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Waste analysis on the production floor and proposed improvements using a lean manufacturing approach aluminium manufacturing company in East Java, Indonesia

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Abstract: This study aims to analyse waste on the production floor, causing delays in the completion of the production process and affecting product delivery to consumers. In addition, this research is also used to explain the types of waste and provide alternative improvements to reduce waste on the production floor using a lean manufacturing approach. Using the value stream mapping method, researchers mapped the flow of information and materials in the production process. Furthermore, the actual condition of the company is described in the current state stream map using the 5W-1H method of waste identification tool. This study found that there were a waste of defective goods in the frame, wastage in the weaving repair process and activities to find boxes and waste of transportation on the production floor. Implementing the proposed improvement is expected to reduce the waste that occurs to reduce the production lead time.

Keywords: waste production floor; lean manufacturing; aluminium manufacturing; value stream mapping; Indonesia.

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1 Introduction

The industrial sector engaged in services and manufacturing will experience competition between business actors operating within the same business scope or with players with different business scopes. This competition makes business people in industry and services face intense competition in serving consumers (Jain and Malik, 2013). The challenges of rapidly changing industry requirements are then used in lean practices to empower performance improvement and facilitate achievement to increase performance satisfaction. In intense competition, every industrial sector must apply a contemporary approach that is not only oriented towards improving productivity but must be able to encourage and help face market competition (Sadiq et al., 2021). The lean manufacturing approach has helped to overcome the previous problems, leading to operational efficiency by identifying and reducing waste (Dixit et al., 2022). For this reason, the company strives to maintain production and quality to remain stable and produce viable products when needed. Companies must meet consumer expectations so that consumers stay loyal and do not switch to other products. However, over the decades and with sustainable development, many questions have been asked about whether lean manufacturing contributes to customer value and has environmental benefits (Choudhary et al., 2019). This literature demonstrates a seamless level of sustainability to lean and ensures waste elimination for increased competitiveness, resources, and environmental performance (Schmitt et al., 2021). In addition to producing quality goods at affordable prices, meeting consumer needs properly when needed is the most critical factor in business competition; companies are also required to create effective and efficient production activities to reduce the use of costs in the production process but not reduce the quality of the goods produced. For this reason, the production process must be regulated in such a way as to minimise errors and deliver quality goods at prices that can compete in the market share. Some of the problems that are often faced by manufacturing companies are frequent repairs to the production of the chair frame or frame because it does not match the mould. This is in stark contrast to the lean methodology used to reform manufacturing processes by reducing waste, reducing unnecessary costs, improving quality, and ultimately maximising customer value (Palange and Dhatrak, 2021). Other problems that often arise in manufacturing companies in the province of East Java, Indonesia, are finishing products that are not the examples provided and approved by the customer, errors in the packing process, besides the arrangement of goods and services does not smoothly cause the transportation process in and out of goods. Inventory is outside the specified limit line.

The lean manufacturing method explains that seven types of waste are recommended: overprocessing, overproduction, high inventory, waiting for time, unnecessary movement, product defects, and unnecessary transportation (Perico et al., 2019). Problems that arise in manufacturing companies in the province of East Java can cause enormous losses in terms of material and non-material if accumulated continuously (Arif et al., 2022). The disadvantages in terms of material are the length of the frame repair process and product repair, which have an impact over time, delays in the production process, time wasted if only doing activities looking for boxes or packaging that takes a lot of time, traffic jams on the production floor due to poor transportation route. From a non-material perspective, it is a complaint from a customer due to a delay in delivery which will result in the termination of the cooperation relationship with the company. Lean manufacturing has proven to improve performance (Setiawan et al., 2021). Companies are also starting to integrate technological approaches to encourage this to happen faster, such as achieving superior performance and competitive advantages over competitors that can be completed more quickly (Tortorella et al., 2021). Based on the problems in manufacturing companies in East Java that produce aluminium, the company needs alternative improvements to reduce waste on the production floor. An ineffective and efficient production process can cause delays in the flow of the production process, such as additional time for repairing frames and repairing the final product (weaving) and extra time on the finished goods production floor due to traffic jams and additional time to find boxes. Using the lean manufacturing system approach, the company can find out the types of waste that occur on the production floor so that companies can use alternative improvements to minimise waste that appears on the unique production floor in manufacturing companies that produce aluminium.

