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Analysis of Machine Maintenance System using Preventive Maintenance Method with Always Better Control (Abc) Classification and Modular Design

Mohammad Fadhli
Industrial Engineering
Universitas Pembangunan Nasional "Veteran" Jawa Timur
Surabaya
muhammadfadhli.dil@gmail.com

Joumil Aidil Saifuddin Z.S
Industrial Engineering
Universitas Pembangunan Nasional "Veteran" Jawa Timur
Surabaya
joumilaidil.ti@upnjatim.ac.id

Yekti Condro Winursito
Industrial Engineering
Universitas Pembangunan Nasional "Veteran" Jawa Timur
Surabaya
yekti.condro.ti@upnjatim.ac.id

Abstract— Companies must pay special attention to the machines used to make goods because if the machine is damaged, the resulting product will be damaged or the product will take a long time in the production process. By performing regular machine maintenance, companies can maintain and extend the service life of the machine. PT XYZ is a company in Indonesia that has an installed production capacity of 29 million tons of cement per year. The company uses a continuous production system, namely ensuring that all machines are in good condition so that the production process does not experience delays or losses. The results of observations show that the packer operation is the production process with the longest waiting time, with the Roto packer 638PM1 being the machine with the longest waiting time. Corrective and preventive maintenance are two types of maintenance currently used, and the current preventive maintenance strategy is currently suboptimal. This study aims to develop an efficient preventive maintenance system by providing preventive maintenance recommendations using the design modularity method and the Always Better Control (ABC) classification. By combining the classification of machines between critical levels and the utility value of each machine component, operational efficiency will increase, the risk of production disruptions caused by critical component shortages and unnecessary storage costs will be reduced. By applying this method, the total maintenance cost incurred is Rp. 771,782,456, this result has a difference of Rp. 406,113,204 smaller than the total maintenance cost currently used by the company, which is Rp. 1,177,895,660. The results demonstrate that the proposed maintenance method is effective and feasible, achieving a 34.47% cost efficiency improvement over the company's current maintenance system.

Keywords—Preventive Maintenance, Modularity Design, Always Better Control, Roto Packer Machine

I. Introduction

The development of the current industrial world, competition between business actors is getting tighter. As a result, companies must increase the efficiency and effectiveness of their production processes, one of which is by carrying out proper machine maintenance so that the machines can function properly and optimally [1]. PT XYZ is a company engaged in the cement industry in Indonesia, which controls around 42% of the domestic market share. PT XYZ uses a continuous process production system, in this production system the company demands that all machines are in good condition, so that the production process does not experience delays or losses [2]. The cement production process at PT XYZ is divided into several main stages, starting from the destruction of raw materials (crusher process), to product packaging (packer operation process).

Based on the observation results, it was found that the production process that had the highest Downtime level was the packer operation process. The researcher conducted observations on the packer operation section of PT XYZ. In the packer operation section owned by the company, they still face various problems related to machine maintenance which cause frequent damage and downtime. The less structured maintenance system and the absence of an effective classification of machine components make it difficult for the company to determine maintenance priorities. The packer operation includes eight Roto Packer machines (631PM1 to 638PM1), among which 638PM1 recorded the highest downtime of 16,518 minutes in one year. As a result, productivity in the packer operation decreased by 0.10%, contributing to the failure to achieve the planned production target and increasing overall operational costs.

In the application of modular design, maintenance of machine components is carried out using a maintenance module which is a combination of several components, this will certainly save the use of machine maintenance time, labor requirements, so that it can increase machine productivity [3]. In addition, the application of modular design to the maintenance system can also increase maintenance efficiency and reduce repair time [4]. However, PT XYZ has not yet implemented an integrated approach combining component classification and modular maintenance design. This study aims to address that gap in order to improve operational efficiency, reduce the risk of production disruption due to shortages of critical components, and minimize unnecessary storage costs [5].

II. RELATED WORKS

A. Maintenance System

The maintenance system is all activities performed on equipment (materials) to maintain or restore the equipment's ability to provide services [6]. In industrial discussions, maintenance can also be interpreted as the maintenance of components or machines and renewing their service life when they are considered unusable or damaged [7]. To ensure that machines or equipment can be used continuously to ensure production continuity, the following maintenance activities are needed, Checking activities, Lubrication, Repair of existing damages, and Adjustment/replacement of spare parts or components [8].

