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ANALYSIS THE APPLICATION OF LEAN MANUFACTURING WITH SYSTEMATIC HUMAN ERROR REDUCTION AND PREDICTION TO REDUCE DEFECT PRODUCTION

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ABSTRACT
Manufacturing companies engaged in wood processing produce products in the turning process. The problem faced by the company is a waste where defects often occur in each production process. The cause of the disability arises in workers with human error. This research aims to minimize the waste in activities that do not provide added value and find the factors that cause a human error in the turning production process. For this reason, the method is used to Value Streaming Mapping illustrate the flow of products, the entry of raw materials to finished products. The research was distributing questionnaires to the production department and then processed with a waste assessment model, waste relationship matrix and waste assessment questionnaire so that the three highest wastes were obtained, namely waste defects (27,979%), waste overproduction (15,471%) and waste inventory (12,363%). Weighting waste with value stream analysis tools by selecting the two highest tools, namely process activity mapping and quality filler mapping. The causes of activities and accuracy are caused by human errors in the production process using the Systematic Human Error Reduction and Prediction method. Five activities are obtained in a critical state. The results of field implementation showed improvement with a decrease in time from 2384.2 minutes to 2247.4 minutes the value of Process cycle efficiency with the improvement of 4.9185%.

Keywords: Defect, Value Streaming Mapping, Ishikawa Diagram, SHERPA.

1. INTRODUCTION

Companies must be more competitive to survive and compete in facing competitors, so it is necessary to implement the right business strategy to stay and face the competition that occurs. Manufacturing products company in producing high-quality products is one of the advantages and guarantees consumers of products produced by the company (Kristianto and Tarigan, 2019). Lean Manufacturing application is to identify and reduce waste. Lean Manufacturing is used to identify and eliminate waste through continuous improvement. Using a pull system approach to understand better customer needs and the level of the company's inventory count is getting smaller (Abu et al. 2019). Kusbiantoro and Nursanti (2019) with the use of Value Stream Mapping (VSM) and Value Stream Analysis Tools (VSAT) state that an enormous waste is found in inventories in the form of raw materials, semi-finished goods and in finished products. Changes made to the production process system increased efficiency by 17.19% and decreased waste by 8.31%. Sinambela (2019) identifies waste in PVC pipe companies with a value stream mapping of 316.17 minutes and the total non-value-added time in 7418.73 minutes. The waste that occurs is defective products, excessive production, waiting time that causes bottlenecks, redundant processes in the form of activities setup extrude machine that requires a long time. Lean Manufacturing provides added value for companies when adequately implemented through the VSM and VALSAT methods (Lukmandono, et al. 2019; Zahra et al., 2013).

Inventory waste ranks first (19.23%), followed by defect waste (18.16%) and overproduction (16.58%), after changes in the layout of activities can reduce waste (Turseno, 2018). Lean Manufacturing with the Single Minutes Exchange of Dies (SMED) tool applied to curing workstations can reduce internal setup time by 127.47 minutes and external setup time by 3.06 minutes. Setup activities reduced in several ways. There are converting activities classified as internal set up activities such as green tire setup, preheat mould, and tool-taking activities reduced by 63.70 minutes (Kasanah et al., 2018). Reduction of waste occurs at each workstation and impacts increasing productivity and reducing production costs caused by debris during production (Dagmar and Tarigan, 2021). The implementation of the value stream mapping that was carried out resulted in a reduction in waste at each workstation. The total waste reduction occurred of 66.97 tons/year or 18.6% in waste gel and 88.8 tons/year or 19.3% in waste powder (Ravizar & Rosihin, 2018).

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Many factors cause wasteful activities or processes in the industry. One of them is an error caused by a system error or human error. System errors are usually caused by the system controlling the process, and if they are corrected, the error will not appear again. Workers can be informed about the correct procedure and have understood the procedure standard (Oliveira et al. 2018). However, due to the intricate work system, there is often inconsistency in work. It is mean known as human error. Human error can be a problem in several matters relating to work safety, work effectiveness, operation, time, economic losses, and others. No one can act more than once with the same precision. Every error action taken by someone is a possibility for an error to occur. The results of research by Rochmoeljati and Firmansyah (2019) using lean Manufacturing show that the waste that occurs in the edamame production process with a total waiting time of 7.5. Suharjo (2019) using the Waste Relationship Matrix (WRM) and Waste Assessment Questionnaire (WAQ) methods in the manual production process and found that the cooling process is one of the techniques where a lot of waste is still located. Operator errors can cause losses to the company due to the many defects in the production process so that rework must be done, and the company cannot reach the specified production target. The data of recapitulation turning production in 2019, (Table 1).

