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Analysis Of Mean Time Between Failure (MTBF) On Oil Production Machines

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ABSTRACT
This study aims to analyze the effectiveness of engine maintenance based on the *Mean Time Between Failures* (MTBF) approach for Engine units A and B during the period from PM 1000 Hours to the end of May 2024. The data analyzed include failure times, shutdown durations, operating hours, and estimated production losses due to operational halts. The results show that Engine A experienced 10 failures with a total downtime of 87 hours, while Engine B experienced 16 failures with 68 hours of downtime. The total loss due to shutdowns throughout the observation period amounted to IDR 4.78 billion, while the potential production revenue loss reached approximately IDR 1.3 trillion. The findings also indicate that mid-interval maintenance is not necessary, as the associated losses are lower than the cost of repairs. This study recommends adopting the MTBF method to support preventive maintenance decisions in order to enhance operational efficiency and minimize financial losses.

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INTRODUCTION

In industrial settings, particularly in the oil production sector, machinery plays a pivotal role in sustaining productivity and meeting operational targets. The complexity and intensity of continuous production activities necessitate reliable equipment performance. However, recurring breakdowns and machine failures pose significant challenges, such as production delays, increased maintenance costs, and loss of competitive advantage. This necessitates a deeper understanding of equipment reliability and the development of preventive strategies to minimize unplanned downtime.

One of the key metrics used to assess machine reliability is Mean Time Between Failure (MTBF), which measures the average operational duration between one failure and the next. MTBF provides valuable insight into how frequently a system experiences failure during operation. As noted by Mobley (2002), MTBF is critical in evaluating system reliability, determining maintenance intervals, and formulating asset management policies. A lower

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MTBF indicates poor machine health, while a higher MTBF suggests stable, reliable performance.

Nakajima (1988), through the Total Productive Maintenance (TPM) framework, emphasizes MTBF as a foundational indicator in the shift from reactive to proactive maintenance. TPM aims to increase machine availability by involving all employees in maintenance-related activities. By analyzing MTBF, industries can implement preventive and predictive maintenance schedules that optimize equipment usage and reduce failure-related costs. Similarly, Wireman (2005) argues that effective use of MTBF can lead to significant reductions in unplanned stoppages and overall operational costs.

The theoretical underpinning of this study rests on reliability-centered maintenance (RCM) theory, which focuses on ensuring that systems continue to do what their users require in their present operating context. According to Moubray (1997), RCM integrates technical failure data such as MTBF into decision-making processes to ensure equipment sustainability. RCM enhances maintenance strategies by prioritizing functions that are critical to operational success, and MTBF serves as a practical metric to assess the effectiveness of such strategies.

Previous studies have highlighted the practical utility of MTBF in diverse industrial applications. Smith and Hawkins (2004) emphasize that MTBF not only reflects machine durability but also helps identify process inefficiencies and opportunities for continuous improvement. Meanwhile, Ben-Daya et al. (2009) suggest that tracking MTBF over time allows engineers to measure the effectiveness of maintenance efforts and adjust resource allocations accordingly. Despite these advantages, many organizations underutilize MTBF as a strategic tool.

The oil industry, in particular, presents unique challenges for reliability management due to its continuous operation, harsh working environments, and high-cost machinery. In such contexts, measuring and improving MTBF is crucial for maintaining production continuity and safety. Companies that actively monitor MTBF can quickly detect abnormal patterns, isolate root causes, and implement timely interventions. This approach ensures not only operational efficiency but also compliance with industry standards for safety and quality.

This study aims to analyze the MTBF values of several machines used in an oil production facility over a defined operational period. The analysis focuses on comparing actual MTBF values with target benchmarks, identifying deviations, and evaluating the effectiveness of current maintenance practices. The data-driven insights from this study are expected to inform recommendations for optimizing preventive maintenance strategies and minimizing future failures.

Ultimately, the research contributes to the growing body of knowledge on industrial maintenance and asset management, specifically within the oil production sector. By integrating theoretical perspectives and empirical findings, the study highlights the importance of MTBF as a strategic tool for enhancing machine reliability. In doing so, it supports the development of more robust, proactive, and cost-effective maintenance systems aligned with international best practices.

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METHODS

This study employed a descriptive quantitative approach to assess the reliability of oil production machinery by analyzing their Mean Time Between Failure (MTBF). The focus was on providing a clear, data-driven understanding of how frequently selected machines experience breakdowns and how long they can operate between each failure. The aim was not only to calculate MTBF values but also to use these figures as a basis for evaluating the current maintenance system and suggesting improvements.

