Lean Maintenance Implementation to Analyze Overlock Machine Maintenance at PT Xyz

Hadi Wilianto, Lina Gozali, Adianto
Industrial Engineering Department
Faculty of Engineering
Tarumanagara University
Jakarta, Indonesia
hadi.545180004@stu.untar.ac.id, linag@ft.untar.ac.id, Adianto@ft.untar.ac.id

Abstract

Maintenance of company facilities or machines has an important role in supporting work productivity within the company to achieve the production targets that have been set. Results Based on the research conducted, it can be seen that PT. XYZ has problems with the current maintenance system. The problem that still occurs is that there is still waste in its maintenance activities. PT. XYZ is a company engaged in the garment sector and has been established in 2003. The products produced by PT. XYZ, namely, polo shirts, t-shirts, sweaters, shirts, field service clothes (PDL) and jerseys. One of the damages is the overlock machine which has a downtime per year from January 2020 to December 2020, which is 11944 minutes. The data is carried out using Maintenance Value Stream Mapping (MVSM) to trace the causes of waste in maintenance activities which will then be deepened with Root Cause Analysis (RCA), which uses five-whys analysis and fishbone diagrams to recommend improvements in these wasteful efforts. Based on the recommendations for improvement, the maintenance efficiency of the servo motor component has increased from 36.36% to 42.90%, while the looper component has increased maintenance efficiency from 24.27% to 32%.

Keywords
Lean Maintenance, Maintenance Value Stream Mapping, Root Cause Analysis (RCA), Five-Whys, Fishbone Diagram

1. Introduction
Recent trends indicate that, in general, many systems in use are not performing as intended, so far as cost-effectiveness in terms of their operation and support is concerned. Particularly in manufacturing systems, some of them often operate at less than full capacity, with low productivity, and the costs of producing products are high. According to the study reported, from 15% to 40% (average 28%) of total production cost is attributed to maintenance activities in the factory. In fact, these costs are associated with maintenance labour and materials and are likely to go even higher in the future with the addition of factory automation through the development of new technologies. In this sense, the lean concept has conquered different economic sectors and most of the company's processes, positioning itself as an inevitable concept to improve the performance of the company.(Mobley 1990) Lean is a lever that enables the company to continually improve its processes, reduce overheads and meet the growing and diverse needs of its customers, but it can never be achieved without maximum reliability and availability of equipment because of their direct impact on the quality, cost and delivery of products or services. Then companies must define the most appropriate maintenance strategy to achieve the required performance of the production system.(Mouzani and Bouami 2018)

PY XYZ is a company specializing in garment products established in 2003 and located in Tangerang. Based on an interview with the head of the company maintenance, the company currently has problems with the maintenance system that is applied because production machines often experience sudden shutdown when the production process takes place and takes a long time to repair. Based on the results of initial observations, the high downtime of machines is due to waste that usually occurs in maintenance activities at PT. XYZ. A lean maintenance approach is expected to minimize waste in the maintenance department by identifying and eliminating activities that disrupt production and creating a smooth flow throughout maintenance activities.

2. Literature Review

2.1. Maintenance

Maintenance is defined as a series of activities needed to maintain and keep a product or system in a safe, economical, efficient, and optimal operating condition. (Gozali et.al. 2019 and Gozali et.al. 2020). Maintenance activities in the company are very necessary because every piece of equipment has a useful life, and humans are always trying to increase the service life by doing maintenance(Abbas et al. 2009).
The main maintenance objectives can be defined as follows: (Asyari 2007)

a. To extend the usefulness of the asset.
b. To ensure optimum availability of installed equipment for production and get maximum return on investment.
c. To ensure operational readiness of all equipment always needed in an emergency.
d. To ensure the safety of people who use these facilities.

2.2. Lean Maintenance

The lean maintenance concept is a relatively new term, introduced in the last decade of the 20th century. The lean maintenance theory is an advanced maintenance concept, and the method aims to minimize the waste phenomenon (Smith et al. 2004). Lean maintenance relies on the combination of approaches, methods and tools of Lean Manufacturing and maintenance and is regarded as a benefit of maintenance to customers with minimal waste and minimum work, management effort, maintenance, spare part and energy (Levit 2008). In summary, Lean Maintenance is a system that encompasses all maintenance principles and existing Lean techniques and aims to eliminate the various wastes identified in maintenance processes (Mostafa et al. 2015). Knowing that production and maintenance are two different processes, the Lean maintenance approach can never be an image of Lean manufacturing. The differences mentioned below show why Lean maintenance needs a different orientation than Lean Manufacturing.

a. Production plans are based on sales forecasts. Therefore, they are driven by a precise schedule of work. However, corrective maintenance work follows a well-defined work schedule due to failures that occur randomly.
b. The concept of "production without wastage" is different between production and maintenance processes. For production, being productive without waste is the rightly daily management of the production process. For maintenance, this notion has an extra time perspective, producing without wastage means not replacing organs too early while avoiding failure.
c. The improvement of production processes can be achieved by recording and acting on dynamic operational data. Data management and data collection are also useful for equipment maintenance, but it also requires static data such as the type and condition of equipment, the failure rate, etc.

2.3. *Maintenance Value Stream Map* (MVSM)

Maintenance Value Stream Mapping (MVSM) is a method for mapping the process flow and information in maintenance activities for equipment. In MVSM, the output obtained is the amount of time that is classified as value-added (VA) and non-value added (NVA) time and maintenance efficiency (Huda et al. 2014). In MVSM, value-added activities are defined as Mean Time to Repair (MTTR). Non-Value Added Activities are defined as Mean Time to Organize (MTTO), and Mean Time to Yield (MTTY). Each activity is calculated to find the Mean Minute Lead Time (MMLT). The term can be interpreted as follows:

a. MMLT= the time between recognizing the need for maintenance on a particular piece of equipment to the actual performance of such maintenance and the repair of the equipment
b. MTTO = time required to coordinate tasks to initiate the maintenance repairs
c. MTTR = time required to repair and maintain the equipment
d. MTTY = time required to yield a good part after maintenance

2.4 Overall Equipment Effectiveness (OEE)

OEE serves as a general and inclusive measurement of how well a company's manufacturing operation are performing. OEE measures the degree to which the equipment is doing what it is supposed to do, based on availability, performance, and quality rate (Williamson 2006)

2.5 Pareto Chart

Statistically, a Pareto chart is simply a frequency block diagram displaying the relative frequency of different attributes in descending order. This classification is an essential step that must precede taking the corrective measures of differentiation and allocation (Grosfeld 2007). The Pareto chart applies 80-20 rule, which is a familiar saying that asserts that 80% of outcomes (or outputs) result from 20% of all causes (or inputs) for any given event.

