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Managing Waste Using the Integration of Lean and Ergonomic Methods

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ABSTRACT
CV. AAA is a manufacturing company engaged in the production of water tanks. Inefficiency caused by non-value-added activities has been found in the water tanks production process. The production process mainly depends on manual labor, which leads to musculoskeletal disorder. This study aims to evaluate activities that cause waste in a water tank production line. The research illustrates the current state map and then instigates the degree of occurrence in terms of non-value-added activities. The results showed three identified wastes, namely Waiting, Defect, and Excess Processing. The Nordic Body Map Scoring results obtained from the four operators showed that the final score was from medium to high level. Improved scenarios presented in future state maps show reduced cycle times and waiting times.

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1. Introduction

The increasingly fierce business competition and the development of science today are forcing companies to make quality improvements to maintain and increase profits. (Wibowo, 2017) . Therefore, the company experiences an increase in production. If production increases, activities that do not have added valuewill also happen frequently. Therefore, each production stage needs to perform principles of work efficiency and effectiveness to be more competitive.

CV. AAA is a medium-sized firm that produces water tanks products. Make to order is considered a production system. The production process includes the mixing process, polishing process, coating process, drying process, refining process, and testing and painting process. Working activity in this firm is primarily dependent on human labor. Moreover, Manual work done with monotonous movements and long working hours can cause work fatigue (Rahdiana, 2017).

In addition, the firm is also challenged with inconsistency in producing good quality products. A problem that manufacturing companies found is that the frequent waste in every production activity leads to the minimum achievement of an effective and efficient production process (Iswandharu et al., 2018). the percentage of *defects* is illustrated in **Figure 1.**

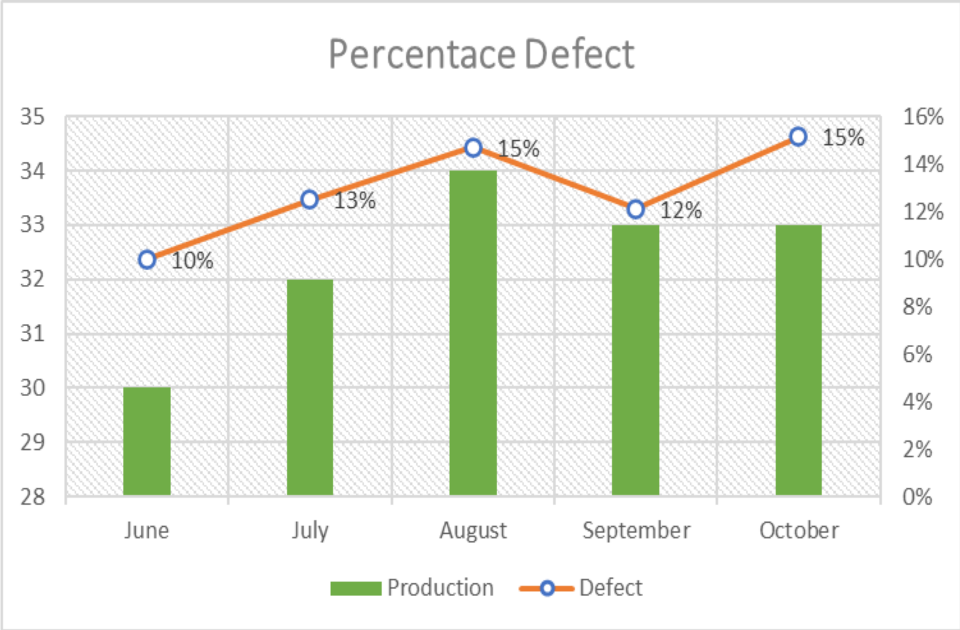


Figure 1. Percentage Defectwater tank
Source: Company Data

It can be seen on Figure 1. that the product defect has been increased which caused extra production cost**.**Non-Value Added Activities are related to actions that do not deliversupplementary value in the eyes of the customer on a processed material or product (Iswandharu et al., 2018). Waste is anything that does not add value. As a result, Customers do not want to pay and do not provide value to the company's output (Sudri et al., 2021). There are seven waste classifications: overproduction, waiting time, transportation, processes, inventories, motion, and defects (Almer Panji Pradana, Mochammad Chaeron, 2018). The concept of this lean approach aims to make changes to an organization in the company to become more efficient and effective (Suparno & Susanto, 2021)

