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PRODUCTION & MANUFACTURING | RESEARCH ARTICLE

Minimizing waste using lean manufacturing and ECRS principle in Indonesian furniture industry

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Abstract: The manufacturing industry is considered as one important sector, which has a significant influence on the economic growth of a country. The increase of fierce competition among products requires the company to satisfy their customers by making high-quality products with competitive prices and at on-time deliveries. This study aims to implement lean manufacturing in one of the furniture companies in Indonesia to minimize waste in the production floor. Value Stream Mapping (VSM) will be used as a tool to identify waste by separating value-added activities and non-value added activities in the production process. A future state map is developed with new and improved processes. Future state map makes the improved process more effective and more efficient. The critical waste found on the production floor in motion. Improvements are made using 5W1H techniques and ECRS principles, two simple tools of kaizen. The workload of operator consideration was also done to avoid bottlenecks and decrease the lead time. The result was quietly remarkable as the lead time decreased by around 4.79% and able to balance the workload received by the operator.

Subjects: Industrial Engineering & Manufacturing; Manufacturing Engineering; Production Engineering

Keywords: 5W1H technique; ECRS principle; lean manufacturing; value stream mapping; workload analysis

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PUBLIC INTEREST STATEMENT

Waste is an activity that wastes resources such as expenditure or extra time but does not add any value to the activity. There are seven types of waste that often occur in the manufacturing industry, including: waste of overproduction, waste of inventory, waste of defects, waste of transportation, waste of motion, waste of waiting, and waste of overprocessing. Eliminating waste is a basic principle in lean manufacturing. The elimination of waste must be taught to each member of the organization so that the effectiveness and efficiency of work can be improved. The critical waste found on the production floor in motion. Improvements are made using 5W1H techniques and ECRS principles, two simple tools of kaizen. The workload of operator consideration was also done to avoid bottlenecks and decrease the lead time. The result was quietly remarkable as the lead time decreased by around 4.79% and able to balance the workload received by the operator.

1. Introduction

Furniture is one of the strategic commodities for the Indonesian economy. Some criteria that make furniture as a strategic commodity because furniture is a high value-added products, globally competitive, export-oriented, absorbing a lot of manpower, and supported by the availability of sufficient raw material sources of wood, rattan, and bamboo (Munadi, 2017).

It is very ironic to see the development of Indonesian furniture industry. In 2000 Indonesia was the fifth largest exporter country in the world, declining in 18th place in 2013 and even only ranked 25th in 2015 with a total export value of only USD 1.81 billion of total exports world furniture that reached USD 240 billion. The ranking of Indonesia as an exporter country is far below the rank of Vietnam which is in the 8th position and Malaysia in 17th position (Munadi, 2017).

There are four pillars that determine the competitiveness of Indonesian furniture export products, namely: raw materials, production process, design and innovation, and marketing (Asosiasi Mebel dan Kerajinan Indonesia [AMKRI], 2015) in Pujiati (2017). One factor in the production process that affects the competitiveness of furniture export products is the efficiency of production. One way to improve the production efficiency of the furniture industry is to eliminate waste.

Company X is one of the furniture companies in Indonesia which its main product is a dining chair. Most of the company's product is exported to various countries, mostly to Australia, Singapore, and Taiwan. The most critical issue faced by the company is the frequent delays in delivering the products to the consumer, with an average 78% of the deliveries are delay for the last three years. Improvements in the product deliveries will have a significant impact on the company.

There are several obstacles faced by Company X that result in longer order completion time. The first obstacle is the delayed assembly process due to the differences in completion time components in the assembly area. This time difference is occurred because the workload of each work station is unbalance and there was a specialization of the product. The second obstacle was the existence of excessive movements that did not give any value added by the operator because of irregular work methods and messy work areas. This resulted in a longer production process and unnecessary energy expenditure. The third obstacle is waiting for material delivery from suppliers, because sometimes some materials are seasonal.

The problems found can be categorized as waste, which is an activity that has no added value in the production process. There are seven types of waste: overproduction, waiting time (delay), over processing, excess transportation, excess inventory, unnecessary motion, and defects (Ohno, 1988). The waste should be eliminated as it will reduce production costs, on time delivery of products, the number of WIPs, and increases resource utilization, resulting in increased corporate productivity (Woehrle & Abou-Shady, 2010).