B. Types of Maintenance

1) Planned Maintenance

Is planned maintenance, control and recording according to a predetermined plan. Planned maintenance consists of three forms of implementation, namely:

a) Preventive maintenance is a maintenance activity conducted to prevent damage to production facilities during the production process.
b) Corrective maintenance is a maintenance activity performed after damage or negligence occurs to the machine/equipment, causing it to malfunction.
c) Predictive maintenance is a maintenance action executed on a specified date based on predictions derived from the analysis and evaluation of operational data, such as vibration, temperature, flow rate, and others.

2) Unplanned Maintenance

Is usually in the form of breakdown/emergency maintenance, which is a maintenance action performed when the machine/equipment is damaged and can no longer function. Through this maintenance, it is expected to extend the life of the machine/equipment and can reduce the frequency of damage.

3) Autonomous Maintenance

Is an effort to increase machine productivity and efficiency through activities performed by operators to maintain the machines they handle themselves [9].

C. Always Better Control (ABC) Classification

Always Better Control (ABC) analysis is a method of classifying goods based on the value ranking from the highest to the lowest value, and is divided into 3 large groups called groups A, B and C. Always Better Control (ABC) analysis divides inventory into three classes based on the value generated by the inventory [10]. ABC analysis is a concept that uses the Pareto principle. This principle states that critical view and trivial many. This principle teaches to focus inventory control on types of inventory that are high value or critical rather than low value or trivial[11]. The classification of Always Better Control (ABC) is as follows:

- **Class A** is goods that provide high value. Although group A is only represented by 10% of the total inventory, the value given is 15% - 30%.
- **Class B** is goods that provide moderate value. This class B inventory group is represented by 30% of the total inventory and the value generated is 5% - 15%.
- **Class C** is goods that provide low value. Class C inventory group is represented by 50% of the total existing inventory and the value generated is 1% - 5% [12].

D. Modularity Design

Modularity is the basis for general use in fast systems, quick repair and/or replacement. With system modularity, the cost in storage and management can be effectively reduced because the module resources are much less than the component resources. In addition, the system downtime in maintenance can also be shortened so that production losses can be reduced reasonably [13]. Along with the advancement of system modularity, parts that have high correlation in function and/or complicated procedures in assembly will be combined as isolated modules. With a modular design, the manufacturing and assembly process will be simpler and cheaper [14].

The main principle of implementing modular design in industry is to minimize downtime, reduce maintenance costs, and increase production flexibility. With this approach, modular design not only improves machine maintenance efficiency but also helps companies achieve continuous improvement in their operations [15].

E. Calculation of Maintenance Costs

Cost calculation is based on component replacement cost, production loss cost and also technician (operator) cost [16]. Cost calculation itself is divided into two, namely:

1) Calculation of Preventive Costs (Cp)

The costs used in the preventive cost calculation are labor costs and replacement of spare parts on components that are focused on determining the expected cost value. These costs are added up to determine the total cost of the maintenance activities performed. [17].

2) Calculation of Cost of Failure (Cf)

The costs used in the failure cost calculation are labor costs, replacement of spare parts on the focused component and the cost of production losses caused by damage to the component [18].

F. Total Maintenance Costs

Maintenance costs consist of raw material maintenance costs, maintenance labor costs [19]. Maintenance costs can also be understood as costs arising from equipment maintenance and care so that work can run normally [20]. The total maintenance cost using the modularity design method can be found using the Weibull distribution, with the formula:

$$TC = \frac{C_f}{\eta^\beta} TM^{\beta-1} + \frac{C_p}{TM} \quad (1)$$

From the calculation of Total Cost using the Modular Design method or the initial calculation of the company's Total Cost, the final step is to calculate the comparison of the proposed maintenance costs with the company's maintenance costs, which can be formulated as follows:

$$\text{Efficiency} = \frac{TC\ Company - TC\ Proposed}{TC\ Company} \text{ x } 100\% \qquad (2)$$

III. METHOD

A. Data Collection Methods

To support the research being conducted, some data is needed which will later be used to analyze the problems that occur and this data is obtained from:

1) Literature Study

A method of collecting data by studying literature that is relevant to the problem being faced so that references are obtained that support or strengthen the research results obtained.

