



OPTIMIZATION OF PUMP MAINTENANCE TIME IN THE STEAM SYSTEM AREA PT XYZ USING A RELIABILITY AND MAINTENANCE VALUE STREAM MAPPING APPROACH

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ABSTRACT

The pumps in Steam System PT XYZ frequently fail, resulting in a cumulative downtime of 15000 hours and potentially affecting output. The goal of this study is to examine the problem by 1) knowing the pump reliability, 2) evaluating the pump maintenance system using MVSM, and 3) offering recommendations based on the reliability and MVSM results in the Steam System Area of PT XYZ. The reliability values of pumps G04-III-A, G04-I-S, G04-I-A, G07-A, and G02-S were calculated as 52,20%, 45,59%, 50,19%, 47,09%, and 43,15%, respectively. The maintenance system was then evaluated using MVSM, yielding a Current State Map with a maintenance efficiency of 51%, a VA activity time of 8927 minutes, and an NVA activity time of 9672 minutes. The Future State Diagram The advice resulted in a 99% gain in maintenance efficiency, and NVA activity time was reduced by 9600 minutes. Maintenance time intervals on pumps G02-S, G04-I-A, G04-III-A, G04-I-S, and G07-A are recommended every 49 days, 31 days, 44 days, 35 days, and 76 days, respectively, while recommendations with the MVSM approach are in the form of eliminating the time delay that occurs when the material is not available, which is done by estimating the time the material is needed and the previous purchase time. This study concludes that by following the recommendations, the pump maintenance system in the Steam System Area of PT XYZ may be optimized.

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1. INTRODUCTION

Every company has various needs to support production activities, including production facilities. One production facility that significantly affects a company's production process is production machinery. Using these machines requires maintenance activities so that the production process in a company can run smoothly, following the company's target to be achieved. According to Ngadiyono (2013), one of the maintenance objectives is to ensure that the necessary equipment is optimally available and suitable to meet the planned production activities so that the production process can achieve maximum investment returns. A well-organized maintenance system is needed to support the smooth production process of the production machinery used.

A well-organized maintenance system will have an impact on the sustainability of the production system. The sustainability of a more assured production system can be achieved in various ways, one of which is by paying attention to the machines' reliability in the production process. Machine accuracy is one of the most critical factors in ensuring the smoothness of the production process and the quality of the products produced. Machine reliability can help predict the ability of a machine component to function following the desired purpose within a certain period (Purba et al., 2021).

PT XYZ is a company in the petrochemical industry that produces chemicals from natural gas. PT XYZ involves various production units consisting of various machines or production facilities in producing these products. One of the PT XYZ production units with various production facilities is the Steam System Area. The unit is an area that provides Boiler Feed Water (BFW). This area has 14 pumps supporting the chemical flow process, which have different capacities. This pump is essential in providing the Boiler Feed Water (BFW) needed to produce steam. Steam is needed in every production process and utility in the company, especially in driving turbines and power generators as one of the sources of electricity used by the company. If the steam supply process is disrupted, it will hamper the production and utility processes that

take place so that the source of electrical energy needed by the company is not optimally accommodated.

The time the equipment is inoperable is called downtime (Dhillon, 2002). The total downtime of all pumps in the Steam System Area of PT XYZ in 2017 – 2022 reached 15,000 hours. Those show that pumps in this area often fail. Frequent failures in a pump indicate that the maintenance system that applies to the pump is still not optimal. The non-optimality of the maintenance system will cause the pump to be damaged more often. Pumps increasingly experiencing damage will interfere with providing steam the company needs as a source of electrical energy so that ongoing production activities can be hampered. Optimizing this pump maintenance system needs to be done direct so that downtime can be minimized and the applicable maintenance system can occur more optimally.

The maintenance system that applies at PT XYZ is in the form of Preventive Maintenance and Corrective Maintenance. Corrective Maintenance (CM) occurs when the pump is damaged, requiring component replacement. The implementation of CM is still being determined because damage to equipment can occur at any time. Meanwhile, Preventive Maintenance (PM) is carried out regularly four times yearly. PM activities include checking the condition of the equipment, such as cleaning components, providing grease, and others. Both maintenance activities have the same sequence of activities. These activities include notification of work orders for equipment damage, checking by the supervisor, briefing the mechanic by the supervisor, making a work permit, carrying out repairs, and testing the equipment. Implementing these maintenance activities needs to be studied further to optimize the time required for each maintenance activity.