Lean manufacturing is a method which can be used to reduce waste. In lean concept, the waste reduction is achieved by identifying and reduce or eliminate non-value added activities. A research that studies the successful implementation of lean manufacturing has been done by Chowdury et al. (2017) in the shoe manufacturing company. The study begins with the creation of VSM to identify all production activities, and on the final results can decrease the lead time of production and increase the production capacity of the company. Another study conducted by Suhardi, Sari, and Laksono (2016) by applying the concept of lean in the furniture industry so as to reduce waste and create a standardization of work. Based on these studies, it is known that the concept of lean manufacturing can be applied to overcome the problem of waste. Therefore, this study aims to minimize waste contained in the production process at Company X. With the reduction of waste in the production process which process production map has been pointed by VSM, it is expected that the company can achieve better efficiency and speed up production time that improved using 5W1H techniques and ECRS principles.

2. Literature review

Taj (2008) and Eatock, Dixon, and Young (2009) defined lean manufacturing as a set of concepts, principles, methods, procedures, and tools geared towards the improvement of the production flow by reducing waste. There are several tools in lean manufacturing that can be used to reduce waste such as VSM (Value Stream Mapping) (Helleno, Isaias de Moraes, & Simon, 2017), 5S and Yamazumi chart (Rahani & Ashraf, 2012), ECRS method (Miranda, 2011), and standardization research (Suhardi et al., 2016). Among several tools of lean manufacturing, VSM can be highlighted since it provides a holistic view of manufacturing processes and has become one of the most used tools in the applications of lean thinking in industrial and service companies (Lasa, Castro, & Laburu, 2009). VSM is developed through four basic stages (Magnier, 2003): firstly, identifying the product or the object of research; second, creating a current state map; third, evaluating the current state map and identify the existing problems; lastly, creating a future state map. The advantage of VSM is that it can visualize the flow of value added (VA), necessary but non-value (NNVA) and non-value added (NVA) processes in the material flow from raw material to finished goods. With this VSM, we will know the flow of information and material flow, so it will be easy to redesign for improvement (Romero & Chávez, 2011).

One of the principles of lean manufacturing is kaizen (continuous improvement). Mundel (1970) and Kato and Smalley (2011) explains that the general pattern recommended was to practice what is known as the 5W 1H (what, why, where, when, who, and how) technique, followed by the principle of ECRS (eliminate, combine, rearrange, simplify). This method is very easy in which with its simplicity, it can lead to new ideas for improvement. When analyzing the current situation and methods used in manufacturing, work element analysis can be used in almost every area. Any job can be broken down into smaller elements so that the job can be analyzed in more detail. By understanding the elements that make up a job we can identify the waste and the optimal work flows. The important thing in this analysis technique is to pick the right level of detail for analysis depending on the job, the scope of work, and the length of the operation involved. We suggest the middle ground of either major steps or work elements for analysis as a starting point. The explanation of the 5W1H method and the ECRS principle is shown in Table 1.

3. Research methodology

Barwon Dining Armchair is a seating product that has a hand and chair back is equipped with woven synthetic ropes. This research method begins with the VSM process to identify production processes including material and information data, then for 5W1H and ECRS to improve the production process (see Figure 1).

The primary data included cycle time of each process, and process flow from raw materials to finished goods. In addition, secondary data are obtained such as demand per period, bill of materials, a number of operators, and machines.