Data were collected from a real-world industrial facility that processes oil using multiple machines over long, continuous operational hours. The researcher relied on secondary data obtained from the company's maintenance records, including machine running hours and the number of recorded breakdowns during a specific one-year observation period. Only machines with significant operational loads and critical roles in the production process were selected for analysis to ensure the findings would have practical relevance for daily operations. MTBF was calculated using the standard formula:

$$MTBF = \frac{\text{Total Operating Hours}}{\text{Number of Failures}}$$

This simple but effective formula provides a reliable measure of how often equipment fails. The analysis was conducted for each machine on a month-to-month basis, helping to identify any trends in reliability, whether improving, worsening, or remaining constant. This allowed the researcher to pinpoint which units were most in need of attention and potentially targeted interventions.

To strengthen the analysis, the researcher also considered additional operational factors that could influence MTBF. These included maintenance schedules, worker behavior, machine usage patterns, and even the availability of spare parts. While these variables were not quantified, they were observed and discussed informally with technical staff and engineers on-site, providing richer context to the raw MTBF data and enhancing the depth of interpretation.

The calculated MTBF values were then benchmarked against both internal standards and external references from similar industries. Machines that performed below the expected threshold were further examined to determine whether their issues stemmed from age, design flaws, or inadequate maintenance practices. This step was vital in identifying whether current procedures were aligned with best practices or needed adjustment.

Ultimately, this methodology aimed to bridge theory and practice. By applying a straightforward yet meaningful metric like MTBF to real operational data, the study was able to offer actionable recommendations for improving machine reliability. The intention was to help shift the facility’s maintenance strategy from reactive to proactive, minimizing downtime, enhancing productivity, and supporting the company’s long-term operational goals.

RESULTS AND DISCUSSION

Data Collection

Period from PM 0 Hours to PM 1000 Hours

Subsection 4.1.1 presents a summary of the data collected during the interval between Preventive Maintenance (PM) 0 Hours and PM 1000 Hours. The data include total hours of machine failure, operating time, and repair execution time. Additionally, this part calculates the elapsed time (in hours) following the engine replacement conducted on June 10, 2019, and the initial system start-up.

Table 1. Total Failure Time (in Hours) from PM 0 Hours to PM 1000 Hours

No	Unit	Description	Start Time	End Time	Total (Hours)
1	A	PM 1000 Hours	10/07/2024 06:00	12/07/2024 21:00	63
2	B	PM 1000 Hours	10/07/2024 06:00	12/07/2024 21:00	63

This table displays the total failure time (in hours) that occurred after the engine replacement until the unit was shut down in preparation for PM 1000 Hours. Since the engine replacement was performed in June 2019 and PM 1000 Hours was scheduled in July 2019, no shutdowns occurred in that period. Thus, the total failure time between the engine replacement and the execution of PM 1000 Hours was recorded as zero.

Table 2. Operating Time (in Hours) from Engine Start-Up to PM 1000 Hours

UNIT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL HOURS
A							449	222					671
B							449	222					671

The total operating time (in hours) from the engine start-up in July 2019 until the execution of PM 1000 Hours was 671 hours. The start-up process was completed on June 13, 2019, at 07:00 WIB. The units then ran until they were manually shut down in July 2019 for PM 1000 Hours scheduled on July 10, 2019, at 06:00 WIB.

Table 3. Repair Time (in Hours) for PM 1000 Hours Execution

No	Unit	Description	Start Time	End Time	Total (Hours)
1	A	PM 1000 Hours	10/07/2024 06:00	12/07/2024 21:00	63
2	B	PM 1000 Hours	10/07/2024 06:00	12/07/2024 21:00	63

This table presents the total repair time (in hours) for executing PM 1000 Hours on both Unit A and Unit B. The repair process began with engine shutdown at 06:00 WIB on July 10 and was completed at 21:00 WIB on July 12, 2024. The total duration for executing PM 1000 Hours was recorded as 63 hours.

Period of PM 1000 Hours to First PM 8000 Hours

This subsection presents a summary of the data recorded during the maintenance period from Preventive Maintenance (PM) 1000 Hours to the First PM 8000 Hours. It includes total failure time (hours), operational time (hours), and repair time (hours). The calculation begins from the completion of PM 1000 Hours on July 10, 2019.