Table 1 shows the amount of production with a defect that exceeds the standard tolerance set by the company, is 5%. The product defects that occur in the production process require completion, namely the lean manufacturing approach, which functions to reduce defect waste with value streaming mapping (VSM). Lean Manufacturing method can be used in identifying waste (Fercoq et al. 2016) and form factors. The production process cause can be carried out using the Systematic human error reduction and prediction method to predict human error by analyzing and identifying potential solutions to mistakes made during the production process.

Table 1. Recapitulation of Total Production Turning Year 2019

Month	Amount of production	Defects					
		size	bent	Split	Leather	knots	dead knots
January	53,000	2,770	543	1,260	1,112	412	560
February	52,500	1,223	120	1,523	670	225	1,250
March	56,000	956	1,017	1,345	1,325	1,110	125
April	53,000	1,135	430	780	1,775	2,056	430
May	53,000	780	2,215	547	320	1,125	560
June	53,000	1,050	2,754	1,110	1,112	430	1,225
July	53,600	580	1,453	1,110	1,050	320	320
August	54,000	1,017	2,112	2,050	320	438	945
September	52,500	1,549	987	1,235	716	345	1,250
October	53,000	670	1,400	2,112	715	556	1,756
November	53,000	1,678	1,070	1,015	540	540	1,011
December	53,500	1,135	430	2,780	1,775	2,056	430

Based on the results of a review of previous research conducted, the authors found several research gaps in the study. Research gap in the first research there is no use of lean Manufacturing with the SHERPA (Systematic Human error Reduction and Prediction) method in eliminating waste defects simultaneously (Mandal et al. 2015), the second application of lean Manufacturing is used to identify waste in activities that have no added value as compared to the SHERPA method to identify activities that cause human error. Third, to the knowledge of the researcher, there is no research that eliminates the waste of defect waste by improving the human error. Based on the results of previous research, this study uses a solution in minimizing defects and the factors that cause human errors that occur in the turning production process, to increase profits for the company. For this reason, an analysis of the application of Lean Manufacturing and the SHERPA method is carried out to reduce defects. The research focuses on one company in the Manufacturing of turning wood processing.

2. LITERATURE REVIEW

2.1. Lean Manufacturing

Lean manufacturing process is a production system that uses very little energy and wastes to fulfill what consumers want (Singh et al. 2018, Kasanah et al. 2018). The analytical method used to identify waste is to use the waste assessment model method. The advantage of this model is the simplicity of the matrix and questionnaires that cover many things and are able to contribute to achieving accurate results in identifying the root causes of waste. The calculation of the linkages between wastes is carried out by discussing with the company and distributing questionnaires using weighting criteria. Through this elimination of waste, lean shows its capabilities that can be applied in a business without increasing the number of workers, capital equipment, without affecting existing businesses and without

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hiring reliable resources. Value stream mapping (VSM) is a tool for identifying value-added and non-value-added activities, which consists of 2 activities, namely the current state map and the future state map (Dadashnejad and Valmohammadi, 2018). The current state map is a product value stream configuration using specific icons and terminology to identify waste and areas for improvement or improvement, while for the Future state map is a blueprint for the desired lean transformation in the future and provides benefits to the company. Value Stream Mapping is a definite tool as a first step in making a change process to achieve lean manufacturing conditions (Huang et al. 2019). Value stream mapping (VSM) is a tool for identifying value added and non-value-added activities in the manufacturing industry, making it easier to find root causes in the process. The purpose of VSM is to identify the production process so that materials and information can run without interruption, increase productivity, and assist in system implementtation. Therefore, VSM helps in finding waste in the production process (Steur et al. 2016).