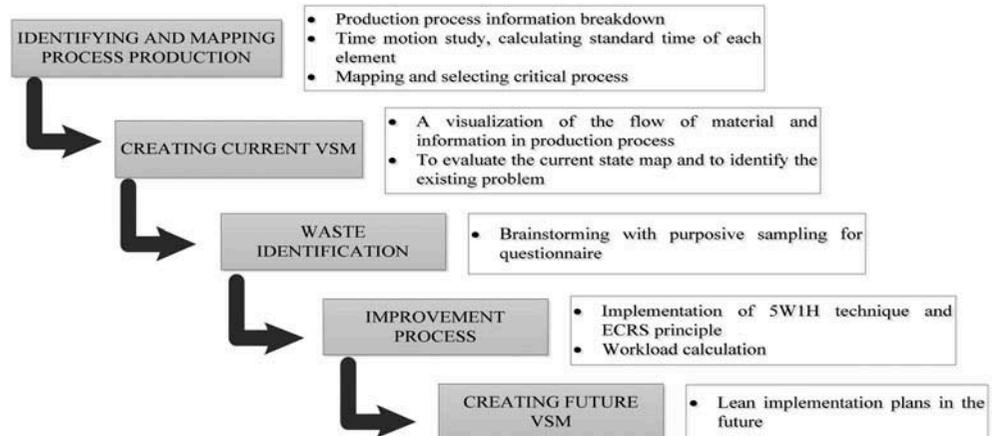
Calculating standard time have been done in the first stage. The standard timing of each process is required to know the lead time of the entire production process. Standard time calculations use the Westinghouse rating (Barnes, 1980) and ILO table allowance recommendations (Niebel & Freivalds, 2003). Furthermore, standard time data is required in the manufacture of VSM.

Describing the work on elements of the work to break down the element of work. The production process of Barwon Dining Armchair is broken down into 24 elements of work. After the breakdown processes have been done, continue with measurement of process time of each work element. The measuring tool used is a stopwatch. Time measurement using stopwatch is the most effective way for repetitive activity and rapid operator movement. Data collection is done by stopwatch time study with 30 samples. Then, testing data

Table 1. 5W1H technique and ECRS principle (Mundel (1970) and (Kato and Smalley (2011))

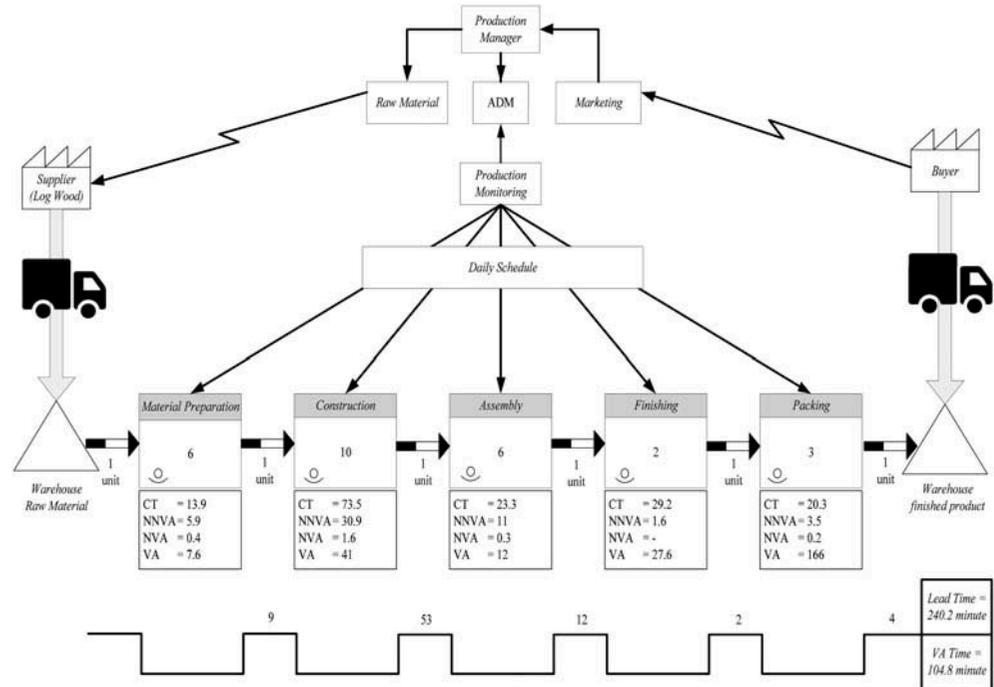
ECRS Framework	Special Question	Priority Improvement
Elimination	Why is the described step necessary? What is its purpose?	<ul style="list-style-type: none"> - Elimination of all possible activities, steps or limb movements. - Elimination of irregular conditions within each activity - Put all work facilities and materials in a location that can cause automatic movements. - Elimination of the use of the hand as holding device because this is an unproductive activity that causes the work of both hands are not balance. - Elimination of abnormal movements, should concern especially those that are safe. - Elimination the use of muscle power to perform static activities or fixed position. We recommend using engine power. - Eliminate idle time or delay time by making good planning or scheduling work.
Combine Rearrange	Where should it be done? When should it be done? Who is the best qualified to do it?	<ul style="list-style-type: none"> - Short-term work movements are discontinuous and tend to change direction with a continuous movement being replaced or combined, not fractured and tend to form curves. - Activities that can be handled by an equipment by creating a multi-use design combined. - Distribute work balance activities between hands. Simultaneous and symmetrical motion patterns will provide the most effective movement. The workload is evenly distributed among working group members when activities are carried out in groups.
Simplify	What is the best way to do it?	<ul style="list-style-type: none"> - Carry out any work activities with the principle of muscle energy requirement that is used minimally. - Reduce the activity of looking for work objects (work equipment, materials, etc.) this can be done when putting the work object in a fixed place. - Put the work facility within a normal range of hands so the time spent will be shorter. - Adjust the location of the equipment by concern into the dimensions of the human body and the required muscle strength. Shorter distance range decreased time used to put equipment.