Data shows the total failure time recorded after the execution of PM 1000 Hours up to the shutdown for First PM 8000 Hours. The recorded shutdowns occurred in September

2019 (4 hours), October 2019 (36 hours), January 2020 (9 hours), and April 2020 (18 hours), totaling 67 hours of failure for both units A and B. Data shows details the operating time from the completion of PM 1000 Hours in July 2019 to the shutdown for First PM 8000 Hours in June 2020. Engine operations began on July 13, 2019 at 07:00 WIB and ended on June 10, 2020 at 06:00 WIB. The total operational time for each unit during this period was 7934 hours.

Repair Time for Issues Found the duration of repair work related to specific issues discovered during this period. Unit A had three repair events: the first took 4 hours, the second 36 hours, and the third 9 hours. Unit B had one repair that lasted 18 hours. The total time required for issue repairs during this interval was 67 hours, and the execution of the First PM 8000 Hours itself took an additional 61 hours.

Period from First PM 8000 Hours to Second PM 8000 Hours

This section outlines the summarized findings for the period between the First and Second Preventive Maintenance (PM) 8000 Hours. The focus is on total downtime due to failures, total operating time, and the duration of repair executions. These data provide an overview of machine reliability after the First PM 8000 Hours conducted on June 10, 2020.

The data shows that both Unit A and Unit B experienced a total of 45 hours of downtime from July 2020 to June 2021. Specific shutdown incidents occurred in July (5 hours), August (3 hours), October (19 hours), December (2 hours), February (3 hours), March (11 hours), and April (2 hours). These figures reflect the frequency and severity of machine failures within the period.

The operational data reveals that after the engine was restarted on June 13, 2020, at 20:00 WIB, both units operated continuously until the second scheduled PM on June 12, 2021, at 06:00 WIB. During this cycle, each unit logged a total of 8,654 operating hours, indicating high machine availability. Furthermore, maintenance activity records indicate five issues requiring corrective actions on Unit A and two on Unit B. The repair durations on Unit A ranged from 2 to 11 hours, while Unit B required 18 and 2 hours for its respective faults. In total, 64 hours were allocated for maintenance activities during this phase, including the execution of the Second PM 8000 Hours.

Overall, the findings reinforce the necessity of structured maintenance intervals and precise failure tracking. Such data-driven approaches help in minimizing unexpected downtimes, optimizing maintenance resources, and improving the long-term reliability of industrial machinery.

Period from Second PM 8000 Hours to Third PM 8000 Hours

The data shows the cumulative duration of downtime due to equipment failures, total engine operating hours, and the total hours required for repair execution. This analysis includes the total working hours after the completion of the Second PM 8000 Hours, conducted on June 12, 2021.

The findings indicate that shutdowns occurred in July, August, and September 2021, with each month registering 2 hours of downtime. In October 2021, downtime increased to 7 hours, followed by 3 hours each in November and December. Similar shutdown durations continued into 2022, with 3 hours reported respectively in January, February, March, and

April. Over the entire period, the accumulated downtime reached a total of 22 hours for each unit.

The total operating time of the engine from the point of reactivation after the Second PM was also calculated. The engine resumed operation on June 14, 2021, at 11:00 PM and continued running until it was shut down for the Third PM 8000 Hours on May 27, 2022, at 06:00 AM. The total operational hours accumulated during this period reached 8,119 hours.

Regarding corrective actions during shutdowns, the records show that one repair incident occurred in Unit A, which required 7 hours to complete. Meanwhile, Unit B experienced six repair events. The first three findings in Unit B each required 2 hours of repair, while the latter three took 3 hours each. Additionally, the total time taken to execute the Third PM 8000 Hours was recorded at 61 hours.

Period from Third PM 8000 Hours to Fourth PM 8000 Hours

This section presents a comprehensive summary of operational and failure data recorded between the Third Preventive Maintenance (PM) 8000 Hours and the Fourth PM 8000 Hours. The data illustrate the total hours of failure events, operational durations, and the time allocated for corrective actions following equipment breakdowns. The monitoring period commenced after the completion of the Third PM 8000 Hours, which was carried out on May 29, 2022.