A lean concept is an approach to thoroughly evaluating waste and production process activities. Lean Manufacturing is ideal for implementing efficient tools and illustrating better production flow with minimum lead time, costs, and effectiveness in meeting customer expectations. (Brito et al., 2018) .Problem Identification related to non-value-added activities, namely excessive processes in the production process and wasted waiting time in the actual drying process, the drying waiting time. Even though the production Division has been figuring out a solution to reduce the number of product defects, this problem still occurs. In addition, the Quality Division needs to analyze non-value-added activities to obtain proposed improvements in eliminating ineffectiveness in the production process.

In addition, a problem related to the workload of the coating process has been identified. This problem occurs due to Overload on the coating operator impacts the health and safety of the operator. Operator fatigue during the coating process needs a solution with a risk ergonomics approach to evaluate and minimize impact fatigue consequence work at a time as effort reminder productivity work. Ergonomics _ risk is something right approach _ To use knowing the risk of excessive workload on poor work posture. Risky jobs could be categorized as discomfort, injury, muscle disorders, and even disabilities caused by non-ergonomic ways of working and workplaces (Rahdiana, 2017). The workers experience fatigue due to muscle problems. In the long term, it can cause complaints to the system musculoskeletal. Musculoskeletal complaints are complaints in the skeletal muscles that a person feels, ranging from mild to very sick (No & Dewi, 2020). Nordic Body Map is a risk ergonomics tool to find out the inconvenience and pain in the body When doing activity work(Wijaya, 2019).

This study aims to evaluate activities that are not value-added and are not effective in the water tank production process using a lean and ergonomics risk approach. Integrating lean ergonomics methods contributes to workers' safety and health. It improves operator productivity across activity production CV AAA water tank. Furthermore, Lean and ergonomics goals are integrated to eliminate waste and unnecessary working movement, which may contribute to the safety and health of workers (Brito et al., 2018).

2. Literature Review

a. Lean Approach

Lean has been implemented in eliminating non-value-added activities in various services and manufacturing enterprises (Wibowo, 2017). The method is known as a better way and a comprehensive approach to viewing activities on the production line. This waste detected from non-value benefits can eliminate by added activities through continuous improvement efforts with the aim of customer satisfaction (Suparno & Susanto, 2021).

b. Waste

Waste is an activity that absorbs or wastes resources such as expenses or additional time. However, it does not add any value to the activity (Nadhir et al., 2019). Waste is all parts, such as raw materials, equipment, and working time in the production process. Because it is a waste is said to be an activity that does not add value to the output company. According to (Iswandharu et al., 2018), there are seven types of waste in the Toyota Production System (TPS) production process, namely Overproduction, Waiting, Transportation, and Overprocessing Inventories, Motion, and Defects.

c. Value Stream Mapping

A value mapping stream mapping can help companies understand the flow in the production process that will provide added value and which will not provide added value. Value Stream Mapping is a tool to streamline the production process, dividing it into individual and non-value increasing steps (Musfita & Mahbubah, 2021). This tool is used to visually identify waste with the current allocation of company needs in illustrating current conditions and future views (Rinaldi & Kurniawan, 2021).

d. Nordic Body Map

Nordic Body Map is a questionnaire intended to find out the parts of the body that experience discomfort or pain at work. Nordic Body Map can identify and assess the pain complaints experienced (No & Dewi, 2020). The questionnaire's assessment can be done using two answers, namely "yes" with a condition if there are complaints of pain in the skeletal muscles. The opposite answer is "no" because there are no complaints or pain in the skeletal muscles. But it is more important to use a four scale score Likert (Rahdiana, 2017).

e. Lean Ergonomics

Lean Ergonomics aims to eliminate or reduce waste, especially in non-value-added operations(Dominguez-Alfaro et al., 2021). Ergonomic movements that do not add value include stretching, bending, awkward postures, and broad reach. Lean Ergonomics contributes to worker safety and health and productivity, and efficiency. A previous study conducted by (Dominguez-Alfaro et al., 2021)(and Brito et al., 2018) in four different production areas in the metallurgical industry found that the rate of absenteeism due to excessive work shoulder pain and high repetition for performing manual tasks.