2.2. Value Stream Analysis Tools (VALSAT)

Value Stream Analysis Tools (VALSAT) are tools used to facilitate understanding of existing value streams and make it easier to improve the waste contained in the value stream (Zahraee et al. 2020). VALSAT is an approach used by weighting waste, and then from that weighting, tools are selected using a matrix (Folinas and Ngosa, 2013). Selection of a detailed mapping tool that matches the type of waste that occurs in the production process.

2.3. Cause and Effect

Diagram A cause and effect diagram is often called a Fishbone Diagram or Ishikawa Diagram is a graphical tool used to help identify, sort, and show the causes of a problem (Simanová and Gejdoš, 2015). The cause-and-effect diagram is one of the tools used to determine and link the factors that are the potential causes of a problem (Abu et al. 2019). This diagram is the only tool that uses verbal (non-numerical) or qualitative data (Dagmar and Tarigan, 2021).

2.4. Systematic Human Error Reduction and Prediction Approach (SHERPA)

Human error is defined as a failure to complete a specific task or job (or take actions that are not permitted) that can interfere with operating schedules or result in damage to objects and equipment (Mandal et al. 2015). Human errors can be classified into many categories, such as errors or errors made by operators. One of the causes of their occurrence is a dirty environment, complex tasks, lack of proper procedures, operator ignorance and poor operator selection and training. Maintenance errors occur in the field due to negligence by maintenance operators. Some examples of maintenance errors are faulty maintenance, incorrectly calibrated equipment, and incorrect repairs to correct equipment points. Assembly errors are the result of human error during product assembly. Some of the causes for assembly errors are low lighting, wrong blueprints and other misleading materials, poorly designed work layouts, and imperfect communication information. Installation errors occur for various reasons, including failure to install equipment or items according to manufacturer specifications and incorrect installation instructions and blueprints. Design errors are the result of inadequate design. Some of the causes for this are the failure to ensure the effectiveness of person-machine interactions to implement human needs in the design and assigning functions that are not suitable for humans. Inspection errors are the result of less than 100% accuracy of the inspection personnel. One typical example of inspection error is accepting and rejecting intolerant and intolerant components and items, respectively. Mishandling occurs due to improper transportation or storage facilities. A method used to identify the mistakes related to human expertise or habits with the SHERPA method. Namely: The Hierarchical Task Analysis (HTA) step, job classification, human error identification, consequence analysis, ordinal error probability assessment, critical level analysis and making strategies for fixing errors (Naweed et al. 2018). HTA is one of the methods used in the task analysis process. HTA is the method most often used because of its very detailed, easy, and straightforward application.

3. RESEARCH METHOD

The research method is a step used to solve a defect waste problem in the turning production. The technique of collecting data by conducting observations in the field and collecting data through measurements is called field research. The second stage, the researchers conducted interviews and distributed questionnaires to workers in the company. Data collection stages are carried out by making value-streaming mapping regarding information flow, physical flow, activity time, and distance in each production process. The data obtained is then used to describe the mapping of Current State Value Stream Mapping or the initial state of the entire activity from the current state in the production process. The depiction of current state value stream mapping then created a questionnaire with the attributes used to be distributed to parties related to employees, supervisors, and managers production.

The selection of Value Stream Analysis Tools (VALSAT) is made by multiplying the average weight value of each waste from the waste identification questionnaire results with the VALSAT value for each type of waste (Zahraee et al. 2020). The tools can add value in the Process Activity Mapping (PAM) (Singh and Singh, 2020), and the Supply chain response matrix. The selected tools can categorize activities in the production process: value-added activities (VA),

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which are essential in the production process, non-value added (NVA). It is not added value and can be eliminated if needed, and activities that are not added value but are required in the production process or necessary non-value added (NNVA). The action that causes the most waste is then analyzed the causes of the problem to be repaired. The most dominant factor driving the waste defect comes from operator error or human error such as negligence in checking the oven process's moisture content, which causes dry and split turning results. The next stage is human error analysis. This stage is carried out because of the waste of defects, mostly by the operator. The worklist is compiled in the Hierarchical task analysis (HTA) table, then classified according to the error type of action, checking and selection (Mandal et al. 2015; Naweed et al. 2018). Work data is collected according to the kind of error. The error identification after which an analysis of human consequences of the error occurs. Ordinal error assessment is carried out to see operator errors, including medium, low or high types, to obtain a critical level of the mistake analyzed. After that, a strategy made to reduce the errors in the form of recommendations for improvement.