Based on the background of the problems above, the researcher determines the main issues that will be raised in this study, namely:

1 What types of waste occur on the production floor in the aluminium manufacturing company?

2 What repair are alternatives used to reduce wastage in companies manufacturing the aluminium sector?

2 Literature review

2.1 Application of lean manufacturing system

Manufacturing companies worldwide have widely practised lean systems by combining efficient, sustainable, integrated manufacturing and correlation with the manufacturing industry (Kumar and Mathiyazhagan, 2020). Other literature (Gochel et al., 2022) this system effectively increases production lead time by minimising unnecessary activities, thereby reducing working time and waiting time, increasing process cycle efficiency (PCE) by reaching 8.9%, and reducing mileage. Lean manufacturing performance appraisal is also a logistical and cross-functional driver of operational activities such as information, pricing, and resources (Galankashi and Helmi, 2017). In the industrial world, many manufacturing companies have difficulty implementing and maintaining lean manufacturing; it is also necessary to identify and understand the factors that drive the success factors in implementing lean manufacturing (Jobin et al., 2021). Performance-based strategies by maximising customer value to reduce waste in lean manufacturing can do a tack time study of the assembly process by reducing inventory by 14% using line balancing, increasing tool preparation time, and reducing work delays. Modern manufacturing focuses on converting raw materials into finished goods without waste. It minimises costs, so a lean manufacturing approach is needed. One uses a value mapping tool to see value-added activities and not added value in the entire running process (Devi et al., 2018). Traditional lean manufacturing methods can reduce seven to eight types of production process losses (Fullerton et al., 2014). In its development for several decades, lean systems have also been considered environmental problems, according to experts (Dieste et al., 2019). It can increase the use of resources and better environmental performance (Rodli et al., 2022). Lean systems have clear implications for better business performance and organisational operations (Henao et al., 2019). In principle, the application of lean manufacturing greatly reduces production time, regardless of the size of the organisation (Matt and Rauch, 2013). In addition, the skeletal system has an impact on reducing waste generated from the production process (Bai et al., 2019).

2.2 Waste in the manufacturing industry

The value stream mapping method will describe and reveal the value of waste in the production process in the manufacturing industry by identifying, eliminating, or streamlining value-added steps and removing non-value-added steps (Sutharsan et al., 2020). In principle, a systematic approach will be able to identify and reduce or even eliminate waste through continuous improvement, and product flow will continue to run for customer satisfaction (de Jesus Pacheco et al., 2023). Fundamentally the existence of lean manufacturing is a process of eliminating waste that is carried out systematically for all aspects of the organisation's operations, where the resulting waste is seen as a loss of useless resources to create the products that customers want (Mathiyazhagan et al., 2021). Lean manufacturing has paid much attention to academics and functional performance to collect proof of efficient production and disseminate it comprehensively (Zahraee et al., 2020). For this reason, Indonesia's aluminium sector manufacturing industry depends on reducing or eliminating waste on the production floor to minimise costs and inefficient raw materials (Ekasari et al., 2022). In multidisciplinary theory, it is explained that financial engineering, planning, and management principles reduce waste by increasing machine performance through quality control of the manufacturing industry (Singh et al., 2020). The application of value stream mapping in the manufacturing industry can review work processes by identifying critical areas using seven lean wastes that are used to find activities that are not of value, and concluded through another theory that the identified waste removed through Kaizen saved 2.5 hours of machining time (Ghatorha et al., 2021).