2.6 Fishbone Diagram

The Fishbone diagram is an analysis tool that provide a systematic way of looking at effects and the case that create or contribute to those effect. Because of the function of the fishbone diagram, it may be referred to as a cause-and-effect diagram (Watson 2004).

2.7 Five Why

Five Whys technique relates to the principle of systematic problem solving: without the intent of the principle, the technique can only be a shell of the process. Hence, there are three key elements to effective use of the Five Whys technique accurate and complete statements of problems, complete honesty in answering the questions, and the determination to get to the bottom of problems and resolve them. The technique was developed by Sakichi Toyoda for the Toyota Industries Corporation (Serrat 2009).

2.8 5S

5S is a management tool or technique developed by Takshi Osada during the 1980s to constitute and sustain better quality, productivity, and a safe environment in an organisation. The concept was first raised in the Japanese manufacturing sector, the element of 5S can be seen in Figure 1 (Randhawa and Inderpreet 2017).

Japanese words (5S)	English meaning (5S)	English meaning (5C)	Meaning	Features
Seiri	Structurize	Clear	Organization	Discarding unnecessary items from the workplace (sort)
Seiton	Systematize	Configure	Neatness	Arrange necessary items in good order for quick retrieval and storage (set in order)
Seiso	Sanitize or shine	Clean and check	Cleaning	Clean the workplace so that there is no dust on floor and equipment
Seiketsu	Standardize	Conformity	Standardization	Maintain high standard of housekeeping, cleanliness and workplace organization
Shitsuke	Sustain	Custom and practice	Discipline	Routine practice of 5S initiatives by imbibing it in the standard operating procedures and making it customary for everybody in the organization

Figure 1. Element of 5S

2.9 Computerized Maintenance Management System (CMMS)

CMMS is a software that helps an organization track the status of maintenance tasks, such as equipment repair, it includes also planning and scheduling function, inventory control and management, and asset historical data.

3. Research Methodology

First of all, observation is done by doing a field study to discover the actual problems. On the other hand, the literature review is also done. After determining the problem, the purpose of the research is identified. Researchers involved all related parties such as production and maintenance teams to list all relevant data and information for developing MVSM. RCA was applied as a problem-solving tool to analyze the collected data. In addition, the Ishikawa diagram (Cause and effect diagram) and Five whys were applied in this research. The research methodology flowchart can be seen in Figure 2.

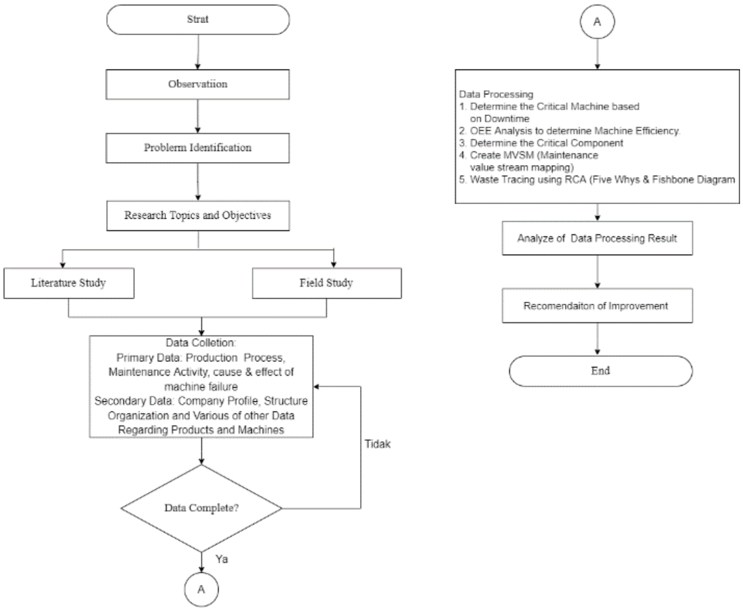

Figure 2. Research Methodology Flowchart

4. Results and Discussion

4.1. Critical Machine Determination and OEE Calculation

Based on the historical downtime data for machine in the sewing division, it is known that the overlock machine has the highest downtime of 11944 minutes compared to other machines. Then it was concluded that the machine became the research focus because it had been determined based on the data that the machine was critical. Machine downtime data in sewing division can be seen in Figure 3.

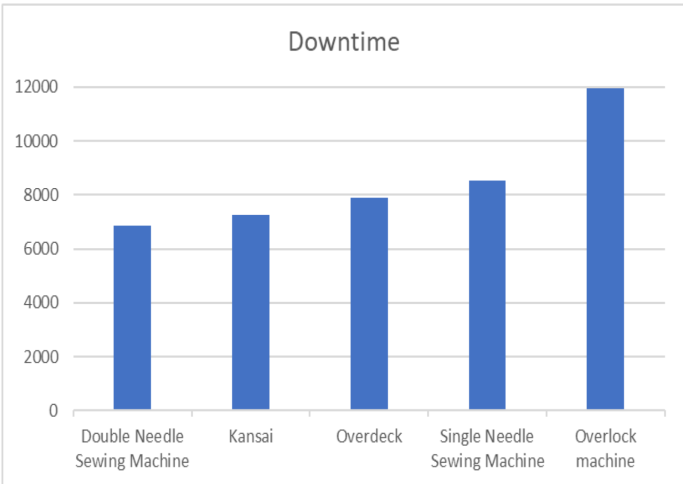

Figure 3. Machine Downtime Data in Sewing Division

Furthermore, the calculation of the overlock machine's OEE is carried out to determine the machine's availability, performance, and quality ratio. The results of the OEE calculation can be seen in Table 1.