4. RESULTS AND DISCUSSION

4.1 Current State Value Stream Mapping

An initial stage in understanding the physical flow and information in the turning production process. The turning process for the formation of motifs is with a turning machine. The wood before being turned is sorted whether there are defects such as holes, if there are defects, then it is put in the putty process. The refinement process using a sanding machine aims to smooth the wood and make it easier for the painting process to be satisfactory. Refining is done on good quality wood or wood that has been putty and then refined. This process takes 0.05 minutes. The painting process takes 0.035 minutes. The method of painting the dry product is then carried out by packaging the product on a unique pallet and wrapped in plastic so that when it is stored (Firmansyah and Lukmandono, 2020), and the next step is sent to the warehouse for storage before sending to the customer Figure 1.

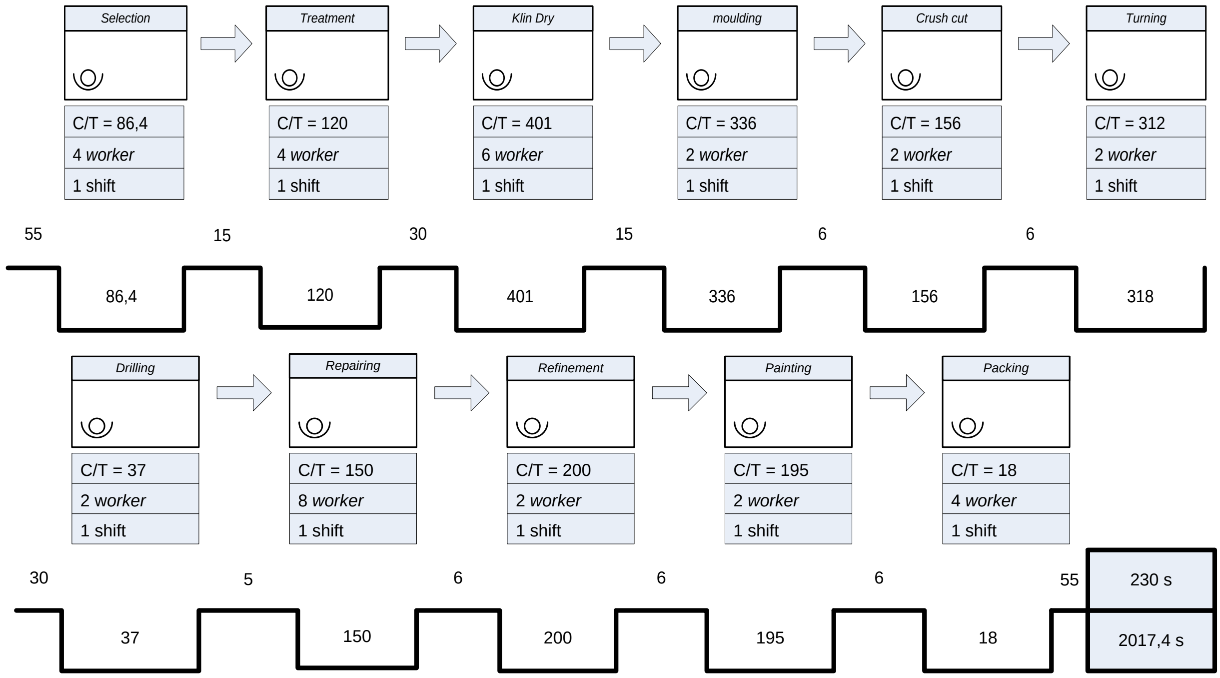

Figure 1. Current State Value Stream Mapping

4.2 **Identification and Weighting of Waste**

The waste identification process is carried out by distributing questionnaires to the production section regarding the relationship between the seven wastes to obtain waste weight. Here are the stages in waste identification with a seven-waste relationship, a waste relationship matrix and a waste assessment questionnaire (Table 1).

