Productivity improvement in the rubber production process using value stream mapping method to eliminate waste

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Abstract – This research was conducted at a company that manufactures rubber in gasket products for hard disk drives, its function is to protect connectors on the hard disk drive. The company continues to develop products and improve productivity performance by trying to improve service quality, production processes, and product delivery to customers at a minimal and timely cost. This study aims to reduce waste and increase the productivity of the production process by using the value stream mapping (VSM) method, which can help identify waste from information flow, material flow, and/or process flow. In this study, VSM with the support of fishbone aids was able to find the highest cessation process that contributed to increased rubber productivity. Rubber, curing, and deflashing have been selected for improvement projects. The improvement results show that the improvement of time for non-added value activities decreased from 88.89 percent to 70 percent.

Keywords: *value stream mapping, improvement, root cause analysis, productivity.*

1. Introduction

Value or added value on a product becomes very important for the company or industry so that the products produced can compete with competitors. Providing added value to the product can be done by designing a more effective and efficient production process. One way is to minimize or eliminate waste or waste in the production process. If this can be achieved, the company can fulfill the value desired by consumers with minimal resources. Achievements to minimize waste can be done by implementing a lean manufacturing approach. Lean manufacturing is a concept that can design the production process for better, faster, and more cheap with minimal space, small inventory, small labor hours, and avoiding waste, Womack et al. (1991). Waste in lean manufacturing is divided into 7 (seven wastes), namely overproduction, waiting time, transportation, overprocessing, inventory, motion, and defects/rejects.

The Company where the research held is producing Gasket product for final assembly into Hard Disk Drive. They have faced bottlenecks in several processes that were resulting from not optimal productivity. Further improvement is needed by identifying the non-value-added processes to gain and achieve an effective, efficient and good productivity of the production. Referring to these conditions and problems mentioned above, the bottleneck that occurs can result in a lack of productivity from the company. The impact of the bottleneck is that found 3 processes has the highest stoppages time and or total change over time in the production floor, to eliminate this waste the company can use the lean method, one of the tools that can be used to implement lean is Value Stream Mapping (VSM), as one method to be able to see and understand the flow of information and material from a product through a value stream, so in the future it will be easy to get any factors that give value-added (VA) or non-value-added (NVA)/waste in the value stream that must be immediately eliminated. Existing processes with the current value stream mapping and proposing improvements/improvements to eliminate wastes that will not be found in the future value stream or can be said that the related process has been able to increase effectiveness and efficiency of the previous process.

The objectives of this research are to reduce waste and increase the productivity of the production process by identifying and improving the non-value-added (set-up and or stoppages time) of the rubber material processes.

2. Literature Review

Lean Manufacturing

Cox and John (2005), define lean as a business philosophy based on minimizing the use of resources (including time) in various company activities. Liker (2004), revealed that there are three main characteristics of companies that implement lean manufacturing:

1. Production speed is arranged in such a way according to consumer demand. With the application of lean manufacturing, the Company will be able to produce according to market demand. This means that the efficiency of the production line is very high.
2. Pull system companies that implement lean manufacturing do production only if there is demand from consumers.
3. Small lots do production per unit from beginning to end or in other terms called one-piece flow. The goal is to avoid stacking semi-finished products between processes.

Liker and Meier (2006), a company called Toyota is still a good example for learning the principles and application of a lean system because indeed various types of waste removal methods are born from the company, reduction or elimination of waste is a basic principle of lean manufacturing processes. They stated that there are eight wastes must be eliminated to get to a lean system. These eight wastes include excess production, displacement, excessive movement, job repetition, waiting, excess process, and unused worker creativity.

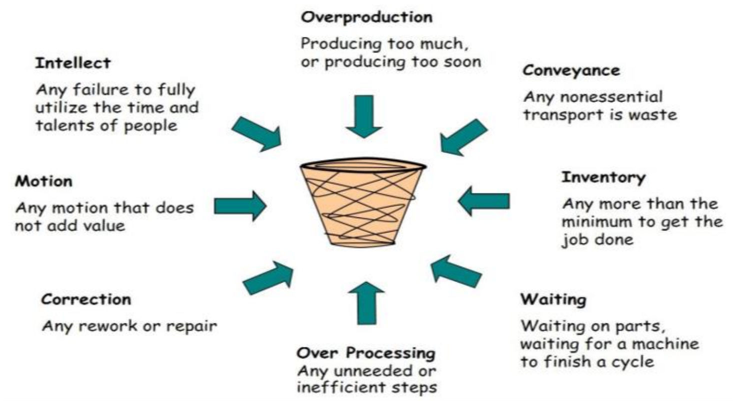


Figure 1 Eight Lean Waste

According to Anvar & Irannejad (2010), there are several methods in lean manufacturing that are used to reduce waste, one of the lean manufacturing methods used to understand current conditions and find potential improvements to reduce and eliminate waste is VSM.