3. Methodology

a. Data collection

This research was conducted by observing the research object and distributing questionnaires and interviews. Observations on the research object were conducted to collect data on production time, production process, company working hours, and the number of operators. Questionnaires were distributed to determine the level of workload risk to the four coating process operators. Interview activities were carried out to discover waste and workload complaints and determine proposed improvements.

b. Research Stage

The research procedures are breakdown into six stages as follows.The first stage was conducting a walk-through survey on the production process and identifying problems using Value Stream map tools. The map is a method to determine the flow of information and production flow in the water tank production system at CV. AAA. The stage was done by describing the production process within the company, from raw materials to finished products in the hands of consumers. The process is described in the form of specific symbols (Kurniati et al., 2020). The results identified waste in product defects, unnecessary motion, time, and excessive processes have been concluded as the second research stage.The third stage was to identify the cause of the problem using the fishbone method with the 4M + 1E approach steps, namely man, machine, material, method, and environment.The next stage was data analysis to provide improvement proposals using 4M + 1EThe fifth stage was distributing and collecting a Nordic body Map questionnaireand then calculating scoring to determine the risk level. The last stage was designing Future State Map to find a better Scenario for improving production effectiveness. Identify the causes of the most frequent complaints experienced by workers.

4. Results and Discussion

a. Current State Map

Information flow in the firm was related make to order system. Once the order was accepted, the order was then submitted to the production planning department to check material availability and bid orders with suppliers. Then the planning section forwards information to the production department. Furthermore, the production department checked the product prototype and the availability of the materials and then executed to production stages. The current State Map isillustrated in Figure 1.

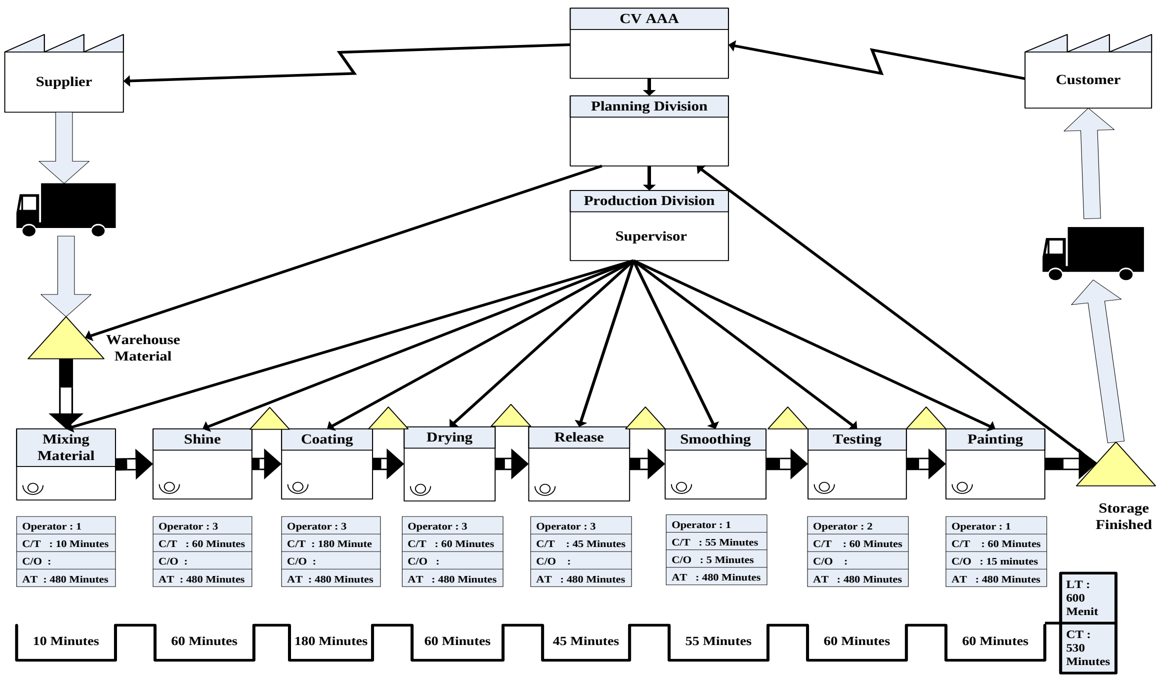
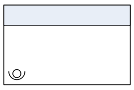
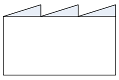
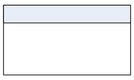