Figure 1. Steps of new VSM.



adequacy and data uniformity. To ensure that the data collected is sufficiently objective then the test data adequacy. After the data collected is sufficient, then the next test is the uniformity of data. The data uniformity test is performed to separate the data having different characteristics.

Figure 2. Current VSM.



VSM is created as a visualization of the flow of material and information in the production process and can map the overall business process. VSM is developed to help in identifying the waste in a process (see Figure 2).

Waste identification can be done using brainstorming and observing the physical and information flows. Purposive sampling with a questionnaire is used to identify the critical waste. The weight of the waste can be found from the questionnaire results using decision-making tool the Borda method (Kharismawati & Herliansyah, 2016).

The improvement stage was to eliminate waste in each process thereby increasing the efficiency and effectiveness of the production process. The work element analysis sheet is used to analyze the current situation with the middle ground details of the working element. Furthermore, the calculation of workload is used to determine the workload level of each operator so that the optimal number of operators can be determined (Suhardi et al., 2016). Lastly, future VSM an idea created for lean implementation plans in the future is created with the aim of improving the production flow to achieve the desired conditions by improving the current VSM.

4. Results and discussions

4.1. Current VSM

Based on the data from Company X has been shown that to make one unit Barwon Dining Armchair is needed by 27 operators. Cycle time was 160.2 minutes/unit. Value added time was 104.8 minutes. The total transportation time was 80 minutes. To calculate the lead time the formula is used as follows:

$$\text{Lead Time} = \text{Cycle Time} + \text{Transportation Time} \tag{1}$$

So the lead time for making a Barwon Dining Armchair was 240.2 minutes/unit.

Figure 2 shows the current VSM of the company. From the current situation, it is known that the value-added time ratio is only 43.63% of the total lead time. That means non-value added (NVA) time

and necessary but non-value added (NNVA) time value are still quite large. Waste identification is performed based on NNVA/NVA activity on current VSM to determine the various waste that exists in the production process. The second waste identification is done based on the results of brainstorming and observation of the Barwon Dining Armchair production process. The purpose of brainstorming is to determine the types of waste that occur but not found by researchers on the current VSM.

4.2. Waste identification

After identifying the types of waste that occur, the next step is to determine of critical waste with distributing questionnaires. The sampling method used in this research was purposive sampling to some parties in the company who understand about each part of production in Company X. Borda method is used to process the data of the questionnaire. Each type of waste is ranked and then multiplied by the appropriate weight. The first rank has the highest weight ($n-1$) and so on until the rank of each waste is found. Waste with the highest weight is the critical waste that becomes the priority of improvement. The waste found in the current VSM is shown in Table 2.