Waste

According to Hines & Taylor (2000), there are seven types of waste, namely overproduction, defects, unnecessary inventory, inaccurate processes, the ineffectiveness of transportation, waiting, and unnecessary movements. The type of activity in the company is divided into three, namely value-added activities (VA), non-value-added activities (NVA), and activities not value-added but needed (NNVA).

Shah & Ward (2003), several applications can be applied to a lean running system, as follows:

1. Reducing the size of the production lot;
2. Reducing set-up time;
3. Focus on a single supplier;
4. Carry out preventive maintenance activities;
5. Decrease cycle time;
6. Reducing inventory (stock) to expose manufacturing, distribution and scheduling problems;
7. Using new process equipment or technology;
8. Using fast change over techniques;
9. Continuous/one-piece flow;
10. The production uses a Pull/Kanban system;

11. Remove bottlenecks;
12. Using the error checking/Poka-yoke technique, and eliminate waste.

Value Flow Mapping (VSM)

VSM is a mapping tool used to compile the current situation of a process by identifying activities that are valuable and not value-added, making it easier to find the root of the problem. The benefits of VSM are to help improve a process as a whole and improve the efficiency and effectiveness of the product process. There are 3 main parts in the VSM, namely:

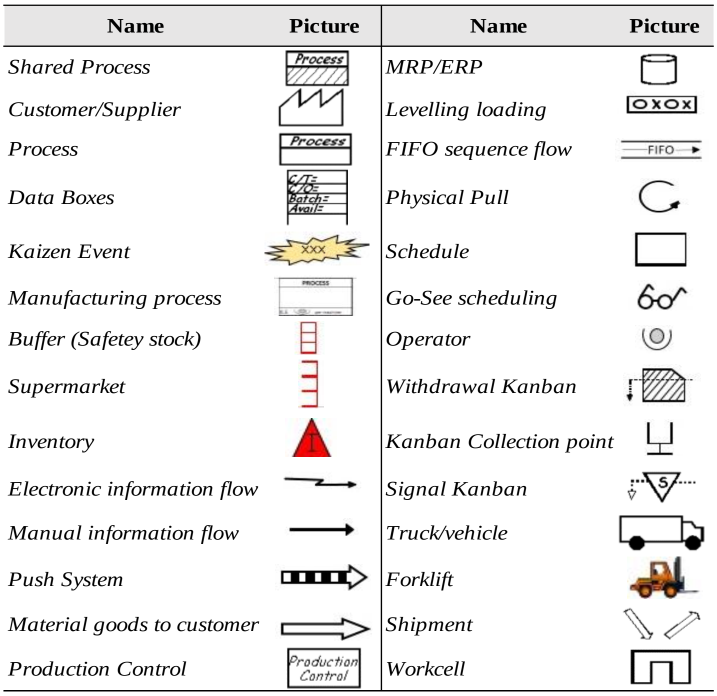
a. Information flow
b. Physical flow/production process
c. Mileage

Chen et al. (2010), more than 20 companies in China began the application of lean manufacturing directly to tools or methods without analyzing the workplace, so that the results obtained were not optimal. In the study there was also a comment from the president of lean horizon consulting, Mark Deluzio, who stated: "most companies start at tool levels, with no tie back to a business strategy, so we suggest lean production by implementing VSM to identify enterprises overall value streams what is Ohno Taiichi said: Decreasing all waste from the whole process. "Kadam et al. (2012), VSM is a method for visualizing material flow and information flow through the production process. Rother & Shook (2004), VSM can be used by various types of companies. Based on the Learning to see book: "whenever there is a product for customer, there is value stream". Womack and Jones (2002), of course VSM can be applied by all companies that produce products for customers. VSM is also used to describe the entire supply chain involving many companies.