The data show that Unit A experienced a cumulative downtime of 17 hours, while Unit B also recorded 17 hours of downtime during this maintenance cycle. Specific shutdown incidents were observed in July 2022 (3 hours), October 2022 (2 hours), November 2022 (3 hours), and December 2022 (3 hours). The trend continued into February 2023 (7 hours) and March 2023 (2 hours), culminating in a total downtime of 17 hours.

Regarding operational performance, the data reveal that both Unit A and Unit B achieved a total operating duration of 8214 hours between the Third and Fourth PM 8000 Hours intervals. This calculation began from the engine start-up on May 29, 2022, at 20:00 WIB, and concluded on May 13, 2023, at 06:00 WIB, when the engine was shut down to initiate the Fourth PM 8000 Hours procedure.

Maintenance activities during this period also included multiple corrective actions due to equipment anomalies. The data show that Unit A required a total of 7 hours for one major issue resolution. Meanwhile, Unit B recorded five issues necessitating cumulative repair times of 3 hours, 2 hours, 3 hours, 3 hours, and 2 hours, respectively.

In addition to these corrective actions, the execution of the Fourth PM 8000 Hours procedure itself required 65 hours, as recorded for both Unit A and Unit B. This time allocation covers the entire span of scheduled maintenance and highlights the importance of accurate planning in minimizing operational disruptions.

Period of Fourth PM 8000 Hours to the End of May 2024

This section presents a summary of the recorded data during the period from the Fourth PM (Preventive Maintenance) 8000 Hours up to the end of May 2024. The data includes total time (in hours) for failures, operational time, and repair execution time. These figures are based on calculations starting from the implementation of the Fourth PM 8000 Hours on May 15, 2023.

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The data shows that failure incidents occurred in September 2023 and April 2024, with each month contributing 2 hours of downtime, summing to a total shutdown time of 4 hours for both Unit A and Unit B during this period. The operational time data illustrates the monthly runtime of each engine unit starting from the Start Up Engine on May 15, 2023, at 00:00 WIB. The total operational time for both Unit A and Unit B from this start date to the end of May 2024 reached 9132 hours. Regarding corrective actions, the data indicates two repair events for Unit B that took place during shutdown periods. Each event required 2 hours to complete, amounting to a total of 4 hours of repair time during the stated period.

Data Processing

The data processing phase in this study was conducted according to the methodological steps outlined in the previous chapter. All findings are presented in the form of descriptive results, derived from the calculation of Mean Time Between Failures (MTBF) across different maintenance intervals. The data focuses on two engine units, referred to as Unit A and Unit B, which were monitored throughout several periods of scheduled preventive maintenance, starting from PM 1000 Hours until the end of May 2024.

The MTBF calculations began from PM 1000 Hours, as no shutdowns were recorded during PM 0 Hours. From PM 1000 Hours to the first PM 8000 Hours, Unit A experienced three incidents of failure—each occurring in September 2019 (4 hours), October 2019 (36 hours), and January 2020 (9 hours)—resulting in a total downtime of 49 hours. With a production runtime of 7934 hours during this period, the MTBF of Unit A was calculated at 2644.67 hours. Meanwhile, Unit B experienced only one failure in April 2020 with a downtime of 18 hours, yielding an MTBF of 7934 hours.

In the next interval, from the first to the second PM 8000 Hours, Unit A recorded five shutdowns with a total failure time of 24 hours. These occurred in July 2020 (5 hours), August 2020 (3 hours), December 2020 (2 hours), February 2021 (3 hours), and March 2021 (11 hours). Referring to the operating time of 8654 hours, the MTBF for Unit A dropped to 1730.8 hours. Unit B experienced two shutdowns in October 2020 and April 2021, totaling 21 hours of downtime and resulting in an MTBF of 4327 hours.

From the second to the third PM 8000 Hours, Unit A encountered only one failure in November 2021 with a downtime of 7 hours, leading to a relatively high MTBF of 8119 hours. In contrast, Unit B experienced six failures distributed evenly across July to April of the following year, with a total of 15 hours of downtime. This brought Unit B's MTBF down to 1353.17 hours during this period.

During the following interval, from the third to the fourth PM 8000 Hours, Unit A experienced a single failure in February 2023 with 7 hours of downtime. With an operating duration of 8214 hours, the MTBF remained at 8214 hours. Unit B, however, had five shutdowns in July, October, November, and December of 2022, and March 2023, totaling 13 hours of failure, thus producing an MTBF of 1642.8 hours.