Table 1. Overlock Machine OEE Calculation

No	Tanggal	Availability (%)	Performance Rate (%)	Quality Rate (%)	OEE (%)
1	Jan-20	91,91	80,80	97,71	72,56
2	Feb-20	90,74	77,64	98,22	69,20
3	Mar-20	92,00	77,50	98,20	70,01
4	Apr-20	91,10	74,00	97,43	65,68
5	Mei-20	92,50	74,08	98,09	67,21
6	Jun-20	90,40	73,00	97,50	64,34
7	Jul-20	90,41	68,70	97,70	60,69
8	Ags-20	92,00	72,10	98,00	65,00
9	Sept-20	89,81	70,30	97,51	61,60
10	Okt-20	91,70	79,08	98,00	71,06
11	Nov-20	90,00	70,88	97,06	61,92
12	Des-20	93,50	81,18	97,30	73,86
Rata-rata		91,34	74,94	97,73	66,93

Based on the results of the OEE calculation which can be seen in Table 1, it is known that the overlock machine has an average OEE value of 66.93%. The value of the OEE is below the world standard results guideline (World Class), which is 85%. Therefore, improvement and further analysis are urgently needed so that the overlock machine can work more effectively and optimally to improve the performance and quality of the machine work.

4.2. Selection of Critical Components

In the selection of critical components, the first thing that must be done is to determine the problems that are the main priority.The Pareto diagram of overlock machine components can be seen in Figure 4.

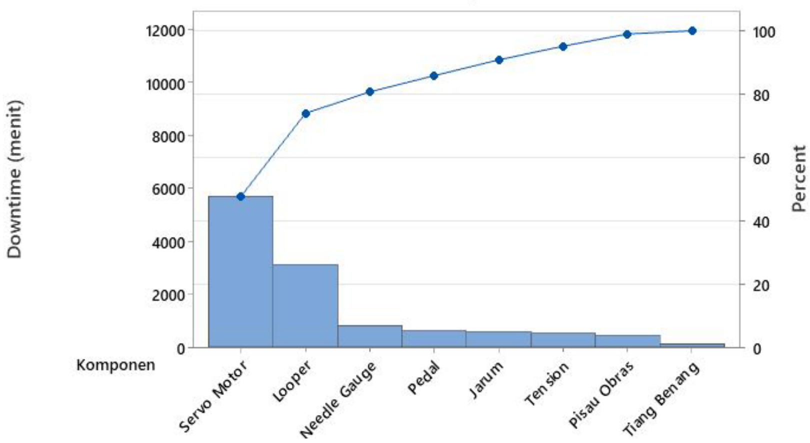

Figure 4. Pareto Diagram of Overlock Machine Components

From Figure 4, the servo motor and looper are components that cause the highest loss. Therefore, further analysis will be carried out on these components through the creation of a maintenance value stream mapping.

4.3 Maintenance Value Stream Mapping

The current state map is a diagram that is created to capture working processes using rules created by Rother and Shook (2003). Value adding and non-value adding activities in the information and physic flows of a value chain Area visualized in the diagram as interconnected processing steps. The current state map developed for repair activities on the Servo motor component can be seen in Figure 5.

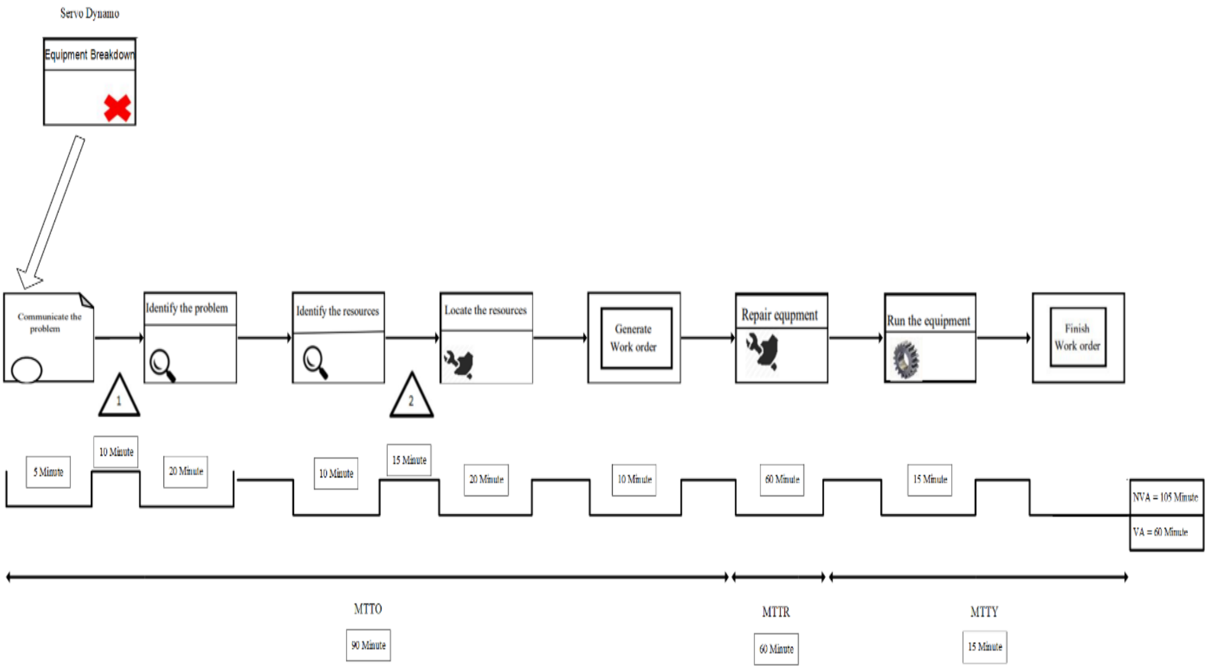

Figure 5. Current State Map of Servo Motor

The following is a observation of servo motor maintenance activity that can be seen in Figure 6:

No.	Kegiatan Perbaikan	Waktu Perbaikan	Kategori MMLT	Kategori Aktivitas
1.	*Equipment breakdown*	-	-	-
2.	Communicate the Problem	5	MTTO	NVA
3.	Delay due to maintenance technician not standby	10	MTTO	NVA
4.	Identify the Problem	20	MTTO	NVA
5.	Identify the Resources	10	MTTO	NVA
6.	Delay due to unavailability of repair tools	15	MTTO	NVA
7.	Locate the resources	20	MTTO	NVA
8.	Generate work order	10	MTTO	NVA
9.	Repair equipment	60	MTTR	VA
10.	Run the equipment	15	MTTY	NVA
11.	Finish work order	-	-	-
	Jumlah MMLT		165	
	Jumlah MTTO		90	
	Jumlah MTTR		60	
	Jumlah MTTY		15	

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Figure 6. Observation of Servo Motor Maintenance Activity

Based on the current state map and observation that has been done. Calculation for servo motor current state map can be seen in Figure 7.