Rother & Shook (1998), there are two types of Value Stream Maps, including:

1. Current State mapping describes the configuration of the current value stream that uses signs and terms to identify waste and areas to be repaired.
2. Future State mapping provides design for lean to the desired future state. Both types of maps show all important information such as lead time, cycle time, inventory levels and others.

The symbols commonly used in VSM are as follows in Figure 2.



Name	Picture	Name	Picture
Shared Process	Process	*MRP/ERP*	
Customer/Supplier		*Levelling loading*	OXOX
Process	Process	*FIFO sequence flow*	FIFO
Data Boxes	C/T= C/O= Batch= Avail=	*Physical Pull*	
Kaizen Event	XXX	*Schedule*	
Manufacturing process	PROCESS	*Go-See scheduling*	
Buffer (Safetey stock)		*Operator*	
Supermarket		*Withdrawal Kanban*	
Inventory	I	*Kanban Collection point*	
Electronic information flow		*Signal Kanban*	S
Manual information flow		*Truck/vehicle*	
Push System		*Forklift*	
Material goods to customer		*Shipment*	
Production Control	Production Control	*Workcell*	

Figure 2 VSM symbol

Drawing Current Condition Mapping

The condition of the map now is a basic map of the entire process where all proposed improvements can appear. Some of the data needed to make the current state mapping including:

1. Data about the customer, such as actual demand in days/weeks/months, forecast demand, cycle issue, order frequency, shipping procedures, delivery reports, etc.
2. Data about suppliers, such as who the supplier is, our order cycle, forecast order, raw material shipments from suppliers, ordering procedures, order lead times etc.
3. Working hours, shifts, overtime, holidays, breaks, meetings, etc.
4. Production control data systems, such as who is in charge of control, manual or automated, etc.
5. Data on the production process, such as workstation characteristics, number of operators, equipment and production equipment, process flow, defect rate, set uptime, change overtime, procedures for giving production orders.
6. Amount of inventory (raw material, WIP and finished good), safety stock, buffer stock in each process.
7. Takt time, the speed of the value stream itself so that it can balance the existing demand. Takt time is obtained by dividing the available time (net available time) in one particular period with the number of demand in that period.
8. Cycle time, the time from completion of one item is processed until the next item is processed.
9. Distance between processes through material, operators, data, etc.
10. Value-added time and non-value-added time after all data has been obtained and processed, the Current state mapping can be drawn according to existing data.

Draw future maps (Future VSM)
Rother & Shook (1999), the purpose of VSM is to identify and eliminate waste sources by implementing the proposed value-state stream that can become a reality in the near future. The goal is to build a production chain in accordance with the lean concept where each process is directly connected to the customer's demand either with continuous flow or with a pull system and every process is optimally managed to produce according to what the customer asks for with the right time and amount. make value stream not lean, it's over production. Over production causes a lot of waste, including: excessive inventory, inventory maintenance costs, places to put inventory, etc.

There are several directives from the Toyota Production System for implementing lean in VSM, namely:
1. Producing according to takt time.
2. Making continuous flow wherever it is possible.
3. Using a supermarket to control production if continuous flow is not possible.
4. Give production orders in one process, namely the last process (pace maker process).
5. Designing the level of production (pitch).

Designing an Improvement Plan
To design an implementation plan for the improvements that have been made, some material is needed such as a future map that has been made and an annual value stream plan. This implementation plan begins by breaking down the implementation plan into several stages or several parts that are in the flow of the production process. Breakdown is made detail of its application to the system and when. This breakdown is written on the annual work plan sheet along with its achievements when it has been implemented.

One important thing to keep in mind in implementing this improvement is to always practice the continuous improvement concept to eliminate waste, reduce lot size, reduce inventory in supermarkets, and expand the application of continuous flow in every process in the value stream.

