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LEAN SIX SIGMA APPROACH TO IMPROVE THE PRODUCTION PROCESS IN THE GARMENT COMPANY: A CASE STUDY

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Abstract A company engaged in the garment industry is facing problems that inhibit the production process. These problems comprise an excess of product defects beyond the specified limits, a considerable rate of product returns, delays in product shipment, and disorderly arrangements in storing raw material. This study aims to determine the root causes of problems and provide recommendations for improvement using the concept of lean six sigma. The waste assessment model is used to identify the dominant waste, while the value stream analysis tools is a method used to analyze the causes of the dominant waste. From the research results, four dominant wastes are identified, namely waste defects, unnecessary inventory, waiting and unnecessary motion, with percentages of 27.02%, 15.92%, 14.32% and 14.0% respectively. The results of the analysis using mapping tools show the details of waste in each dominant waste. Proposed recommendations for improvement are made using the failure mode and effect analysis based on the highest risk priority number for each dominant waste. The recommendations proposed by the researchers include implementing a standard operating procedure and work instruction for the sewing process; scheduling machine maintenance using reliability centered maintenance II; planning and scheduling materials using material requirement planning; implementing line balancing; and designing name tags, visual displays, and storage rack layout.

Keywords: Lean Six Sigma, SMAI, WAM, VALSAT, FMEA

1. Introduction

A garment company located in Malang City produces various kinds of garments including T-shirts, jerseys, shirts, uniforms, almamater suits, hoodies, and office uniform. The total production capacity is 6500 pcs per month. Production is carried out based on orders placed by customers (make to order). The production process stages include preparation, sampling, cutting, bundling, sewing, inspection, ironing, and packaging.

To meet consumer demand, this company is facing several problems that hinder the progress of the production process. These problems include the emergence of defects waste. The quality control inspection data indicates product defects with an average of 8.95% in 2022. Meanwhile, the specified limits applied by the company is 5.0%. In addition to product defects, there are also a number of returned products from customers. The average total return order reached 39.2% in one year. With a relatively high percentage of order returns, the company incurs losses due to the need for rework activities, resulting in additional time and costs. The additional time required for rework causes waste waiting because the company prioritizes returning orders from customers for immediate repair. As a result, customer satisfaction with the company's performance decreased. On the other hand, providing the best service is one of the things that must be applied by the company in order to continue to maintain customer confidence [1]. Another problem faced by the company is inventory waste, which involves the accumulation of raw materials on the production floor due to the procurement of raw materials not being in accordance with regulations. Additionally, the improper arrangement of raw materials and production equipment necessitates additional time for employees to search for the materials and equipment needed.

The integration between Six Sigma and Lean is used to achieve zero defects, optimize production performance, make better product quality and fast delivery at optimal costs [2],

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[3]. The application of Lean Six Sigma on the production process reduces production defects and increases the sigma value [4], [5]. The use of Waste Assessment Model (WAM) and Value Stream Analysis Tools (VALSAT) solves the problem by identifying and analyzing waste occurring within the company [6], [7] and [8]. Therefore, this research has chosen Lean Six Sigma, employing the WAM, VALSAT, and Failure Mode and Effect Analysis (FMEA) methods to propose improvements in garment production processes aimed at reducing defects and overcoming delays.

2. Methods

Lean Six Sigma is one method that can be used to increase stakeholder value by increasing the number of improvements that focus on quality, process speed, customer satisfaction, cost, and investment capital [9]. The Define, Measure, Analyze, Improve, and Control (DMAIC) cycle is a structured problem-solving procedure widely used and employed in quality improvement and processes. DMAIC is not always associated with Six Sigma but rather a very common procedure. For example, it is also used for lean projects focusing on cycle time reduction, throughput improvement, and waste elimination [10], [11]. This research is limited to providing recommendations in the improvement stage.

2.1 Define

2.1.1 Supplier-Input-Process-Output-Control

The depiction of the production process using a Supplier-Input-Process-Output-Control (SIPOC) diagram aims to illustrate the scope of the physical flow, which will be further clarified in the Value Stream Mapping (VSM).

2.1.2 Value Stream Mapping

The purpose of the development of VSM is to facilitate the process of identifying waste in the production process [12]. In the process of creating VSM, several data are required, obtained through direct observation and interviews with related operators. This data is used as step-by-step information for the VSM diagram. The required data include cycle time data, actual time data, product changeover setup time, and machine uptime percentage data during the production process.

2.1.3 Determination of the Weight of Each Waste with Waste Assessment Model

Waste Assessment Model (WAM) is one of the models used to facilitate the search of a problem related to waste so that it can be identified and eliminated [12]. The process of identifying the relationship between waste is carried out in 2 stages, including [12]:

1) Creating a Waste Relationship Matrix (WRM) by weigthing each waste relationship based on the results of the seven waste relationship questionnaires. The sum of weights within each row or column was calculated to derive a score, indicating the influence of one waste type on others. This score was then converted into a percentage to offer a more simplified metric.
2) Creating a Waste Assessment Questionnaire (WAQ). The first step starts with calculating the answers to "from" and "to" questions of the same waste type. The second step involves normalizing the impact of varying question quantities for each question type. This is achieved by dividing each weight in the row by the corresponding number of questions (N_i) related to that question type. Let $W_{j,k}$ represent the relationship weight the waste type j for each question number k. The values in each column under each waste type can then be aggregated to calculate a score using equation 1.

$$S_j = \sum_{k=1}^{k} \frac{W_{j,k}}{N_i} \quad (1)$$

where:
k = question number (ranges between 1 to 68)
Sj = score of the waste

The third step involves mitigating the impact of null responses. For every waste type, denoted by the waste columns, each cell with an assigned weight was counted. Here, F_j is the frequency (number) of cells that were assigned a weight other than 0, for each type of waste j. The fourth step was completely dependent on answering the assessment questionnaire. The obtained rows for each type of waste are multiplied by the weight of each answer, which is

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given the symbol X_k. The values in each column under each type of waste were summed to obtain the new score (s_j), as in equation 2. Following the multiplication, the count of non-zero cells within each column was conducted to acquire the occurrence frequency (f_j) of a specific scenario.

$$s_j = \sum_{k=1}^{k} X_k \ x \ \frac{W_{j,k}}{N_i} \quad (2)$$

The fifth step is to obtain the initial indication factor of each type of waste. Equation 3 was applied for each type of waste:

$$Y_j = \frac{s_j}{S_j} x \frac{f_j}{F_j} \quad (3)$$

In order to capture the mutual influence between different waste types, considering that each type of waste can impact others while being influenced itself, Y_j is multiplied by P_j to derive the final waste factor (Y_j*final*), as illustrated in equation (4).

$$Y_j final = Y_j \ x \ P_j = \frac{s_j}{S_j} x \frac{f_j}{F_j} x \ P_j \quad (4)$$

Based on the Y_j*final* value of each waste, the types of waste were ranked in descending order. Next, the dominant waste will be determined based on the highest-ranking waste.