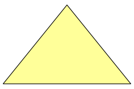
Figure 22. Current state map
Source:Data processing result

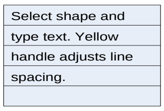

Process


Customers/Supplier


Production Control


Shipments


Inventory/inventory work in process



Data Box Informatio

Based on **Figure 2**, the process flow and formation flow in the water tank production process can be seen, namely the total cycle time of 530 minutes and total lead time of 600 minutes which requires 17 operators for each production. Waste identification is carried out that occurs throughout the flow of the production process. The observation result identified three types of waste. They were namely Waiting for product defects and unnecessary excess processing. This research is focused on waste waiting. In the drying process have been identified non-value-added activities such as excessive drying process and waiting time due to machine's shutdown. A waste Defect in the coating process is the water tank leaked. Waste excess Processing of the coating process was found because a leaky water tank product was found in the product testing process. At this work station, the operator experiences a continuous and repeated peeling workload, resulting in waste Health and Safety, which causes operators to experience fatigue at work.

b. Analysis of the Causes of Waste

Fishbone is a diagram showing the relationship between quality characteristics and the factors causing waste. The causes of the main potential problems must be immediately analyzedand identified so that solutions can be found (Zakaria & Rochmoeljati, 2020). The following Figure 3. and Figure 4. identify the causes and consequences of wastage in the production of water tanks.

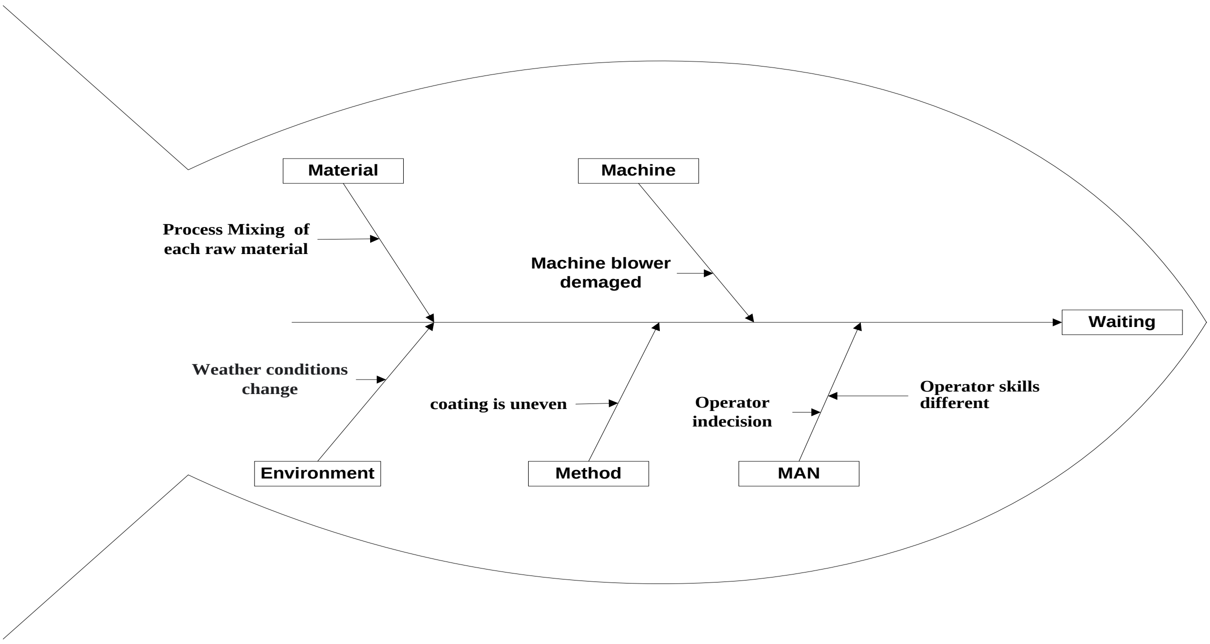


Figure 3. Fishbone diagram waste waiting
Source: Data processing result

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Figure 3.shows that the drying process was delayed due to the malfunctioning of the blower machine and the mixing process of raw materials that is not following the provisions. This defect also affects the processing time of the product.