Non-Value Added Activity	$MTTO + MTTY = 90 + 15 = 105$
Value Added Activity	$MTTR = 60$
% Non-Value Added Activity	$\frac{MTTO+MTTY}{MMLT} \times 100\% = \frac{105}{165} \times 100\% = 64\%$
% Value Added Activity	$\frac{MTTR}{MMLT} \times 100\% = \frac{60}{165} \times 100\% = 36\%$
Maintenance Efficiency	$\frac{MTTR}{MMLT} \times 100\% = \frac{60}{165} \times 100\% = 36\%$

Figure 7. Calculation of Servo Motor Current State Map

The current state map developed for repair activities on the Looper component can be seen in Figure 8.

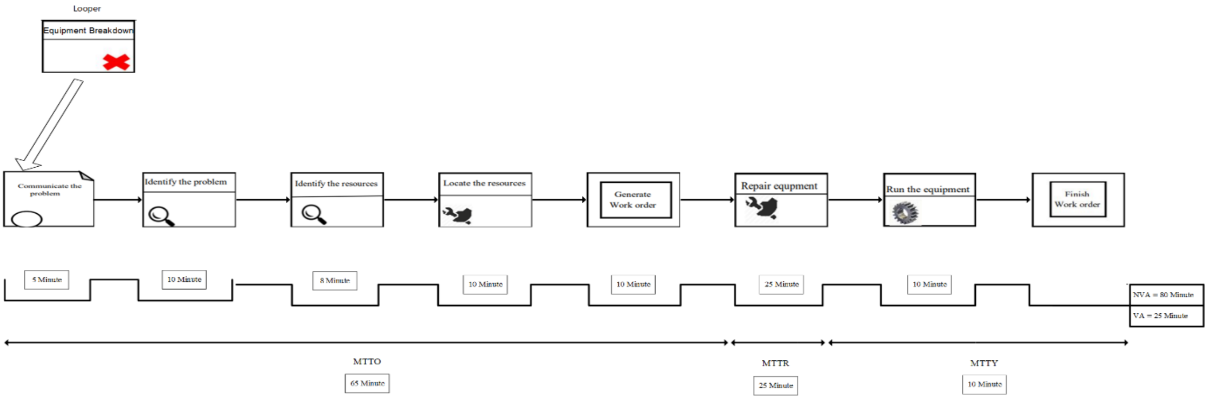

Figure 8 Looper Cuurent State Map

The following is a table for Observation of Looper Maintenance Activity that can be seen in Figure 9:

No.	Kegiatan Perbaikan	Waktu Perbaikan	Kategori MMLT	Kategori Aktivitas
1.	Equipment breakdown	-	-	-
2.	Communicate the Problem	5	MTTO	NVA
3.	Delay due to maintenance technician not standby	10	MTTO	NVA
4.	Identify the Problem	10	MTTO	NVA
5.	Identify the Resources	8	MTTO	NVA
6.	Delay due to unavailability of repair tools	15	MTTO	NVA
7.	Locate the resources	10	MTTO	NVA
8.	Generate work order	10	MTTO	NVA
9.	Repair equipment	25	MTTO	NVA
10.	Run the equipment	10	MTTR	VA
11.	Finish work order	-	-	-
	Jumlah MMLT		103	
	Jumlah MTTO		68	
	Jumlah MTTR		25	
	Jumlah MTTY		10	

Figure 9. Observation of Looper Maintenance Activity

Based on the current state map and observation that has been done. The calculation for looper current state map can be seen in Figure 10.

Non-Value Added Activity	MTTO + MTTY = 68 + 10 = 78
Value Added Activity	MTTR = 25
% Non-Value Added Activity	$\frac{MTTO+MTTY}{MMLT} \times 100\% = \frac{78}{103} \times 100\% = 76\%$
% Value Added Activity	$\frac{MTTR}{MMLT} \times 100\% = \frac{25}{103} \times 100\% = 24\%$
Maintenance Efficiency	$\frac{MTTR}{MMLT} \times 100\% = \frac{25}{103} \times 100\% = 24\%$

Figure 10. Calculation of Looper Current State Map

4.4 Five Whys Analysis

Based on the mapping with MVSM there is waste in the maintenance activity. The waste that appears during the maintenance activity is waste of motion. Waste of defect, waste of waiting and waste of process. The following is a root cause analysis for each waste that occurs using five-whys analysis. Five Whys analysis can be seen in Table 2-5.

a. Waste Motion

Table 2. Root Cause Analysis of Waste Motion

Problem Type	Why 1	Why 2	Why 3	Why 4	Why 5
Waste of Motion	Movement takes a relatively long time	Technicians do Excessive Movement	Go back and forth between warehouse and production line to pick up repair equipment	Equipment and spare parts are not in one location	Maintenance procedures are not optimal and the number of toolboxes is not enough

b. Waste Defect

Table 3. Root Cause Analysis of Waste Defect

Problem Type	**Why 1**	**Why 2**	**Why 3**	**Why 4**	**Why 5**
Waste of Defect	Rework on the machine that has been repaired	Components cannot function properly after being repaired	The repair process is carried out in a hurry and is not thorough	Lack of Technial Expertise	There are no training and SOP given to workers

c. Waste Waiting

Table 4. Root Cause Analysis of Waste Waiting \

Problem Type	**Why 1**	**Why 2**	**Why 3**	**Why 4**	**Why 5**
Waste of Waiting	Technicians not standby	There is engine priority	The engine is in urgent status	TAT (Turnaround Time) engine has exceeded or is near	Lack of Manpaower and Inefficiency in maintenance actiivty
	Waiting for tools	Tools not in the warehouse	No backup tools	The equipmentp procurement process took a long time to be done	Inaccurate Data because no system that records equipment availability

d. Waste Process

Table 5. Root Cause Analysis of Waste Process

Problem Type	**Why 1**	**Why 2**	**Why 3**	**Why 4**	**Why 5**
Waste of Process	Creating work orders	The process of making work orders takes a long time	Because it is still done manually (paper-based)	Not using software such as computerized maintenance management system (CMMS)	A Company considering the cost of using the software and also the training that needs to be provided
	The process of identifying problems that occur on the machine takes a long time	Disassembling the engine for identification	High level of difficulty in repair	Lack of Technical Expertise	There is no training and SOP regarding machines or damage that can occur to machines
	Technicians take a long time to repair the machine	It is necessary to check each part of the component	Damage to components that are complex and require a detailed inspection	The preventive maintenance that has been implemented so far is not optimal	servo motor and looper do not receive preventive maintenance and there is no record of machine damage to speed up technicians in the component repair process.

