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Comparative Analysis of Repair Policy and Preventive Maintenance Policy Methods in Machine Maintenance on the Production Floor of PT. Metro Riau

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A B S T R A C T

PT. Metro Riau is a newspaper printing company facing significant challenges due to high machine breakdown rates, which have impacted maintenance costs and production output. This study aims to compare machine maintenance costs using repair policy and preventive maintenance policy methods and provide recommendations for the most efficient maintenance approach. The data utilized includes types of breakdowns, maintenance costs, and production rates during the 2023 period. The research employs a quantitative analysis method to calculate repair and preventive maintenance costs based on the probability of breakdowns for each type of machine. The findings reveal that for type A breakdowns, the repair policy is more cost-effective, with a maintenance cost of IDR 143,829 compared to IDR 176,384 for the preventive maintenance policy. Conversely, for type B and C breakdowns, the preventive maintenance policy is more efficient, with costs of IDR 259,616 and IDR 375,950, respectively, compared to the repair policy. Based on these results, it is recommended to implement the repair policy for type A breakdowns and the preventive maintenance policy for types B and C. This combined approach is expected to reduce maintenance costs while enhancing the reliability of the company's production machinery.

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1. INTRODUCTION

The advancement of industry has brought intense global competition. The manufacturing sector is under pressure to deliver high performance and meet customer expectations (Atikno et al., 2022). In this industry, machinery and equipment play a critical role in supporting the production process (Wardhani & Widjajati, 2023). Technological progress in the printing industry has greatly influenced the evolution of information dissemination since Johannes Gutenberg introduced the printing press in 1440. This breakthrough paved the way for the emergence of various forms of printed media, including newspapers, which once served as the primary news source for the public. Despite the decline in newspaper popularity due to the rise of digital media, printed newspapers continue to hold relevance for specific audiences. For some individuals, cultural influences and long-standing habits make them prefer print formats over digital alternatives for accessing news (Nugraha et al., 2021).

PT. Metro Riau, a newspaper printing company in Pekanbaru, produces up to 900,000 copies annually. However, over the past three years, the company has faced significant challenges related to machine breakdowns that disrupted production. There were 505 recorded breakdowns, categorized into three types: type A (minor), type B (moderate), and type C (severe), with type A being the most frequent. Repair costs increased significantly from IDR 50,241,000 in 2021 to IDR 62,542,000 in 2023. Additionally, newspaper production failed to meet annual targets, dropping from 860,000 copies in 2021 to 830,000 copies in 2023. These issues indicate that machine breakdowns have adversely affected production schedules and customer trust.

Previous research has shown that the adoption of proactive maintenance strategies, such as preventive maintenance, can significantly reduce maintenance costs compared to reactive approaches (Nurbani & Seftiadie Y.P., 2019) and (Permana & Arvianto, 2020). These findings highlight the importance of maintenance as a strategic element that influences a company's competitiveness. Although the benefits of preventive maintenance have been proven, PT Metro Riau still relies on corrective maintenance, which only addresses damage after it occurs. The weakness of corrective maintenance is that failures in production assets (which are complex) are highly likely and often unpredictable (Taufik et al., 2019). The recurring damage to critical components, such as gears and paper pullers, indicates the need for a reevaluation of the maintenance policies implemented within the company.

Every company aims for an optimally performing system, particularly in equipment maintenance. To achieve this, many companies are shifting from reactive to proactive maintenance strategies. On the contrary, poorly maintained equipment is more prone to frequent breakdowns, has a shorter lifespan, and operates less efficiently, which can lead to production delays. Additionally, malfunctioning equipment poses the risk of producing defective products or those with substandard quality (Romadhon & Trimarjoko, 2024)

The research at PT. Metro Riau was driven by recurring machine breakdowns that severely disrupted production, increased maintenance costs, and hindered the company from meeting its annual production targets. Over the past three years, 505 breakdowns across various machine types-categorized as minor, moderate, and severe-resulted in significant repair costs and operational inefficiencies. These challenges highlight the urgent need for a reevaluation of maintenance strategies to enhance operational reliability, reduce costs, and improve overall production efficiency. This study aims to address this issue by comparing the cost efficiency and operational benefits between a repair policy and a preventive maintenance policy at PT. Metro Riau. The research question that serves as the focus is: Which maintenance policy, repair or preventive, is more effective in reducing costs and maintaining machine productivity at PT. Metro Riau?