After identifying the types of waste that occurred, then the next questionnaire is distributed to determine the most common waste. Each respondent was asked to rank each type of waste and then calculate the weight using the Borda method. Borda method is used to process data from questionnaires. Each type of waste is ranked and then multiplied by the appropriate weight. The first rank has the highest body weight ($n-1$) and so on until the rank of each waste is found. The highest weight waste is critical waste which is the priority of repairs. Table 3 shows the results of the questionnaire from the respondents.

The Borda method is used to process questionnaire data, namely by giving a rating for each type of waste and multiplying it by the appropriate weight. Where for rank 1 has the highest weight, that is ($n-1$), and so on until the waste is obtained with the highest amount of weight which is the most frequent waste. Weighting results using the borda method are shown in Table 4.

Example of calculation of waste weight:

$$\begin{aligned}
 \text{Transportation} &= \sum (\text{Ranks} \times \text{Weight Rating}) \\
 &= 2(4) + 2(3) + 1(1) \\
 &= 15
 \end{aligned}
 \tag{2}$$

The results of processing the waste questionnaire (Figure 3) indicate that the most common waste is motion. This result is consistent because it is similar to the waste that found at current VSM. Therefore, the proposed improvements will be focused on motion.

4.3. Workload before improvement

The highest workload is in the load of the operator at the finishing department with a workload of 0.09 whereas the lowest workload is the workload of operators in material preparation department with 0.01 workload. The calculation of operator workload before improvement is shown in Figure 4. The high value was due to the lack number of operators in the finishing department. A large workload indicates a bottleneck in the production process. Thus, there were two factors considered

Table 2. Waste found in the current VSM			
Waste	Work Category	Time (minutes)	Percentage
Motion	NNVA	62.9	58.57%
	NVA	2.3	2.14%
Transportation	NNVA	24.8	23.09%
	NVA	17.4	16.20%

Table 3. Waste rating questionnaire results recapitulations

Waste	Respondent				
	QC Company	QC Buyer	Head of Logistics	Production Monitoring	Administration
Transportation	2	1	4	1	2
Inventory	4	4	3	2	5
Motion	1	2	1	3	1
Waiting	3	3	2	5	3
Defects	5	5	5	4	4

Table 4. Waste rating questionnaire ranks

Waste	Ranking According to Respondent					Weight	Percentage	Rank
	1	2	3	4	5			
Transportation	2	2	0	1	0	15	30%	2
Inventory	0	1	1	2	1	7	14%	4
Motion	3	1	1	0	0	17	34%	1
Waiting	0	1	3	0	1	9	18%	3
Defects	0	0	0	2	3	2	4%	5
Weight	4	3	2	1	0			

Figure 3. The result of waste questionnaire.

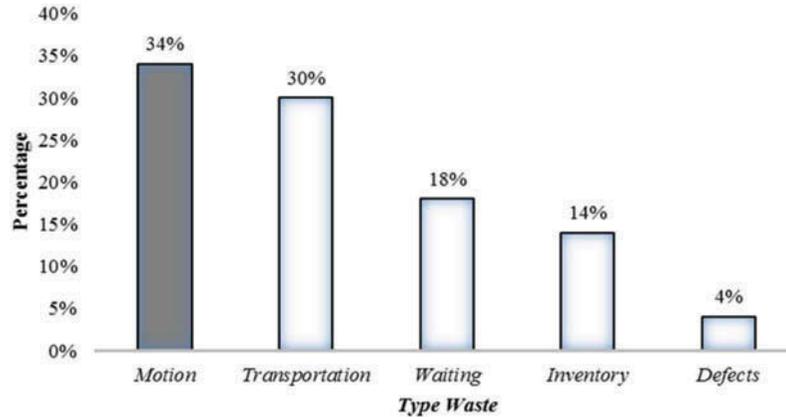
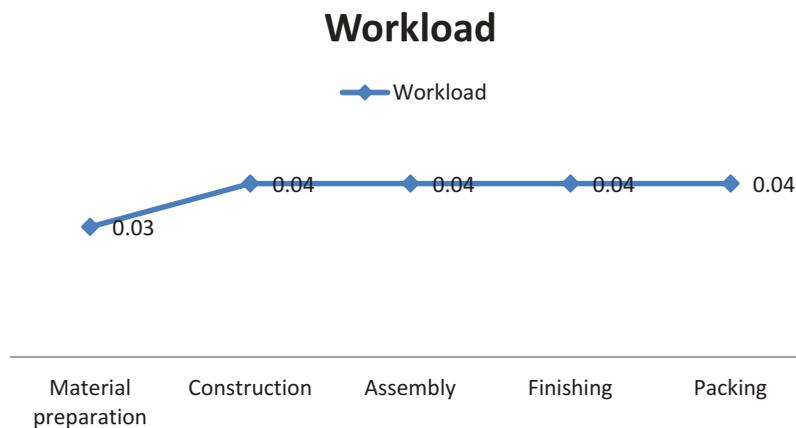