4.5 Fishbone Analysis

The following is a fishbone analysis which can be seen in Figure 11.

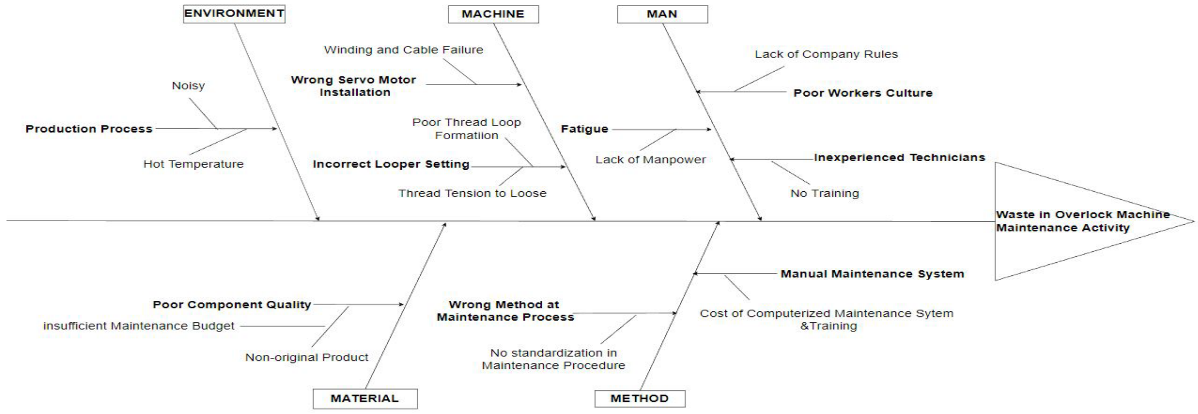

Figure 11 Fishbone Analysis

4.6 Future State Map

After creating the current state map, the last step in Maintenance Value Stream Mapping (MVSM) is compiling a future state map. Future State Map or future maps can be a basis for improvement to be applied in real work areas (Effendi 2019). The future state map is created based on the elimination of delays that occur in the current state map. The following can be seen depicting the future state map on the maintenance activities of the servo motor components in Figure 12

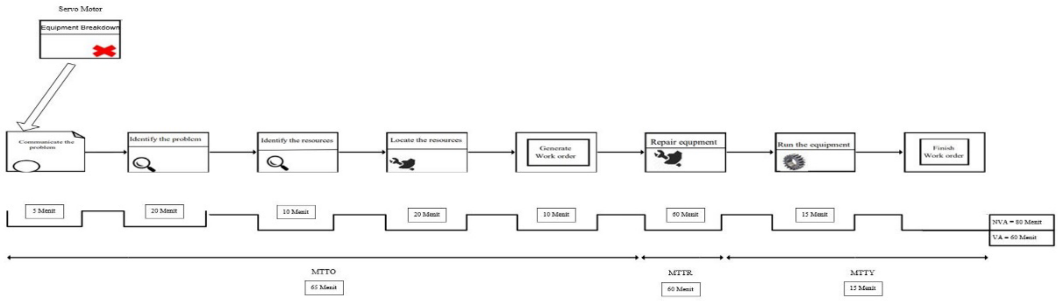

Figure 12. Future State Map Servo Motor Component Repair Activities

Based on the current state map and observation that has been done. Calculation for servo motor future state map can be seen in Figure 13.

Non-Value Added Activity	$\text{MTTO} + \text{MTTY} = 65 + 15 = 80$
Value Added Activity	$\text{MTTR} = 60$
% Non-Value Added Activity	$\frac{\text{MTTO+MTTY}}{\text{MMLT}} \times 100\% = \frac{80}{140} \times 100\% = 57\%$
% Value Added Activity	$\frac{\text{MTTR}}{\text{MMLT}} \times 100\% = \frac{60}{140} \times 100\% = 43\%$
Maintenance Efficiency	$\frac{\text{MTTR}}{\text{MMLT}} \times 100\% = \frac{60}{140} \times 100\% = 43\%$

Figure 13. Calculation of Servo Motor Future State Map

The future state map for looper component maintenance activities can be seen in Figure 14

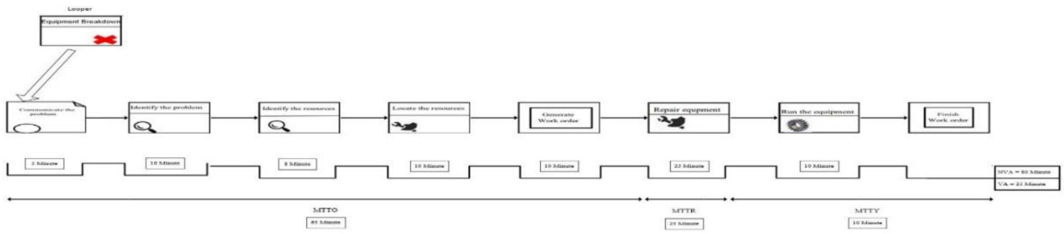

Figure 14. Future State Map Looper Component Repair Activities

Based on the current state map and observation that has been done. The calculation for the looper future state map can be seen in Figure 15.