3 Research methods

This study uses steps that begin with the creation of future value stream mapping, identification of value added and non-value added creation of current state value stream mapping, and calculation of product standard time.

Table 1 Approaches to reducing waste in the manufacturing industry

Waste category	*Type of waste*	*The waste reduction approach*	*Examples of performance improvement methods*	*Improvement focus*
People	Processing, motion, waiting	Workplace management	Setting work standards, organising the workplace, Kaizen, 5-S	Layout, labelling, tools/parts arrangement, work instructions, efficiency, takt time, skilling training, shift meetings, cell/area teams, visual displays
Quantity	Inventory, moving things, making too much	Just-in-time (JIT)	Levelling, Kanban, quick setup, preventive maintenance	Work balance, work-in-process (WIP) location/amount, Kanban types, lot sizes, changeover, analysis, preventive maintenance analysis
Quality	Fixing defects	Error (mistake) proofing, automation	Detection, warning, prediction, prevention, Jidoka	Fixture modifications, successive checks, limit switches, check sheets, appropriate automed assistance, templates
Information	Planning, scheduling, execution	Process-focused information technology	Plan, schedule, track, anticipate, optimise	Queue analysis, dynamic scheduling of order/job status by process element, timing/completion

The research was conducted by recording all the data obtained from the observations and calculating the data. The formulas commonly used are:

a Mean:

$$\bar{X} = \frac{\sum_{i-1}^{n} x_i}{n}$$

b Standard deviation:

$$\sigma = \sqrt{\frac{\sum \left(X_i - \bar{X}\right)^2}{n-1}}$$

The level of confidence and accuracy affects the number of measurements made; the higher the level of accuracy and a high level of trust, the researcher hopes that more measures will be carried out.

$$N' = \left[\frac{\frac{k}{s}\sqrt{N\sum X^2 - \left(\sum X\right)^2}}{\sum X} \right]^2$$

Information:

- k = level of confidence (k = 2 untuk 95%)
- s = accuracy level (10%)
- N = amount of measurement data collected
- N' = amount of measurement data that should be collected.

The next step is to calculate the standard time from the research data results. How to calculate normal time is:

1 Calculating the average cycle time:

$$W_s = \frac{\sum X_i}{N}$$

Information:

- $\sum X_i$ = total observed completion time
- N = number of observations made

2 Calculate normal time:

$$W_n = W_s \times P$$

- W_s = cycle time
- P = adjustment factor.

This allowance factor is used as input to calculate the standard time (W_b), where:

$$W_b = W_n \times \frac{100\%}{100\% - \%\ \text{allowance}}$$

Information:

- W_n = normal time.

The latter uses the value stream mapping method with a formula to calculate efficiency:

$$\textit{Process cycle efficiency} = \frac{\textit{Value added activity}}{\textit{Total lead time}} \times 100\%$$

4 Result

4.1 Calculation of standard time of work element

1 Mean:

$$\bar{X} = \frac{\sum_{i-1}^{n} x_i}{n}$$
$$= \frac{1.23 + 1.22 + \ldots + 1.26}{35}$$
$$= 1.27 \text{ minute}$$