In the final interval, from the fourth PM 8000 Hours to the end of May 2024, Unit A did not experience any failure, while Unit B experienced two—one in September 2023 and one in April 2024, both with 2 hours of downtime each. Given the total runtime of 9132 hours, Unit B's MTBF was 4566 hours.

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When looking at the cumulative MTBF from PM 0 Hours through the fourth PM 8000 Hours, both Unit A and Unit B operated for the same total time, 42,724 hours. Unit A recorded 10 failures, giving it an overall MTBF of 4272.4 hours, while Unit B experienced 16 failures, leading to a lower MTBF of 2670.25 hours. These findings are further illustrated in a chart showing the number of failures per maintenance interval.

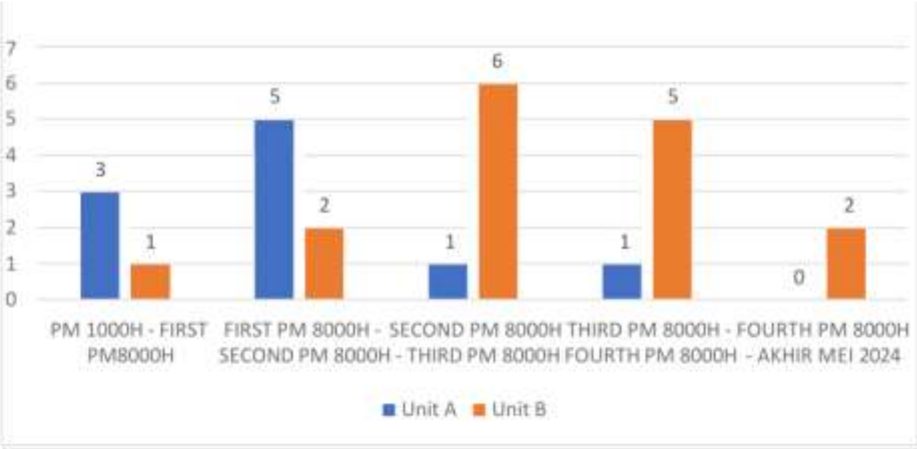

Figure 1. Total Failures Chart from PM 1000H to End of May 2024

The graph shows that Unit A experienced its highest failure rate during the second PM 8000 Hours interval, but the rate steadily declined afterward until the end of the observation period. Conversely, Unit B's failure rate spiked between the second and third PM 8000 Hours, followed by a gradual improvement toward the final period. This trend suggests that Unit A had more consistent reliability over time, while Unit B required more focused maintenance to address recurring issues.

Production Volume Calculation

This section elaborates on the estimated production value, total production loss due to shutdowns, and the resulting financial impact across each period. No calculation is made for the interval between PM 0 Hours and PM 1000 Hours because no shutdown events occurred during this time. The loss estimation adopts a conversion approach using the exchange rate of 1 USD = IDR 16,297 and the price of crude oil per barrel at 91 USD, equating to IDR 1,483,027 per barrel. Under normal operating conditions, daily production (24 hours) is assumed to reach 500 barrels, with a daily income of approximately IDR 741,513,300. Therefore, the hourly revenue is estimated at IDR 30,896,395.83.

Revenue and Loss Estimation for Each Preventive Maintenance Period

For the period between PM 1000 Hours and the First PM 8000 Hours, the total expected operating time was 8001 hours. During this interval, the potential revenue amounted to IDR 247,202,063,062.50. However, due to 67 hours of shutdown, the loss was estimated at IDR 2,070,058,520.83. Thus, the effective income for this period was IDR 245,132,004,541.67.

In the subsequent phase, from First PM 8000 Hours to Second PM 8000 Hours, the machine was scheduled to operate for 8699 hours, which should have generated a revenue of IDR 268,767,747,325.17. However, with 45 hours of shutdown causing a loss of IDR 1,390,337,812.35, the net revenue during this period was IDR 267,377,409,512.82.

From Second PM 8000 Hours to Third PM 8000 Hours, the expected operation time was 8141 hours, with a projected income of IDR 251,227,558,452.03. The actual shutdown time recorded was 22 hours, resulting in a financial loss of IDR 679,720,708.26. Therefore, the total revenue achieved was IDR 250,547,837,743.77.

During the Third PM 8000 Hours to Fourth PM 8000 Hours interval, the equipment was anticipated to run for 8231 hours. The ideal revenue under normal conditions was IDR 254,308,234,076.73. Nonetheless, 17 hours of production loss caused financial damage amounting to IDR 525,238,729.11, which brought the final gain to IDR 253,782,995,347.62.