Figure 4. Workload before improvement.



in making the improvement with ECRS principle, which was the existing waste and operator workload so that the workload of all operators will be balanced.

4.4. The implementation of 5W1H technique and ECRS principle

The methods used to improve the working methods are 5W1H technique and ECRS principle. Improved work methods will impact on the efficiency and effectiveness of work that will result in reduced processing time. One proposed improvement of working methods is related to the activity of looking for old tools because the equipment is mixed with other items (proposed solution: combine activities). Companies can buy special equipment for items that have bigger potential in search such as dowels, nails, knockdowns, screws, and hammers. Using those tools, the workers will work more easily tools searching and replacement. The eye-catching color of the equipment also makes searching easier. The results of the improvement analysis using 5W1H technique and ECRS principle shown in Table 5.

4.5. Workload after improvement

Balancing the workload can be done in two ways, which are by changing the job description and the move of the operator to departments. The merger of the job description can be done in department material preparation, construction, assembly, and finishing. The addition of the number of operators by changing the job description occurs in department construction and finishing. While the reduction in the number of operators by changing the job description occurs in the department material preparation and assembly. Similar results were obtained from previous studies conducted by (Nurchahyo & Hartono, 2012). Workload after improvement is shown in Figure 5.

Table 5. The results 5W1H technique and ECRS principle

Departement	Works Elemen	Why	What	Where	When	Who	How	Improvement Ideas	E	C	R	S	
Material preparation	<ul style="list-style-type: none"> Take wood pattern Move wood pattern Move wood Discard rest of the wood 	√						Eliminate, not necessary	√				
					√				Take with both hands, make clearer		√		
									Eliminate, not necessary	√			
Assembly	<ul style="list-style-type: none"> Take knockdown Move knockdown Take dowel Move hammer 	√											
					√						√		
								√	Take front crossbar and back crossbar with both hands, do the same for pair crossbar				√
Assembly	<ul style="list-style-type: none"> Take hammer Hammering Move hammer 	√						Eliminate, not necessary	√				
									Eliminate, not necessary	√			
Packing	<ul style="list-style-type: none"> Take cross T Move hammer Move candle Take wiper Take carton Pair right carton Turn the chair Take carton Pair left carton Turn the chair Take plastic wrap Pair wrap for holder Turn the chair Pair wrap for backrest 	√											
					√				Do with both hands, make clearer		√		
								√	Simplify the process, too much activities to turn the chair				√

Figure 5. Workload after improvement.