3. Method

The research methodology is a method or procedure that contains clear stages and is systematically arranged in the research process. Every stage and part that determines the next stage must be passed carefully. In this study, the company that manufactures rubber for Hard Disk components in the location of Batam City, Indonesia, which is the subject of discussion in this reseach is rubber material for gasket products from Rubber Department. The methodology for implementation of value stream mapping is essentially having five steps. These all steps are to be performed in a sequential way. The sequence is as follows:

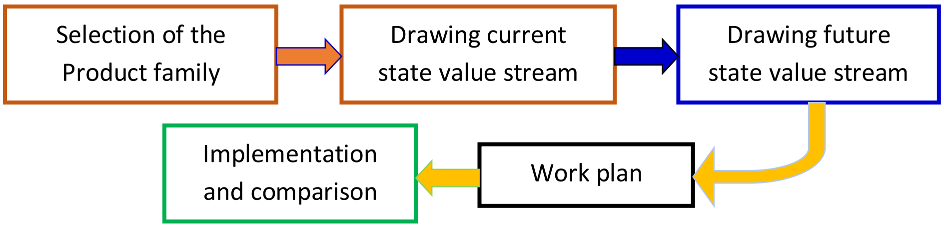


Figure 3 Research step

a. Selection of product family

The first step is the selection of the similar product family from the total available mix products. This similar product family should be chosen after studying the product mix thoroughly. This product family will be the ground for further study on others model.

b. Drawing current state value stream map

Creating Current State Mapping. Describe the process sequence based on the state of the condition/work process that is currently taking place along with the flow of information, material flow and time calculation. Information will be obtained where the activities that are classified as value-added, non-value-added, so that the causes of the problems appear.

Identification of wastage (Value-added and Non Value-added). Identifying and determining the critical waste (Value-added and Non Value-added)/most frequent or influencing the work process, from the seven waste data that has been previously observed, the most common waste is determined. Knowing waste/defect and Waste (Value-added and Non Value-added) which have the most influence on the production process, the research can be focused on solving the most frequent waste obtained from the VSM method.

c. Drawing future state value stream map

After all processes are analyzed, both the workflow and information that occurs in the current state map. Data obtained, then processed both work process data and time. Set-up time, after that we recalculate the value-added and nonvalue-added ratio and defect percentage, then the researcher makes the future state mapping based on the analysis. RCA (Root Cause Analysis) was performed to support on this stage, such as Fishbone Diagram Analysis, RCA is used to trace the causes of the impact of a problem that occurs, with this RCA can be known the causes of waste that occurs.

d. Work plan

By using various lean tools, an organisation have to develop and select best and optimized implantation plan in order to achieve improvements in best acceptable ways.

Recommendations will be proposed in this level for improvements to the production system operation process as an effort to minimize waste in order to increase productivity.

e. Implementation and comparison

This step shows the implementation of various suggestions made in FVSM. After implementation it becomes necessary to compare the outcomes with existing data. This shows us that how effectively the improvements are made and what the possible benefits could be.

4. Results and discussion

The choice of products to be examined in this company is based on products in one family, some products are said to be one family if they go through the same process and use common facilities. In the product family, there are several products and the selection of products to be mapped is based on several considerations such as the number of outputs per day, demand and frequency in a given period. One method that can be used is using the production process matrix. This production process matrix is a matrix that contains all types of products. As the table below:

Table 1 Rubber Product Matrix

PRODUCT FAMILY	PRODUCT NAME	PROCESS									
		Rubber	Curing	Postcure	Screening sheet	De-Flashing	Pre - Washing (Hand Rub & Jet Wash)	U/S washing	Oven Drying	Final Screening	Packing
DB00	Wider Lip	X	X	X	X	X	X	X	X	X	X
DB01	3,5" Seal Connector	X	X	X	X	X	X	X	X	X	X
DB02	2,5" Seal Connector	X	X	X	X	X	X	X	X	X	X
DB03	Connector Packing	X	X	X	X	X	X	X	X	X	X
DB04	Flex Gasket	X	X	X	X	X	X	X	X	X	X
DB05	Flex Gasket Blade	X	X	X	X	X	X	X	X	X	X
DB06	AK Connector Packing	X	X	X	X	X	X	X	X	X	X
DB07	Connector Packing	X	X	X	X	X	X	X	X	X	X

General description the rubber process that is sent to the customer, as illustrated in the process flow below, consists of: the rubber process, curing and deflashing and several inspection and cleanliness processes as a support process until it becomes part of the process, and seal/packing and preparation before sending to the customer.