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Table 1. Summary of the results of WAM, WRM and WAQ

Description	O	I	D	M	T	P	W
Score Yj	1.133	1.235	1.146	1.0548	1.070	1.045	0.980
Factor Pj	211.450	155.063	378.260	176.208	155.063	148.798	180.907
Result	239.728	191.565	433.539	185.870	165.937	155.429	177.435
Result %	15.471	12.363	27.979	11.995	10.709	10.030	11.451
Rank	2	3	1	4	6	7	5

From table 1, the recapitulation of waste results obtained the highest level of waste in the defect (D) with a percentage of 27,979%. Followed by overproduction (O) of 15,471%, inventory of 12,363 %, motion (M) 11,995%, waiting (W) 11,451%, transportation (T) of 10,709% and process (P) of 10,030. After knowing that the most dominant weighting is, then the mapping is carried out accurately using VALSAT. The selection of detailed mapping is carried out to further identify the location of waste in the value stream. Value stream Analysis Tools are a tool used to map waste by multiplying the waste weighting result from the WAQ with the scale in the VALSAT. Process activity mapping to score as many as 478 218 then Quality Filter mapping (QFM) is in second place with a score of 277,316.

4.3. Process Activity Mapping (PAM).

Process Activity Mapping is an approach that can be used for activities on the production floor. The following is the recapitulation of the turning production process activities with process mapping tools which can be seen in Table 3.

Table 3. Results of Process Mapping Tools Recapitulation

Activities	Number of activities	Time (minutes)	Percentage
Operation	12	20171.4	95.973
Transport	12	190.8	0.907
Inspection	9	193.4	0.920
Storage	2	240	1.141
Delay	3	222	1.056
Total	38	21017.6	100
VA	20	20415.8	97.136
NNVA	12	294	1.398
NVA	6	307.8	1.464
Total	38	21017.6	100

4.5. Quality Filter Mapping (QFM)

Quality Filter Mapping is a tool used to identify defects or defects in the supply chain wherein the turning production process has six types of defects. The product's highest defect was the type of split defect with a percentage of 22.55%, the kind of defect in size that was not following the percentage of 19.45% and the type of bent defect 19.43%. The following is a Pareto diagram of Product defects which can be seen in Figure 2.

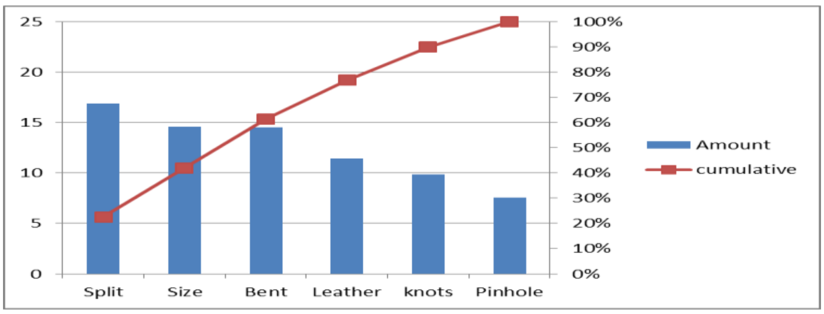

Figure 2. Pareto Diagram of Product Disability Turning

4.6. Cause and Effect Diagram

The diagram is used to analyze the factors causing the problem so that corrective action can be taken (Simanová and Gejdoš, 2015). The following is a cause-and-effect diagram of turning product defects (Figures 3, 4 and 5).

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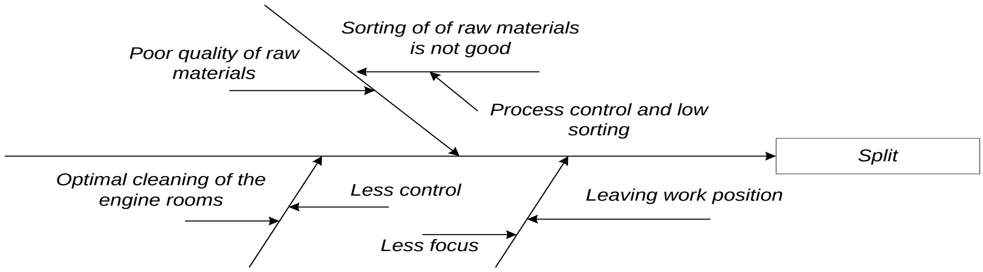