Based on the existing problems, a reliability analysis of the pumps in the Steam System Area of PT XYZ needs to be carried out. Reliability analysis will help the company know the pump's reliability level and maintenance time interval. The company can determine the best decision on handling the pump if the level of reliability is

known. In addition, identification needs to be done on a more extensive system, namely the maintenance system. The maintenance system consists of several activities carried out to carry out maintenance activities. Identification is done by using Maintenance Value Stream Mapping (MVSM). MVSM helps in evaluating the current maintenance system. That way, the company can optimize the current maintenance system based on the activities that make up the maintenance activities at PT XYZ.

2. METHODS

2.1. Reliability

Reliability reflects the state or condition of a facility. These conditions can be positive or negative. Reliability involves using statistical methods to measure and understand the condition and performance of equipment owned by the company. Those allow the company to make predictions and decisions regarding decisions regarding the maintenance and treatment of the equipment. According to Ebeling (1997), reliability is generally defined as the likelihood that a system will perform its intended function for a specified period under a specified set of conditions. The times below represent a specific set of conditions.

Calculating the reliability of a component or equipment begins with determining the failure distribution model of a component or equipment expressed statistically. Distributions that are commonly used in calculating the reliability of a component or equipment include the Exponential, Weibull, Lognormal, and Normal distributions. According to Ebeling (1997), the distribution can be identified using least-square curve fitting to obtain damage and repair times. The most common method for calculating least-square curve fitting is the following formula:

- Medium Rank

$$F(ti) = \frac{i-0,3}{n+0,4} \quad (2.1)$$

- Index of Fit

$$= \frac{n \sum x_i y_i - (\sum x_i)(\sum y_i)}{\sqrt{[n(\sum x_i^2) - (\sum x_i)^2][n(\sum y_i^2) - (\sum y_i)^2]}} \quad (2.2)$$

The formula for each distribution is described as follows:

a. Exponential Distribution

The equations used in determining the distribution, parameters, MTTR and reliability of this distribution include:

$$Xi = ti \quad (2.3)$$

$$Yi = \ln \left(\frac{1}{1-F(ti)} \right) \quad (2.4)$$

$$\lambda = \frac{n}{T} \quad (2.5)$$

$$MTTR = \frac{1}{\lambda} \quad (2.6)$$

$$R(t) = e^{-\lambda t} \quad (2.7)$$

b. Weibull Distribution

The equations used in determining the distribution, parameters, MTTR and reliability of this distribution include:

$$Xi = \ln ti \quad (2.8)$$

$$Yi = \ln \left(\frac{1}{1-F(ti)} \right) \quad (2.9)$$

$$\beta = \frac{n \sum x_i y_i - (\sum x_i)(\sum y_i)}{n \sum x_i^2 - (\sum x_i)^2} \quad (2.10)$$

$$\alpha = \frac{\sum y_i - (\beta)(\sum x_i)}{n} \quad (2.11)$$

$$\theta = e^{\alpha/\beta} \quad (2.12)$$

$$MTTR = \theta \Gamma \left(\frac{1}{\beta} + 1 \right) \quad (2.13)$$

$$R(t) = e^{-\left(\frac{t}{\theta}\right)^\beta} \quad (2.14)$$

c. Normal Distribution

The equations used in determining the distribution, parameters, MTTR and reliability of this distribution include:

$$Xi = ti \quad (2.15)$$

$$Yi = \varphi^{-1}[F(ti)] \quad (2.16)$$

$$\mu = \frac{\sum ti}{n} \quad (2.17)$$

$$\sigma = \sqrt{\frac{\sum (ti - \mu)^2}{n}} \quad (2.18)$$

$$MTTR = \mu = \ln t_{med} \quad (2.19)$$

$$R(t) = 1 - \Phi \left[\frac{t - \mu}{\sigma} \right] \quad (2.20)$$

d. Lognormal Distribution

The equations used in determining the distribution, parameters, MTTR and reliability of this distribution include:

$$Xi = \ln ti \quad (2.21)$$

$$Yi = \varphi^{-1}[F(ti)] \quad (2.22)$$

$$\mu = \frac{\sum \ln(ti)}{n} \quad (2.23)$$

$$s = \sqrt{\frac{\sum (\ln(ti) - \mu)^2}{n}} \quad (2.24)$$

$$t_{med} = e^\mu \quad (2.25)$$

$$MTTR = t_{med} e^{\frac{s^2}{2}} \dots\dots\dots(2.26)$$

$$R(t) = 1 - \Phi \left[\frac{1}{s} \ln \frac{t}{t_{med}} \right] \dots\dots\dots(2.27)$$

Regular inspections are essential to control defect rates, maintain machine performance, and reduce unexpected downtime due to component failure. Those can ultimately avoid increased costs. Based on research conducted by Taufik and Septyani (2015), optimal inspection time can be calculated using the following calculation:

- Average time required for repair

$$\mu = \frac{MTTR}{Average\ Working\ Hours} \dots\dots\dots(2.28)$$

- Average inspection time

$$\frac{1}{i} = \frac{Average\ 1\ time\ maintenance}{Average\ working\ hours\ per\ month} \dots\dots\dots(2.29)$$

- Average time of damage

$$k = \frac{Average\ time\ of\ breakdown}{period\ of\ breakdown} \dots\dots\dots(2.30)$$

- Calculation of inspection frequency

$$n = \sqrt{\frac{k \times i}{\mu}} \dots\dots\dots(2.31)$$

- Maintenance time interval

$$t_i = \frac{Maintenance\ time\ interval}{n} \dots\dots\dots(2.32)$$

2.2. Maintenance Value Stream Mapping

The Maintenance Value Stream Map (MVSM) method is a development methodology of the Value Stream Mapping (VSM) method that is specialized for maintenance activities (Kannan et al., 2007). VSM can assist in visually depicting the flow of the production process as well as identifying waste and sources of waste through the value stream (Rother & Shook, 1999). On the other hand, MVSM aims to map the flow of processes and information in maintenance activities. The results obtained include time that can be categorized as value-added (VA) and non-value-added (NVA), as well as maintenance efficiency.

The MVSM development process involves creating a Current State Map that depicts the company's maintenance process. Maintenance activities are evaluated at this stage to determine whether they provide added value. Time components such as MTTO, MTTR, and MTTY are used as the basis for creating the Current State Map in the creation of the framework (Nainggolan, 2017). Future State Map is the result of improving the Current State Map by eliminating activities that do not provide added

value. This stage is the final stage in the approach using the MVSM method. Using the MVSM method, the percentage increase in maintenance efficiency on components that experience damage that is prioritized (Lukodono et al., 2013) can be calculated. This maintenance efficiency is obtained by comparing the actual maintenance conditions (current state map) with the recommended maintenance (future state map).

Mean Maintenance Lead Time (MMLT) refers to the average time required to perform machine maintenance until the machine can operate normally. Mathematically, MMLT is formulated with the equation (Huda et al., 2015): $MMLT = MTTO + MTTR + MTTY \dots\dots\dots(2.33)$

Description:

MTTO = Mean Time to Organize (Average time required to coordinate tasks to initiate machine or equipment maintenance activities after a breakdown or according to a predetermined schedule)

MTTR = Mean Time to Repair (Average time required to carry out maintenance activities on machinery or equipment)

MTTY = Mean Time to Yield (Average time required to verify readiness to reuse machinery or equipment after the maintenance process)

In the MMLT representation, only MTTR is a time component that provides value to maintenance activities, as only this time is required to perform maintenance or repair on machinery or equipment. Other time components, such as MTTO and MTTY, are considered non-value-added time. Those are shown by the equation (Huda et al., 2015):

$$VA\ time = MTTR \dots\dots\dots(2.34)$$

$$NVA\ time = MTTO + MTTY \dots\dots\dots(2.35)$$

Maintenance efficiency is mathematically calculated by comparing MTTR with MMLT in the following formula (Huda et al., 2015):

$$\%maintenance\ efficiency = \frac{MTTR}{MMLT} \times 100\% \dots\dots\dots(2.36)$$

3. FINDINGS AND DISCUSSION

3.1. Reliability

The calculation of the reliability value is preceded by conducting a data distribution test of each pump. The data distribution test was carried

out on the TTR and TTF data of the pumps in the Steam System Area of PT XYZ, which consisted of five, namely pumps with codes G02-S, G04-I-A, G04-III-A, G04-I-S, and G07-A. An example of calculating the fit index for each distribution is as follows:

- Normal Distribution

$$r = \frac{10(214,21)-(1512)(0)}{\sqrt{[10(240192)-(1512)^2][10(7,53)-(0)^2]}}$$

$$r = \frac{2142,14-0}{\sqrt{[2401920-2286144][75,32-0]}}$$

$$r = \frac{2142,14}{2953,11} = 0,72538$$

- Lognormal Distribution

$$r = \frac{10(1,8163)-(49,8327)(0)}{\sqrt{[10(249,1632)-(49,8327)^2][10(7,5325)-(0)^2]}}$$

$$r = \frac{18,1630-0}{\sqrt{[2491,632-2483,301][75,325-0]}}$$

$$r = \frac{18,1629}{25,0513} = 0,72503$$

- Exponential Distribution

$$r = \frac{10(1538,780)-(1512)(9,2757)}{\sqrt{[10(240192)-(1512)^2][10(14,7617)-(9,2757)^2]}}$$