2 Standard deviation:

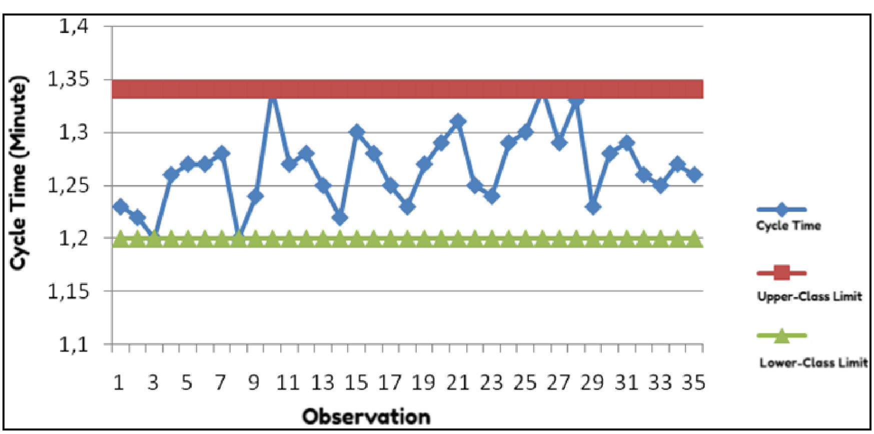
$$S = \sqrt{\frac{\sum\left(X_i - \bar{X}\right)^2}{n-1}}$$
$$= \sqrt{\frac{(1.23-1.27)^2 + (1.22-1.27)^2 + \ldots + (1.26-1.27)^2}{35-1}}$$
$$= 0.035 \text{ second}$$

3 Upper-class limit (UCL) and lower-class limit (LCL):

$$UCL = \bar{X} + Z(S)$$
$$= 1.27 + 2(0.035)$$
$$= 1.34 \text{ second}$$

$$LCL = \bar{X} - Z(S)$$
$$= 1.27 - 2(0.035)$$
$$= 1.20 \text{ second}$$

Figure 1 Aluminium pipe cutting process cycle time control chart (see online version for colours)



From the control chart data above, it can be seen that all data are within the control limits, and it can be concluded that the processing time data for cutting aluminium pipe raw materials are uniform.

- Data sufficiency test:

$$N' = \left[\frac{\frac{k}{s}\sqrt{N\sum X^2 - \left(\sum X\right)^2}}{\sum X} \right]^2$$

$$N' = \left[\frac{\frac{2}{0.05}\sqrt{35\left(1.23^2 + 1.22^2 + \ldots + 1.26^2\right) - (1.23 + 1.22 + \ldots + 1.26)^2}}{1.23 + 1.22 + \ldots + 1.26} \right]^2$$

$$N' = 1.189$$

- Calculation of average cycle time:

$$\begin{aligned} W_s &= \frac{\sum X_i}{N} \\ &= \frac{1.23 + 1.22 + \ldots + 1.26}{35} \\ &= 1.267 \text{ minute} \end{aligned}$$

- Normal time calculation:

$$\begin{aligned} W_n &= W_s \times P \\ &= 1.267 \times (1) \\ &= 1.267 \text{ minute} \end{aligned}$$

- Standard time calculation:

$$\begin{aligned} W_b &= W_n \times \frac{100\%}{100\% - \% \text{ allowance}} \\ &= \frac{1.267 \times 100\%}{100\% - 15\%} \\ &= 1.49 \text{ minute} \end{aligned}$$

- Value added activity (VA):

Table 1 Value added activity time data

No.	*Activity*	*Times*
1	Raw material cutting	1.49 minutes
2	Drilling	1.51 minutes
3	Bending and adjust	4.09 minutes
4	Assembly	6.35 minutes
5	Frame accessories installation	2.47 minutes

Table 1 Value added activity time data (continued)

No.	*Activity*	*Times*
6	Full welding	6.03 minutes
7	Grinding	2.15 minutes
8	Frame wash	5.15 minutes
9	Covenant I	0.17 minutes
10	Frame colouring	5.33 minutes
11	Covenant II	1.15 minutes
12	Weaving	10.17 minutes
13	Item accessories installation	7.43 minutes
14	Packing	7.41 minutes
Total		*61.30 minutes*

- Non-value added activity (non-VA):

$$\begin{aligned} \textit{Process cycle efficiency} &= \frac{\textit{Value added time}}{\textit{Total lead time}} \times 100\% \\ &= \frac{61.30}{185.61} \times 100\% \\ &= 33.03\% \end{aligned}$$