Non-Value Added Activity	MTTO + MTTY = 43 + 10 = 53
Value Added Activity	MTTR = 25
% Non-Value Added Activity	$\frac{\text{MTTO+MTTY}}{\text{MMLT}} \times 100\% = \frac{53}{78} \times 100\% = 68\%$
% Value Added Activity	$\frac{\text{MTTR}}{\text{MMLT}} \times 100\% = \frac{25}{78} \times 100\% = 32\%$
Maintenance Efficiency	$\frac{\text{MTTR}}{\text{MMLT}} \times 100\% = \frac{25}{78} \times 100\% = 32\%$

Figure 15. Calculation of Looper Future State Map

Based on the calculations that have been carried out, it can be seen that the percentage of non-value-added activity has decreased, while the percentage of maintenance efficiency for the servo motor and looper components, increasing. The following is a comparison between the result of the calculation from the current state map and the future state map in the servo motor and looper component which can be seen in Figure 16 and Figure 17

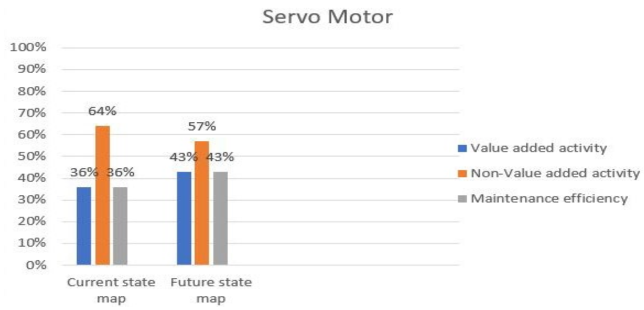

Figure 16. Comparison of Servo Motor's Current State Map and Future State Map

Based on the comparison of Servo Motor's current state map and future state map, it can be seen that there is an increase in the maintenance efficiency and value-added activity on the servo motor components by 7% from the initial 36% to 43% also non-value added activity decreasing from 64% to 57%.

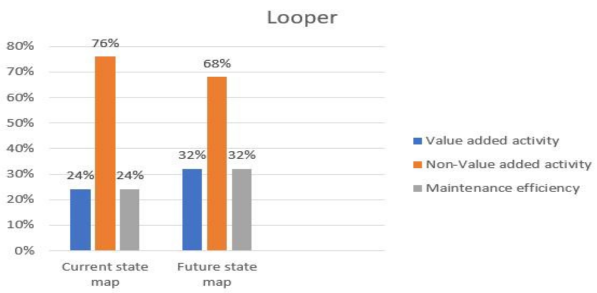

Figure 17. Comparison of Looper's Current State Map and Future State Map

Based on the comparison of Looper's current state map and future state map, it can be seen that there is an increase in the maintenance efficiency and value-added activity on the servo motor components by 8% from the initial 24% to 32% also non-value added activity decreasing from 76% to 68%.

4.7 Improvement Suggestion

The following are some suggestions for improvement:

1. Proposed Implementation of 5S
   This proposal includes creating cleaning procedures, standard operating procedures for maintenance and also the 5S audition checklist.
2. Providing Training
   The training will be carried out by a service company that handles maintenance, so that training is used as a distribution of knowledge to maintenance technicians
3. Digitizing the Maintenance System

This implementation will use a computerized maintenance management system (CMMS), the CMMS itself combines several maintenance processes in one system, increasing productivity and equipment performance by removing manual elements from the series of maintenance responsibilities.

4. Making a Checklist
   Making a checklist in maintenance activities is used to help workers check back during the maintenance process. This checklist sheet aims to ascertain whether component faults, so that it can be detected early because an inspection is carried out using the checklist.

4.8 Computerize Maintenance Management System

The following is an example of a CMMS system display using Odoo software which can be seen in Figures 18 to 25 below