2.2 Measure

2.2.1 Determining Critical to Quality for the Dominant Waste

Critical to Quality (CTQ) is one of the quality characteristics that influences a product, both during the production process and when it is already used by customers. CTQ is used to identify the crucial or essential quality characteristics for a product or service, which have a significant impact on customer satisfaction or meeting specific requirements.

2.2.2 Calculating DPMO and Sigma Level

This stage is carried out to standardize the quality measurements at each production stage. Thus, a comparison can be made of which production stage is currently in the worst condition. Defect Per Million Opportunity (DPMO) is the value of product defects calculated in one million opportunities. After obtaining the DPMO value, the sigma level is known by converting based on the obtained DPMO value.

2.3 Analyze

2.3.1 Analysis with Value Stream Analysis Tools

Value Stream Analysis Tools (VALSAT) is a tool used to facilitate the process of analyzing the value stream to facilitate the identification of waste improvements that occur [13],[14]. This method is used to make improvements to waste within the value stream. The previously weighted results from the WAQ will be multiplied by the correlation value between the waste type and the mapping tool to obtain scores for each mapping tool. The selection of mapping tools is done by identifying the highest score and then detailed of waste will be analyzed.

2.3.2 Determining the Root Causes of Detailed Waste Using Fishbone Diagram

The fishbone diagram is used to identify and organize the root causes of detailed waste that have been detailed in the previous stage. Identification is done by conducting interviews with the production manager to find out more about the root causes of detailed waste through analysis of people, machines, work methods, materials, and the environment.

2.4 Improve

Based on the causes of detailed waste previously analyzed using the fishbone diagram, the next step involves proposing recommendations for improvement using the FMEA method. FMEA is used to analyze potential failures based on the causes of potential process failures and evaluation of risk priorities [15], [16]. In the FMEA, there exists a value denoting the frequency of failures (occurrence), the effect of current failures (severity), and the likelihood of detecting failures and anticipating them through the monitoring process (current detection) on a scale ranging of 1 to 10. In this reserach, the assessment of severity, occurrence, and current detection is carried out by the production manager. The value of Risk Priority Number (RPN) is obtained from

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the results of multiplying these three values. Thus, the highest RPN value will serve as the priority reference for urgent improvements aimed at reducing detailed waste.

3. Results

3.1 Define Stage

The first stage of this research is the define stage. The objective of this stage is to identify the most frequent waste occurrences (dominant waste) within the company. In this stage, waste identification is carried out using SIPOC diagrams, VSM, and WAM.

3.1.1 SIPOC diagram

The SIPOC diagram is designed to illustrate the activities or physical flow of the production process in outline form, which is subsequently utilized to create the VSM. Table 1 provides an overview of the SIPOC diagram for the garment production process.

3.1.2 Value Stream Mapping

Figure 1 shows the Current Value Stream Mapping (VSM) at Mack Garment. Based on the VSM diagram results, it is found that there are 8 production processes and 1 work in process (WIP). The WIP occurs between the cutting process and bundling process for 1900 seconds. The cycle time stated in the VSM is the standard time added with the rating factor and allowance. From Figure 1, the process with the highest cycle time is sampling.

3.1.3 Waste Identification

Waste identification was collected using questionnaires and interviews. The data suggests that companies conditionally experience seven types of waste during production:

a. **Overproduction**. There is an excessive production of semi-finished products. This activity occurs in the cutting process because operators cut based on the quantity of inspected fabric rolls rather than the production demand. As a result, there is an excess of cut fabric that will be used for future orders.
b. **Waiting**. The occurrence of waiting waste in the company is caused by several activities. The first activity is the frequent rework process that often occurs in the sewing process. With this activity, the scheduled production process for that day will halt and wait until the products that need to be reworked can be completed according to the specified standards. Another activity causing this waste is waiting for materials to proceed to the bundling process because they are held up in the cutting process. Another waiting activity is machine breakdowns in the sewing department, causing sewing operators to wait until the sewing machines can be repaired and used again.
c. **Transportation**. The waste of transportation in the company occurs due to poor and disorganized layout of material storage and production tools. Consequently, during the movement and storage of materials, additional time may be required. Another transportation activity is the separate location of the sewing process from other production processes.
d. **Inappropriate processing.** This type of waste occurs due to the presence of additional processes that should not be necessary. The additional process is rework activity. This activity often occurs in the sewing process, resulting in the company's production process becoming inefficient.
e. **Unnecessary inventory**. It was found that there are additional handling activities for materials, semi-finished products, and finished products. This occurs due to the company's inaccuracy in meeting production needs, accumulation of semi-finished products, and lengthy delivery processes for finished goods. As a result of these three causes, the storage warehouse becomes congested and requires extra space for storage processes.
f. **Unnecessary motion**. This waste occurs in the company due to poor workplace organization in material and tool storage areas. This results in operators requiring additional effort and time to prepare materials for the production process. Additionally, in the sewing process, operators are still frequently observed consciously making unnecessary movements. For example, erasing sample markings and recounting the number of accessories.

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g. **Defects**.Product defects are still frequently found in the sewing process. This occurs because the products produced do not meet the quality standards set by the company. Inconsistencies include imperfect stitching, incomplete accessory parts in some product areas, and inadequate product cleanliness.