Table 2 Non-VA time data

No.	*Activity*	*Times*
1	Fixed a frame that does not fit the print	12.38 minutes
2	Repairing a broken box	4.56 minutes
3	Searching for boxes	14.03 minutes
4	Fix the woven results that do not match the sample	11.08 minutes
Total		*42.05 minutes*

Table 3 Percentage of time use of production process activities

No.	*Activity group*	*Times (minutes)*	*% time usage*
1	Value added activity	61.30	33.03%
2	Necessary but non-value-added activity	82.26	44.32%
3	Non-value added activity	42.05	22.66%
Total		*185.61*	*100*

4.2 Identify waste on the production floor

1 Frame production results are often repaired because the frame height does not match the sample; inaccuracies cause this in the installation of each part in the assembly process. The influence of the print used is also a factor in the error in the frame. The print’s condition, which can change at any time according to changes in temperature,

is the most significant factor in making the wrong frame because the pattern is made of plywood.

2 The webbing on the Sonoma all series cannot be uniform from one item to another between production and samples. This is because the weave sample image is only shown when we first make the Sonoma all series sample; the subsequent output of workers is only based on the Sonoma all series sample, which is only 1. At the same time, the weaving workers are 80 people. The unavailability of the weaving sample images significantly affects the workers' weaving results, which results in dissimilarity between the workers' weaving results and the weaving samples.

3 In the packing process, there are still activities to find boxes that are needed while the packing process are running, which can hinder the smooth running of this process. The storage box still has not implemented a good arrangement and storage system, so it will take a long time to find the needed item box.

4 In the production line, especially in the finished goods production area, the packaging of finished goods is still around or beyond the transportation boundary line; this causes the flow of transportation within the finished goods production line to be hampered. If there is the delivery of goods to the warehouse, as well as when transporting manufactured goods, many of the packing boxes must be repaired because the goods box was damaged due to being hit by a trolley carrying goods.

4.3 Future state value stream mapping design

The design of the future state value mapping is carried out by considering the proposed improvements based on the analysis results from the current state value mapping. The first thing suggested by the researcher is to check the print regularly and replace the pattern with plywood with images from aluminium to reduce the risk of changing the shape of the photo and giving detailed drawings of weavers to weavers to minimise errors in weaving figures and weave models. In addition, the application uses transportation boundary lines in the finished goods production area to reduce congestion in the production area and avoid damage to the box due to being hit by a freight trolley. In addition, improvement of work methods and for the entire production floor using the 5 S method (Seiri, Seiton, Seiso, Seiketsu, and Shitsuke). An overview of the future state value stream mapping can be seen in Figure 2.

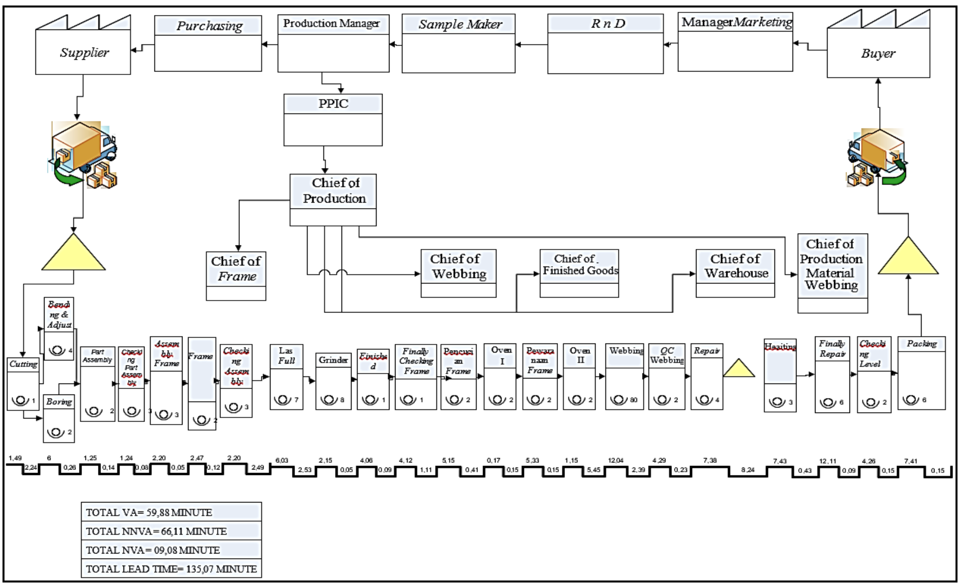
Table 4 Percentage of production process activity group time usage