2. LITERATURE REVIEW

Newspaper Printing Industry

Printing is an industry that mass-produces written text and images using printing machines. Printing activities play a crucial role in the publishing sector (Daniel et al., 2023). Newspapers serve as a means of communication presented in written language. They are a type of mass media containing information that includes writings about events in society, such as accidents, political systems, market news, and more (Duwi et al., 2022).

In the past, the newspaper industry was primarily centered in major cities and published nearly twice a day. This meant that newspaper printing facilities were always bustling, eagerly awaiting the latest news to be printed and distributed. Newspapers were also seen as a hallmark of intellectual life, embodying the idea that through reading, one could gain insight into the world. This connection established a special place for newspapers in the hearts of their readers. Moreover, reading newspapers became a trend among successful individuals in Indonesia (Fikri et al., 2020). The newspaper production process begins with the input of materials, starting with receiving material files and creating printing plates. This is followed by print preparation, which involves machine setup, selecting the paper type, and adjusting the machine settings. The offset printing process includes test runs until achieving optimal production quality. Next is the folding and cutting process, where newspapers are folded and trimmed. Subsequently, the newspapers are counted and stacked, followed by packaging and labeling according to the order quantities from agents to facilitate distribution (Sulaksana, 2023).

Maintenance

Maintenance is a series of activities conducted to preserve or maintain the quality of a machine, ensuring it functions as originally intended. Maintenance can be defined as efforts made to restore or sustain an item in a condition that ensures it continues to function effectively. Therefore, maintenance includes all activities aimed at keeping units in operational and safe conditions. In the event of a breakdown, maintenance ensures that the machine remains controllable and operates in a reliable and safe manner (Widiasih & Aziza, 2019). Maintenance includes various activities such as repair, upkeep, cleaning, adjustment, measurement, and inspection (Saroinsong et al., 2021).

Generally, the goal of maintenance is to ensure that machines remain in optimal condition by performing necessary repairs, adjustments, or replacements, so that production operations meet the planned objectives. Once the maintenance goals are achieved, the next consideration is the function of maintenance, which is to extend the economic lifespan of existing production machinery or equipment. It also aims to keep the machinery or equipment in peak condition, always ready for use in production activities (Leke & Saifuddin, 2024). Maintenance activities are typically classified into two main categories. The first is Planned Maintenance, which involves scheduled maintenance activities based on prior preparation. This includes preventive maintenance, aimed at ensuring products meet set standards, as well as corrective maintenance, which addresses unforeseen issues related to quality, cost, or timing, with the intention of improving these factors. The second category is Unplanned Maintenance, which occurs when unexpected issues arise during the manufacturing process, often triggered by notifications or instructions. This includes emergency maintenance, where urgent actions are taken to repair machinery and avoid more serious consequences. Preventive maintenance is further divided into sustained maintenance, conducted during ongoing production, and shutdown maintenance, which takes place when production halts for maintenance activities (Muhaemin & Nugraha, 2022).

The types of maintenance can be categorized into several different types. Corrective maintenance involves actions taken to repair and improve the condition of facilities or equipment to restore them to an acceptable state. This repair process may include modifications or design changes to make the equipment better. Emergency maintenance is required immediately when an unexpected disruption or breakdown occurs. Running maintenance is carried out while facilities or equipment are still in operation, aimed at maintaining the performance of equipment that continues to support the production process. Some activities in running maintenance include cleaning, inspection, and adjustment. Shutdown maintenance is performed when facilities or equipment must stop operating, and it is planned maintenance, which includes activities such as cleaning, inspection, and overhaul. Breakdown maintenance is performed after a failure has occurred in the equipment, requiring spare parts, materials, tools, and labor for repair. Lastly, overhaul maintenance involves a series of routine activities such as disassembly, cleaning, checking, measuring, repairing, reassembling, and testing (Mahatma & Aidil, 2023).