3.1.4 Determination of The Weight and Rangking of Each Waste using the WAM Method

Weighting waste using WAM involves two stages as follows:

1. Table 2 shows the relationship between waste that occurs in the company using WRM. The next step is to convert each symbol with reference to A = 10, E = 8, I = 6, O = 4, U = 2, and X = 0. The purpose of creating a waste relationship value is to find the results and percentage value of each waste in the matrix.

Table 2. Waste Relationship Matrix

F/T	**O**	**I**	**D**	**M**	**T**	**P**	**W**
O	A	E	U	U	E	X	U
I	I	A	I	I	I	X	X
D	E	E	A	A	E	X	A
M	X	I	E	A	X	O	A
T	O	U	I	O	A	X	O
P	E	I	A	E	X	A	A
O	E	A	A	X	X	X	A

Table 3 shows the conversion results and percentage of WRM. It is discovered that the highest percentage are identified in from defects (D) with a value of 54 and a percentage of 19.42%. This means that if defect (D) waste occurs, then this waste has a big potential to cause other wastes to appear.

Table 1. SIPOC Diagram

Suppliers	**Inputs**	**Processes**	**Outputs**	**Customers**
X Fabric	Unstitched Cloth	Preparation	Apparels (T-shirts, jerseys, shirts, uniforms, alma mater jackets, hoodies, daily official clothing, etc.)	Y
	Machinary	Sampling		Z
	Thread	Cutting		
	Needles	Bundling		
	Accessories	Sewing		
	Button	Finishing & Inspection		
	Zipper	Ironing		
	Label	Packaging		

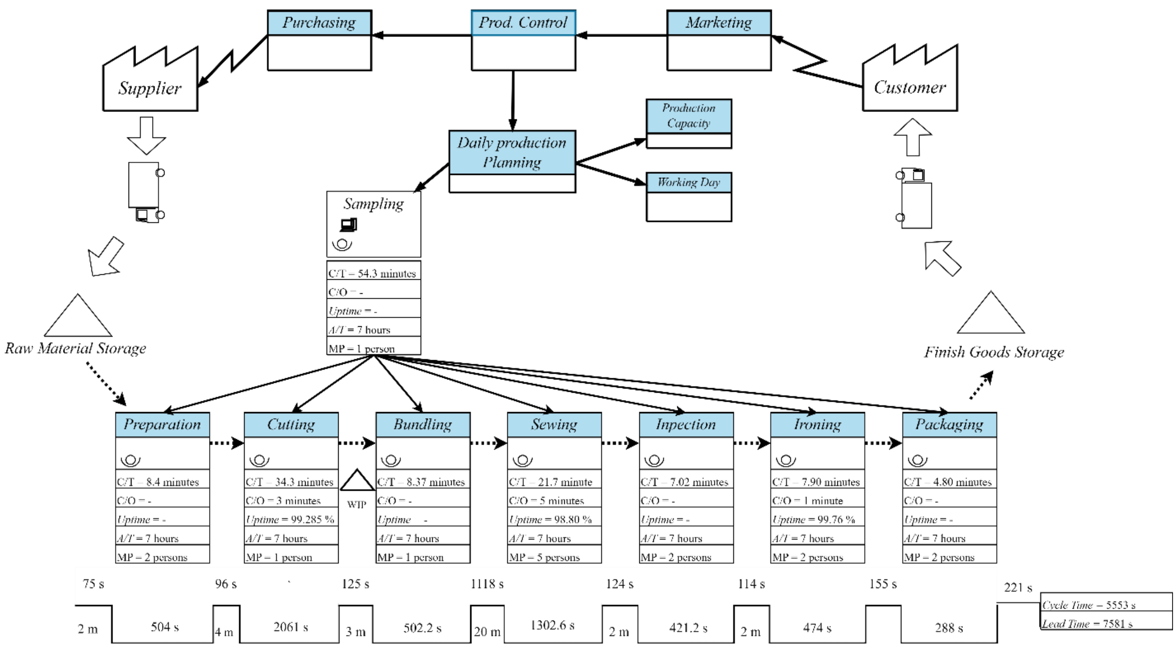

Fig 1. Value stream mapping

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Meanwhile, the value of to defects (D) also has a high value and percentage with values of 52 and 18.71% respectively. This shows that the existence of defects is caused by the effects from other waste. Overproduction (O), Unnecessary Inventory (I), Defect (D), Unnecessary Motion (M), Transportation (T), Inappropriate Processing(P), Waiting (W).

2) Determining the final result for each waste using WAQ. Based on the calculations shown in Table 4, it can be concluded that the four most common wastes are defects, unnecessary inventory, waiting, and unnecessary motion. With the respective percentages of 27.02%, 15.92%, 14.32%, and 14.0%. These four wastes are selected based on the Pareto diagram principle, which is 80:20, where 80% of the problems account for the causes of 20% of the problems. Next, these four wastes are referred to as dominant waste.

3.2 Measure Stage

In the measure stage, Critical to Quality (CTQ) is determined, and performance is measured in terms of DPMO values to find the sigma level for each dominant waste. The establishment of CTQ is used to identify the factors that serve as benchmarks for desired quality characteristics. Quality characteristics that influence products in the company, both when they have reached customers and when they are still in the production process. Table 5 represents the CTQ for each dominant waste.

Table 6 represents the summary of sigma levels for the four dominant wastes. Based on the overall results of DPMO calculations and sigma levels, it can be concluded that the production process performance at the company before improvement is already good, with an average sigma level of 3.50σ.

Table 6. DPMO and Waste Level

No	Dominant Waste	DPMO	Sigma Level
1	Defects	37,994	3.27
2	Unnecessary Inventory	20,095	3.55
3	Waiting	19,228	3.56
4	Unnecessary Motion	16,243	3.63
		Average	3.50

However, the principle of continuous improvement to eliminate waste remains essential until the production process performance reaches a sigma level of 6σ. Because at a sigma level of 3.50σ, it still indicates that there are opportunities for improvement during the production process. Therefore, the next step is to identify and analyze the root causes of waste occurrences.

