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Implementation of Lean Manufacturing Concepts to Increase Process Cycle Efficiency (A Case Study of Glove Production Process)

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Abstract

Sport Glove Indonesia is a glove manufacturing company chosen for the study case in the implementation of lean manufacturing approach. The aim is to increase Process Cycle Efficiency (PCE) by reducing waste. This research focuses on epic cutter style gloves which have a fairly large production percentage in January 2024. Value Stream Mapping (VSM), Fishbone Diagram and Failure Mode and Effect Analysis (FMEA) were used to identify waste and prepare recommendations for appropriate improvement proposals to overcome the problem. The results of the VSM analysis show that embellishment and final inspection as well as the sewing department are needed to be evaluated. Apart from that, it is known that the most dominant waste that occurs and has the greatest potential to hinder the production process is defects with a percentage of 23.13%. According to the RPN value from FMEA analysis, it shows that the root causes are operators who are not focused, as well as machines that often experience problems and tools that are worn out. Then, improvement proposals are designed to reduce and eliminate waste. According to the analysis, after some improvements have been made the PCE value increased by 3.91%, from 46.94% to 50.84%.

Keywords
Lean manufacturing, PCE, VSM, Fishbone diagram, FMEA

1. Introduction

Sport Glove Indonesia is a company engaged in glove manufacturing which is located in Krandon, Sleman, Yogyakarta. PT. SGI focuses on supplying gloves to overseas customers. PT. SGI continuously strives to produce quality products and strives to meet customer needs. However, in implementing the production process, there are still several obstacles so that the production process is hampered and the daily production target is not achieved. The product that is the focus of this research is epic cutter style gloves, which are the newest style and have a fairly large production percentage in January 2024 and are products with high defects. Apart from that, several wastes were found on the production floor such as defects, waiting time, and buildup. One approach that can be applied to reduce waste and increase efficiency is using the Lean Manufacturing concept. Lean Manufacturing is an approach carried out with the aim of creating value for customers by reducing activities that do not add value (non-value-added activities) or waste and focusing on processes that provide added value (value-added activities) so as to increase the efficiency cycle in the production process(Womack & Jones 1991). The Value Stream Mapping (VSM) tool is used to describe the overall state of the production process by paying attention to information flow and physical flow (Alfiansyah & Kurniati 2018). To identify the most dominant type of waste on the production floor, the Waste Assessment Model

(WAM) will be used (Rawabdeh 2005). After the waste has been identified, the root cause of the waste is searched using the Fishbone Diagram method. Then, the FMEA method was also used in this research to obtain the highest RPN value for each known cause of waste. Finally, improvement proposals will be designed based on the root of the problem with the highest RPN value and the Future State Value Stream Mapping will be created which is a mapping illustration of the company's production flow in the future. The use of the Lean Manufacturing concept is expected to be able to identify the dominant and most critical types of waste and their causes, making it possible to design recommendations for improvement proposals to minimize waste and increase efficiency in the company's production process.

1.1 Objectives

The research study aims to occupy the implementation of a lean manufacturing approach and subsequently propose recommendations to improve the production process in the chosen industry. In detail, the research mainly focuses on discovering and eliminating wastes occurring in the process to improve efficiency. Further, root cause analysis will be performed to determine the most dominant waste and find the root causes of it. By having information related to the root causes, recommendations can be proposed to minimize the waste in the production process. The proposed recommendations then can be implemented and the increasing value of PCE conceivably can be attained.

2. Literature Review

Novitasari & Iftadi (2020) conducted research on the PU door production process at PT. XYZ uses the VSM, PAM, and root cause analysis – 5 whys methods. Based on data processing, it is known that the waste identified is waiting and defective, with a VA value of 11.54%, NVA of 7.69%, and NNVA of 76.43%. The improvement suggestions given succeeded in reducing the total process activities from 26 to 24 and increasing the PCE value by 31.45%. Kartika & Dony (2019) conducted research on the knitting fabric production process at PT XYZ. conducted research on the knitting fabric production process at PT. Finally, suggestions for improvements are given to minimize this waste Finally, suggestions for improvements are given to minimize this waste. Dozza (2022) conducted research on the production of printed sarongs at PT. Pismatex Textile Industry. Based on the analysis results, it is known that there are 3 dominant wastes, namely 23.08%, inventory waste 19.28%, and waiting waste 13.32%. Then suggestions for improvement were given in the form of an appeal to carry out activities alternately, provide frequent guidance and training, add more printing machine units, and carry out routine maintenance and inspections of the machines.
Referring to several previous studies that have been mentioned, by implementing the Lean Manufacturing approach on the production floor, problems related to waste can be identified, and their root causes with the aim of reducing non-value-added waste. Waste identification is carried out so that companies can design appropriate improvement proposals or actions to reduce or even eliminate waste.