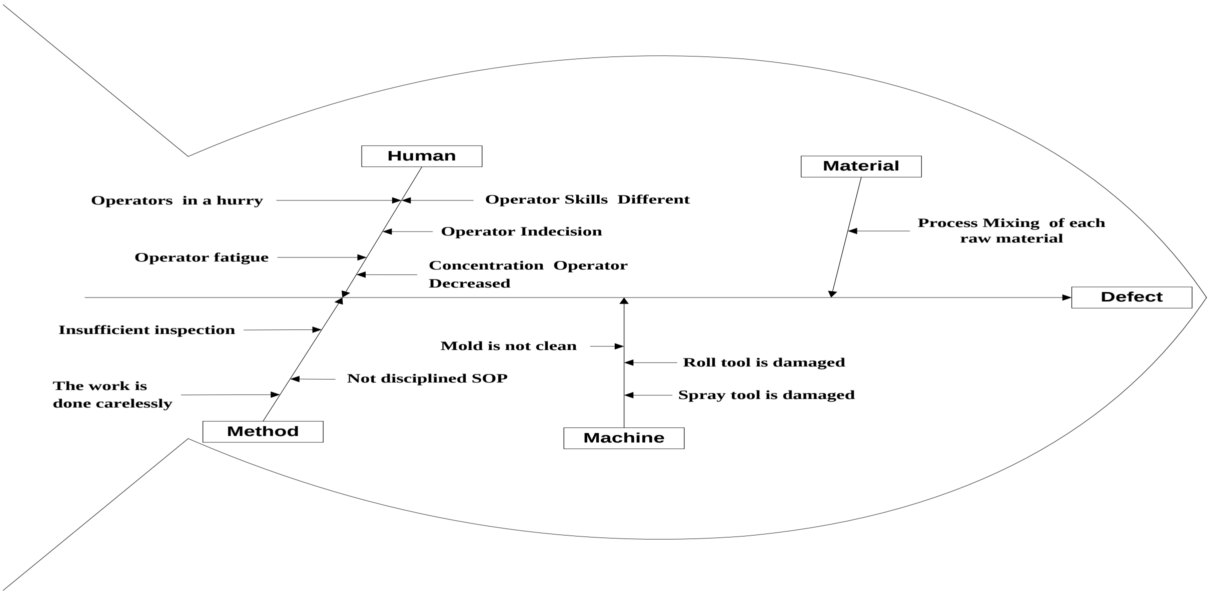

Figure 4. Fishbone diagram of waste defects
Source: Data processing result

Figure 4shows a defective product resulting from the above causes: leakage or water-absorbing out of the tank. This defective product can be reworked.

Based on the analysis described in the fishbone diagram in **Figure 3**and **Figure 4**, the next step is to analyze the proposed improvement using the 4 M + 1E method in **Table 1**.

Table 1. Analysis improvement scenario of waste waiting

Factor	Reason	The root of the problem	Improvement Proposal
Human	• Different operator skills • Operator uncertainty	• Lack of learning how to do the coating process from each operator • The operator was negligent in seeing the results of the coating doing the work.	• Conducted learning on operators for technical skills in the coating process in a precise and directed manner. • Operators and supervisors carry out a re-check on the product to proceed to the following process.
Machine	• Broken blower machine	• Dirty and damaged blower machine stuck.	• Performed maintenance on the blower machine after use and scheduling in the procurement of a new blower machine
Method	• Uneven coating process	• The coating work on the mold is uneven, so the dry results of the raw materials are different.	• The operator in the coating process carries out supervision and accuracy.
Material	• The mixing process of each raw material	• Lack of insight or rules in the mixing process	• Making rules in the mixing process
Environment	• Changing weather conditions	• The drying process requires hot temperature conditions to speed up drying.	• Mixing the suitable raw materials is carried out in not hot weather conditions and the help of a blower machine to optimize the drying process.

Source: Data processing result

The cause-effect analysis results in **Table 1.**found that waste waiting the cause is the human-machine factor materials and environment methods. The proposed problem solving on waste waiting is the need to teach the operator the skills of the coating process in a precise and directed manner and re-check the product to proceed to the following process. In addition, manual guidance needs to provide the need for checking and scheduling in the procurement of new blower machines. Scenario improvement in eliminating waste defect can be seen in Table 2.