Table 3. Conversion Results and Percentage of WRM

F/T	O	I	D	M	T	P	W	*Score*	%
O	10	8	2	2	8	0	2	32	11.51
I	6	10	6	6	6	0	0	34	12.23
D	8	8	10	10	8	0	10	54	19.42
M	0	6	8	10	0	4	10	38	13.67
T	4	2	6	4	10	0	4	30	10.79
P	8	6	10	8	0	10	10	52	18.71
W	8	10	10	0	0	0	10	38	13.67
Score	44	50	52	40	32	14	46	**278**	**100**
%	15.83	17.99	18.71	14.39	11.51	5.04	16.55	**100**	

Table 4. Waste Assessment Questionaire Results

	O	I	D	M	T	P	W
Score (Y_j)	0.58	0.61	0.62	0.59	0.62	0.61	0.53
P_j *Factor*	182.18	219.96	363.33	196.67	124.21	94.19	226.17
Final Result (Y_j *final*)	106.54	134.47	228.15	117.9	77.87	58.29	120.95
Final Result (%)	12.61	15.92	27.02	13.97	9.22	6.90	14.32
Ranking	5	2	**1**	4	6	7	3

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Table 5. Critical to Quality (CTQ)

Dominant Waste	Critical to Quality (CTQ)
Defect	Imperfect stitching
	Incomplete accessories
	Product cleanliness issues
Unnecessary Inventory	Fabric inventory due to excessive purchasing/stocking
	Semi-finished product inventory due to waiting for processing (bundling)
	Finished product inventory due to lengthy delivery periods to customers
Waiting	Waiting during the sewing process due to the priority of rework activities
	Waiting occurs because the bundling process is halted, waiting for the arrival of materials (WIP) from the cutting process
	Operator negligence during work leading to product damage
	An irregular production schedule
	Material or raw material inspections take too long
	Repair of problematic/damaged machines
Unnecessary Motion	Operators engaging in unnecessary activities and working without standard procedures during the production process
	Unorganized storage racks
	The absence of labels on shelves

3.3 Analyze Stage

The third stage of completing this research is the analyze stage, which is carried out to identify and find the root causes of problems or issues in the production process based on the data obtained and processed in the define and measure stages. Some of the steps involved include analyzing waste with VALSAT and creating cause-and-effect diagrams.

3.3.1 *Analysing Waste Using VALSAT*

The VALSAT method is employed to analyze detailed waste associated with dominant waste. Detailed waste is identified based on selected mapping tools, where the selection is based on the score calculation from the seven available mapping tools. The score for each mapping tool is obtained by multiplying the weight of each waste with the correlation value between the waste and that mapping tool.

Table 7 shows the top 3 tools with the highest scores, namely: Process Activity Mapping (PAM), Supply Chain Response Matrix (SCRM), and Quality Filter Mapping (QFM). Subsequently, the identification of detailed waste using each mapping tool is explained as follows:

1) *Process Activity Mapping*

Process Activity Mapping is used to map and classify activities into value-added (VA), necessary non-value added (NNVA), and non-value added (NVA) categories. The activities include 5 components: Operation (O), Transportation (T), Inspection (I), Storage (S), and Delay (D). Based on the recapitulation in Table 8, the total time used for the entire production process is 16469 seconds across 55 activities. There are 23 Operation activities with a total completion time of 7940 seconds, 10 Transportation activities with a total completion time of 2194 seconds, 5 Inspection activities with a total completion time of 1061 seconds, 5 Storage activities with a total completion time of 971 seconds, and 12 Delay activities with a total completion time of 4303 seconds.

From Table 8, it is known that non-value added (NVA) activities have a percentage of 30.91%, indicating that these activities should be reduced or minimized as they do not add value to the company. Upon review, most of the non-value added (NVA) activities arise due to a significant amount of delay time. Delay occurs due to waiting waste and unnecessary motion waste. The detailed waste for waiting waste includes waiting time for semi-finished products, such as bundles, to be continued or sent to the sewing process. Meanwhile, the detailed waste for unnecessary motion waste includes the additional activities of preparing and searching for tools to be used during the production process, resulting in a considerable amount of waiting time.

2) *Supply Chain Response Matrix*

With the Supply Chain Response Matrix, the company can more easily monitor increases and decreases in lead time and inventory levels in each area of the supply chain.Based on figure 2, it is known that the time used to meet customer demand is 20.78 days with a cumulative value of physical stock days of 2.78 days or 13.37% of the total production fulfillment time.

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Table 7. Selection of Mapping Tools

Waste	Weight	PAM	SCRM	PVM	QFM	DAM	DPA	PS
Overproduction	12.61	12.61	37.83		12.61	37.83	37.83	
Waiting	14.32	128.88	128.88	14.32		42.96	42.96	
Transportation	9.22	82.98						9.22
Inappropriate Processing	6.90	62.1		20.7	6.9		62.1	
Unnecessary Inventory	15.92	47.76	143.28	47.76		143.28	47.76	15.92
Unnecessary Motion	13.97	125.73	13.97					
Defect	27.02	27.02			243.18			
	Score	487.08	323.96	82.78	262.69	224.07	190.65	25.14
	Rank	**1**	**2**	6	**3**	4	5	7

Table 8. Recapitulation of PAM results

Activities	Total	Total time (s)	Percentage (%)
Operation	23	7940	44.93
Transportation	10	2194	12.41
Inspection	5	1061	6.00
Storage	5	971	5.49
Delay	12	4303	31.14
Total	**55**	**16469**	
Value Added	16	6717	38.01
NonValue Added	12	4262	30.91
Necessary NonValue Added	27	5490	31.07
Total	**55**	**16469**	