Current Flow Map (Current State Value Stream Mapping/CSVSM)

CSVSM is a flow configuration current product. Data obtained from results direct observation on the production processes and or interviews with related parties to get information data and the total time needed for change over, setup, setting, curing, drying, screening etc, and field observations by observing and recording the time needed for each process with the help of a stopwatch and taken from different days for several weeks. The result showed as Figure 4 and Table 2.

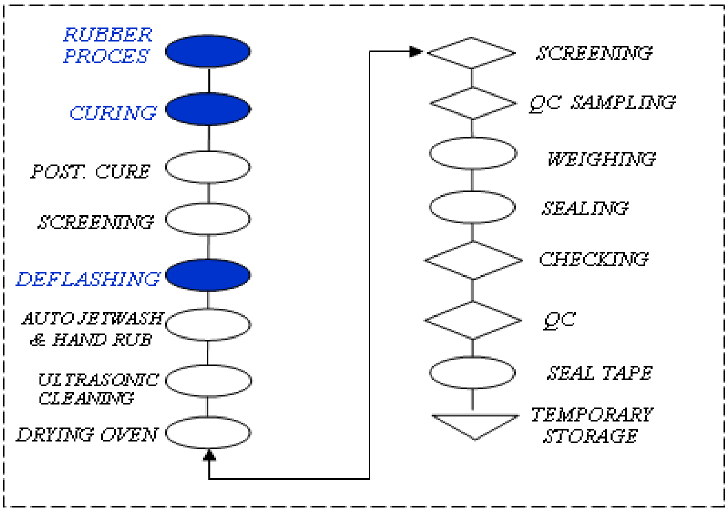


Figure 4 Flow of rubber production process.

Table 2 Data set-up time/change over time dan production time

No.	Process	Prod Lot (Pcs)	Cycle time (Sec)	Set Up Time (min)	QC time (min)	Material Change time (min)	Prod Time (Min)	Tot time/item (Min)	Ave Item/day	Tot. Prod Time (hr)	Tot Change Over Time /Day (hr)	Loading Total Time (hr)
		a	b	c	d	e	= (a x b)/60	= ((a x b)/60)+c+ d+e	f	(prod Time x Ave item per day) / 60	= ((c+d+e)xf)/ 60	(Tot Prod Time + Tot. Change over time)
1	Rubber	600	7.32	17.4	1	1	73.2	92.6	5	6.1	1.62	7.72
2	Curing	800	4.4	10	1	1	58.67	70.67	3	2.93	0.6	3.53
3	Hand Press Jig	800	4.2	10	1	1	56	68	3	2.8	0.6	3.4
4	Screening	800	3	1	0	1	40	42	3	2	0.1	2.1

The high set-up and change over time in the 3 above production processes is due to technicians and production operators having to re-qualify the machines since its has create a stoppages activity (NVA), shown as above table.

Based on the explanation from the previous data, the researcher can draw the CSVSM on the production line (below). As in Figure 4 which will be a reference, improvements will be made by looking at the current situation. Based on the CSVSM image above the total cycle time for the main activity/observation is 18.92 seconds (0.32 minutes), set-up time is 37.4 minutes and Stock Lead Time production is 2.9 days.

Based on data from the Set-up time/Total change over and production time we can divide VA and NVA, so that we can make an improvement plan in areas that have high/large NVA percentages, while VA and NVA data can be seen in the Table 3.

Table 3 Value-added and Non Value-added

No.	Process	Tot. Prod Time (Hr)	Tot Change Over Time /Day (Hr)	Loading Total Time (Hr)	VA	Non VA	VA	Non VA
		(Prod TimeXave item/day)/60	= (c+d+e)/60	(Tot Prod Time + Tot. Change over time)				
1	Rubber Process	6.1	1.62	7.72	6.1	1.62	79.05%	20.95%
2	Curing	2.93	0.6	3.53	2.93	0.6	83.02%	16.98%
3	Hand Press Jig	2.8	0.6	3.4	2.8	0.6	82.35%	17.65%
4	Screening	2	0.1	2.1	2	0.1	95.24%	4.76%