Table 2. Analysis and improvement scenario of waste defects

Factor	Reason	The root of the problem	Improvement Proposal
Human	• Operators in a hurry • Different operator skills • Operator uncertainty • Operator concentration decreased • Operator fatigue	• Operators are in a hurry and still do not care about company SOPs • Lack of learning how to do the coating process from each operator • The operator is negligent in carrying out the work. • Operator concentration decreases due to the hot room temperature, and the coating process takes too long. • Operator fatigue is caused by poor working posture.	• Supervise and discipline SOPs to operators who carry out the coating process regarding craft and work safety to anticipate work damage and accidents. • Conducted learning on operators for technical skills in the coating process in a precise and directed manner. • Operators and supervisors carry out checks on the product to proceed to the following process • Rotation is performed on operators who experience fatigue • in working posture.
Machine	• The print is not clean. • The rolling tool is broken. • The spray tool is broken.	• The mold is not clean. There are still remnants of raw materials attached to the mold. • Tool Roll Hardening is caused by too constant working and lack of maintenance on the Roll after use • The paint spray tool is broken, stuck, and the adjustment is not good	• It is necessary to repeatedly clean the mold after removing it and before coating it. • Doing cleaning on Roll Tools after use and scheduling the procurement of new Roll Tools • spray tool before use and doing maintenance and cleaning after use, and scheduling the procurement of new spray tools
Method	• Insufficient inspection • Not disciplined SOP • Work done carelessly	• Inspection on the coating is uneven / there are still less thick. • There are no sanctions if an operator violates the SOP. • Lack of direction and supervision between operators and supervisors	• Provide manual guidance regulations to operators • Better supervision and provide training for operators. • evaluation and briefing between supervisors and operators are carried out
Material	• The mixing process of each raw material	• Lack of insight or rules in the mixing process	• Making rules in the mixing process

Source: Data processing result

Based on the results in **Table 2**, waste defects whose causes are human, machine, method, and material factors. Waste is also found in excess processing rework against product defects that cause operators to experience fatigue due to the repetition of the coating process.

Moreover, the scenario in reducing waste defects, namely the need for SOP in supervision to coating process operators, rotate operators who experience fatigue and improve their working position. The need to clean the mold, roll the tool, and adjust the spray tool before use. Regulations need to be made, strict SOP discipline monitoring is carried out, and periodic evaluations of operators.

c. Future State Map

Future state map is part of continuous improvement so that the proposed improvement conditions in the future stream mapping are achieved (Damanik et al., 2017). The current value stream mapping identified waste and then analyzed the causes of waste using the fishbone method. It also

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figures out recommendations for improvement using 4M + 1E, then envisages the model to support continuous improvement in the future value stream mapping seen in **Figure 5.**