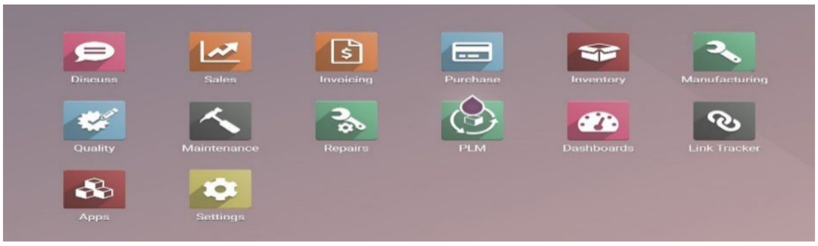

Figure 18 Odoo Main Dashboard

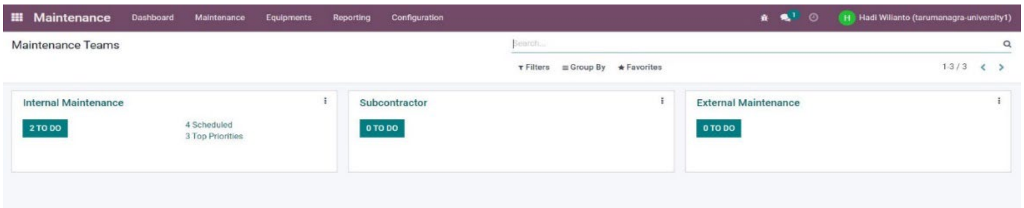

Figure 19 Maintenance Apps Dashboard

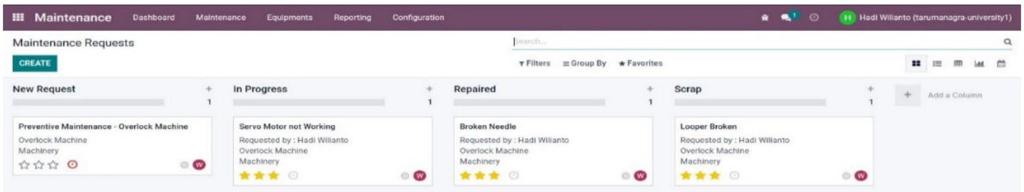

Figure 20 Maintenance Request Menu

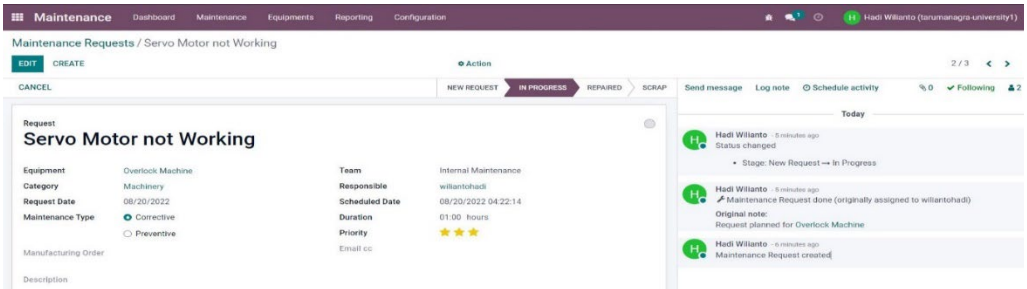

Figure 21 Maintenance Request Form Menu

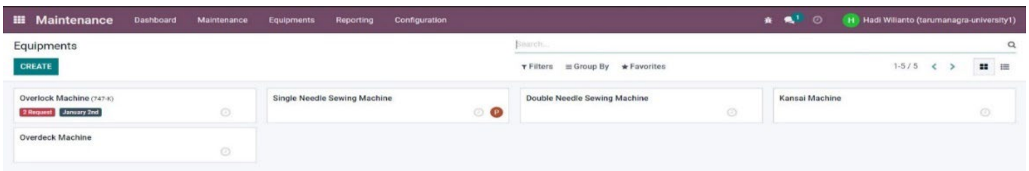

Figure 22 Equipment Menu

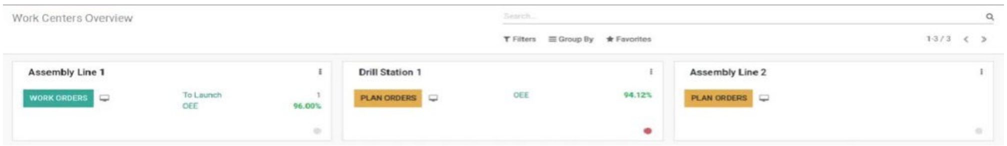

Figure 23 Production OEE Menu

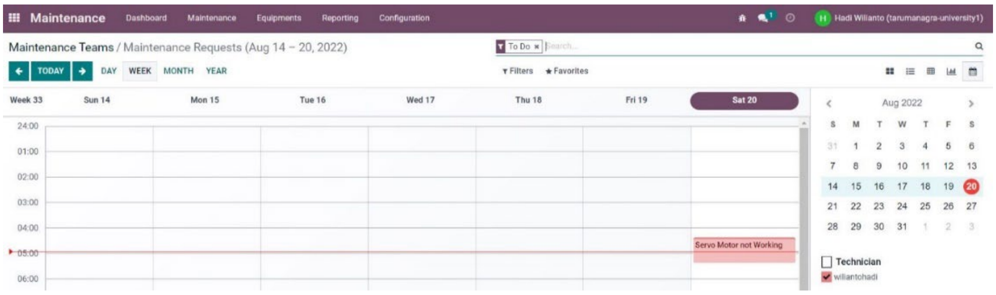

Figure 24 Maintenance Teams Scheduled Menu

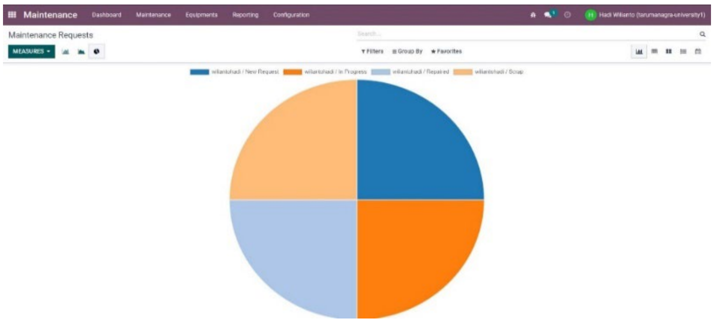

Figure 25 Report Menu

The implementation of ERP certainly makes the processes within the company easier and more effective and of course faster. The following is a comparison after ERP implementation which can be seen in Table 6 below

Table 6. Comparison of CMMS Implementation

Before Implementation	**After Implementation**
Manual data entry related to assets into spreadsheet causing inconsistency in data entry, room for errors and mis keying information	CMMS software eliminates most, if not all, manual data entry as it relates to maintenance management. Utilizing barcoding technology in conjunction with maintenance software, users can actually perform data entry in a matter of seconds.
Employees spend significant amount of time is needed to shuffle through folders and file cabinets to find documents like work orders, manufacturers' manuals, vendor contact information and work histories	Employees' time spent on locating necessary files will be significantly reduced by implementing a CMMS system, which stores all maintenance-related information and eliminates the need for hard copies. Staff time can then be spent on more productive job duties.
Poorly maintained assets and prematurely retired assets add to the cost of capital expenses, but also have an impact on the environment by filling landfills. Replacement assets hurt as well, contributing to carbon emissions through production and shipping.	CMMS allows Employees to implementing preventive maintenance and detecting minor issues before they cause equipment failure by schedule work orders and maintenance requirements to ensure equipment is checked consistently
Parts in various locations may hard to locate when needed. This leads to reordering, overstocking and/or the stocking of obsolete parts, which can be hard to manage. The end result is increased inventory	CMMS inventory tracking features allow parts can be found by any criteria including supplier, vendor, manufacturer part number, serial number, part type (all filters or bearing), etc. All quantities are

carrying costs for the organization, as well unplanned equipment downtime and lost productivity if parts aren't available when needed.	automatically tracked, including links to the work order and purchasing modules in the CMMS system

5. Conclusion

Based on the waste identification carried out for the component with the highest downtime, there were 4 types of waste found in the maintenance process of PT. XYZ is waste process, motion, waiting and defects. In the identification of waste carried out on components with the highest downtime, it was found 5 factors causing waste contained in the maintenance process of PT. XYZ. These factors include man, method, machine, material, environment. The results of the comparison between the maintenance efficiency of the current state map and the future state map that have been carried out by eliminating delays in the maintenance process, show that the value of the maintenance efficiency of the servo motor component increased by 7% with an efficiency value of 7%. previously by 36% to 43% while for the looper component it increased by 8% with the previous efficiency value of 24% to 32%. The suggestions for improvement recommended by the author are the application of 5s, the proposed digitization of the maintenance system, the proposed training/training plan for technicians and the proposal for making a checklist on maintenance activities. Some of these proposals are expected to help companies improve the effectiveness of overlock machine maintenance.

References

Abbas, B.S., Steven, E., Christian, H. and Sumanto, T., Penjadwalan Preventive Maintenance Mesin B. Flute Pada PT. AMW. *Inasea*, *10*(2), pp.97-104. 2009.

Asyari D, Sc IM. Manajemen Pemeliharaan Mesin. Jurusan Teknik Mesin, Fakultas Teknik, Universitas Darma Persada, Jakarta. 2007.

Effendi, Mahfud. *usulan penerapan metode lean maintenance guna meningkatkan efisiensi sistem pemeliharaan mesin heating* di pt. indospring *Tbk*. Diss. Universitas Muhammadiyah Gresik, 2019.