Finally, in the phase from Fourth PM 8000 Hours until the end of May 2024, the equipment was planned to be operational for 9136 hours, with an expected revenue of IDR 282,269,472,302.88. However, only 4 hours of shutdown occurred, resulting in a minor loss of IDR 123,585,583.32, leading to a realized income of IDR 282,145,886,719.56.

Calculation of Total Production for Each Period

Based on the data, during the period from PM 1000H to First PM 8000H, the expected total profit amounted to Rp 247,202,063,062.50, while losses due to shutdown reached Rp 2,070,058,520.83. This results in a net realized profit of Rp 245,132,004,541.67.

In the First PM 8000H to Second PM 8000H period, the potential profit was Rp 268,767,747,325.17, with shutdown-related losses totaling Rp 1,390,337,812.35, leaving an actual profit of Rp 267,377,409,512.82. For the Second PM 8000H to Third PM 8000H period, the expected earnings were Rp 251,527,558,452.03, with Rp 679,720,708.26 in shutdown losses, yielding Rp 250,847,837,743.77 in net profit.

During the Third PM 8000H to Fourth PM 8000H period, the expected profit was Rp 254,308,234,076.73. After accounting for shutdown losses of Rp 525,238,729.11, the actual profit reached Rp 253,782,995,347.62.

In the final observed period, Fourth PM 8000H to the End of May 2024, the production was expected to generate Rp 282,269,472,302.88. However, shutdown-related losses of Rp 123,585,583.32 reduced the net realized profit to Rp 282,145,886,719.56.

The average expected profit per period across all phases is Rp 260,815,015,043.86, the average shutdown loss is Rp 957,788,270.77, and the average actual profit achieved is Rp 259,857,226,773.09. Summing all values from the five periods, the total expected profit is Rp 1,304,075,075,219.31, the total shutdown-related loss is Rp 4,788,941,353.87, and the total realized profit is Rp 1,299,286,133,865.44.

Discussion

In this study, the Mean Time Between Failure (MTBF) method was employed to measure the average time between machine failures, offering insights into the reliability and operational performance of equipment. The purpose of this approach is to reduce losses incurred by the company due to prolonged downtime. MTBF analysis aids in planning preventive maintenance activities by identifying optimal intervals for servicing. With accurate MTBF results, companies can manage downtime more effectively, minimize operational interruptions, and reduce the costs associated with equipment failures. Additionally, this information can support decision-making processes regarding equipment replacement, repair, and the allocation of maintenance resources.

The findings revealed that Machine B, which recorded a relatively low MTBF of 2,670.25 hours, experienced the lowest total downtime at 68 hours. This suggests that failures occurred more frequently, though each incident resulted in shorter repair times. Conversely, Machine A exhibited a higher MTBF of 4,272.4 hours but had the highest total downtime at 87 hours, indicating less frequent failures but longer repair durations.

The total average financial loss was calculated at IDR 957,788,270.77, with an overall loss of IDR 4,788,941,353.87. The maintenance cost during the mid-period was estimated at IDR 1,030,000,000. Summing all mid-period maintenance and repair expenses yielded a total cost of IDR 5,150,000,000. Based on the difference between total and average loss values, it was concluded that mid-period maintenance was not economically justified. The average loss cost remained lower than the maintenance cost by a margin of IDR 72,211,729.23, while the total loss cost was also below the mid-period maintenance cost by IDR 361,058,646.13.

CONCLUSION

This study reveals the average failure time for each period, with Machine A experiencing 10 failures totaling 87 hours of downtime and Machine B undergoing 16 failures totaling 68 hours. These figures highlight the operational reliability differences between the two machines and provide essential data for evaluating performance and scheduling maintenance. The analysis indicates that Machine A experienced slightly longer downtimes despite fewer failures, suggesting that the severity or repair complexity may vary between units. Furthermore, the findings support informed decision-making regarding whether mid-period maintenance is necessary. The results suggest that mid-period maintenance may not be required, as the potential financial losses caused by downtime remain below the estimated cost of repairs. The company is encouraged to implement more detailed maintenance planning, especially by examining the quality and specifications of replacement components. These component-level improvements could significantly reduce future downtime and improve the overall efficiency of maintenance strategies.

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