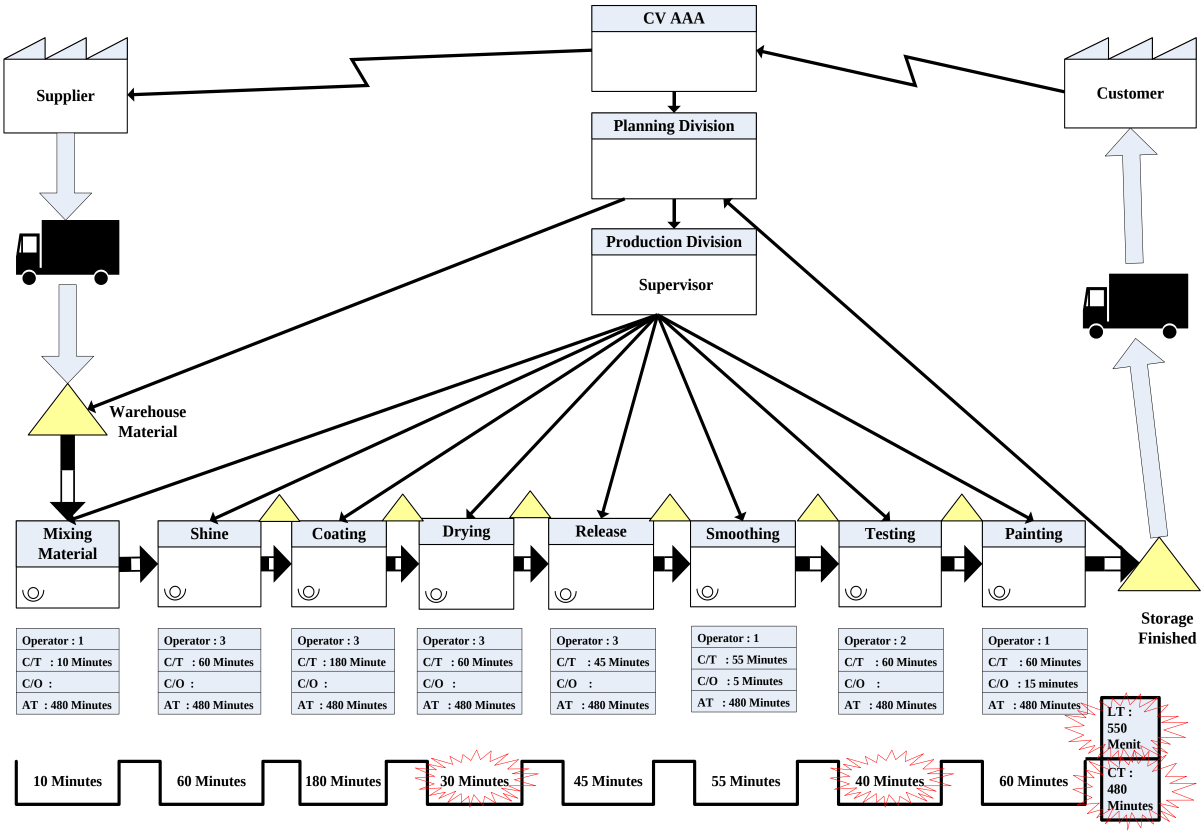

Figure 5. Future State Map
Source: Data processing result

Based on **Figure 5,** the future state map illustrates an improvement scenario caused by waste waiting on the drying process. It also illustrates an improvement scenario on excess processing rework on product defects at the product testing department. The solution scenario includes a reduction in lead time in the drying process from 60 minutes to 30 minutes. In addition, it is also decreasing in the testing process from 60 minutes to 40 minutes. Moreover, the total lead was reduced from 600 minutes to 550 minutes.

d. NBM Analysis

NBM is gathered as a result of Ishikawa Diagram. It was related to work postures and worker complaints, there are work activities in the coating process. The first step was distributing the Nordic questionnaire Body Map to four coating operators. Then, from the obtained results, scoring was done by operators with a predetermined Likert scale. Moreover, the Likert scale consists of a score of 1 to 4. 1 related to no pain. A score of 2 is considered a slight soreness. A score of 3 with a condition if there is discomfort in any part of the body. Finally, a score of 4 is considered severe with the condition of discomfort in body parts. (Mahardika & Hudaningsih, 2021). Furthermore, the results can be seen in the Table 3.

Table 3 Recapitulation of the Total Score of Individual Operators

No	Complaint Type	Complaint Rate															
		Operator 1				Operator 2				Operators 3				Operators 4			
		TS	US	S	SS	TS	US	S	SS	TS	US	S	SS	TS	US	S	SS
0	Pain/stiffness in the upper neck	√					√			√					√		
1	Pain/stiffness in the lower neck		√				√			√					√		
2	Pain in the left shoulder			√				√				√				√	
3	Pain in the right shoulder				√			√				√				√	
4	Pain in the left upper arm			√					√		√						√
5	Pain in the back			√			√				√						√
6	Pain in the right upper arm				√			√		√						√	
7	Pain in the waist		√			√				√					√		
8	Pain in the buttocks	√				√				√				√			
9	Pain in the ass	√					√			√				√			
10	Pain in the left elbow			√					√		√				√		
11	Pain in right elbow			√					√		√					√	
12	Pain in the left forearm			√					√			√		√			
13	Pain in the right forearm			√					√			√			√		
14	Pain in left wrist		√						√				√				√
15	Pain in the right wrist			√				√					√				√
16	Pain in the left hand				√				√				√				√
17	Pain in the right hand				√			√					√				√
18	Pain in the left thigh		√				√				√				√		
19	Pain in the right thigh	√					√				√				√		
20	Pain in the left knee	√					√			√						√	
21	Pain in the right knee	√					√			√						√	
22	Pain in the left calf		√				√			√							√
23	Pain in the right calf		√				√				√						√
24	Pain in the left ankle		√			√				√							√
25	Pain in the right ankle		√			√				√							√
26	Pain in the left leg		√			√					√					√	
27	Pain in the right leg		√			√					√					√	
	TOTAL		66				69				57				81		

Source: Data Processing Result

Based on the results of the data that has been processed that the level of complaints that have a risk of muscle injury is the right shoulder, left shoulder, right hand, left hand, and wrist. Furthermore, the risk level is classified based on the individual's total score with a Likert scale in **Table 4** below.