$$r = \frac{15387,8-14024,88}{\sqrt{[2401920-2286144][147,6166-86,0389]}}$$

$$r = \frac{1362,9197}{2670,0594} = 0,51045$$

- Weibull Distribution

$$r = \frac{10(47,3695)-(49,8327)(9,2757)}{\sqrt{[10(249,1632)-(49,8327)^2][10(14,7617)-(9,2757)^2]}}$$

$$r = \frac{15387,8-14024,88}{\sqrt{[2491,6320-2483,301][147,6167-86,0389]}}$$

$$r = \frac{11,4609}{22,6502} = 0,50600$$

The results of the index of fit value of TTR and TTF for entire pump can be seen in the Table 1 and Table 2.

Table 1. Index of Fit of TTR Data

Pump	Normal	Lognormal	Eksponential	Weibull
G02-S	0,72694	0,72543	0,86092	0,86272
G04-I-A	0,64232	0,81252	0,75274	0,78483
G04-III-A	0,72538	0,72503	0,51045	0,50600
G04-I-S	0,78523	0,78651	0,42181	0,41167
G07-A	0,9365	0,93470	0,85555	0,86453

Table 2. Index of Fit of TTF Data

Pump	Normal	Lognormal	Eksponential	Weibull
G02-S	0,93685	0,97642	0,99068	0,99953
G04-I-A	0,97282	0,96007	0,97783	0,81287

Pump	Normal	Lognormal	Eksponential	Weibull
G04-III-A	0,92661	0,96541	0,96612	0,90147
G04-I-S	0,97607	0,94834	0,96527	0,77197
G07-A	0,93650	0,90016	0,85875	0,80783

The appropriate data distribution type is continued by calculating the parameter values used in each data. Calculating parameter values in TTR data is needed to obtain the average repair or MTTR value used in calculating maintenance time intervals and repair activity times in the details of maintenance activities in MVSM. Calculating parameter values in TTF data is needed to obtain parameter values in calculating reliability values. The results of the calculation parameter values of each type of pump data distribution can be seen in the Table 3.

Table 3. Pump Distribution Parameters

Pump	Data	Distribution	Parameter
G02-S	TTR	Weibull	$\alpha =$ -4,5196
			$\beta =$ 0,9975
			$\theta =$ 92,8527
	TTF	Weibull	$\alpha =$ -13,2315
			$\beta =$ 1,5960
			$\theta =$ 3985,2575
G04-I-A	TTR	Lognormal	$\mu =$ 4,9993
			$s =$ 0,4996
	TTF	Eksponential	$t_{med} =$ 148,3075
G04-III-A	TTR	Normal	$\lambda =$ 0,000597
			$\mu =$ 151,2
	TTF	Eksponential	$\sigma =$ 34,0259
G04-I-S	TTR	Lognormal	$\lambda =$ 0,000341
			$\mu =$ 5,0152
			$s =$ 0,2721
	TTF	Normal	$t_{med} =$ 150,6884
			$\mu =$ 1291,5
			$\sigma =$ 1524,31
G07-A	TTF	Normal	$\mu =$ 12688
			$\sigma =$ 7323,6406
	TTR	Lognormal	$\mu =$ 5,1533
			$s =$ 0,1649
			$t_{med} =$ 173,0024

The Mean Time to Failure (MTTR) value is calculated using a formula according to the type of distribution of each data. MTTR G02-S uses the formula in Equation 2.13. MTTR G04-I-A, G04-I-S, and G07-A use the formula in Equation 2.26. MTTR G04-III-A uses the formula in Equation 2.19. The recapitulation of MTTR

calculations for the entire pumps can be seen in Table 4.

Table 4. MTTR

Pump	MTTR (hour)	MTTR (hour)
G02-S	92,9521	3,87
G04-I-A	168,020	7,00
G04-III-A	151,20	6,30
G04-I-S	156,3708	6,52
G07-A	175,3706	7,31
Average	148,7827	6.20

The reliability value of the equipment is calculated by adjusting the type of data distribution obtained. The reliability value of pump G02-S can be calculated using the formula in Equation 2.14. The reliability value of pumps G04-I-A and G04-III-A can be calculated using the formula in Equation 2.7. The reliability value of the G04-I-S and G07-A pumps can be calculated using the formula in Equation 2.20. The results of the reliability value of each pump can be seen in Table 5.