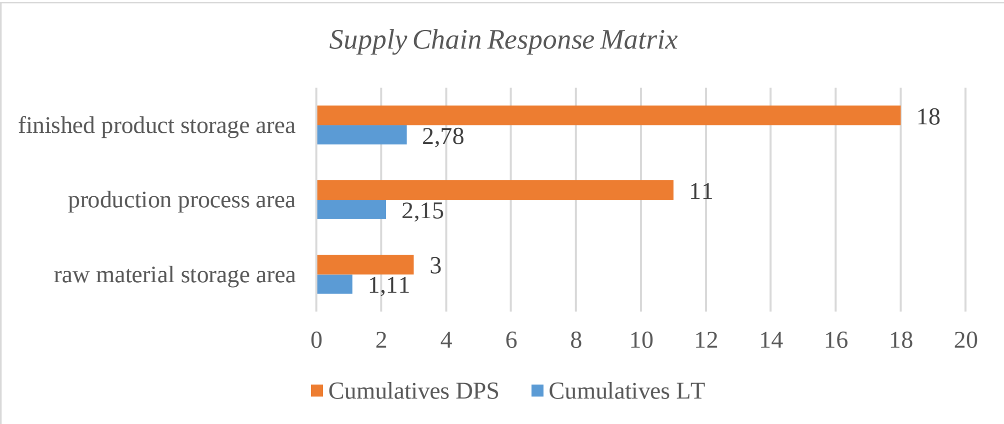

Fig. 2 SCRM

The raw material storage area has the highest physical stock days value at 1.11 days. This occurs due to the accumulation of raw materials in the storage area.

3) *Quality Filter Mapping*

Quality Filter Mapping is a tool used to evaluate overall defect waste. In this study, the most common and recurring defect wastes are product defects and internal scrap defects. These defects refer to flaws that pass through to the customer and those identified visually during inspection processes. Table 9 presents QFM data on products. According to Table 9, it can be concluded that imperfect stitching is the most frequently encountered detailed waste. These defects occur during the sewing process.

3.3.2 Identifying Root Causes of Detailed Waste with Fishbone Diagram

Figures 3-6 represent the identification of the root causes of detailed waste based on interviews and discussions with the production manager. Based on Figure 3, it can be observed that the activity of waiting on bundling process to be sent to the sewing process is caused by several root causes, including:

- Human factor: causes of detailed waste in the waiting type include operator negligence due to monotonous work movements, operators

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working at different speeds, and rework due to products not meeting company standards.

- Material factor: one cause is the lengthy inspection time for raw materials.
- Method factor: the cause is unclear production schedules and uneven workloads in each process.
- Machine factor: problems with waiting time detailed waste occur due to machine breakdowns and require additional time for repairs.

From Figure 4, it can be seen that the activity of searching for materials and tools during the production process is caused by several root causes, including: operator indiscipline, lack of direct supervision from the company, absence of SOP provided by the company leading operators to work based on initial training, disorganized storage racks for raw materials and tools, and inadequate air circulation and lack of air conditioning. Based on Figure 5, it can be observed that the accumulation of raw materials during the production process is caused by several factors:

- Human factor: The unnecessary inventory waste due to human factors occurs because of the company's lack of accuracy in fulfilling raw material requirements for production. This happens because there is no forecast method for replenishing/stocking raw materials.
- Material factor: The analysis of the root causes of unnecessary inventory waste from material factors can be viewed from three causes. Firstly, excessive raw material replenishment occurs because the company has not properly scheduled production replenishment. Secondly, there is additional warehouse space for storing raw materials or defective products. Thirdly, the cutting process generates excessive semi-finished products

Based on Figure 6, it can be determined that the defects in imperfect stitching are caused by several causes and root causes:

- Human factor: The cause of operator negligence during work and the lack of operator skill during sewing. Operator negligence occurs because the operator works in a hurry to meet targets. Additionally, a lack of knowledge about defect criteria in the sewing process leads to operators being unaware of product defects.
- Material factor: The cause of imperfect stitching is slippery raw materials, making it difficult to control the fabric during sewing.
- Method factor: The root causes of imperfect stitching can be examined from four causes. Firstly, incorrect thread component installation methods due to rushed installation and lack of understanding of the correct installation method. Secondly, incorrect sewing methods due to insufficient operator skills. Thirdly, unstable operator hands when holding fabric, resulting in unstable and untidy stitches. Lastly, the lack of SOP for sewing.
- Machine factor: The cause of imperfect stitching defects is old machines. Additionally, the absence of specific maintenance schedules for sewing machines.
- Environmental factor: The cause of stitching defects is inadequate lighting in the room due to dim lighting.

Table 9. Percentage of Each Defects

Waste Type	Detailed waste	Pcs	Total percentage (%)
Defect	Imperfect stitching	3686	56.81
	Incomplete accessories	1408	21.7
	Product cleanliness issues	1394	21.48

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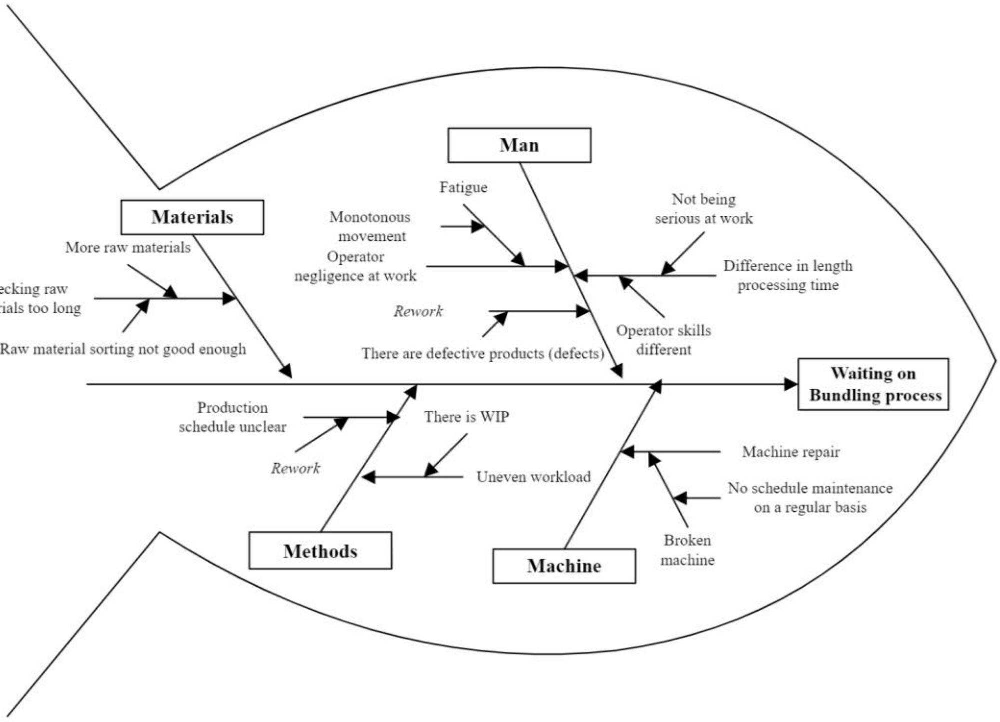