Lean Manufacturing

Initially the concept of Lean Manufacturing was initiated by the Toyota company, a manufacturing industry in Japan. This concept was developed so that resource use can be maximized by reducing waste in the process flow, while remaining focused on improving quality in producing products. By implementing this concept well, a lean and efficient manufacturing system can be formed by finding and eliminating waste (Satao, et.al. 2012). In the lean manufacturing concept, types of activities are divided into three, namely *Value Added* (VA), Necessary Non-Value Added (NNVA), and Non-Value Added (NVA) (Hines 2014). Value Added (VA) activities are activities that provide direct added value to the products or services produced. Necessary Non-Value Added (NNVA) activities are activities that do not provide added value to a product or service but are still necessary in the production process. Non-value-added (NVA) activities are activities in the process that do not add value to the product or service and can be eliminated or reduced. Value Stream Mapping (VSM).

VSM is a tool in the Lean Manufacturing approach that functions to analyze the flow of materials and information from the purchase of product raw materials to the hands of consumers(Anugrah & Emsosfi 2016). In general, there are two types of mapping in VSM, namely Current State Value Stream Mapping (CSVSM) and Future State Value Stream Mapping (FSVSM). CSVSM depicts the actual state of the current production process which is useful for identifying waste and its roots (Hartini 2021). Meanwhile, FSVSM is a mapping of the company's future state with a draft recommendation for improvement based on the Current State Map. Future State Map provides information to reduce or even eliminate waste (Damanik et al. 2017). Value Stream in the context of the production process can include customers, raw material suppliers, manufacturing processes and assembly times, as well as distribution of goods (Gasperz 2007).

Process Cycle Efficiency (PCE)

Process Cycle Efficiency (PCE) is a measure that identifies a number of processes that provide added value. PCE can be calculated with the following equation.

$$PCE = \frac{Value\ added\ time}{Total\ lead\ time} * 100\% \tag{1}$$

PCE increases by reducing production process cycle times and eliminating activities that do not provide added value (waste). The higher the PCE value, the more efficient the production process will be.

Waste Assessment Model (WAM)

The WAM method was developed by Ibrahim Rawabdeh with the aim of facilitating the search for waste problems so that they can be identified and eliminated based on the most critical waste levels in a production process (Rawabdeh, 2005). This method is divided into 3 stages, namely Seven Waste Relationship (SWR), Waste Relationship Matrix (WRM) and Waste Assessment Questionnaire (WAQ). SWR is the relationship between seven types of waste which impact and influence each other both directly and indirectly. WRM is a matrix used to analyze the criteria for each relationship measurement consisting of rows and columns.WAQ is a questionnaire that is processed to determine and classify waste generated during the production process.

Fishbone Diagrams

Fishbone Diagrams or Cause and Effect Diagram namely tools that can be used to identify the root causes of events or processes. This diagram is called a "fishbone" diagram because it is a fishbone skeleton (Kartika & Dony 2019). This method is widely used in production systems because it can solve problems so that they can be repaired from the source of the problem.

Failure Mode Effect Analysis (FMEA)

Failure Mode Effect Analysis (FMEA) is a method that uses Table s in reasoning and thinking procedures by engineers in identifying the possibility of failure and its consequences (Permana et al.2022). FMEA is also designed to identify actions that can eliminate or minimize potential failures. In the FMEA procedure, the Risk Priority Number (RPN) value is calculated which is the result of multiplying the three failure modes with the following formula.

$$RPN = S * O * D \tag{2}$$

Information:
RPN = Risk Priority Number
S = level of severity
O = occurrence or frequency of events
D = detection level

Methods

The model of analysis in this research follows quantitative descriptive analysis by observing and determining the actual problem. The research study employs a case study method with a single industry chosen in order to increase the production performance. The analysis stages performed in the research begin with describing the current state value stream mapping in order to attain the actual condition of the case study object and determine the actual PCE value. It follows by identifying the wastes occurring in the process and finding out the dominant and critical ones using WAM. A waste assessment questionnaire will be filled out by the manager of the industrial engineering department in the company, production supervisor and quality assurance manager. In order to find the root causes of the problem in the production failure, a fishbone diagram is carried out. After that, FMEA analysis is performed to prioritize the causes of failures by establishing the RPN based on the severity, occurrence, and detection level.