Cost Of Repair Policy

Repair maintenance is a maintenance approach used when machinery breaks down or experiences damage. Repair maintenance focuses on restoring damaged machine components, such as replacing faulty parts with new ones (Fitriyah & Hariono, 2023). The formula used to calculate repair maintenance (Azizah et al., 2021):

$$Cr = \frac{\text{Total cost of components}}{\text{Number of components replaced}} \quad \ldots(1)$$

TMC = TCr + TCd Cr

$$B = \frac{N}{Tb}$$

$$Tb = \sum_{t}^{n} Pi.\,Ti$$

TCr = B x Cr

Explanation of Variables :

B : Average number of breakdowns Per month for N machines
N : Number of tools or machines
Tb : Average runtime per machine before failure
TMC (n) : Total maintenance cost per month
TCr (n) : Repair cost per month
TCm (n) : Preventive maintenance cost per month
TCd : 0 (Labor cost is neglected)

Cost of Preventive Maintenance

Preventive maintenance is a periodic maintenance action based on a planned maintenance schedule. This maintenance activity is performed according to the planned maintenance time without waiting for a machine breakdown (Islam et al., 2020). formula used to calculate preventive maintenance (Azizah et al., 2021):

1. CM (Total Maintenance Cost) = (Labor Cost x Working Time x Number of Workers) + (Component Cost) …(2)
2. Cumulative Number of Breakdowns per 1 Month of Operation
   B1 = N x P1 ...(3)
3. Average Breakdown per 1 Month of Operation
   $B = \frac{Bn}{n} = \frac{B1}{1}$ ...(4)
4. Estimated Repair Cost per 1 Month of Operation
   TCr1 = B x Cr ...(5)
5. Preventive Maintenance Cost per 1 Month of Operation
   $TCm1 = \frac{NxCm}{n}$ …(6)
6. Total Cost of Preventive Maintenance Policy per 1 Month of Operation
   TMC1 = TCr1+ TCm1+ TCd …(7)

Explanation of Variables:

B : Average number of breakdowns per month for N machines
N : Number of tools or machines
Tb : Average runtime per machine failure
TMC (n) : Total maintenance cost per month
TCr (n) : Repair cost per month
TCm (n) : Preventive maintenance cost Per month
TCd : 0 (Labor costs are excluded from the calculation)

The literature review highlights gaps in understanding the comparative effectiveness of repair and preventive maintenance policies under varying operational conditions. While prior research emphasizes the benefits of preventive maintenance, there is limited exploration of how specific breakdown types and cost structures influence the optimal maintenance policy. Additionally, there is a lack of studies on the practical applications of hybrid or predictive maintenance approaches in the printing industry. This study aims to address these gaps by providing a detailed cost comparison for different maintenance strategies.

3. RESEARCH METHOD

This research is designed using a quantitative approach by analyzing historical data of machine breakdowns at PT. Metro Riau during the period of January to December 2023. The aim of the study is to evaluate the effectiveness of two maintenance methods, namely the repair policy and preventive maintenance policy, in reducing the company's operational costs. This approach ensures that the analysis is based on real, relevant data that aligns with the company's needs.

The data for this research were collected from two primary sources. Primary data were obtained through direct observations of the machine conditions and the production processes on-site, covering types of breakdowns and their frequencies. Secondary data consisted of company documentation, including breakdown recaps, types of failures, maintenance costs, and production data. The combination of these data types ensures the accuracy and completeness of the information, supporting the analysis.