No.	*Activity group*	*Times (minutes)*	*% time usage*
1	Value added activity	59.88	44.33%
2	Necessary but non-value-added activity	66.11	48.94%
3	Non-value added activity	09.08	6.72%
Total		*135.07*	*100*

Below is the calculation of PCE future state value stream mapping in the production process. Process:

$$Cycle\ efficiency = \frac{Value\ added\ time}{Total\ lead\ time} \times 100\%$$
$$= \frac{59.88}{135.07} \times 100\%$$
$$= 44.33\%$$

Figure 2 Value stream mapping (see online version for colours)



5 Discussion

5.1 Current state value stream mapping analysis

Based on data from the current state value stream mapping, the flow of information is quite good. The PPIC section has determined the product criteria with approval and confirmation with the sample maker for further production with a predetermined capacity. Initial determination from the buyer for delivery of goods is carried out within three months with gradual delivery of at least 40 days from the purchase order (PO) down. It will be the duty of the production department to complete the ordered goods no later than the deadline determined by the buyer.

PCE is a way to measure a factory's efficiency because this metric shows the percentage of processing time to the factory's overall production time. Thakur et al. (2023) explains in his book *The Executive Guide To Implementing Lean Six Sigma* the PCE of the Japanese Toyota company is 53%, American companies are around 30–40%, and local companies in Indonesia are still under 10%, If the PCE is lower than 30%, the process is called: un-lean.

The results of the use of time for the Sonoma all series production process in the current state value stream mapping, both activities that provide value-added activities,

activities needed to help run activities that provide added value (necessary but non-value added activities), and Activities that do not offer added value can be seen in Table 5.

From Table 5 results, it can be calculated that the PCE is 33.03%.

Table 5 Percentage of time use on current state value stream mapping for Sonoma all series production process

No.	*Activity group*	*Times (minutes)*	*% time usage*
1	Value added activity	61.30	33.03%
2	Necessary but non-value-added activity	82.26	44.32%
3	Non-value added activity	42.05	22.66%
Total		*185.61*	*100*

5.2 Analysis of waste identification results

The waste identification process is carried out using the 5W-1H method, which aims to identify the causes of waste and propose improvements to reduce waste on the production floor.

From the observations on the current state value stream mapping, several activities do not provide added value (NVA), namely the Number of frames that are not by the print, so they must correct the error to get a suitable structure for the pattern. From the results of the identification of waste using 5W-1H, the error of the frame is not by the print is the inaccuracy of the installation of components in the frame assembly, parts that are deemed inappropriate by the pattern are still forced to be assembled, the condition of the print is not good because it is made of plywood which at any time will change if there is a temperature change. By assembling using panels first, the shape of components that are not compatible with the print can be minimised. The replacement of image raw materials that initially used plywood by using aluminium will be able to reduce damage to print conditions that are not known to workers due to temperature changes. In the weaving process, errors also often occur because of the absence of a sample image of weaving; the results of workers' handicrafts can change at any time. Giving a picture of a woven model will be very helpful in reducing weaving errors.

The arrangement of the place can impact the smooth flow of transportation lines in the production line if the placement of goods that are not in the right place will cause damage to the goods due to the goods being hit by the trolley during the transportation process. The arrangement of the storage area can also make it easier to find boxes; the box's condition will always be protected from damage. The transportation line is very influential in transportation flow on the production floor. Standardisation and boundaries are expected to be applied by workers on the production floor.