2) Field Study

A method of collecting data by conducting a direct survey to the factory location which aims to identify the problems being faced. The data obtained are as follows:

a) Machine and component data
b) Critical sub-component data of the 638PM1 roto packer machine
c) Damage time data
d) Repair time data
e) Component purchase price
f) Labor costs, product prices, and employee salaries
g) Maintenance costs at the Company

B. Data Processing Method

Data processing will be done when the required data has been collected. Data processing aims to resolve and discuss the problems being analyzed. Steps taken data processing are:

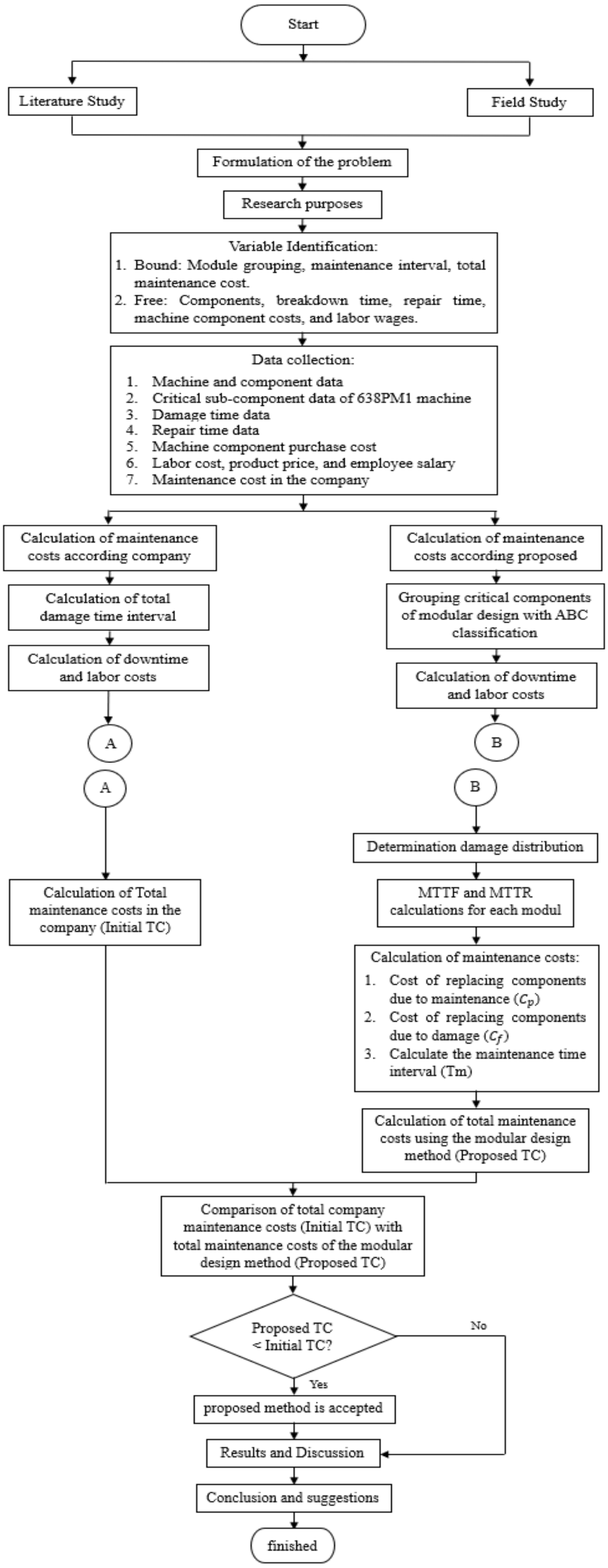

Fig 1. Flowchart

IV. RESULT AND DISCUSSION

A. Calculation of Maintenance Costs in the Company (Initial TC)

1) Determination of Critical Components of Roto Packer Machine 638PM1

Based on the Roto Packer 638PM1 machine components, there are several critical sub-components in each of these components, including:

Tabel 1. Critical Sub Components of Roto Packer Machine 638PM1

Machine Unit	Machine Components	Critical Sub-Components
Roto Packer Unit	Motor	Stator-rotor
		Bearing
		Winding
	Spout Filling	Nozzle
		Load Cell
Conveyor Unit	Gear Box	Coupling
		Oil Seal
	Belt Conveyor	Belt
		Proximity Sensor

2) Sub Component Maintenance Costs in Companies

Based on data obtained from the company, information regarding the total maintenance of the 638PM1 roto packer machine components is presented in the following table:

Tabel 2. Maintenance Cost Data in Companies

No	Machine Components	Sub-Components	1 Year Maintenance Cost (January – December 2024)
1	Motor	Stator-rotor	Rp. 91.729.115
		Bearing	Rp. 115.960.460
		Winding	Rp. 79.963.450
2	Spout Filling	Nozzle	Rp. 27.246.805
		Load Cell	Rp. 10.715.640
3	Gear Box	Coupling	Rp. 19.465.850
		Oil Seal	Rp. 18.200.433
4	Belt Conveyor	Belt	Rp. 27.812.200
		Proximity Sensor	Rp. 53.632.048
TOTAL			**Rp. 444.726.001**

3) Calculation of Downtime Costs and Labor Costs

Tabel 3. Losses of Each Sub Component

No	Component	Damaged Sub-Component	Losses Due to Downtime (Rp)	Operator Fees (Rp)	Mechanical Fees (Rp)
1	Belt Conveyor	Proximity Sensor	2.175.000	1.389.984	2.871.000
2	Motor	Stator-rotor	2.985.000	1.907.634	3.940.200
3	Motor	Winding	7.710.000	4.927.255	10.177.200
4	Belt Conveyor	Proximity Sensor	2.355.000	1.505.018	3.108.600
5	Motor	Winding	9.090.000	5.809.177	11.998.800
6	Gear Box	Oil Seal	3.915.000	2.501.972	5.167.800
7	Spout Filling	Load Cell	3.255.000	2.080.184	4.296.600
8	Belt Conveyor	Proximity Sensor	2.970.000	1.898.048	3.920.400
9	Spout Filling	Load Cell	2.985.000	1.907.634	3.940.200
10	Belt Conveyor	Proximity Sensor	2.715.000	1.735.084	3.583.800
11	Motor	Winding	7.725.000	4.936.842	10.197.000
12	Belt Conveyor	Proximity Sensor	2.745.000	1.754.256	3.623.400
13	Gear Box	Coupling	4.155.000	2.655.350	5.484.600
14	Belt Conveyor	Belt	2.670.000	1.706.326	3.524.400
15	Belt Conveyor	Belt	2.805.000	1.792.601	3.702.600
16	Spout Filling	Nozzle	2.490.000	1.591.293	3.286.800
17	Motor	Stator-rotor	4.365.000	2.789.555	5.761.800
18	Gear Box	Oil Seal	3.480.000	2.223.975	4.593.600
19	Motor	Bearing	7.800.000	4.984.772	10.296.000
20	Motor	Winding	8.115.000	5.186.080	10.711.800

No	Component	Damaged Sub-Component	Losses Due to Downtime (Rp)	Operator Fees (Rp)	Mechanical Fees (Rp)
21	Gear Box	Coupling	3.945.000	2.521.144	5.207.400
22	Motor	Bearing	7.935.000	5.071.047	10.474.200
23	Spout Filling	Nozzle	3.390.000	2.166.459	4.474.800
24	Belt Conveyor	Proximity Sensor	1.890.000	1.207.849	2.494.800
25	Motor	Bearing	8.295.000	5.301.113	10.949.400
26	Motor	Bearing	6.975.000	4.457.537	9.207.000
27	Belt Conveyor	Belt	3.075.000	1.965.151	4.059.000
28	Spout Filling	Nozzle	3.720.000	2.377.353	4.910.400
29	Motor	Stator-rotor	3.720.000	2.377.353	4.910.400
30	Motor	Bearing	8.175.000	5.224.425	10.791.000
31	Belt Conveyor	Belt	3.825.000	2.444.456	5.049.000
32	Motor	Stator-rotor	4.860.000	3.105.896	6.415.200
33	Gear Box	Coupling	3.540.000	2.262.320	4.672.800
34	Gear Box	Oil Seal	3.195.000	2.041.839	4.217.400
35	Motor	Bearing	7.965.000	5.090.219	10.513.800
36	Motor	Bearing	7.185.000	4.591.742	9.484.200
37	Motor	Bearing	7.830.000	5.004.000	10.335.600
38	Motor	Winding	9.105.000	5.818.763	12.018.600
39	Motor	Bearing	7.665.000	4.898.497	10.117.800
40	Spout Filling	Nozzle	2.595.000	1.658.395	3.425.400
41	Motor	Bearing	7.395.000	4.725.947	9.761.400
42	Belt Conveyor	Proximity Sensor	1.815.000	1.159.918	2.395.800
43	Gear Box	Coupling	3.465.000	2.214.389	4.573.800
44	Motor	Winding	8.925.000	5.703.730	11.781.000
45	Motor	Stator-rotor	5.220.000	3.335.963	6.890.400
46	Belt Conveyor	Proximity Sensor	2.385.000	1.524.190	3.148.200
47	Motor	Winding	8.985.000	5.742.074	11.860.200
48	Spout Filling	Nozzle	2.760.000	1.763.842	3.643.200
49	Gear Box	Coupling	3.840.000	2.454.042	5.068.800
50	Motor	Bearing	7.590.000	4.850.566	10.018.800
TOTAL			**247.770.000**	**158.343.259**	**327.056.400**