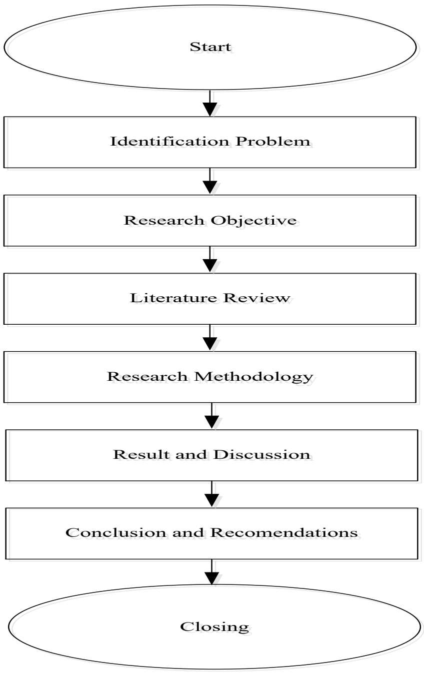

Figure 1. Study framework

The data processing was conducted systematically to yield valid results (Azizah et al., 2021): (1) Involves determining the distribution of breakdowns over the course of one year. (2) Calculates the repair costs for both Repair Maintenance and Preventive Maintenance. (3) Performs cost calculations for machine maintenance using the repair maintenance policy. (4) Computes the costs incurred when maintenance is conducted using the preventive maintenance policy. (5) Compares the total costs of the two maintenance methods and selects the maintenance policy with the lowest Total Maintenance Cost (TMC).

4. RESULT AND DISCUSSION

A. Probability of Damage

Determine the chance of machine damage that has occurred during production during the January - December 2023 period. By dividing the number of damages per month by the total number of all damages.

Type A Probability

$$Pn\ (a) = \frac{\text{Number of breakdowns in n months}}{\text{Total damage}} \quad ...(8)$$

The data from this calculation will be used in the calculation of repair policy costs, namely the average runtime (Tb). The following are the results of the probability calculation on type A engine damage during the 2023 period:

Table 1. Type a probability

Month	Type A	Machine Breakdown Probability
P1	15	0.106
P2	13	0.092
P3	10	0.070
P4	14	0.099
P5	8	0.056
P6	12	0.085
P7	10	0.070
P8	10	0.070
P9	12	0.085
P10	11	0.078
P11	12	0.085
P12	14	0.099
Total	**141**	

From Table 1 it can be seen that each month's probability of damage from damage type A, and the most damage in January.

Type B Probability

$$Pn\ (b) = \frac{\text{Number of breakdowns in n months}}{\text{Total damage}} \quad ...(9)$$

Table 2. Type B probability

Month	Type B	Machine Breakdown Probability
P1	3	0.071
P2	3	0.071
P3	1	0.023
P4	2	0.047
P5	4	0.095
P6	7	0.166
P7	6	0.142
P8	5	0.119
P9	3	0.071
P10	2	0.047
P11	4	0.095
P12	2	0.047
Total	**42**	

From Table 2 it can be seen that each month's damage probability of damage type B, and the most damage in June.

Type C Probability

$$Pn\ (c) = \frac{\text{Number of breakdowns in n months}}{\text{Total damage}} \quad ...(10)$$

Table 3. Type C probability

Month	Type C	Machine Breakdown Probability
P1	1	0.125
P2	1	0.125
P3	0	0
P4	0	0
P5	0	0
P6	1	0.125

P7	1	0.125
P8	1	0.125
P9	1	0.125
P10	0	0
P11	1	0.125
P12	1	0.125
Total	**8**	

From Table 3 it can be seen that each month's damage probability of damage type C is relatively the same.

B. Calculation of Repair Costs

Calculate repair costs by processing data in the calculation by dividing all repair costs by the number of damage components replaced. The following is the total cost of damage from each type of damage in the 2023 period.