5.3 Future state value stream mapping analysis

In the future state value stream mapping, before assembling the seat frame (assembly frame), the components or panels are first created to ensure that the details have not changed and are by the print. By making the panels beforehand, errors in the frame assembly process will be minimised, especially in the final checking process, and reduce the time to correct the frame shape that does not match the sample, which can indirectly slow down the production process of the Sonoma all series.

In the production process of finished goods, especially in the packing section, if there is a label on the inventory box in the warehouse inventory and placing the goods are using the alphabetical system, there will be no more searching for packages. If transportation and production boundary lines are implemented appropriately, there will no longer be activities to repair boxes or traffic jams in the production line.

The proposed improvement that can be applied continuously in the work environment is to use the 5S method to create cleanliness, tidiness, and order in the work environment and provide convenience in the arrangement and collection of work equipment. The first step is Seiri (concise). This process sorts out items that are often used, rarely used, or not used at all into separate storage areas according to the level of need. Items that are seldom used or not used are separated from the storage area for items that are often used so that the workplace is neatly organised.

The second step is Seiton (neat), by arranging items that are often used so as not to interfere with smooth work. Items not used or rarely used are neatly arranged in a place far from the workplace. The third step is Seiso (resik) routinely cleaning the workplace and the environment around the workplace. The fourth step is Seiketsu (treatment), by creating a culture or rules in the production environment for workers so that awareness arises from the workers themselves. The last step is Shitsuke (diligent), by conducting an inspection by the leadership and head of each division regarding the implementation of 4S in the work environment.

The results of the use of time for the Sonoma all series production process in the future state value stream mapping, both activities that provide added value (value added activities), actions needed to help run activities that provide added value (necessary but non-value added activities), and Activities that do not offer added value can be seen in Table 6.

Table 6 Percentage of time use on future state value stream mapping for Sonoma all series production process

No.	*Activity group*	*Times (minutes)*	*% time usage*
1	Value added activity	59.88	44.33%
2	Necessary but non-value-added activity	66.11	48.94%
3	Non-value added activity	09.08	6.72%
Total		*135.07*	*100*

Based on the data in Table 6, it can be seen that there was a decrease in the production time of the Sonoma all series from 186 minutes 1 second to 135 minutes 7 seconds. PCE increased from 32.45% to 44.33% from before the repair until the repair was carried out.

Future state value stream mapping made by making suggestions for improvements is not the best result in reducing waste for the company. Future state value stream mapping is part of a continuous improvement process, which means that the improvement process that has been proposed in the future state value stream mapping is achieved, the company needs to remap the company's condition as a current state value stream mapping and analyse it again and make a design. Re-improvement (future state value stream mapping) to achieve even better conditions than the previous improvements.

6 Conclusions

The conclusions obtained from this study include the following:

1. The types of waste in the manufacture of the Sonoma all series on the production floor are:
   a. Wasting defects frames do not match the print due to inaccuracies in component installation and poor print conditions.
   b. The absence of a woven sample image handle causes process wastage in the weaving repair process.
   c. Motion wasted in looking for boxes caused by a poor inventory system.
   d. Transportation wastage in the packing section resulted in some boxes being damaged and had to be repaired due to neglect of the function of the transportation line dividing line.
2. There are four proposed improvements to the future state value stream mapping and the application of the 5S method to reduce the causes of waste, namely:
   a. We are assembling panels before assembling frames and replacing prints from plywood with images from aluminium.
   b. Provide details of weaving drawings to weaving workers.
   c. We are carrying out a storage arrangement system for boxes using an alphabetical and labelling system.
   d. I am applying the function of the line dividing the transportation route.

Based on the results of the proposed improvements, it was found that the production lead time decreased from 186.01 minutes to 135.07 minutes, and the PCE increased from 32.45% to 44.33%

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