Data Collection

Data collecting procedures begin with determining the sample that will be used in the research. According to the methods, non-probability sampling, namely purposive sampling, is used with manager, production supervisor, and expert worker as respondents. Primary data was obtained by using direct observation and interviews with the expert. Primary data used in this research such as cycle time, production flow, standard time, data resulting from the waste assessment questionnaire, cause and effect data, and data obtained for FMEA analysis. Meanwhile, the secondary data used in this research contains the company profile, the working processes, the material and information flow, the number of workers, work-in-progress data in each department, production data, and defect data.

Results and Discussion

Current State Value Stream Mapping

VSM displays data on cycle time, manpower, changeover time, availability time, and production output/day for each process or department. The determination of process time is based on calculations for processing one epic cutters-style glove product. The processing time was taken 30 times to ensure the data met the adequacy test and uniformity test.

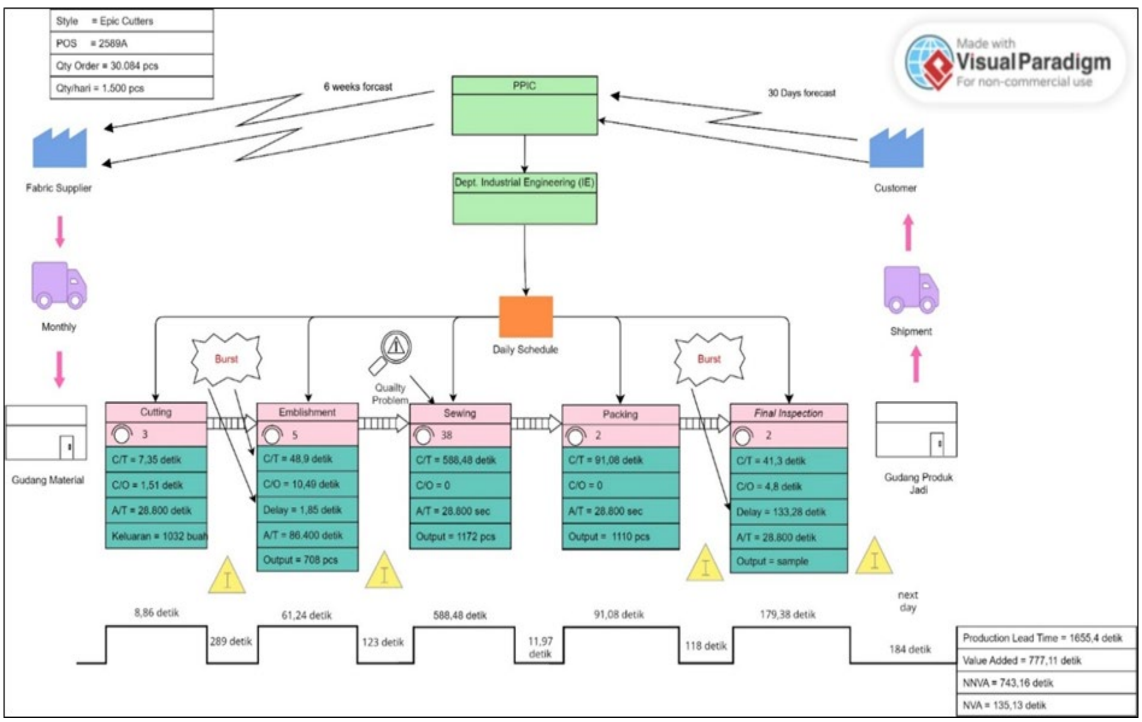

Figure 1. Current State Value Stream Mapping

To produce one type of epic cutter glove requires a total production lead time of 1655.4 seconds, which consists of VA activity of 777.11 seconds, NNVA activity of 743.16 seconds and NVA activity of 135.13 seconds. Apart from that, based on CSVSM, areas that are problematic and require improvement can also be identified, namely marked on the project burst icon. There are 2 areas for improvement, namely the embellishment and final inspection departments, as well as the sewing department which has quite serious quality problems.