Figure 3. Cause and Effect Diagram of Split Defects

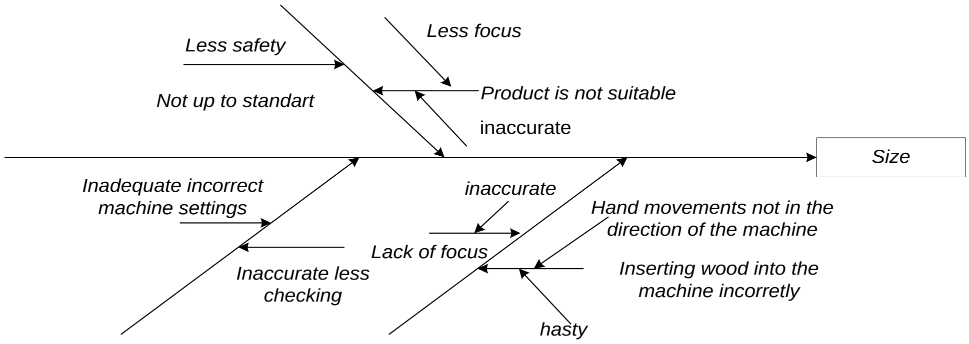

Figure 4. Cause and Effect Diagram for Size Defects

The cause-and-effect diagram of a split defect in the turning production process shows that defects occur because workers are not focused, resulting in less cleaning of the machine room. Anticipate that mistake will not happen repeatedly; it is necessary to carry out consistent supervision. Figure 4 above shows the defect size is not suitable in the turning production process due to workers' inaccuracy in inserting wood into the machine.

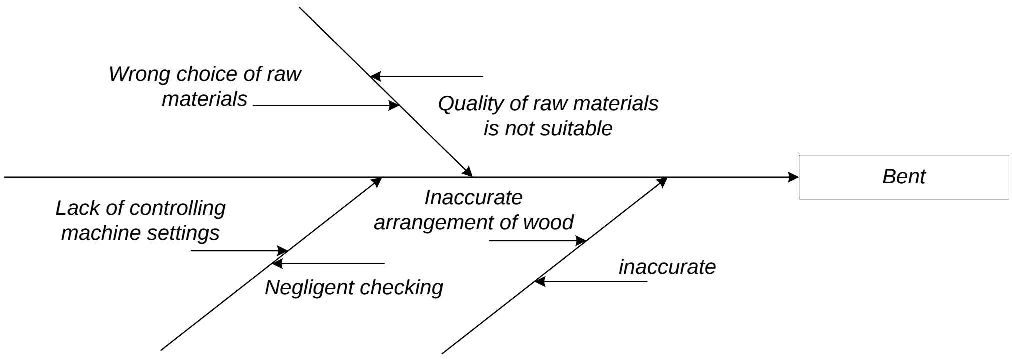

Figure 5. Cause and Effect Diagram for Bend Defects

4.7. Human Error Prediction Using by SHERPA

Method SHERPA is used to identify errors related to human expertise or habits. First, to identify a human error, create an HTA in the form of a chart of the tuning production process. The results from the HTA provide a code (!) to indicate the critical level, the turning product is likely to have many defects and require reprocessing (Table 4). The next stage of the strategic plan is drawn up as actions that must be taken to correct errors or minimize human errors. The action is adjusted according to the consequences, the critical level and the value of the probability of error.

The whole strategic plan can be concluded that there is a need for standard checklist forms for machine checking, SHS training such as personal protective equipment during production and training to improve the skills needed have an operator. After obtaining the improvements that will be carried out, it is not sure to reduce the waste defect, cycle time and lead time in each process. The next step is to use PAM analysis tools again. Recapitulation of PAM results which can be seen in table 5.