Table 4. Total cost of damage period 2023

Type of Damage	Quantity of spare parts	Total Cost of Damage (IDR)
Type A	141	32.500.000
Type B	42	20.242.000
Type C	8	9.800.000

To calculate the cost of repair for each type of damage a, b, and c can be explained from the following calculations:

The formula for calculating repair costs can be referred to the following formula:

$Cr(a) = \frac{32.500.000}{141}$ = IDR. 230.496 type A damage

$Cr(b) = \frac{20.242.000}{42}$ = IDR. 481.952 type B damage

$Cr(c) = \frac{9.800.000}{8}$ = IDR. 1.225.000 type C damage

From the above calculations, the results obtained on the total cost of damage have been divided by the total number of components that have been replaced, the data from this calculation will be used in the calculation of repair policy costs, namely repair costs per month (TCr).

C. Calculation of Repair Policy Cost

Calculate the costs incurred in the repair policy and the costs when the machine cannot function or can be called downtime costs. The following are repair policy maintenance costs for 3 types of damage:

Table 5. Recapitulation of total repair policy cost

Type of Damage	Average Runtime (Tb)	TCr/Month (IDR)	TMc/Month (IDR)
Type A	6.404	143.829.504	143.829.504
Type B	6.605	291.580.96	291.580.96
Type C	7	699.475	699.475

Calculation of Preventive Maintenance Costs

The costs incurred by machine maintenance include labor costs. This is because labor costs are paid monthly to employees, it can be concluded that labor costs are ignored at the time of machine maintenance. While other maintenance costs are the cost of spare parts in small components such as bolts, nuts, lubricants, etc.

Table 6. Preventive maintenance spare parts and equipment costs

No	Sparepart	Price (IDR)
1.	Bolt, Nut, Gasket	150.000
2.	Tap Eye	100.000
3.	Lubricant (Oil)	100.000
	Total	**300.000**

Calculation of preventive costs

Cm = (TK Cost x Work Time x Number of TKs) + (Component Costs)

= 0 + 300.000

= IDR. 300.000

From the above calculations, the results obtained on preventive costs are IDR. 300,000, the data from this calculation will be used in calculating the cost of preventive maintenance policy, namely in calculating the cost of preventive maintenance per 1 month (TCm1).

D. Calculation of Preventive Maintenance Policy Costs

Is a calculation of the costs incurred during machine maintenance using the preventive maintenance policy method from January to December period 2023.

Type A

The following are the total results of the calculation of preventive maintenance policy costs based on type A from January to December for the 2023 period.

Table 7. Recapitulation of preventive maintenance cost policy type A

Month	Probability	Bn	B	TCr (IDR)	TCm (IDR)	TMc (IDR)
1	0.106	0.424	0.424	97.730	1.200.000	1.297.730
2	0.092	0.792	0.396	91.276	600.000	691.276
3	0.070	1.072	0.357	82.287	400.000	482.287
4	0.099	1.468	0.367	84.592	300.000	384.592
5	0.056	1.692	0.338	77.907	240.000	317.907
6	0.085	2.032	0.338	77.907	200.000	277.907
7	0.070	2.312	0.330	76.063	171.428	247.491
8	0.070	2.592	0.324	74.608	150.000	224.680
9	0.085	2.932	0.325	74.911	133.333	208.244
10	0.078	3.244	0.324	74.680	120.000	194.680
11	0.085	3.584	0.325	74.911	109.090	184.001
12	0.099	3.98	0.331	76.294	100.090	176.384
		Total				**4.687.179**

From the recapitulation table above. it can be seen that the total results of the calculation on the minimum maintenance for type A damage are in month 12. with a cost result of IDR. 176.384.

Type B

The following Table 8, the total results of the calculation of preventive maintenance policy costs based on type B from January - December 2023.