Process Cycle Efficiency (PCE)

PCE is calculated using the Value Added Time and Total Lead Time values obtained from the analysis results using VSM. The PCE calculation results are as follows.

$$PCE = \frac{1655{,}4\ detik}{777{,}11\ detik} * 100\% \ = 46{,}94\% \tag{3}$$

Waste Assessment Model (WAM)

WAM was obtained by distributing questionnaires to 6 respondents who were experts in the field of production including the Industrial Engineering manager, Quality Engineering manager, Industrial Engineering staff and 3 production supervisors. The results of data calculations using the WAM method in this research are as follows.

Table 1. Recapitulation of Seven Waste Relationship (SWR) Answers

No.	Connection	r.1	r.2	r.3	r.4	r. 5	r.6	Average	Symbol
1	O_I	16	18	15	16	15	19	16.50	E
2	O_D	11	10	10	18	10	12	11.83	I
3	O_M	11	11	14	16	14	11	12.83	I
4	O_T	12	18	9	18	9	2	11.33	I
5	O_W	16	5	4	16	4	4	8.17	O
..	..	..	..	..	..	..	..	..	..
29	W_I	6	1	6	14	6	18	8.50	O
30	W_O	4	1	4	12	4	1	4.33	U
31	W_D	8	3	6	10	6	11	7.33	O

SWR was obtained by distributing questionnaires regarding the relationship between waste proposed by Rawabdeh. The questionnaire consists of 6 questions on each of the 31 existing relationships.

Table 2. Waste Relationship Matrix (WRM) Results

From/To	O	I	D	M	Q	P	W
O	A	E	I	I	I	X	O
I	I	A	E	I	I	X	X
D	A	E	A	I	E	X	I
M	X	O	O	A	X	I	E
Q	O	O	I	E	A	X	A
P	O	I	E	I	X	A	A
W	O	U	O	X	X	X	A

The use of WRM is to calculate the percentage of waste types based on the relationship between waste. WRM also shows the possibility of waste that will influence or be influenced by other waste. Then the matrix weighting is carried out by converting the symbols into numbers. The WRM conversion results are as follows.

Table 3. Waste Matrix Value in WRM

From/To	O	I	D	M	Q	P	W	Score	%
O	10	8	6	6	6	0	4	40	15.27%
I	6	10	8	6	6	0	0	36	13.74%
D	10	8	10	6	8	0	6	48	18.32%
M	0	4	4	10	0	6	8	32	12.21%
Q	4	4	6	8	10	0	10	42	16.03%
P	4	6	8	6	0	10	10	44	16.79%
W	4	2	4	0	0	0	10	20	7.63%
Score	38	42	46	42	30	16	48	262	100.00%
%	14.50%	16.03%	17.56%	16.03%	11.45%	6.11%	18.32%	100.00%	

Based on Table 3 It is known that the highest percentage of "from waste" value is from defects at 18.32%, which means that the waste that has the most influence or dominant influence on other waste is defect waste. Meanwhile, the largest percentage of "to waste" value is to wait at 18.32%, which means that waste waiting is the biggest impact caused by other waste.

Table 4. Waste Assessment Questionnaire (WAQ) Weighting Results

Mark	O	I	D	M	Q	P	W
Yj's score	0.11722	0.1071	0.1125	0.1067	0.122	0.0809	0.1368
Pj Factor (%)	2.21%	2.20%	3.22%	1.96%	1.84%	1.03%	1.40%
Yj final	0.0026	0.0024	0.0036	0.0021	0.0022	0.0008	0.0019
%	16.59%	15.08%	23.13%	13.36%	14.31%	5.30%	12.23%

The use of WAQ is to select waste with the highest or dominant ranking and has an influence on the production process. Based on Table 4, it is known that the waste with the highest percentage is defect waste with a percentage of 23.13%.

Critical Waste Identification

To determine the most critical types of defects in the production process, an analysis was carried out based on inspection data from the quality department in each production department.

