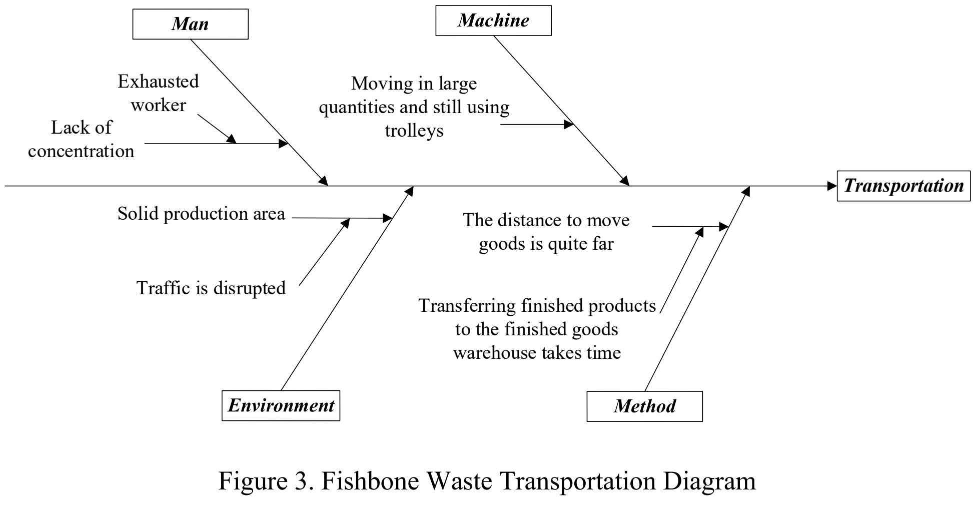

Figure 3. Fishbone Waste Transportation Diagram

After creating a fishbone diagram, then proceed with making a 5 why's analysis to find out the root causes of transportation waste. The following is an analysis of the 5 why's which can be seen in Table 9.

Table 9. 5 Why's Analysis Waste Transportation

Factor	Why 1	Why 2	Why 3	Why 4	Why 5
Man	Workers lack concentration	Workers are tired when working	Large capacity, continuous work, monotonous and static body posture	-	-
Machine	There are not enough trolleys available	Moving large amounts of goods requires more trolleys	-	-	-
Environment	Solid production area	Many workers passing by in the production area	There is manual movement of goods using human hands	-	-
Method	The distance to move goods is quite far	The finished products are on a different floor from the finished goods warehouse	-	-	-

Based on fishbone diagram and 5 why's analysis, it is known that the factors causing waste transportation can occur due to workers lacking concentration due to worker fatigue. This occurs because of the high capacity, continuous work, monotony, and static body posture. Waste transportation often occurs because large amounts of goods are moved using trolleys; this can result in not enough trolleys being available. Congested areas can disrupt traffic movements because many workers pass by in the production area due to the manual movement of goods using human hands. The distance to move finished goods is quite far, so moving finished products to the finished goods warehouse takes more time because the finished products are on a different floor from the finished goods warehouse.

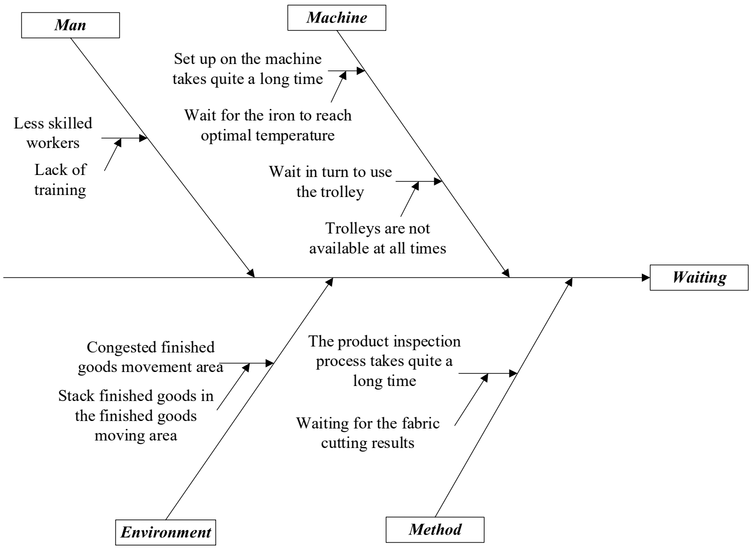

Figure 4. Fishbone Waste Waiting Diagram

After making a fishbone diagram, proceed with making a 5 why's analysis to find out the root causes of waste waiting. The 5 why's analysis can be seen in Table 10.

Table 10. 5 Why's Analysis Waste Waiting

Factor	Why 1	Why 2	Why 3	Why 4	Why 5
Man	Less skilled workers	Absence of training	-	-	-
Machine	Wait in turn to use the trolley	Trolleys are not available at all times	The number of trolleys available is small	-	-
	Wait for the iron to reach optimal temperature	Set upon the iron long enough to reach the optimal temperature	-	-	-
Environment	Congested finished goods moving area	There is a build-up in the finished goods transfer area	Waiting for your turn to move finished goods using a trolley via the elevator	Limited trolley availability	-
Method	The product inspection process takes quite a long time	The number of inspection operators is inadequate	-	-	-

Based on fishbone diagram and 5 why's analysis, it is known that the factors causing waste waiting can occur due to less skilled workers due to lack of training, this occurs due to the absence of training. Waste waiting In turn, use the trolley because the trolley is not available at all times. This occurs because the number of trolleys available is small. Set up on the machine takes quite a long time because you wait for the iron to reach the optimal temperature. The area for moving finished goods is congested because piles of finished goods are in the area for moving finished goods; this occurs because trolleys are limited. The product inspection process takes quite a long time because there are waiting for the results of the fabric cutting; this happens because the number of inspection operators is insufficient.