Fig. 3 Fishbone Diagram for The Detailed Waste on Waiting

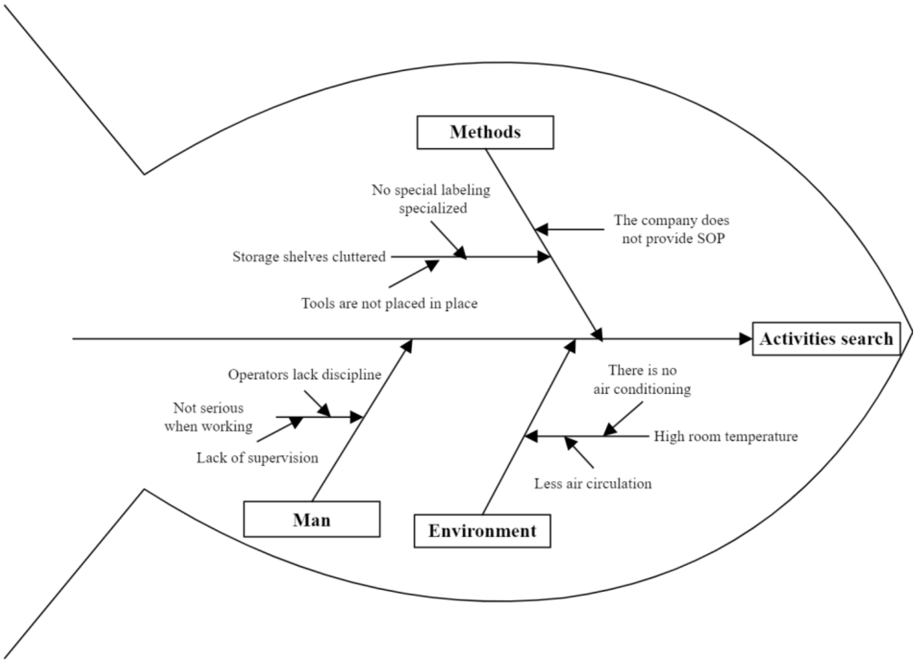

Fig. 4 Fishbone Diagram for Detailed Waste on Unnecessary Motion

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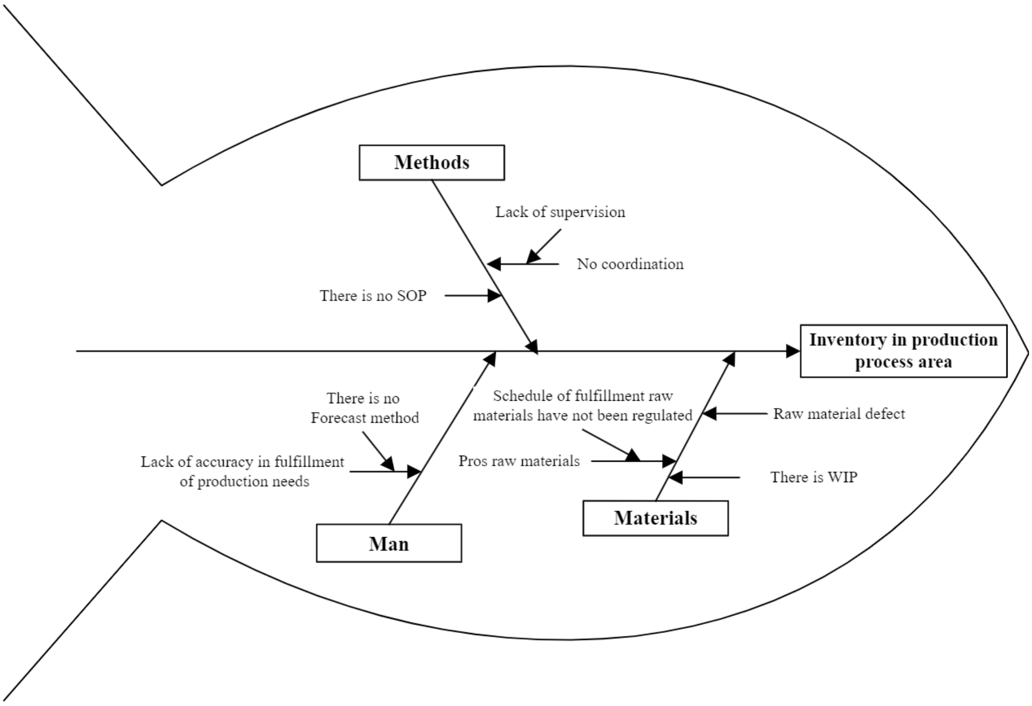