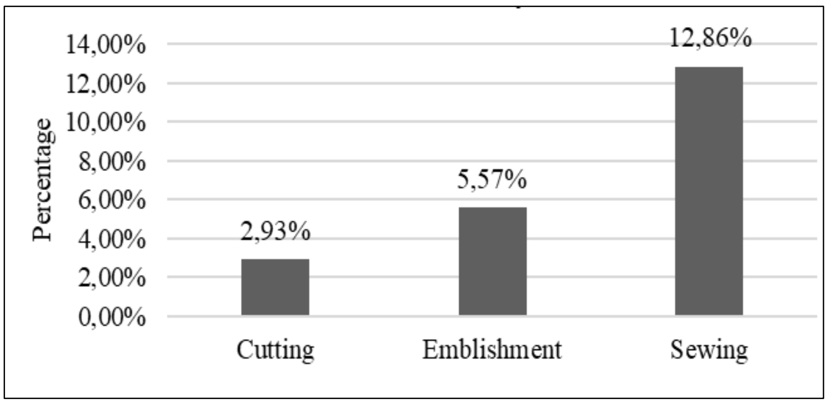

Figure 2. Defect Data for Each Department in January 2024

Based on Figure 2, it is known that the percentage of departments with the highest defects occurred in the sewing department, namely 12.86%. Then An analysis will be carried out using a Pareto diagram to sort the frequency of defects from highest to lowest.

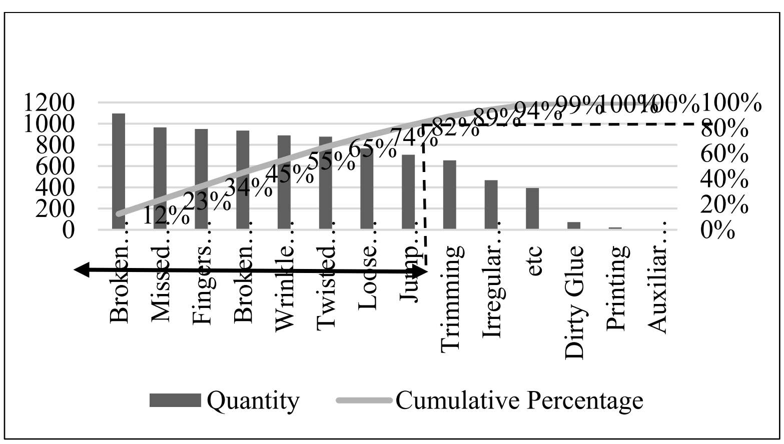

Figure 3. Pareto Diagram for Defect Sewing

Based on the Pareto diagram in Figure 3, it is known The causes of defects that are often found in the sewing department are breaks, missed stitches, non-oval fingers, broken stitches, wrinkles/folds, twisted fingers, loose stitches, and skipped stitches.

Fishbone Diagram

Analysis to determine the problem was carried out by brainstorming with the company and was based on direct observation for one month at the Company. The following is a fishbone diagram that displays the root causes of the overall waste defect problem.