Based on the analysis of the causes of waste, several proposed improvements are expected to help reduce waste as implementation steps that can make the production process more efficient in the future. Improvements that can be proposed and allow for implementation include maintenance activities, warning signs, additions, and utilization of work facilities.

1. This maintenance activity is proposed to reduce waste in the production process. Based on the analysis of the root causes of waste in the production process, it was found that the machine often gets stuck and dirty, causing defects in the product. Hence, the author proposes to implement a preventive maintenance system on the machine after it is used in making 25 dozen clothes by making a maintenance card/ checking/repairing machines that will be given to the company. This is done by carrying out routine maintenance, such as lubricating the machine every day and checking the machine once every two weeks or twice every four weeks to check for problems with components that often experience damage to the machine. The company plans maintenance activities, accompanied by data recording or collection, to determine which parts have been repaired.
2. Warning signs can be used as an effective means of conveying information that can make readers understand the information. It was found that there were no warning signs at the company. Therefore, a warning sign was needed on the sewing table so that workers would check the needle before using it and a warning sign on the scouring table to preheat the iron a few minutes before use.
3. Additional work facilities. Based on the results of the identification that has been carried out, the root cause was machine and environmental factors that caused clothes to be cut, namely due to the size of the scissors being too large. Workers are disturbed by the noisy work environment. Therefore, it is proposed to add work facilities, such as thread clip scissors and earplugs, which are used for the sewing process so that workers do not have difficulty reaching parts that are difficult to reach and can be more focused on carrying out the production process.

4. Utilization of work facilities in moving finished products is proposed. This waste occurs because workers still move manually using stairs rather than lifts. Using an elevator can reduce transportation waste in the garment production process.

After the proposed improvements have been implemented, future value stream mapping is carried out to describe the new process flow. By creating future value stream mapping, there is an increase in process cycle efficiency.

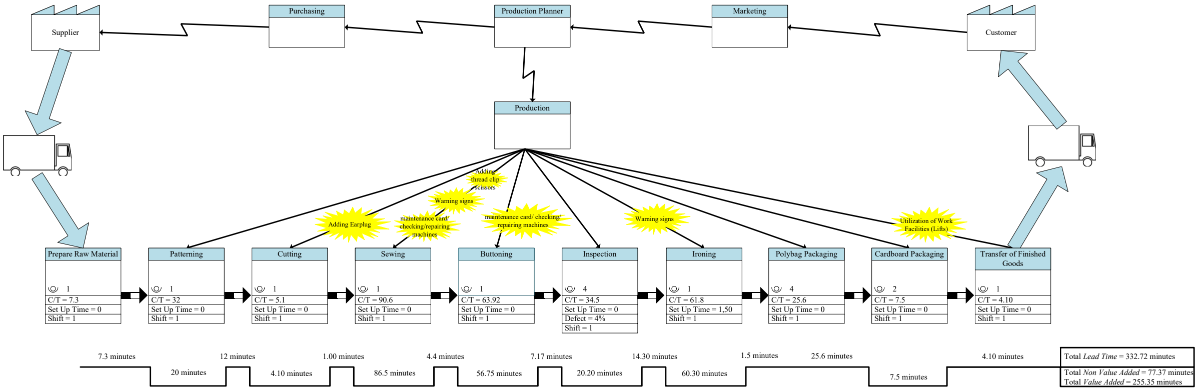

Figure 5. Future Value Stream Mapping

Based on the creation of the current value stream mapping, it is known that the total lead time was reduced by 13.78 minutes, from 346.50 minutes to 332.72 minutes. The decline in non-value-added activity decreased by 8.9 minutes, from 86.27 to 77.37; this increased process cycle efficiency from 75.10% to 76.75% or 1.65%. It is also estimated that there will be a decrease in the defect rate in the production process by 1%, from 5% to 4%.

6. Conclusion

Based on the results that have been carried out, it can be concluded that:

1. The three highest wastes occur in the production line based on the weighting results that have been carried out, namely waste defects, transportation, and waiting.
2. Five main causal factors were found in the production process, including man, machine, material, method, and environment. Waste defects occur due to workers' lack of concentration, dirty machines that frequently jam, fabric being cut, poor needle quality, and a noisy work environment. Waste transportation due to moving goods in large quantities still uses trolleys; congested areas create traffic because goods are often moved using human hands, which can hinder traffic movement, and the distance of moving goods is quite far. Waiting occurs due to unskilled workers waiting in turns to use trolleys, setting up the machine for quite a long time, the finished goods transfer area being congested due to piles of finished goods in the finished goods moving area, the product inspection process taking quite a long time due to waiting for the results fabric cutting.
3. The proposed improvement given by the company to increase the value of the process cycle efficiency is maintenance activities, such as making a machine maintenance/checking/repair card, which will be given to the company. Warning signs include warning signs on sewing tables and warning signs on rubbing tables. Additional work facilities, such as additional thread clip scissors and earplugs. Utilization of work facilities, such as elevator facilities, in the company. The proposed improvements can result in a reduction in the total lead time of 13.78 minutes and an increase in process cycle efficiency of 1.65% based on future value stream mapping results.

7. Suggestion

In the field of garment production, it is hoped that future research will carry out comprehensive analyses to dig deeper into the ins and outs of waste in the production process. The emphasis is expected to go beyond current exploration and include careful investigation of various types of waste. The focus will primarily be on identifying and mitigating other forms of waste, including but not limited to excess inventory, overproduction, over-processing, and unnecessary movement or motion. By expanding their investigations to cover a broader spectrum of waste elements, this research aims to contribute to ongoing efforts in the industry to optimize production processes and improve overall efficiency.

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Biographies

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