Table 5. Index of Fit of TTF Data

Pump	Reliability Value
G02-S	43,15%
G04-I-A	45,59%
G04-III-A	52,20%
G04-I-S	50,19%
G07-A	47,09%

Based on Table 5, it is known that the pump reliability value in the PT XYZ Steam System Area from the highest to the lowest is pump G04-III-A of 52.20%, G04-I-A of 45.59%, G04-I-S of 50.19%, G07-A of 47.09%, and G02-S of 43.15%. These results show that the pump's performance in the process has decreased. Those are what underlie the many failures that occur in the pump. The number of failures that occur makes the pump downtime in the Steam System Area of PT XYZ will continue to increase. Failures that occur can be optimized by

performing proper routine maintenance of each pump. Determination of the maintenance time interval can be done using the formula in Equations 2.28 - 2.32. The results of the maintenance time interval of each pump can be seen in Table 6.

Table 6. Maintenance Time Interval

Pump	Mtc. Interval (hour)	Days
G02-S	1194,88	49
G04-I-A	749,03	31
G04-III-A	1077,60	44
G04-I-S	840,49	35
G07-A	1834,97	76

The implementation of routine maintenance at PT XYZ is currently carried out every four months or about 120 days for each piece of equipment. A comparison of the current maintenance time interval with the results of the previous reliability calculation can be seen in Table 7.

Table 7. Comparison Maintenance Time Intervals

Pump	Existing Mtc. Time (day)	Mtc. Time Recommendation (day)	Mtc. Time Difference (day)
G02-S	120	86	34
G04-I-A	120	31	89
G04-III-A	120	45	75
G04-I-S	120	34	86
G07-A	120	76	44

3.2 Maintenance Value Stream Mapping

The Maintenance Value Stream Mapping (MVSM) stage begins with creating a Current State Map diagram based on activity data and pump maintenance activity time at PT XYZ. The Current State Map diagram of pump maintenance activities at PT XYZ can be seen in Figure 1. The results of observations of pump maintenance activities at PT XYZ based on the Current State Map diagram are summarized in Table 8.

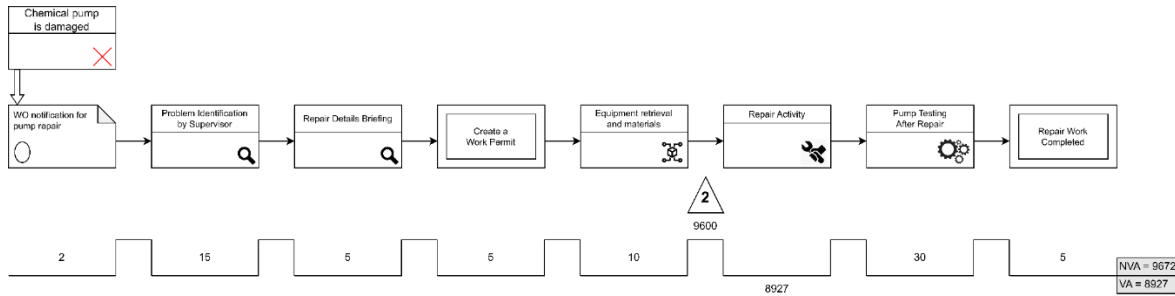


Figure 1. Current State Map

Table 8. Observations Maintenance Activities

No.	Maintenance Activity Details	Duration (minute)	MMLT Categories	Activity Categories
1	Work Order (WO) notification is issued by the operator through SAP.	2	MITO	NVA
2	Problem identification by Supervisor based on WO	15	MITO	NVA
3	Supervisor directs mechanics on repair details	5	MITO	NVA
4	Making work permit by mechanic	5	MITO	NVA
5	Retrieval of repair materials and equipment	10	MITO	NVA
6	Delay due to material unavailability	9600	MITO	NVA
7	Repair activities by mechanics	8927	MTTR	VA
8	Operator testing of tools	30	MTTY	NVA
9	Validation of completed improvements to WO	5	MITO	NVA
		9642	Jumlah (MMLT)	
		8927		
		30		18599

The calculation of VA, NVA, and maintenance efficiency activity time is described in the following points:

- Value-Added Time

$$VA \text{ time} = MTTR$$

$$VA \text{ time} = 8927 \text{ minutes}$$

- Non-Value-Added Time

$$NVA \text{ time} = MTTO + MTTY$$

$$NVA \text{ time} = 9642 + 30$$

$$NVA \text{ time} = 9672 \text{ minutes}$$

- Maintenance Efficiency

$$\% \text{Maintenance Efficiency} = \frac{MTTR}{MMLT} \times 100\%$$

$$\% \text{Maintenance Efficiency} = \frac{8927}{18599} \times 100\%$$

$$\% \text{Maintenance Efficiency} = 47,9972\% \sim 48\%$$

Based on these calculations, the value-added time is 8927 minutes, the non-value-added time is 9672 minutes, and the percentage of maintenance efficiency is 48%. Those need further identification to determine the cause of the hampered pump maintenance activity implementation time. The causes of hampered maintenance activities can be identified using a fishbone diagram or cause-and-effect diagram. The results of the cause-and-effect diagram can be seen in Figure 2.

