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Periodic Maintenance Analysis Of Locomotive Series CC201 And CC203 Using Markov Chain Method at UPT.Balaiyasa Yogyakarta

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ABSTRACT

The objectives of this study are: (1) To get and provide the right periodic maintenance implementation time on CC201 locomotive maintenance. (2) To get and provide the right periodic maintenance implementation time on CC203 locomotive maintenance. The method used in this research is Markov Chain, using the type of applied research. This research uses a quantitative approach. The data collection techniques used are (1) Primary Data Collection; and (2) Secondary Data Collection. Meanwhile, the research instruments used (1) Observation Sheet; and (2) Documentation. The data analysis used is (1) Determination of Condition or State; (2) Creating a Transition Matrix; and (3) Steady State Analysis to get the probability of locomotive conditions in good condition, lightly damaged, moderately damaged or severely damaged. The results of this study show that: (1) The right periodic maintenance implementation time on CC201 locomotive maintenance is proposal II at interval P2 with the highest probability of good condition of 0.609 and the lowest probability of heavy condition of 0.021. With this, a maintenance scheduling policy is obtained for every 1 month to perform periodic maintenance on day 7,128. (2) The right periodic maintenance implementation time for CC203 locomotive maintenance is proposal II at interval P2 with the highest probability in good condition of 0.619 and the lowest probability in severe condition of 0.142. With this, a maintenance scheduling policy is obtained for every 1 month to perform periodic maintenance on day 24,516.

1. Introduction

Transportation is an important part of Indonesian life because it plays a role in supporting daily mobility and fulfilling daily needs [1]. There are three main types of transportation, namely land, air and sea transportation. Indonesian people tend to choose land transportation because it is considered more practical and economical [2]. Transportation also helps speed up travel time and distance, which has a significant impact on social, economic and political development [3].

One of the most widely used modes of land transportation is the train, especially in Java and Sumatra. In recent years, the railway system in Indonesia has developed rapidly, along with the improvement of facilities and services provided by PT Kereta Api Indonesia (KAI). This has made more and more people switch to using trains as the main mode of transportation.

One of the key facilities in the train maintenance system is UPT Balai Yasa Yogyakarta, which serves as a locomotive maintenance facility in Java and Sumatra. Balai Yasa Yogyakarta is in charge of ensuring that locomotives are in good condition and ready for usage. However, continual use of locomotives without proper maintenance might degrade engine reliability [4]. Reliability is a capacity of the system to work successfully under specific operational conditions over a set length of time. As a result, adequate and frequent maintenance is essential to extend the service life of the locomotive and keep maintenance expenses from rising.

Locomotive maintenance seeks to keep the engine in good condition and decrease the danger of component damage. However, some issues still arise. Yogyakarta Yasa Center reported frequent breakdowns on CC201 and CC203 locomotives between January and December 2023, leading in delays and higher operational costs. Diesel motors, compressors, turbochargers, and electrical systems are the most common components to fail. Downtime records show that CC201 locomotives had 4,400 hours of downtime with maintenance expenses of Rp4.57 billion, while CC203 locomotives had 1,766 hours of downtime with maintenance costs of Rp2.68 billion.

Locomotive maintenance is carried out in stages, ranging from daily maintenance to annual maintenance at their respective depots. Locomotives will undergo Final Periodic Service (SPA) every 325,000 km or 2 years, and Final Maintenance (PA) every 650,000 km or 4 years. The maintenance includes replacing components such as engine heads, turbochargers, diesel motors, checking compressors, radiators, and electrical systems. In order for the locomotive to operate optimally, maintenance must be carried out with the right method and according to a predetermined schedule

Table 1. Variety and Quantity Data of Locomotives CC201 and CC203

No	Locomotive Type	Total	In Units
1	CC201	8	Locomotive
2	CC203	4	Locomotive

This study focuses on the locomotives CC201 and CC203 where the number of locomotive can be seen in Table 1. To give the finest service, locomotives must be ready and serviceable. As a result, it requires regular and proper maintenance. The budget for preventive and downtime will be impacted by maintenance. If they are not properly maintained, frequently utilized engines will frequently fail, making it impossible to travel or conduct work. To avoid damage and significant maintenance expenses, machine maintenance must be performed properly. In the process of repairing locomotives CC201 and CC203, researchers collected historical data on the total maintenance downtime during the one-year period from January to December 2023 shown in Table 2.

Table 2. Locomotive Damage Data (January to December 2023)

Locomotive	**Month**	**Total Downtime (Hours)**	**Budget (Rp)**
CC201	January 2023 - December 2023	4,400	4.570.000.000
CC203	January 2023 - December 2023	1,766	2.680.000.000
Total		6,166	7.250.000.000

Based on the data Table 2, locomotive CC201 has a total downtime maintenance budget of Rp4,570,000,000 for 4,400 hours and locomotive CC203 has a total maintenance budget of Rp2,680,000,000. The historical maintenance data shows that locomotive CC201 has the most problems and is most likely to break down, but the two locomotives are not too far apart. To solve these two locomotives, maintenance policy planning will be carried out because the damage is quite severe.

There are three categories of locomotive damage: lightly damaged, moderately damaged, and severely damaged. In a lightly damaged condition, the locomotive will still be able to serve perfectly although there is still a possibility of minor damage. For moderate conditions, locomotives can generally still operate but are in a worrying condition and need component replacement. As for heavy damage, the locomotive cannot function because a major disassembly or overhaul must be carried out

The purpose of locomotive maintenance is to prevent unexpected breakdowns and ensure that the locomotive will continue to operate until it will not be subject to breakdown interruptions. An organized locomotive maintenance planning strategy, therefore, is essential to reduce locomotive failures in service. Appropriate calculations must be used to estimate changes that are likely to occur in the future in order to provide maintenance recommendations in the locomotive maintenance policy. By using the right calculation method, it is expected to provide an orderly and organized solution for locomotive maintenance planning, so that maintenance can run without incidents and can reduce maintenance budgets [5], [6].