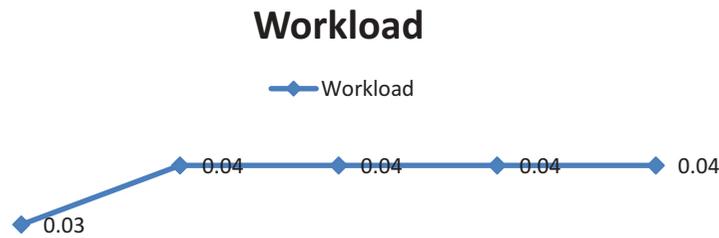
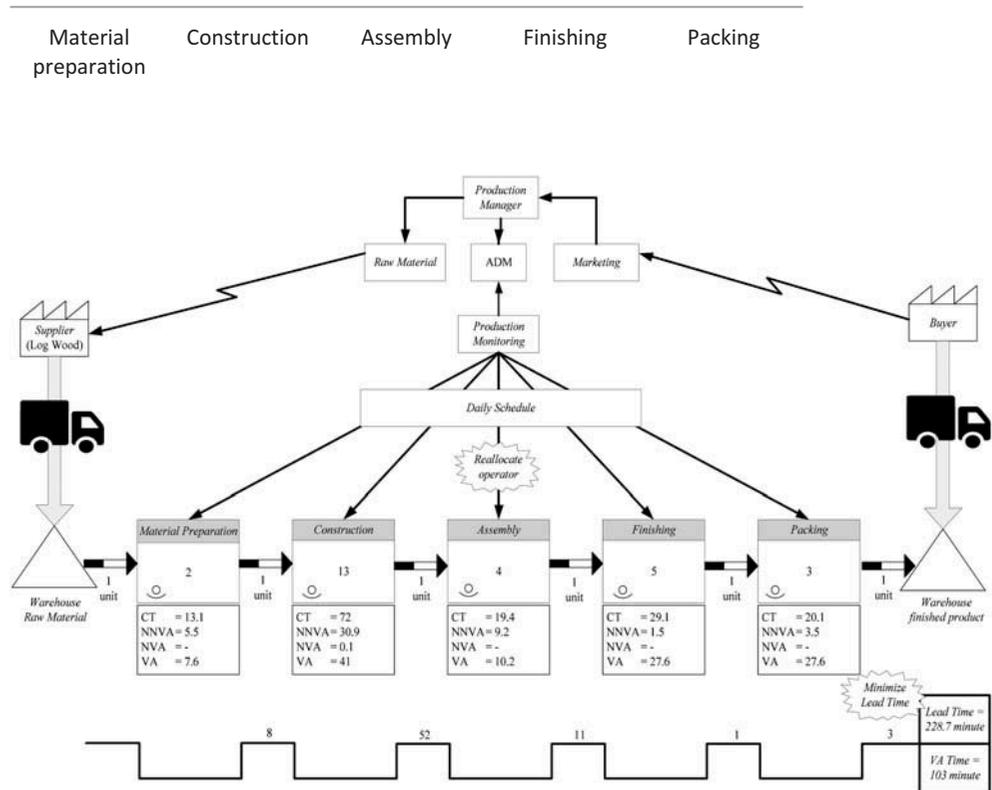


Figure 6. Future VSM.



4.6. Future VSM

The future VSM is used to identify and improve the current value stream that will lead to a shorter lead time. The results of the improvement are shown in Figure 6 in term of future VSM. From the figure, significant time reductions occur due to two improvements, namely improving working methods by practicing 5W1H techniques and ECRS principles and improving the allocation of operators with workload considerations.

5. Conclusions

In conclusion, VSM that has been improved using 5W1H techniques and ECRS principles as solutions has proven to be an effective tool to analyze Company X current production state and thus recommendation are suggested. In future VSM there is a reduction of lead time around 4.79%. Company X can take advantage of the remaining time to complete other orders without hiring more workers because the firm could deliver on time by implementing this improvement. Moreover, research conducted in the company were used to increase the efficiency and effectiveness of the

production line that enables to create and modify the respective processes. In addition, there are two things that are proposed for further research. First, in addition to knowing the waste reduction must also know the cost reduction due to waste reduction. Second, it must know the potential waste causes of the process by using the method of failure mode effect analysis (FMEA).