The results of the cause-and-effect diagram analysis can be used as a reference in providing improvement recommendations. Improvement recommendations are made to increase the value of maintenance efficiency by reducing or eliminating the time of current repair implementation activities. Based on the current maintenance activities, delays can occur when materials are unavailable in the warehouse during maintenance implementation. The causes of delay based on material factors on the cause-and-effect diagram are materials that are not yet available and materials that have not been inspected. The improvement recommendations given based on the causes of delay from the material factor are described in Table 9.

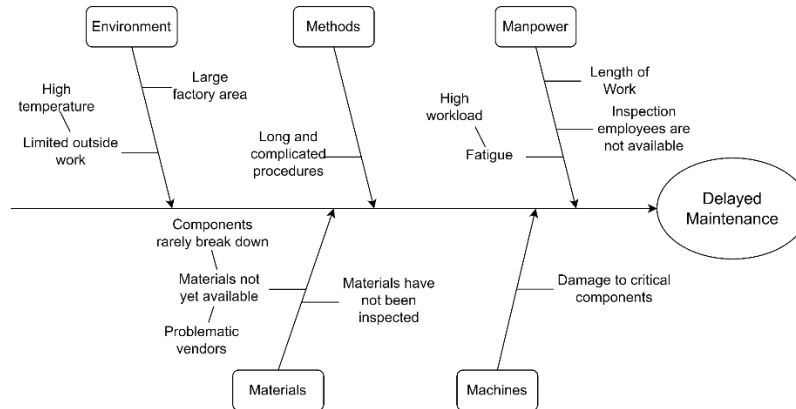


Figure 2. Cause & Effect Diagram of Delayed Maintenance

Table 9. Observation of Future

Factor	Causes	Recommended Action
Material	Materials not yet available	Estimating material time needed based on previous repair history
		Estimate the purchase time according to the timeliness of the vendor completing the order
		Change vendors who violate the agreement
	Material has not been inspected	Materials that are classified as safe and easy to inspect can be directly assigned
		Reconfirm the inspection schedule so that it can be completed before the implementation of the repair.
		Increase manpower in the inspection department

Delays can be eliminated by implementing the improvement recommendations given. The elimination of the delay time is used as a reference in making the Future State Map diagram and calculating the maintenance efficiency of the pump maintenance implementation at PT XYZ. The Future State Map diagram and the results of observations of future maintenance activities can be seen in Figure 3 and Table 10.

Table 10. Observation of Future

No.	Maintenance Activity Details	Duration (minute)	MMLT Categories	Activity Categories
1	Work Order (WO) notification is issued by the operator through SAP.	2	MTTO	NVA
2	Problem identification by Supervisor based on WO	15	MTTO	NVA
3	Supervisor directs mechanics on repair details	5	MTTO	NVA
4	Making work permit by mechanic	5	MTTO	NVA
5	Retrieval of repair materials and equipment	10	MTTO	NVA
6	Repair activities by mechanics	8927	MTTR	VA
7	Operator testing of tools	30	MTTY	NVA
8	Validation of completed improvements to WO	5	MTTO	NVA
MTTO		9642		42
MTTR		8927		8927
MTTY		30		30

The calculation of VA activity time, NVA, and maintenance efficiency after the

recommendation is made is described in the following points:

- Value-Added Time

$$VA\ time = MTTR$$

$$VA\ time = 8927\ minutes$$

- Non-Value-Added Time

$$NVA\ time = MTTO + MTTY$$

$$NVA\ time = 42 + 30$$

$$NVA\ time = 72\ minutes$$

- Maintenance Efficiency

$$\%Maintenance\ Efficiency = \frac{MTTR}{MMLT} \times 100\%$$

$$\%Maintenance\ Efficiency = \frac{8927}{8999} \times 100\%$$

$$\%Maintenance\ Efficiency = 99,1999\% \sim 99\%$$

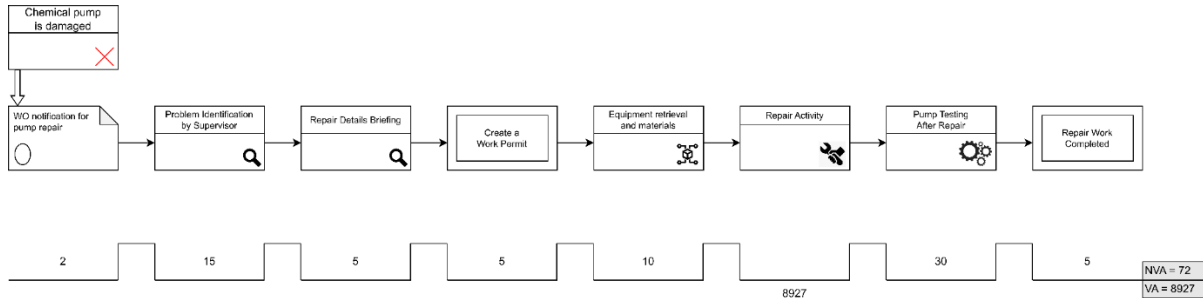


Figure 3. Future State Map

3.3 Discussion

Based on the reliability results, the maintenance interval times of G02-S, G04-I-A, G04-III-A, G04-I-S, and G07-A are 49 days, 31 days, 44 days, 35 days, and 76 days, respectively. There needs to be more than the current maintenance time interval (120 days) to meet the maintenance needs of each pump. Those are shown in the difference between the current maintenance time, which is different from the recommended maintenance time from calculating the maintenance time interval for each pump. Improper implementation of routine maintenance can accelerate the decline in pump reliability so that downtime will increase. The recommended maintenance time interval can be considered to optimize the pump maintenance time.

Based on the results of the MVSM recommendations provided, the value-added time is 8927 minutes, the non-value-added time is 72 minutes, and the percentage of maintenance efficiency is 99%. Changes occur in non-value-added time due to improvement recommendations in the form of time delays that are eliminated by estimating the time the material is needed and the time to purchase. A comparison of the value of the time component and maintenance efficiency between previous maintenance activities and after

recommendations are made can be seen in Table 11.

Table 11. Comparison of Current and Future State

	VA Time (minute)	NVA Time (minute)	%Mtc. Efficiency
Current	8927	9672	51%
Future	8927	72	99%

These improvement recommendations have an impact on non-value-added time which is getting lower from the previous 9672 minutes to 72 minutes. The maintenance efficiency value has also increased by 51% from the previous maintenance efficiency.

4.CONCLUSION AND SUGGESTION

4.1 Conclusions

The value of pump reliability in the PT XYZ Steam System Area from the highest to the lowest is pump G04-III-A at 52.20%, G04-I-A at 45.59%, G04-I-S at 50.19%, G07-A at 47.09%, and G02-S of 43.15%. These results show that the pump's performance in the process has decreased. This is what underlies the many failures that occur in the pump.

Evaluation of the pump maintenance system in the Steam System Area of PT XYZ with Maintenance Value Stream Mapping (MVSM) provides an overview of the Current State Map with the results of the current maintenance

efficiency percentage of 19.88% with a core maintenance activity time of 8927 minutes and other activity time of 9672 minutes. Recommendations are given in the form of delay time elimination which results in a Future State Map picture with an increase in the percentage of maintenance efficiency by 51%, and non-value-added time has decreased by 9600 minutes from the previous maintenance implementation.

Based on the reliability results of the pumps in the Steam System Area of PT XYZ, the recommendation is to provide recommendations for routine maintenance schedules. Routine maintenance schedules are carried out by calculating maintenance time intervals. The maintenance time intervals for pumps G02-S, G04-I-A, G04-III-A, G04-I-S, and G07-A are every 49 days, 31 days, 44 days, 35 days, and 76 days respectively. Based on the results of MVSM to the current pump maintenance system at PT XYZ, recommendations are in the form of eliminating the delay time that occurs when the material is unavailable, which is done by estimating the time the material is needed and the previous purchase time. Based on the results of calculating the reliability value and MVSM, the maintenance system on the pump in the Steam System Area of PT XYZ can be optimized.

4.2 Suggestions

The company is expected to consider implementing the recommendations given. The results showed that these recommendations make the maintenance system in the Steam System Area of PT XYZ more optimal, especially in terms of maintenance time.

Time constraints and company privacy caused this research not to discuss costs. Therefore, further research is expected to analyze costs so that the implementation of maintenance at PT XYZ can produce a more optimal system. Cost factors need to be analyzed so that companies can optimize the expenses needed to implement maintenance. That way, the maintenance system takes place more efficiently.