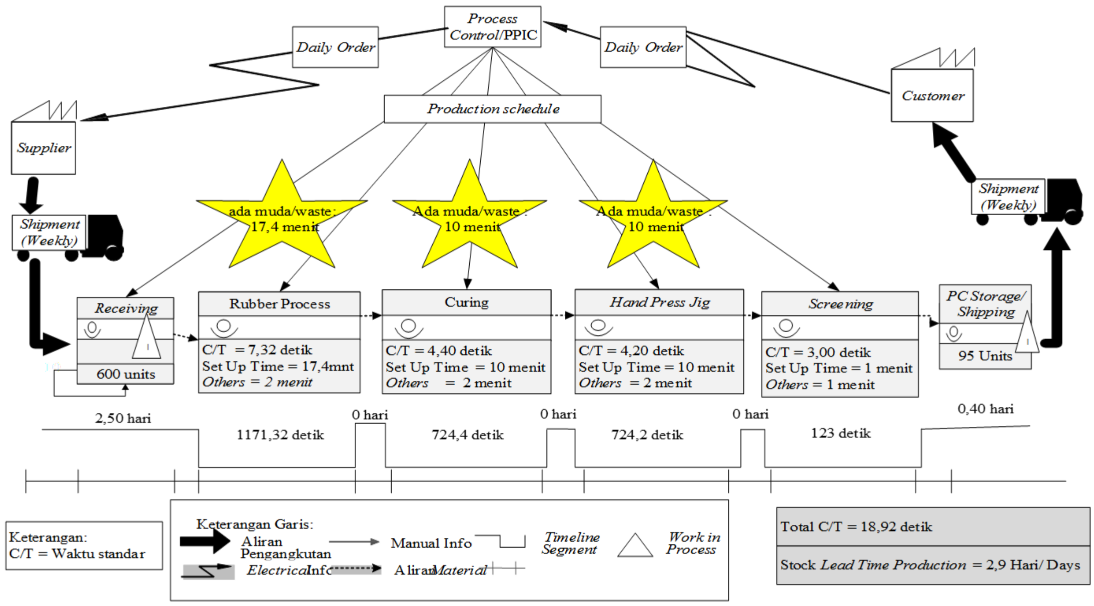


Figure 5 Current State Value Stream Mapping Rubber Product Process

The results of identification of the causes of waste are used to continue the improvement in the production process, to be able to reduce the NVA (Set-up time) process from 37.40 minutes to lower then that, further improvement plan are setted to produce an effective and efficient production process, as for the indicators that are comparisons we can use to see the effectiveness of the improvement, which are:

a. Set-up Time Efficiency (NVA activities)

b. Total Change Over Time (NVA activities)

Table 4 Root cause Analysis and Improvement Plan Activity

Process	Potensial Failure Mode	Potensial Failure Effect	Potensial cause of failure	Current process control	Before S	Before O	Before D	RPN	Action Taken	After S	After O	After D	RPN
Rubber Material	Loading Rubber Not stable by operator	*Short Mold*	Rubber shape unstable	Checking the product by shiftly basis	9	5	4	180	Improve mini rool machine by Change Cutter Belt to Improve rubber shape & Size	2	3	3	18
Curing	Low pressure from *mold plate*	*Short Mold*	*Retrainer plate & Heater plate* tidak rata	Checking the temperature every early shift	6	4	6	144	Grinding the Heater & Retrainer Plate machine to increase the Parallelism	2	3	3	18
Deflashing	*inner flash* stick on the punch surface	*Rubber Flash* and *Tear*	*punch deflashingmachine suface uneven/ rough*	Visual inspection the Mc condition every early shift	7	4	6	168	Install Air Blow to avoid inner flash stick on the punch surface	2	3	4	24

Improvement program from those 3 main processes has been implemented and has give a good result on the production process to reduce the setup and change over time process at the respective process.. One of the example of the improvement item mentioned on the above table, can see at below figure the improvement of mini roll cutter belt by oversize the cutting dimension from 6.5 mm into 8.5 mm, to improve the ruuber shape and size on the rubber material.