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Table 4. Strategic Plan for Turning Production Process

Code	Consequences	Probability of ordinal error	Critical level	Strategic plan
1.1	Fingers punctured uneven wood surface	M	-	Implementing Safety and health system (SHS) on PPE (personal protective equipment)
1.2	Product quality decreases	L	-	Doing repetition to select wood to be more careful
2.1	Workers are hit by wood which can cause injury	M	-	Give a warning not always to apply Safety and health system (SHS)
2.2	Quality of wood that is easy to eat	L	-	Operators must carefully mix according to procedure
2.3	Eyes can be splashed with liquid and interfere with concentration	M	-	Use PPE (personal protective equipment)
3.1	Woodpiles fall from the forklift	L	-	Pick up limited according to capacity
3.2	Workers' hands are injured, or fingers scratched by wood	M	-	Apply Safety and health system (SHS) on PPE (personal protective equipment)
3.3	Eyes are exposed to dust	L	-	Use of PPE
3.4	Burns leather or workers are cold	M	-	Routine of checks
3.5	Wood becomes stringy causing the quality to decrease	H	!	Make a checklist form for routine inspection
3.6	There are parts of the wood that have not dried causing dark wood colour	M	-	Operator training and loading checklist forms
4.1	Workers are crushed by wood causing injury	M	-	Applying SHS with PPE
4.2	Products are not suitable	L	-	Repetition of the process according to size
4.3	Side surfaces are different / not match the size of	M	-	The operator must carefully
4.4	Product size does not equal	L	-	Create a form checklist routine checking
5.1	length of the product not to order	M	-	training on operator
5.2	timber quality declining	L	-	perform repetition to select wood to be more careful
5.3	cutting out of size causes defects	H	!	loggers must be careful to
5.4	fall and repeat the work	M	-	limit the extraction of wood / according to the capacity of
5.5	when the woodturning is broken or deformed	H	!	The operator must be careful
6.1	logs fall from the forklift	M	-	limit taking to capacity
6.2	fingers hit by cutting machines/accidents	M	-	increase awareness when processing is carried out
6.3	products become defective	H	!	carry out routine checks for the replacement of the chisel
6.4	wood is crushed on the leg causing injury	L	-	use of PPE
6.5	repetition time	M	-	motivation training for operators
6.5	product results are mixed between defects and good	L	-	The operator must be careful
6.6	product quality decreases	L	-	repeating to choose wood more carefully
7.1	The product falls from the forklift hitting the leg causing injury	L	-	limiting take to capacity
7.2	feet of falling wood	L	-	applies SHS with PPE
7.3	drilling depth is not suitable	M	-	The operator must be careful
7.4	process time to restart	M	-	improve operator skills
8.1	fingers pricked on uneven wood surfaces	M	-	applies SHS with PPE
8.2	some defects are not covered	M	-	The operator must be careful
8.3	many products are not suitable	M	-	The operator should be careful
9.1	[illegible]	L	-	[illegible]

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Table 5. Recapitulation of PAM Results

Activities	Number of activities	Time (minutes)	percentage
Operation	13	1951.4	86.829%
Transport	8	90	4.005%
Inspection	6	96	4.272%
Storage	2	110	4.895%
Delay	0		0
Total	29	2247.4	100
Type of activity	**Number of activities**	**Time (minutes)**	**Percentage**
VA	15	1926.4	85.717%
NNVA	14	321	14.283%
NVA	0	0	0
Total	29	2247.4	100

Table 5 shows the number of activities in the turning production process as many as 29 activity with a total time of 2247.4 minutes. In the type of activity, the value-added value is omitted because it has no value-added

5. FUTURE STATE STREAM MAPPING

Future state stream mapping is described after the mapping of current value stream mapping and identification of waste. This mapping depiction shows the parts that need improvement so that the turning production system conditions are improved. The following is an improvement in the mapping's turning production process, which can be seen in Figure 6. Next, compare the Current Value Stream Mapping Figure 1 and Future State Stream Mapping Figure 6. The