Fig. 5 Fishbone Diagram for Detailed Waste on Unnecessary Inventory

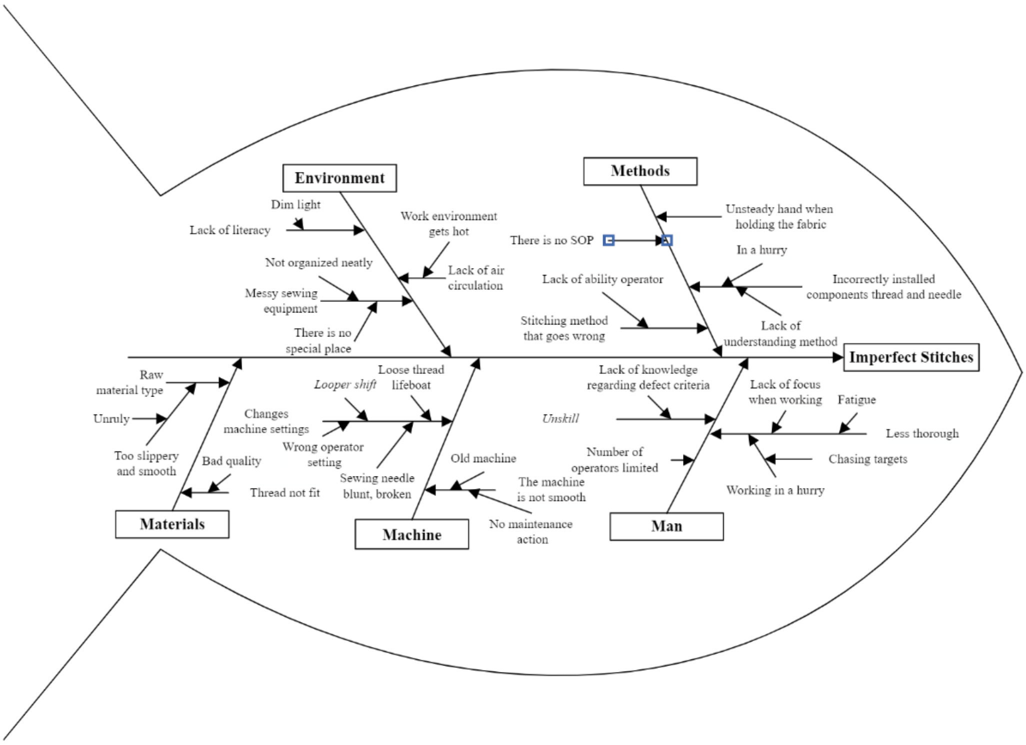

Fig. 6 Fishbone Diagram for Detailed Waste on Defects

4) Improve Stage

The final stage of this study is the improvement stage, which aims to determine and identify recommendations for improvement to reduce the problem experienced by the company during the production process. Based on the detailed waste causes previously analyzed using the fishbone diagram, recommendations for improvement will be provided using the FMEA method. Table 10 shows the potential failure causes with the highest RPN values for each dominant waste.

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Table 10. Summary of improvement proposals using FMEA

Dominant waste	*Ranking*	RPN	Cause of Failure	Proposed Recommendations
Defects	1	512	Additional time is required for reworking product defects or products returned by customers	• Implementing the establishment of SOPs and work instructions for the sewing process, along with supervision to ensure that the SOPs are properly followed by operators • Providing and enforcing maintenance scheduling for sewing machines before the production process begins [17].
Unnecessary inventory	2	448	Accumulation of semi-finished products in the storage area	• Planning and scheduling material requirements to prevent the company from leaving behind excess raw materials (overstock) that may occupy storage space unnecessarily [18].
Waiting	3	448	Production processes are hindered and inefficient	• Conducting inspections and checks at production process stages that are prone to causing defects and waiting time, while implementing the creation of SOPs (Standard Operating Procedures) on how to conduct proper production processes. • Dividing workload to achieve greater efficiency using line balancing methods [19], [20].
Unnecessary motion	4	392	Additional time is needed to search for materials or tools to be used	• Creating tag names for storage racks for each type of material color and tools. • Establishing visual display warnings for placing items after use. • Designing a new rack layout for organizing materials and tools.

4. Discussion

Based on Table 10, the proposed recommendation can be explained in detail as follows:

Proposed recommendation 1: Implementing the establishment of SOPs and work instructions for the sewing process

Based on the results of the highest RPN value in the detailed waste defect and waiting, the researcher proposes Standard Operating Procedure (SOP) for the sewing process. The SOP will function as a written rule for operators in order to reduce errors while carrying out production activities. The implementation of SOPs in the company can significantly increase productivity and has the possibility to eliminate waste in the long run [21].

Proposed recommendation 2: Scheduling machine maintenance using Reliability Centered Maintenance II

Reliability Centered Maintenance (RCM) II is a systematic method in determining what needs to be done to prepare each equipment, machine, and physical facility to continue to fulfill its function in the operation process. The use of the RCM II method is useful for knowing the level of machine reliability and subsequent machine maintenance. The output obtained of this method is the selection of maintenance intervals and maintenance policies. The maintenance policy is divided into 3 categories:

1. Scheduled on condition task, which is used to detect and check the occurrence of potential failures. Based on the typical cases that occur in the company, maintenance scheduling should be carried out for the following activities: overdeck sewing machine components (looper and foot pressure), by lubricating every 12 hours and Kansai machine components (feed dog), by lubricating every 12 hours.
2. Scheduled discard task, used to schedule component replacement before its lifetime expires, without having to wait for the machine to be damaged. Based on the typical case that occurs in the company, scheduling

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should be done for the replacement of the following components: single needle machine on needle component, every 81 hours and kansai machine on needle component, every 54 hours.

3. Scheduled finding task, which is used to perform component maintenance before identifying the cause of the damage. In this case, the identification of the cause of damage is assumed to be conducted on several machines, including the obras machine (feed dog component) and overdeck machine (feed dog component and thread tension).

Proposed recommendation 3: Planning and scheduling material using Material Requirement Planning (MRP)

Based on the analysis of the potential causes of failure regarding the detailed waste unnecessary inventory, it is known that the highest RPN value lies in the company's unavailability in determining or scheduling material inventory before carrying out the production process. The company only considers the availability of raw materials when the company receives an order and the existing inventory in the warehouse. Because of this, the company still experiences overstock in the warehouse which results in stacking. Therefore, it is necessary to plan and schedul raw materials using MRP. The implementation of the Lot For Lot technique required production plan to carry out production only as needed and to keep the amount of inventory to a minimum or sufficient level [22].

Proposed recommendation 4: Implementing line balancing

One of the causes of the waste waiting is the existence of bottleneck in one of the workstations, namely the bundling process. The imbalance of the production line can be seen from the accumulation of semi-finished products (WIP) in the storage area. As a result, the production process in the company becomes slow, inefficient and causes delays in product delivery. Thus, the right trajectory balance is needed to solve production efficiency problems. The Largest Candidate Rule method is a method of combining workstations in order from the largest to smallest processing time while still considering the position on the precedence diagram. The Largest Candidate Rule (LCR) method is the most commonly used method because it is convenient and produces good results [19].