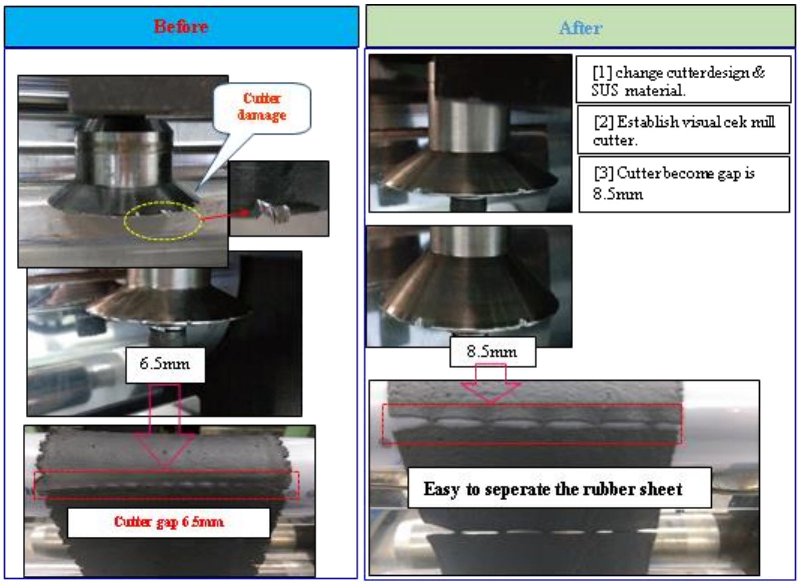


Figure 6 Improve the Mini Roll by changed Cutter Belt from mil Cutter 6.5 mm into 8.5 mm

Set-up Time Efficiency (NVA activities)

We can see the magnitude of the improvements planned in the future state mapping in the table below through the results of the Set-up Time comparison (Table 5 and Figure 7) between current state mapping and future state mapping.

Table 5 Set-up time current vs future state mapping efficiency

Process	Set-up Time Current State Mapping Efficiency	Set-up Time Future State Mapping efficiency	Improvement result
Rubber Material	17.40 minutes	9 minutes	48.28%
Curing	10 minutes	9 minutes	10%
Deflashing	10 minutes	8 minutes	20%

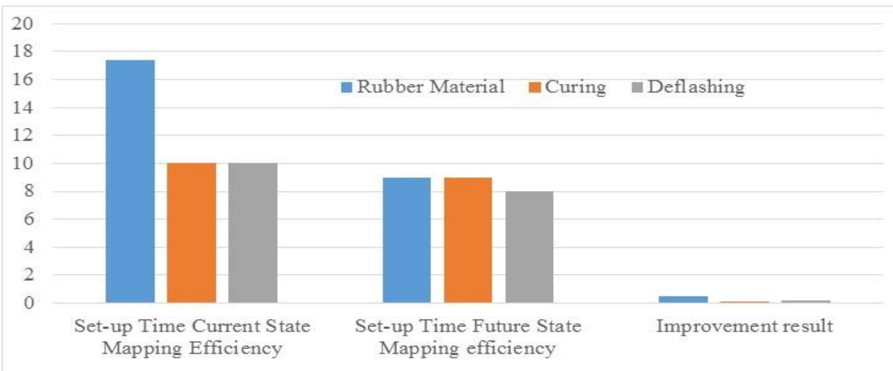


Figure 7 Setup time efficiency comparasion

Based on comparisons (Table 5) and (Figure 7), it can be seen that the future state mapping decreases the time (NVA Activities) processed by rubber material, curing and the process of deflashing, after making improvements proposed by using future state mapping to produce overall improvement of set-up time from 37.40 minutes to 26 minutes by getting an efficiency of 10% ~ 48.28%.

Total Change Over Time (NVA Activities)
We can see the efficiency for total change over time between Current State Mapping and Future State Mapping (Table 6 and Figure 8).

Table 6 Total Change Over time efficiency between Current State Mapping vs Future State Mapping

Process	Total Change Over Time (Current State Mapping)	Total Change Over Time (Future State Mapping)	Improvement Result efficiency
Rubber Material	1.62 hour	0.18 hour	88.89%
Curing	0.60 hour	0.18 hour	70%
Deflashing	0.60 hour	0.17 hour	71.67%