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References

- Asosiasi Mebel dan Kerajinan Indonesia (AMKRI). (2015). *Roadmap Industri Mebel dan Kerajinan Indonesia "Target Pencapaian Ekspor 5 Milyar USD"* [Roadmap of Indonesian furniture and handicraft industry "Target of export achievement 5 billion USD"]. Jakarta: AMKRI.
- Barnes, R. M. (1980). *Motion and time study design and measurement of work*. 7th ed. Singapore: John Wiley & Sons.
- Chowdhury, A. H., Shahriar, S., Hossen, T., & Mahmud, P. (2017). Reduction of process lead time using lean tool-value stream mapping (vsm). *Applied Mechanics and Materials*, 860, 74-80. doi:10.4028/www.scientific.net/AMM.860.74
- Eatock, J., Dixon, D., & Young, T. (2009). An exploratory survey of current practice in the medical device industry. *Journal of Manufacturing Technology Management*, 20, 218-234. doi:10.1108/17410380910929637
- Helleno, A. L., Isaías de Moraes, A. J., & Simon, A. T. (2017). Integrating sustainability indicators and Lean manufacturing to assess manufacturing processes: Application case studies in Brazilian industry. *Journal of Cleaner Production*, 153, 405-416. doi:10.1016/j.jclepro.2016.12.072
- Kato, I., & Smalley, A. (2011). *Toyota kaizen methods six steps to improvement*. New York, NY: Productivity Press.
- Kharismawati, A., & Herliansyah, M. K. (2016, October). Implementasi lean healthcare pada pasien BPJS rawat jalan di rumah sakit bethesda yogyakarta [Implementation of lean healthcare in outpatient of BPJS at bethesda hospital yogyakarta]. *Proceeding SENTI 2016* (pp. 408-417), Yogyakarta, Indonesia.
- Lasa, I. S., Castro, R. D., & Laburu, C. O. (2009). Extent of the use of Lean concepts proposed for a value stream mapping application. *Production Planning & Control*, 20, 82-98. doi:10.1080/09537280802685322
- Magnier, P. (2003). *Lean flow mapping - module LFM101-value stream mapping*. Lean Flow Consulting. Retrieved from https://www.leanflowconsulting.fr/xLFM101_201US.pdf.
- Miranda, F. A. A. (2011, June) Application of work sampling and ECRS (eliminate, combine, re-lay out, and simplify) principles of improvement at TO1 assembly. *21st ASEM National Technical Symposium* (pp 1-7), Manila, Philippines.
- Munadi, E. (2017). Furniture, produk berdaya saing yang butuh perhatian. In *Info komoditi furniture, edisi pertama, Bab I, hal.1*, (Furniture, competitive products that need attention. In *Info commodity furniture*, (1st ed, Chapter I, pp. 1). Jakarta: Badan Pengkajian dan Pengembangan Perdagangan Kementerian Perdagangan Republik Indonesia.
- Mundel, M. E. (1970). *Motion and time study: Principles & practices*. New Delhi: Prentice-Hall Of India Private Ltd.
- Niebel, B., & Freivalds, A. (2003). *Methods, standards, and work design*, 11th ed. USA: McGraw-Hill.
- Nurchahyo, D. I., & Hartono, G. (2012). Optimalisasi beban kerja dan standarisasi elemen kerja untuk meningkatkan efisiensi proses finishing part outer door di PT TMMIN [Workload optimization and standardization work to improve work efficiency in finishing outer door process in TMMIN company]. *Journal of INASEA*, 3, 124-131.
- Ohno, T. (1988). *Toyota production system, beyond large scale production*. Portland, Oregon: Productivity Press.
- Pujiati, R. (2017). Produksi furnitur indonesia. In *Info komoditi furnitur (edisi pertama, Bab II, hal. 22)*. (Indonesian furniture production. In *Info commodity furniture*, (1st ed, Chapter II, pp. 22). Jakarta: Badan Pengkajian dan Pengembangan Perdagangan. Kementerian Perdagangan Republik Indonesia.
- Rahani, A. R., & Ashraf, A. M. (2012). Production flow analysis through value stream mapping: A lean manufacturing process case study. *Procedia Engineering*, 41, 1727-1734. doi:10.1016/j.proeng.2012.07.375

- Romero, D., & Chávez, Z. (2011, July). Use of value stream mapping tools for manufacturing systems redesign. *Proceedings of the World Congress on Engineering 2011* (Vol 1), London, U.K.
- Suhardi, B., Sari, A. P., & Laksono, P. W. (2016). Implementation of standardization work to improve productivity in Indonesian furniture industry. *Journal of Engineering and Applied Sciences*, 11(12), 2602–2606.
- Taj, S. (2008). Lean manufacturing performance in China: Assessment of 65 manufacturing plants. *Journal of Manufacturing Technology Management*, 19, 217–234. doi:10.1108/17410380810847927
- Woehrle, S. L., & Abou-Shady, L. (2010). Using dynamic value stream mapping and lean accounting box scores to support lean implementation. *American Journal of Business Education*, 3, 8.



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