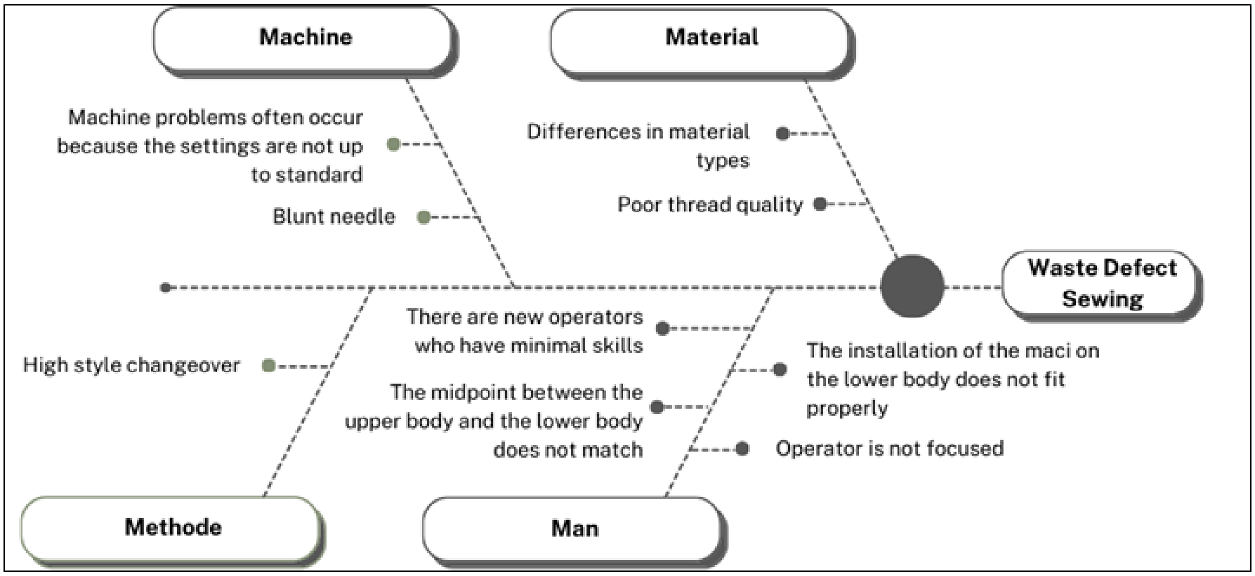

Figure 4. Fishbone Diagram Waste Defect Sewing Overall

Apart from that, this research also analyzed the causes of waste identified in Current State Value Stream Mapping (CSVSM), namely waiting time and overproduction in the embellishment department. The following is a fishbone diagram that displays the causes of wasted waiting time and over-processing.

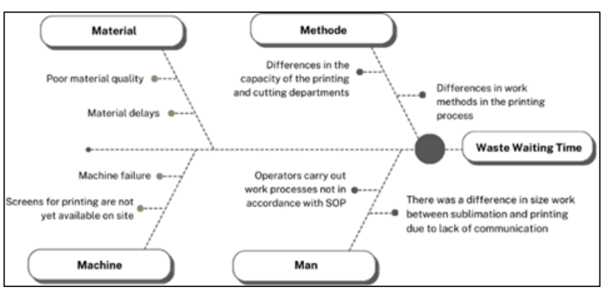

Figure 5. Fishbone Diagram Waste Waiting Time

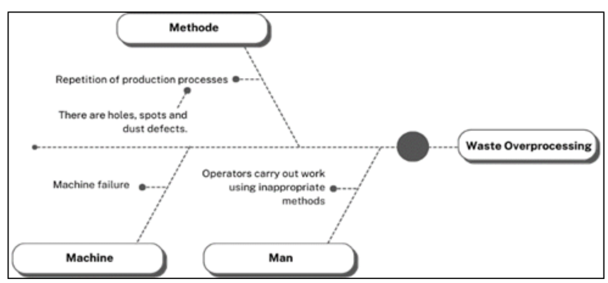

Figure 6. Fishbone Diagram Waste Overprocessing

Failure Mode Effect Analysis (FMEA)

Data processing using the FMEA method is carried out to determine the Risk Priority Number (RPN) value based on the root causes of waste that have been obtained using a fishbone diagram. The results of the FMEA analysis to obtain the RPN value are as follows.

Table 1. FMEA Analysis of the Roots of Waste Defect Problems

No.	***Potential Failure Mode***	***Potential Effects of Failure***	S	***Potential Cause of Failure***	O	***Current Control***	D	RPN
1	There are new operators with minimal skills	*Defect*	7	Lack of training for new operators	5	There has been training	3	105
2	Operator is not focused	*Defect*	6	Sleepy, in a hurry	5	Yes, but not optimal	5	150
3	The midpoint between the upper body and the lower body does not match	*Defect*twisting fingers	6	Operators are in a hurry	4	Yes, but not optimal	4	96
4	The installation of the maci on the lower body is not correct	*Defect*twisting fingers	5	Operators are in a hurry	3	Yes, but not optimal	4	60
5	The trimming process is too tight for the product	*Defect*Broken-down	6	Operators are in a hurry	4	Yes, but not optimal	3	72
6	High style changeover	Operator skill does not increase	6	Diverse requests	5	Planning	4	120
7	Machine problems often occur	*Defect*wrinkled/folded, saggy	5	Lack of supervision and maintenance of machines	5	Corrective repair	6	150
8	Worn Tools/Machines (ex: Blunt needles)	Broken stitches, jump,	6	Lack of supervision and maintenance of machines	5	Corrective repair	5	150
9	Differences in material types	Operator has difficulty sewing	6	there is no special soup yet	3	There isn't any yet	5	90
10	Thread quality is not good	*Defect*	6	There is no thread inspection process	4	There isn't any yet	5	120