Table 4. Classification of Levels Based on Individual Risk Levels

Likert scale	Total Individual Score	Risk Level	Corrective action
1	28-49	Low	No corrective action is needed
2	50-70	Medium	Action may be needed in the future
3	71-90	High	Immediate action needed
4	92-122	Severe	Comprehensive action is urgent

Source: (Wijaya, 2019)

the Scoring Results obtained a scoring of 66 for operator one. The following result for operator two scoring results of 69. The third operator score result is 57. The results scored 81 for operator four. The level of risk was "medium" and "high" categories, which means that corrective action on the workstation must be carried out, and immediate action is also required. Table 5 illustrates pain due to excessive work.

Table 5. Summary of Causes of Complaints

No	Parts of body	Cause of Complaint
1	Shoulder	Pain when pressing on the coating process
2	Right and left hand	Feeling sore due to repeated movements in the coating process
3	Wrist	Feel sore to the point of pain due to emphasis on the coating process

Source: Data Processing results

Working in a standing position can cause leg pain, muscle fatigue, back pain, stiffness in the shoulders and wrists, and aches and pains. **Table 5.**describesthe causes of pain felt by the four operators, such as pain in the shoulder when pressing on the coating process. Then the right and left arms feel sore due to repeated movements in the coating process. The wrist feels sore and aches.

e. Discussion

The current state map identified three wastes in the production process: waste waiting in the drying process, waste defects in a leak in the water tank product, and Waste excess processing. During the product testing process, there is a rework of craft on defective products. In the next stage, an analysis of the causes of waste is identified using fishbone and proposed improvements using the 4M + 1E method on waste identified. After analyzing the proposed improvement, a future state map shows a better scenario for eliminating non-value-added activity. Furthermore, based on the proposed improvement that 4 M + 1 E obtained a reduction in total lead time by 8% previously total lead time 600 minutes to 550 minutes. The next step is to identify the work posture on the coating operator worker load and analyze the Nordic body Map questionnaire results. The Nordic body Map found that the complaints at risk of muscle injury are the shoulders, right and left hands, and wrists.

5. Conclusion

The results of this study are to evaluate which are non-value added and ineffective activities in the production process flow. There are three types of identified waste: waiting time, defect, and processing excess. Ishikawa Diagram and 4M+1E are proposed to improve the production process's effectiveness. An action recommendation in eliminating wasted *waiting* is performing regular maintenance to the blower engine. In addition, a proposed scenario in eliminating defective products related to Leakage defects related to performing regular training and supervision to upgrade operators' skills. Upgrading operators' coating techniques will lead to minimizing product defects. Moreover, better working conditions and regularly paying extra working hours are better scenarios for mitigating workload problems.

Result related to working postures shows that the muscles in the four coating operators are at risk, namely the shoulders, right and left hands, and wrist. The NBM score result is considered on the medium to high category level. It means that corrective action on the workstation may be taken in the future, and immediate action is also required. The last recommendation to eliminate non-value-added activities is for the firm's management to consider providing layouts design and ergonomic workstation design. Moreover, further observations to determine the level of risk to the repair operator are needed to improve production line effectiveness. Finally, training in awareness of using personal protective equipment is needed to maintain health and safety.

The limitations of this study are described as follows. The first limitation is the incompleteness of analytical 5M + E tools in detecting the current state map depiction in the production and information flow. Furthermore, by combining Lean Valsat with other methods such as the Six Sigma and Layout Approach, better research recommendation scenarios with specific measuring tools. The second limitation is that the ergonomics risk assessment was only an early assessment stage. Further assessment using both the ergonomic risk approach and human error is needed to understand better why and how to integrate ergonomics with the Lean approach. The third limitation is that this research only proposes improvement scenarios and has not yet reached the implementation stage of the proposal. A study of macro ergonomics problems is also needed as an analytical tool to improve research results.

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