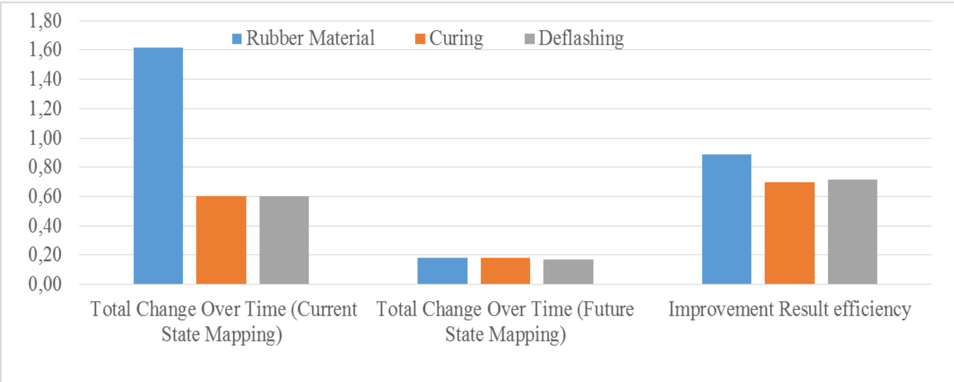


Figure 8 Total Change over time efficiency comparasion

Based on Table 6 and Figure 8 it can be seen that there is a decrease in the total time of Change over which is the result of improvements in an effort to decrease one type of waste).

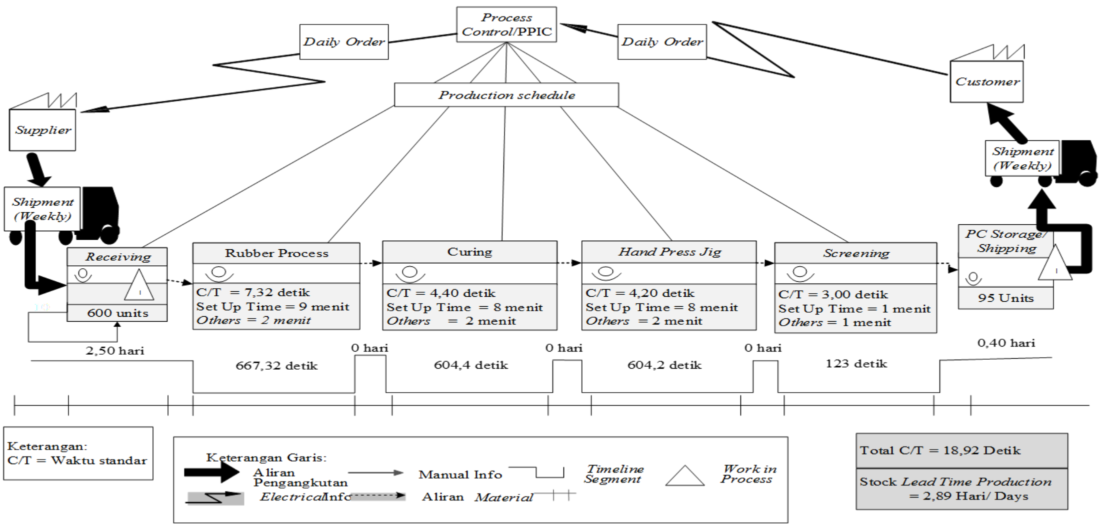


Figure 9 Future Value Stream Mapping

Future State Analysis of VSM
From the current state data the results of the total C/T is 18.92 seconds and the set-up time is 26 minutes. The process of repairing the rubber material process, curing process, deflashing process that has been done to get a better set-up time is explained in table 03 (set-up time/total change over and production time) and table 04 (VA and NVA activities) where total change over time which is NVA activity decreases from 1.62 hours to 0.18 hours for rubber processes and 0.6 hours to 0.18 hours for curing process and the deflashing process also decreases from 0.6 hours to 0.17 hours.

5. Conclusion

Based on the results of research with the method of Value Stream Mapping (VSM) can be drawn the following conclusions:

a. Recommended improvements to reduce waste and increase the productivity of the production process where the non-value-added (set-up time) of the rubber material process from 17.40 minutes to 9 minutes, curing process from 10 minutes to 9 minutes and manual hand press jigs (Deflashing) from 10 minutes to 8 minutes. This also results in improvements to the Total Change Over Time from 2.82 hours to 0.53 hours from the 3 related processes (Rubber material, Curing and Deflashing) identified after making the Current State Value Stream Mapping.
b. To minimize waste it needs to be analyzed first for activities that provide added value and those that do not provide added value then determine which ones are in the real value-added and nonvalue-added categories as well as analysis with the QC tool to help reduce stoppages from rubber production process.
c. Based on the result and literature we can say that VSM also works for the integration of man, machine and material along with methods. VSM should not be end with one improvement, it should be continued with continuous improvements

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