Table 2. FMEA Analysis of the Roots of Waste Waiting Time Problems

No	***Potential Failure Mode***	***Potential Effects of Failure***	**S**	***Potential Cause of Failure***	**O**	***Current Control***	**D**	***RPN***
1	Operators carry out work processes that do not comply with the SOP for the embellishment process	A problem occurred which resulted in the production process stopping temporarily	5	Lack of supervision from supervisors	5	there is, but not optimal	4	100
2	The operator carried out the work process not in accordance with the SOP after the final inspection process	A problem occurred which resulted in the production process stopping temporarily	3	Lack of supervision from supervisors	5	there is, but not optimal	5	75
3	There is a difference in size work between sublimation and printing	The product is delayed for further processing	6	Lack of communication between sublimation and printing management	5	there is, but not optimal	4	120
4	Differences in the capacity of the printing and cutting departments	Products that have been cut cannot be processed immediately	8	Limited printing machine capacity	5	Already there, adding a manual printing process	4	160
5	Poor material quality	*Waiting time*	5	Must be renovated and repaired	4	there is, but not optimal	5	100
6	Material delays	Production process is delayed	5	Errors in material planning	5	Planning	4	100
7	Machine failure	Idle time	7	Lack of supervision and maintenance of machines	5	Corrective repair	4	140
8	*Screen* Printing is not yet available locally	Production process is delayed	5	Lack of tools, operator negligence	8	Waiting from other parts	4	160

Table 3. FMEA Analysis of the Roots of Waste Overprocessing Problems

No	*Potential Failure Mode*	*Potential Effects of Failure*	S	*Potential Cause of Failure*	O	*Current Control*	D	RPN
1	Operators carry out production processes that do not comply with standards (reject)	A problem arose so the process had to be redone	5	Lack of supervision from supervisors	5	Yes, but not optimal	3	75
2	Carry out the re-production process due to defective products	Must repair defective products (rework)	5	Open and dirty work environment	7	Just do weekly cleaning using simple tools	4	140
3	Machine failure	Carry out the printing process manually	7	Limited printing machine capacity	4	Already there, adding a manual printing process	3	84

5.7 Proposed Recommendations

The proposed improvements given are based on the part that has a project burst using the VSM method, and data processing using WAM to the FMEA method, namely the highest RPN value. The recommendations for proposed improvements for each waste are as follows.

Table 8. Proposed Improvements to Waste Defects

No	Root of the problem	Proposed Improvements
1.	Operator is not focused	1. Provide training to equalize operator skills, especially during style changeovers so as to reduce errors in sewing techniques. 2. Monitor and measure performance for each sewing operator. 3. Provide understanding to operators to care about product quality. 4. The company can provide rewards to operators who have good performance with the aim of increasing work morale so that operators can focus more on completing work.
2.	Machine problems often occur and tools or machines wear out.	1. Implementing scheduled machine maintenance activities (preventive maintenance) so that machine problems can be identified early and reduce the risk of machine damage which can cause product defects. 2. Provide understanding to sewing operators (not just mechanics) regarding the correct use of tools so that they can identify problems with worn tools/machines. 3. Speed up the process of identifying the location of a sewing machine where problems are occurring, for example by sending signals in the form of sound and light to identify machine damage.

Table 9. Proposed Improvements to Waste Waiting Time

No	Root of the problem	Proposed Improvements
1.	*Screen*Printing is not yet available locally.	1.Providing appropriate screens or production process tools so that production activities are not delayed. 2. Applying the 5S principles, one of which is seiton (arrangement), so that everything must be placed according to the specified position and schedule so that it is ready for use.
2.	There is a difference between the capacity of the cutting and printing processes	1. Aligning the capacity of the two departments can be done by adding 1 printing machine with a capacity of 700-800 pcs in order to reduce buildup and waiting time.

Table 10. Proposed Improvements to Waste Overprocessing

No	Root of the problem	Proposed Improvements
1.	*Defect Products* resulting from an unclean and open work environment	1. Ensure that the screen used for the printing process is clean. 2. Move the location for the printing process to a closed room and not accessible to the public. 3. Provide adequate room cleaning tools such as a vacuum cleaner because the printing process is very susceptible to dust.

5.8 Validation

The proposed improvements that have been designed can be used to increase PCE and reduce waste. An illustration of whether the proposed improvements can be implemented and waste is reduced can be seen in the Future State Value Stream Mapping (FSVSM). The FSVM in this research is as follows.