Table 8. Recapitulation of preventive maintenance cost policy type B

Month	Probability	Bn	B	TCr (IDR)	TCm (IDR)	TMc (IDR)
1	0.071	0.284	0.284	547.497	1.200.000	1.747.497
2	0.071	0.568	0.284	136.874	600.000	736.874
3	0.023	0.66	0.22	106.029	400.000	506.029
4	0.047	0.848	0.212	102.173	300.000	402.173
5	0.095	1.228	0.245	118.078	240.000	358.078
6	0.166	1.892	0.315	151.814	200.000	351.814
7	0.142	2.46	0.351	169.165	171.428	340.593
8	0.119	2.936	0.367	176.876	150.000	326.876
9	0.071	3.22	0.357	172.056	133.333	305.389
10	0.047	3.408	0.340	163.863	120.000	283.863
11	0.095	3.788	0.344	165.791	109.090	274.881
12	0.047	3.976	0.331	159.526	100.000	259.616
Total						**5.893.683**

From the recapitulation table above. it can be seen that the total results of the calculation on the minimum maintenance for type B damage are in month 12. with a cost result of IDR. 259.616.

Type C

The following Table 9, the total results of the calculation of preventive maintenance policy costs based on type C from January - December 2023.

Table 9. Recapitulation of preventive maintenance cost policy type C

Month	Probability	Bn	B	TCr (IDR)	TCm (IDR)	TMc (IDR)
1	0.125	0.5	0.5	612.500	1.200.000	1.812.500
2	0.125	0.25	0.125	153.125	600.000	753.125
3	0	0.25	0.245	0.083	101.675	501.675
4	0	0.25	0.062	75.950	300.000	375.950
5	0	1.25	0.25	306.250	240.000	546.250
6	0.125	1.5	0.25	306.250	200.000	506.250
7	0.125	2	0.285	349.125	171.428	520.533
8	0.125	2.5	0.312	382.200	150.000	532.200
9	0.125	3	0.333	407.925	133.333	541.258
10	0	3	0.3	367.500	120.000	487.500
11	0.125	3.5	0.318	389.550	109.090	498.640
12	0.125	4	0.333	407.925	100.090	508.015
Total						**7.583.896**

E. Maintenance Cost Comparison

After the calculation of the repair policy and preventive maintenance policy methods. the results of the calculation of maintenance costs used in data processing are obtained as in the table below:

Table 10. Comparison of maintenance costs

No	Maintenance System	Total Cost (IDR)
1.	PT. Metro Riau	62.542.000
2.	Repair Policy	1.134.885
3.	Preventive Maintenance Policy	18.164.757

Based on the 10, it can be seen that the maintenance costs obtained from the results of research and data processing using the repair policy and preventive maintenance policy methods are lower than the costs incurred by the company. Of the two methods. the cheapest and recommended cost is the repair policy cost. which is IDR 1.134.885. while the cost for preventive maintenance policy reaches IDR 18.164.757. In accordance with the results of research. it is concluded that the most efficient maintenance cost is to use a repair maintenance policy. because on multpacking machines. preventive maintenance costs are proven to be higher (Marpaung & Bakhtiar. 2019). Other research also shows that the optimal maintenance policy on huller machines in a three-year period (2021-2022) is to use a repair maintenance policy. because the costs incurred are lower than the preventive maintenance policy (Irnain & Hariono. 2023). The breakdown of costs at PT Metro Riau. listed in Table 4. shows the company's total damage costs as follows: type A amounted to IDR 32.500.000. type B amounted to IDR 20.242.000. and type C amounted to Rp 9.800.000. bringing the total cost to Rp 62.542.000. Meanwhile. the results of cost calculations using the repair policy and preventive maintenance policy methods resulted in a total cost of IDR 19.299.642. which shows significant efficiency compared to the company's costs.

Discussion

The application of repair policy and preventive maintenance policy methods provides significant efficiency to the maintenance costs of production machinery at PT Metro Riau. Historical data shows that the traditional method applied by the company resulted in maintenance costs of IDR. 62.542.000 for the period January-December 2023. This cost is much higher than the application of the repair policy and preventive maintenance policy method which only requires IDR. 19.299.642. resulting in savings of IDR. 43.242.358.

Repair Policy Cost

The calculation shows the minimum maintenance cost compared to the company's initial cost. as seen from the total cost for type A of IDR. 143.829 per month. lower than the initial cost of IDR. 230.496. This shows that maintenance with this method is able to reduce the company's expenses in the case of damage that occurs.