4) *Total Maintenance Costs In The Company*

The results of the calculation of total company maintenance costs (Initial TC) are as follows:

$$\text{Initial TC} = \text{Total Cost of Maintenance} + \text{Losses Due to Downtime} + \text{Operator Fees} + \text{Mechanical Fees}$$
$$= \text{Rp. } 444.726.001 + \text{Rp. } 247.770.000 + \text{Rp. } 158.343.259 + \text{Rp. } 327.056.400$$
$$= \text{Rp. } 1.177.895.660$$

B. Maintenance Cost Calculation Using Modularity Design & ABC Classification Method (Proposed TC)

1) *Grouping of Critical Components According to ABC Classification*

Grouping of critical sub-components of the Roto Packer 638PM1 machine based on their usage value (ABC Classification) as follows:

Tabel 4. Roto Packer Machine Component Module 638PM1

Module	Percentage of Annual Usage Value	Cumulative Annual Usage	Component	Sub Components
Module 1	21%	65%	Motor	Stator Rotor
	26.07%			Bearing
	17.99%			Winding
Module 2	6.99%	19%	Belt Conveyor	Belt
	12.06%			Proximity Sensor
Module 3	4.99%	7%	Spout Filling	Nozzle
	2.42%			Load Cell
	4.39%	8%	Gear Box	Coupling
	4.09%			Oil Seal

2) *Determining the Suitability of Damage Data Distribution*

Distribution test was conducted using Minitab 18 Software. Distribution 1 is a test of component Downtime distribution while distribution 2 is a test of the distribution of the time interval between component failures. The results of the distribution test for each module are shown in the following table:

Tabel 5. Distribution Test Results

Component	Distribution Types	Parameter		Information
		β (shape)	η (scale)	
Module 1	Weibull	5.78460	521.181	Distribution 1
	Weibull	1.91901	24977.8	Distribution 2
Module 2	Weibull	5.12816	189.138	Distribution 1
	Weibull	1.44740	45802.7	Distribution 2
Module 3	Weibull	8.30164	239.323	Distribution 1
	Weibull	2.03642	72450.3	Distribution 2

3) *Calculation of MTTR and MTTF*

After obtaining the distribution and parameters of each distribution in table 5, The Mean Time To Repair (MTTR) and Mean Time To Failure (MTTF) calculations can be performed. The following are the calculations of MTTR and MTTF for each module:

Tabel 6. MTTR and MTTF Calculation Results

Component	MTTR (Minute)	MTTF (Minute)
Module 1	482,98	22.156,3
Module 2	174,17	41.533,06
Module 3	225,83	64.186,98

4) *Calculation of Component Replacement Costs Due to Maintenance (Cp) and Component Replacement Costs Due to Damage (Cf)*

Replacement Cost of Components Due to Maintenance includes operator, mechanic, and sub-component costs. The Cp calculation for each module can be seen in the table below.

Tabel 7. Replacement Cost of Components Due to Maintenance (Cp)

Module	Sub Components	MTTR (Minute)	Cp	Cp Module
Module 1	Stator Rotor	482.98	Rp. 32,539,309	Rp. 82.891.492
	Bearing		Rp. 24,735,346	
	Winding		Rp. 25,616,836	
Module 2	Belt	174.17	Rp. 12,071,227	Rp. 23.893.410
	Proximity Sensor		Rp. 11,822,183	
Module 3	Nozzle	225.83	Rp. 12,085,623	Rp. 47.312.210
	Load Cell		Rp. 11,994,082	
	Coupling		Rp. 10,529,432	
	Oil Seal		Rp. 12,703,073	

Replacement Cost of Components Due to Damage includes operator costs, mechanics, Loss of Production Costs, sub-component prices, and Number of Damages. The calculation of Cf for each module can be seen in the table below.