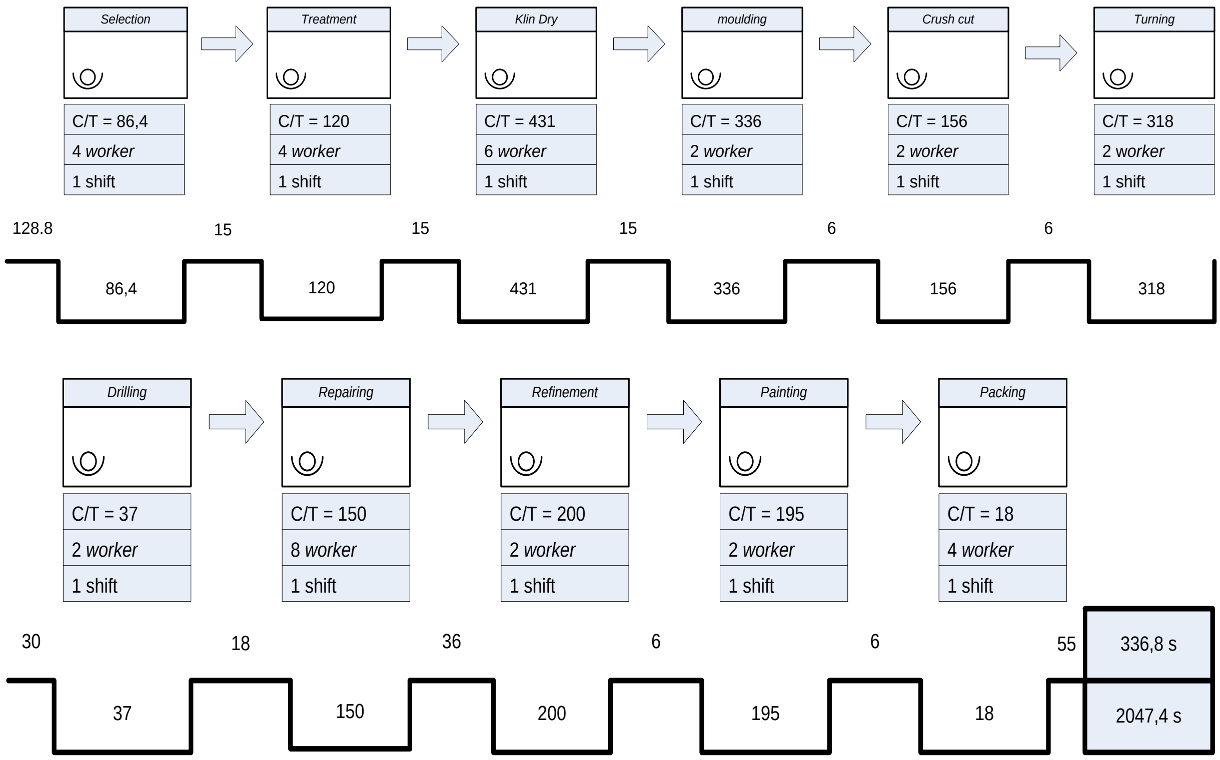

Figure 6. Future State Stream Mapping

comparison results are shown in Table 6.

Results Table 6 shows changes in the increase in results PCE calculation with an improvement of 4,918% (136.8 minutes). Improvement was obtained by comparing the PCE before the improvement was 80.799% (2384.2 minutes) and after the improvement was 85.717% (2247.4 minutes)

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Table 6. Comparison of PAM Results

Indicator	Current (minutes)	Future (minutes)	Improvement (minutes)
VA	1926.4	1926.4	-
NNVA	333	321	12
NVA	124.8	0	124.8
Total	2384.2	2247.4	136.8
Process cycle efficiency (PCE)	80.799%	85.717%	4.918%

6. CONCLUSIONS

Data analysis identified waste from current steam mapping by distributing questionnaires to production employees regarding the relationship between the seven wastes to obtain weight. Waste that has been recognized with a seven-waste relationship between the seven wastes to obtain weight. Waste that has been recognized with a seven-waste relationship, waste relationship matrix and waste assessment questionnaire. The waste brought with the highest waste is: The highest level of waste is in defects (D) with a percentage of 27,979%. Followed by waste in overproduction (O) of 15,471%, inventory (I) of 12,363%, motion (M) of 11,995%, waiting for (W) of 11,451%, transportation (T) of 10,709% and process (P) of 10,030. The weighting of waste by selecting tools: Value stream Analysis Tools to be an obtained process activity mapping and obtained quality filter mapping. The results are 34 activities (13 operations, 12 transportation, six inspections, two storage and one delay) with the type of activity value-added 80.789%, necessary non-value-added 13,967%, and non-value added 5,234%. The comparison result of the current value stream mapping value is 80.799% (2384.2 minutes), and future state stream mapping is 85.717% (2247.4 minutes). The comparison shows the value of Process cycle efficiency with an improvement of 4.9185% (136.8 minutes). This study contributes to manufacturing companies in the turning production process in increasing value-added.

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