Preventive Maintenance Policy

The calculated maintenance costs include replacement of parts such as bolts. nuts. gaskets. and oil. Based on the data. the total cost for this method in type A is IDR. 4.687.179. type B is IDR. 5.893.683. and type C is IDR. 7.583.896. which is lower than the cost before preventive maintenance which reached IDR. 32.500.000. IDR. 20.242.000. and IDR. 9.800.000 respectively. The structured application of this method shows significant savings by minimizing the risk of major damage through periodic maintenance and component replacement before total damage occurs.

Comparison of Maintenance Costs from Companies with Repair Policy and Preventive Maintenance Policy Methods

A comparison between the company's maintenance costs with the repair policy and preventive maintenance policy method shows that the savings obtained are not only due to the reduction of breakdowns. but also to better planning. This method ensures that machines are in a ready-to-use condition. reducing the frequency of emergency repairs that require sudden purchases of spare parts. The company's previous high maintenance costs were due to the absence of fixed schedules and machine operating standards. which led to irregular expenditures that were only made when major breakdowns occurred.

With the implementation of this method. the company was able to drastically reduce maintenance costs while improving operational efficiency. This research confirms the importance of regular maintenance schedules. breakdown classification. and a proactive approach to machine maintenance management to maintain operational stability and reduce costs in the future.

The results of this study align with previous research, confirming the cost-effectiveness of preventive maintenance over reactive repair for certain breakdown types. However, unlike earlier studies, this research identifies cases where a repair policy may be more suitable for specific breakdown categories, demonstrating a nuanced application in which repair policies are more cost-effective for minor breakdowns, while preventive maintenance is optimal for moderate and severe issues. Limitations of this study include its reliance on historical data from a single company, the exclusion of indirect costs such as downtime, customer dissatisfaction, and labor, as well as the absence of a comprehensive analysis of operational impacts, including production delays and quality variations. Although the repair policy calculations show lower costs compared to preventive maintenance, these calculations account for only a small portion of the total costs. Factors such as damage costs, downtime, lead time for sudden spare part procurement, and other indirect expenses could make the repair policy more expensive than preventive maintenance in the long run. This highlights the importance of considering all related costs when evaluating maintenance strategies.

5. CONCLUSION

Based on the research conducted at PT. Metro Riau. it can be concluded that there is a difference in maintenance costs between the repair policy and the preventive maintenance policy. depending on the classification of machine breakdown types. For type A breakdowns. the repair policy incurs lower costs at IDR. 143.829 compared to the preventive maintenance policy. which costs Rp. 176.384. Conversely. for type B breakdowns. the preventive maintenance policy is more cost-efficient at IDR. 259.616. compared to the repair policy. which costs IDR.. 291.580. A similar trend is observed with type C breakdowns. where the preventive maintenance policy has a lower cost of IDR. 375.950. compared to IDR. 699.475 for the repair policy. Based on this comparison. maintenance policies should be tailored to the type of breakdown. For type A breakdowns. the repair policy is more efficient. focusing on replacing oil. bolts. nuts. and machine gaskets. For type B breakdowns. the preventive maintenance policy is more optimal. emphasizing routine servicing and machine component inspections. Lastly. for type C breakdowns. the preventive maintenance policy is also more effective. incorporating major servicing and urgent replacement of critical machine components.

Future research could explore a hybrid maintenance strategy combining elements of repair and preventive maintenance tailored to breakdown types and frequencies. Additionally, studies should investigate the broader operational impacts of maintenance policies, such as on production efficiency and customer satisfaction, while assessing the feasibility of predictive maintenance technologies for long-term cost optimization. Incorporating a comprehensive cost model that includes labor, downtime, and lead time costs would provide a more holistic understanding. Further exploration of predictive maintenance methods and their influence on production efficiency and product quality could offer valuable insights for optimizing maintenance strategies.

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