Tabel 8. Component Replacement Cost Due to Damage (Cf)

Module	Sub Components	MTTR (Minute)	Cf	Cf Module
Module 1	Stator Rotor	482.98	Rp. 198.921.546,5	Rp. 780.738.210
	Bearing		Rp. 351.783.809,3	
	Winding		Rp. 230.032.854,1	
Module 2	Belt	174.17	Rp. 58.736.880	Rp. 174.218.288
	Proximity Sensor		Rp. 115.481.408	
Module 3	Nozzle	225.83	Rp. 77.314.325	Rp. 225.831.288
	Load Cell		Rp. 30.742.648	
	Coupling		Rp. 69.533.370	
	Oil Seal		Rp. 48.240.945	

5) *Calculation of Maintenance Time Interval (TM)*

The following is a calculation of efficient maintenance intervals for each module:

Tabel 9. Maintenance Time Interval

Component	Parameter		Cp (Rp)	Cf (Rp)	TM (Minute)
	β (shape)	η (scale)			
Module 1	1,91901	24.977,8	82.891.492	780.738.210	8.111,80
Module 2	1,44740	45.802,7	23.893.410	174.218.288	20.235,27
Module 3	2,03642	72.450,3	47.312.210	225.831.288	33.042,72

6) Calculation of Total Maintenance Costs Using Modularity Design & ABC Classification Method

The total maintenance cost is calculated according to the time unit used. Because the data above uses minutes, then based on the data distributed by Weibull, the total maintenance cost is shown in the following table:

Tabel 10. Recapitulation of TC Calculations Per Minute for Each Module

Component	TC (Rp/Menit)
Module 1	Rp. 21.337,81/minute
Module 2	Rp. 3.819,99/minute
Module 3	Rp. 2.813,38/minute

So that the total maintenance costs per year are obtained, which are shown in the following table:

Tabel 11. Calculation of Total Cost per Year Using the Proposed Method

Module	Total Cost (Rupiah/Year)
Module 1	Rp. 709.895.444
Module 2	Rp. 30.985.922
Module 3	Rp. 30.901.090

From the table above, it can be concluded that the total maintenance cost of the Roto Packer 638PM1 machine calculated using the proposed method is Rp. 771,782,456 per year.

C. Comparison of Total Company Maintenance Cost and Proposed Method

Based on the calculation results, the maintenance comparison can then be calculated in the following table:

Tabel 12. Comparison of Total Company Maintenance Cost and Proposed Method

Total Company Maintenance Cost (Initial TC)	Total Maintenance Cost with ABC Classification & Modular Design (Proposed TC)
Rp. 1.177.895.660	Rp. 771.782.456

The table shows that the company's maintenance cost is Rp. 1,177,895,660 per year, while the modular design method produces a maintenance cost of Rp. 771,782,456 per year. The proposed method can also be used to calculate the efficiency between the company's maintenance costs. Here is the calculation of efficiency:

$$\text{Efficiency} = \frac{TC\ Company - TC\ Proposed}{TC\ Company} \text{ x } 100\%$$

$$= \frac{\text{Rp.1.177.895.660} - \text{Rp.771.782.456}}{\text{Rp.1.177.895.660}} \text{ x } 100\%$$

$$= 34{,}47\ \%$$

From the comparison between the proposed TC and the company TC, the costs incurred by the proposed TC are less than the costs of the company TC each year and have an efficiency level of 34.47%, which means that the proposed maintenance method is acceptable.

V. CONCLUSION

The proposed results of the maintenance module classification based on the Always Better Control (ABC) classification of the 638PM1 roto packer machine allow the company to allocate resources more effectively, prioritizing the procurement of high-value components. So the machine sub-components are divided into several modules as follows:

- Module 1 (cumulative usage 65%): Stator-rotor, Bearing, and Winding

- Module 2 (cumulative usage 19%): Belt, and Proximity Sensor
- Module 3 (cumulative usage 15%): Nozzle, Load Cell, Coupling, and Oil Seal

Based on the results of the calculation of the optimal component replacement time interval, module 1 was obtained as 8.111,80 minutes, module 2 as 20.235,27 minutes, and module 3 as 33.042,72 minutes. Thus, the annual maintenance cost using the proposed method is Rp. 771.782.456. Then a comparison can be made between the maintenance cost for the proposed modular design method and the company's maintenance cost, which is Rp. 1.177.895.660 per year. The costs incurred by the selected proposed method can save maintenance costs for the company every year with an efficiency value of 34,47%. So the proposed maintenance method with a modular design can be accepted.

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