From Figure 7, it is known that there is a reduction in the problematic parts (project burst), namely the embellishment, sewing and final inspection parts. Apart from that, there are processes that are eliminated so that production lead time is reduced from 1655.4 seconds to 1511.94 seconds. The PCE calculation is as follows:

$$PCE = \frac{1511{,}94}{743{,}16}\ x\ 100\% = 50{,}85\% \qquad (4)$$

Based on the results of this study, it can be seen that waste identification is an important thing to do in order to determine the right actions to improve and minimize the risks or losses caused by waste. Lean manufacturing is an appropriate approach to be implemented on a scheduled basis by companies. Based on the research resulted from this study, the increase in PCE value can be attained by minimizing and eliminating unnecessary activities that are not adding additional value to the final product. As a result, having a higher percentage of PCE means that the company will be able to increase their output target since the cycle time is getting leaner in the same availability time.

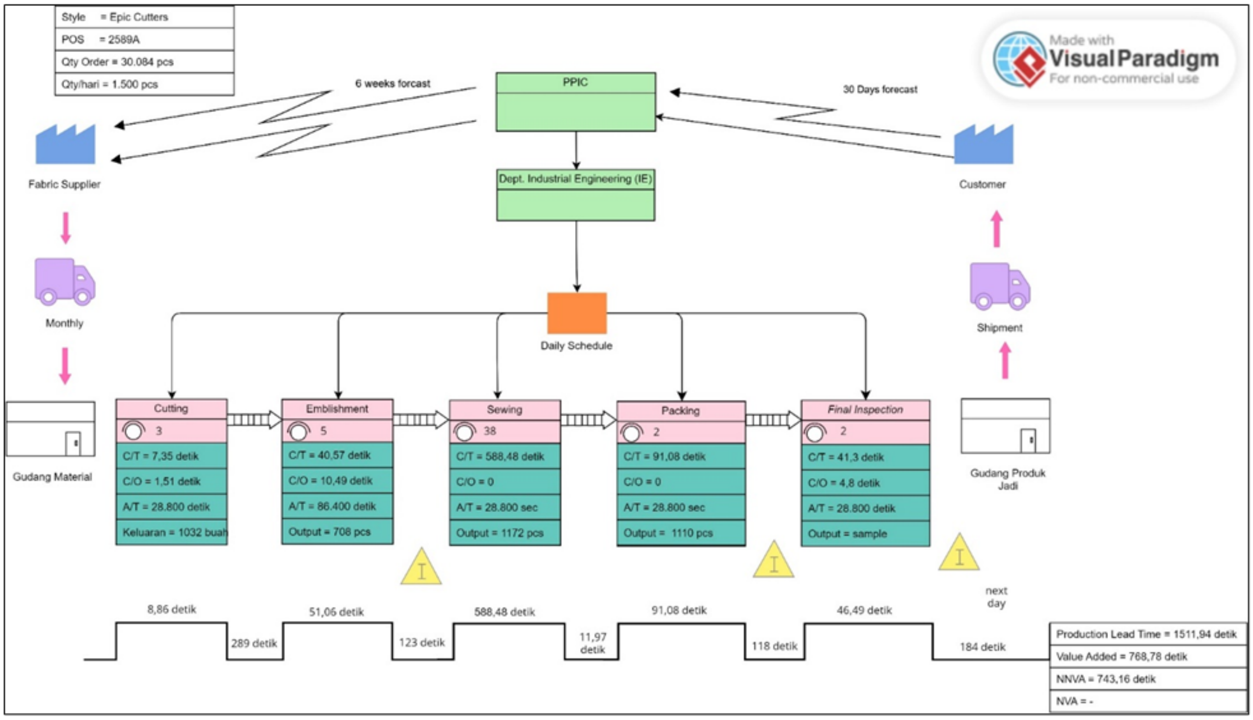

Figure 7. Future State Value Stream Mapping (FSVSM)

6. Conclusion

To produce one type of epic cutter glove requires a total production lead time of 1011.24 seconds, which consists of value added activity of 777.11 seconds, necessary but non-value added activity of 99 seconds and non-value added activity of 99 seconds. added activity of 135.13 seconds. The most dominant waste that occurs and has the greatest potential to hamper the production process is defect waste with a percentage of 23.13%. From the results of the analysis of the causes of defects using FMEA, it is known that the causes with the highest RPN values are operators who are not focused, as well as machines that often experience problems and tools that are worn out. Then proposals for improvements are prepared to reduce and eliminate waste. If the proposed improvements can be implemented well, it can reduce the Production Lead Time to 1511.94 seconds and PCE value increased by 3.91% from 46.94% to 50.84%. By increasing PCE, production output can be achieved because the production cycle time is directly proportional to the product produced.

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