References

Damanik, G.M., Soekarno, S. and Suryaningrat, I.B. (2020), "Perancangan Sistem Perawatan Komponen V-Belt Pada Sistem Transmisi Dengan Metode RCM Dan MVSM (Studi Kasus PT Perkebunan Sentool Zidam V/Brawijaya Jember)", *Jurnal Teknik*

- Pertanian Lampung*, Vol. 9 No. 4, pp. 287–296, doi: 10.23960/jtep-l.v9.i4.287-296.
- Darusman, I. (2017), "Usulan Waktu Perawatan Bus Berdasarkan Kendalan Suku Cadang Kritis Di PT. Suryaputra Adirpradana", *UNIKOM Repository*.
- Dhillon, B.S. (2002), *Engineering Maintenance: A Modern Approach*, CRC Press, Boca Raton.
- Ebeling, C.E. (1997), *An Introduction to Reliability and Maintainability Engineering*, edited by Munson, E.M. and Morriss, J.M., British Library Document Supply Centre, West Yorkshire.
- Gaspersz, V. (2002), *Total Quality Management*, PT Gramedia Pustaka Utama, Jakarta.
- Huda, A.T.N., Novareza, O. and Andriani, D.P. (2015), "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*, Vol. 3 No. 2.
- Lukodono, R.P., Pratikto and Soenoko, R. (2013), "Analisis Penerapan Metode RCM Dan MVSM Untuk Meningkatkan Keandalan Pada Sistem Maintenance (Studi Kasus PG. X) Mahasiswa Jurusan Teknik Mesin Program Magister Fakultas Teknik UB 1)", *Jurnal Rekayasa Mesin*, Malang, Vol. 4 No. 1, pp. 43–52.
- Nainggolan, E. (2017), "Penerapan Metode Reliability Centered Maintenance Menggunakan Software SPSS pada Sistem Pendingin Generator Mitsubishi Kapasitas 62500 kVA", *Repository Institusi Universitas Sumatera Utara*.
- Nasution, M.N. (2005), *Manajemen Mutu Terpadu (Total Quality Management)*, PT Gramedia Pustaka Utama, Jakarta.
- Ngadiyono, Y. (2013), *Pemeliharaan Mekanik Industri*, 1st ed., Deepublish, Yogyakarta.
- Nursanti, E., Avief, S., Sibut and Kertaningtyas, M. (2019), *Maintenance Capacity Planning: Efisiensi & Produktivitas*, Dream Litera Buana, Malang.
- Oktalisa, P., Matondang, N. and Ishak, A. (2013), "Perancangan Sistem Perawatan Mesin Dengan Pendekatan Reliability Engineering Dan Maintenance Value Stream Mapping (MVSM) Pada PT XXX", *Jurnal Teknik Industri FT USU*, Vol. 3 No. 1, pp. 52–56.
- Pranowo, I.D. (2019), *Sistem Dan Manajemen Pemeliharaan (Maintenance: System and*

- Management*), 1st ed., Deepublish, Yogyakarta.
- Purba, S., Parinduri, L. and Harahap, B. (2021), “Penentuan Interval Waktu Preventif Maintenance pada Mesin Open Top Roller Menggunakan Metode Reliability Centered Maintenance di Unit Pabrik Teh Kebun Tobasari PT. Perkebunan Nusantara IV”, *Cetak) Buletin Utama Teknik*, Online, Vol. 16 No. 2, pp. 1410–4520.
- Ramadhan, M.A.Z. and Sukmono, T. (2018), “Penentuan Interval Waktu Preventive Maintenance Pada Nail Making Machine Dengan Menggunakan Metode Reliability Centered Maintenance (RCM) II”, *PROZIMA (Productivity, Optimization and Manufacturing System Engineering)*, Universitas Muhammadiyah Sidoarjo, Vol. 2 No. 2, pp. 49–57, doi: 10.21070/prozima.v2i2.1349.
- Rambuna, O. (2019), “Penerapan Metode Reliability Centered Maintenance (RCM) pada Mesin Produksi Obat-Obatan [XYZ]”, *Jurnal Valtech*, Malang, Vol. 2 No. 2, pp. 117–123.
- Sari, N.S. (2017), *PERENCANAAN ULANG INSTALASI POMPA AIR BERSIH PADA GEDUNG PUSAT RISET ITS SURABAYA*, Surabaya.
- Sugiyono. (2016), *Metode Penelitian Kuantitatif, Kualitatif Dan R&D*, PT Alfabet, Bandung.
- Taufik dan Septyani, S. (2015), “Penentuan Interval Waktu Perawatan Komponen Kritis pada Mesin Turbin di PT PLN (Persero) Sektor Pembangkit Ombilin”, *Jurnal Optimasi Sistem Industri*, Vol. 14 No. 2, pp. 238–258.