Proposed recommendation 5: Designing name tag, visual display, and storage rack layout

The highest RPN value in the detail of waste unnecessary motion are the condition of the material storage rack and messy tools. This happens because the storage rack does not have any description of each type of fabric and tools. This causes operators or workers to spend additional time to find and return materials and tools that they need. In addition, the incidence of missing tools can also occur. Therefore, based on these problems, the researcher has developed proposals in the form of designing name tag, visual display, and new layout for storage racks Most of the material arrangements in the company are mixed up and do not follow the fabric color grouping. Upon the latest observation in the storage area, it was seen that there have been name tag on the edges of the storage shelves. However, they are only made of HVS paper, making them very fragile and shabby. In addition, the writing was almost illegible and some had even been removed from the rack. To overcome these problems, the researcher designed a new name tag as shown in Figure 7.

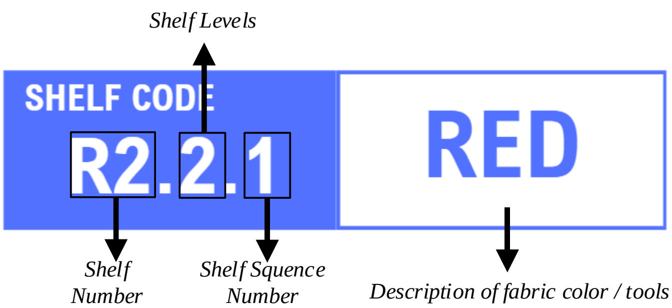

Fig. 7 Name tag for storage rack

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Fig. 8 visual display in the storage area

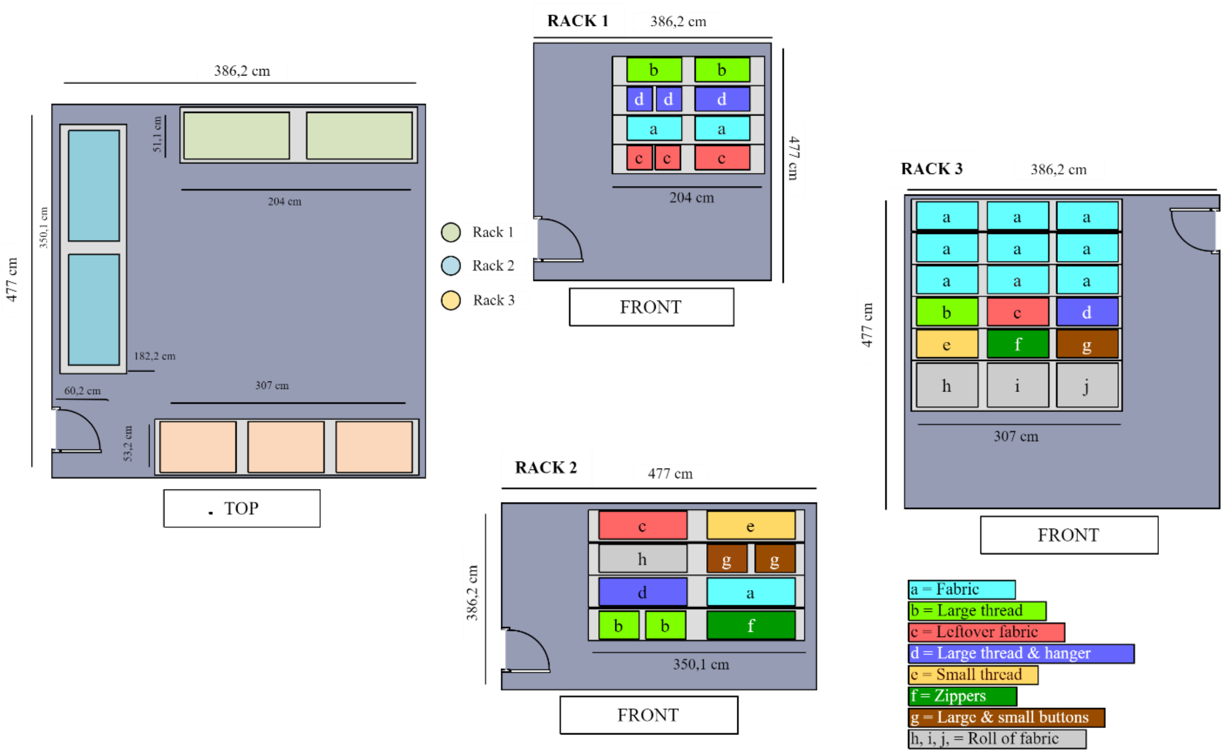

Fig. 9 Proposed new storage rack layout

In addition to making a name tag design, the researcher also added a proposal in the form of making a visual display. The goal is to familiarize operators with the habit of tidying up and returning tools after each use. Figure 8 demonstrates the visual display proposed by the researcher. Figure 9 depicts proposed layouts for rack 1, 2 and 3. The arrangement and placement of fabric in these layout proposals are based on the results of classification using the ABC method. In this approach, items categorized as A are placed at the bottom of the shelves to allow operators easy access to fabric materials or tools that will be used frequently. On the other hand, items in categories B and C are positioned at the top shelves because materials with colors falling within these categories are infrequently used during the production process. As a result, this new layout prioritizes the arrangement of frequently used production necessities.

In our research, it should be acknowledged that the proposed recommendation for the company lack consideration for the cost aspect of implementation, and furthermore, the prioritization of these recommendations has not been determined. These factors represent limitations of this study.

5. Conclusion

The result of waste identification using the WAM method shows that the dominant waste that often occurs in the company during the production process is defects, unnecessary inventory, waiting time, and unnecessary motion. Based on the calculation results of the sigma level for all dominant wastes, it is known that the average sigma level obtained is 3.50σ

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with a DPMO value of 22,750. Based on the highest RPN values in the FMEA, the researchers propose improvement suggestions to reduce each dominant waste in the production process. These proposed recommendations include implementing the establishment of SOPs and work instructions for the sewing process, scheduling machine maintenance using Reliability Centered Maintenance II, planning and scheduling material using Material Requirement Planning, implementing line balancing, and designing name tag, visual display, and storage rack layout. For further research, it is advisable to carry out this study until the stage of implementing the proposed recommendations and conducting the development of control stages.

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