Gozali, L., Lieanda, K., Jap, L., & Daywin, F. J. Analysis of Mak Diesel Engine Services at Merawang Power Plant Using FMEA Method. In IOP Conference Series: Materials Science and Engineering (Vol. 508, No. 1, p. 012083). IOP Publishing. (2019, April).

Gozali, L., Daywin, F. Y., & Doaly, C. O. Root Cause Analysis and Overall Equipment Effectiveness of Press Machine in Line H and Hirac At Pt. Xyz. Jurnal Muara Sains, Teknologi, Kedokteran dan Ilmu Kesehatan, 4(2), 285-294. (2020).

Grosfeld-Nir, A., Ronen, B. and Kozlovsky, N., The Pareto managerial principle: when does it apply?. *International Journal of Production Research*, *45*(10), pp.2317-2325. 2007.

Huda, A.T.N., Novareza, O. and Andriani, D.P., Analisis Aktivitas Perawatan Mesin Hds Di Stasiun Gilingan Menggunakan Maintenance Value Stream Map (MVSM)(Studi Kasus PG. Kebon Agung Malang). *Jurnal Rekayasa dan Manajemen Sistem Industri*, *3*(2), p.132637. 2014.

Kannan, S., Li, Y., Ahmed, N. and El-Akkad, Z., Developing a maintenance value stream map. In *Institute of Industrial Engineers, Technical Societies and Divisions Lean Conference Proceedings*. 2007.

Levitt, J., *Lean maintenance*. Industrial Press Inc.. 2008.

Mobley, R.K., *An introduction to predictive maintenance*. Elsevier. 2002.

Mouzani, I.A. and Bouami, D.R.I.S.S., The integration of lean manufacturing and lean maintenance to improve production efficiency. *International Journal of Mechanical and Production Engineering Research and Development*, *9*(1), pp.601-612. 2019.

Mostafa, S., Dumrak, J. and Soltan, H.,. Lean maintenance roadmap. *Procedia Manufacturing*, *2*, pp.434-444. 2015

Muchiri, P. and Pintelon, L., Performance measurement using overall equipment effectiveness (OEE): literature review and practical application discussion. *International journal of production research*, *46*(13), pp.3517-3535. 2008

Randhawa, J.S. and Ahuja, I.S., 5S–a quality improvement tool for sustainable performance: literature review and directions. *International Journal of Quality & Reliability Management*. 2017.

Rother, M. and Shook, J., *Learning to see: value stream mapping to add value and eliminate muda*. Lean enterprise institute. 2003.

Smith, R. and Hawkins, B.,. *Lean maintenance: reduce costs, improve quality, and increase market share*. Elsevier. 2004

Watson, G.,. The legacy of Ishikawa. *Quality progress*, *37*(4), p.54. 2004

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Biographies

Hadi Wilianto is an undergraduated student majoring in Industrial Engineering. He went to Universitas Tarumanagara for his bachelor’s degree and graduated in July 2022. He is currently work as an intern in Toyota Astra Motor and responsible for creating 16 Standard Operating Procedure (SOP) for Area Management 2 Division to qualifying ISO 9001:2015 certification.

Lina Gozali is a lecturer at the Industrial Engineering Department of Universitas Tarumangara since 2006 and a freelance lecturer at Universitas Trisakti since 1995. She graduated with her Bachelor's degree at Trisakti University, Jakarta - Indonesia, then she got her Master's Degree at STIE IBII, Jakarta – Indonesia, and she recently got her Ph.D. at Universiti Teknologi Malaysia, Kuala Lumpur – Malaysia in 2018. Her apprentice college experience was in paper industry at Kertas Bekasi Teguh, shoes industry at PT Jaya Harapan Barutama, and automotive chain drive industry at Federal Superior Chain Manufacturing. She teaches Production System and Supply Chain Management Subjects. She did a research about Indonesian Business Incubator for her Ph.D. She has written almost 70 publications since 2008 in the Industrial Engineering research sector, such as Production Scheduling, Plant Layout, Maintenance, Line Balancing, Supply Chain Management, Production Planning, and Inventory Control. She had worked at PT. Astra Otoparts Tbk before she became a lecturer.

Adianto was born in Semarang, Indonesia on 29th April, 1955. Adianto completed his "Sarjana Fisika Degree" in 1982 from the Physics Department of the Faculty of Sciences and Mathematics, Gadjah Mada University, Yogyakarta. In 1978 when he got his Bachelor of Science in Physics (B.Sc.) he started working as a Staff of "Field of Nuclear Physics Laboratory"," Pure Materials Research Center and Instrumentation Yogyakarta", Atomic Energy Agency (BATAN). In 1986 to 1993 he received a scholarship from the Ministry of Research and Technology of the Republic of Indonesia to continue his studies in England at the Department of Electronic and Electrical Engineering, University of Salford, England. He received his M.Sc. degree in the field of Computer Instrumentation in 1988 and a Ph.D. degree in the field of Material Science in 1993. He returned back to Indonesia, then in 1994 he moved to Jakarta and appointed as a "Head of Engineering and Advanced Technology", (Echelon IIIA) at "Nuclear Science and Technology Empowerment Center", Atomic Energy Agency, BATAN, Jakarta. In 2000 he was assigned to the Ministry of Research and Technology to serve as Assistant Deputy fpr Science Accreditation and Development Center (Echelon IIA) and in 2005 he was assigned as Assistant Director for Academic Affairs, to Organize Graduate Research in PUSPIPTEK Serpong. In 2008, he took early retirement as a Governmen Official to take a full time lecturer at Universitas Tarumanagara, Jakarta. Adianto started his profession as a lecturer in the Department of Mechanical Engineering, Faculty of Engineering, Tarumanagara University and the Department of Mechanical Engineering, Faculty of Industrial Technology, Trisakti University of Indonesia from 1994 until now. He has taught mathematics, mechatronics, English and physics, but Physics is the main subject he teaches. As a full time lecturer at Universitas tarumanagara, in 2012 he was appointed as a Vice Dean for Academic and Student Affairs, Faculty of Engineering, and in 2016 up to now, he was appointed as a Director for Student Affairs, Universitas Tarumangara. During his profession as a researcher at the Atomic Energy Agency, the Ministry of Research and Technology and as a lecturer at Tarumanagara University, Adianto as an Associate Professor has published scientific and research papers of more than 35 titles at home and abroad.