This research aims to make a maintenance planning strategy, especially for locomotives with codes CC201 and CC203. It is hoped that with a maintenance planning strategy, it will make the maintenance process more efficient and effective.

2. Methodology

The type of research used is applied research. Applied research is an investigation in a careful, systematic and sustainable manner related to a problem that aims to be used immediately for specific purposes [7].This research uses a quantitative approach. Quantitative research is an approach to testing objective theories through examining correlations between variables. These variables can be measured, generally with instruments, as a result numerical data can be analyzed using statistical procedures [8].

The location that acts as a place for this research is UPT. Balai Yasa Yogyakarta which is located at Jl. Kusbini No.1, Demangan, Gondokusuman, Yogyakarta, Yogyakarta Special Region. This research was conducted from April 22 to May 22, 2024. The subjects in the analysis in this study are UPT. Balai Yasa Yogyakarta as the main source of data on locomotive maintenance procedures and schedules. Supervisors and Technicians as individuals directly involved in the locomotive maintenance process and a source of information about data, maintenance processes and experiences in the field. Operations Manager as the party responsible for locomotive scheduling and as a source of data on operational policies and maintenance strategies.

The objects of this research include CC201 and CC203 series locomotives, periodic maintenance systems according to maintenance period schedules, historical maintenance data, and reliability and performance of locomotives including data on damage and downtime. This research also utilizes the Markov Method [9], [10] to model the transition probabilities between locomotive conditions, such as operational, maintenance, and failure states, based on historical maintenance data. The method helps to analyze the likelihood of locomotives transitioning between these states and to evaluate the reliability and performance over time.

The data collection methods used are primary and secondary data collection. Primary data collection through observation, namely through direct data collection by seeing, paying attention and observing the surrounding conditions directly. While secondary data is secondary data in the form of documents, files, archives or industrial records for a period of 1 year.

The research instrument used was an observation sheet to facilitate observation. Then documentation is used in the process of writing, photographing, and recording information about research data.

3. Result and Discussion

A. CC201 Locomotive

Fig. 1 showing the frequency of the locomotive CC201 operational for past 1 year. After analyze the probability of proposal I and proposal II on locomotive CC201 according to the data, the steady state probability results are obtained as in the following table.

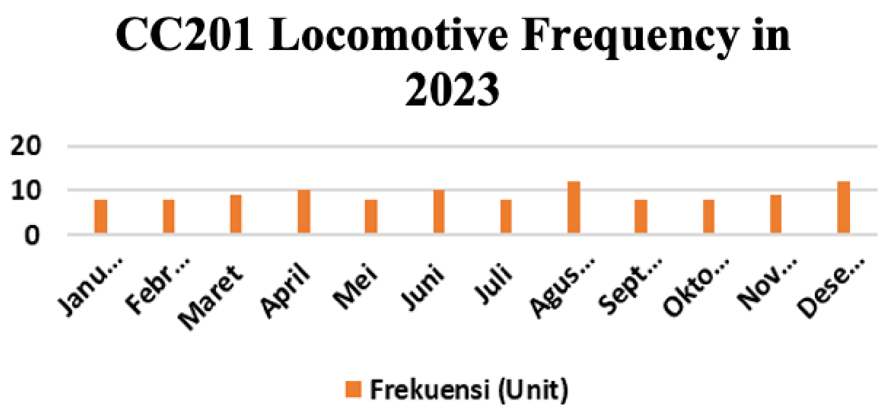

Figure 1. CC201 Locomotive Frequency

Table 3. Locomotive Steady State Probability

Maintenance Activities	Probability of Proposal			
	Good	Lightweight	Medium	Weight
P0	0,321	0,215	0,255	0,207
		Probability of Proposal II		
Maintenance Activities	Good	Lightweight	Medium	Weight
P1	0,139	0,505	0,398	0,089
P2	0,609	0,281	0,086	0,021
P3	0,561	0,339	0,079	0,019
P4	0,432	0,290	0,206	0,069

From the Table 3, where P0 or proposal I with the action taken is monthly check (MC) in status 4 results in the possibility of CC201 locomotive in good condition 0.321, the possibility of light damage 0.215, the possibility of medium damage 0.255, and the possibility of heavy damage 0.217. As for P1, P2, P3, and P4 in proposal II, the policy carried out in P1 is to conduct monthly checks in status 4 and daily checks in status 3, 4 resulting in the possibility of CC201 locomotives in good condition 0.139, the possibility of light damage 0.505, the possibility of medium damage 0.398 and the possibility of heavy damage 0.089. Furthermore, the policy carried out in P2 is to conduct monthly checks in status 3, 4 and daily checks in status 2, resulting in the possibility of CC201 locomotives in good condition 0.609, the possibility of light damage 0.281, the possibility of medium damage 0.086 and the possibility of heavy damage 0.021. The policy carried out in P3 is to conduct monthly checks in status 4 and daily checks in status 2, 3 obtained the results of the possibility of CC201 locomotives in good condition 0.561, the possibility of light damage 0.339, the possibility of medium damage 0.079 and the possibility of heavy damage 0.019. Furthermore, the last policy carried out in P4 is to conduct a monthly check in status 4, 3, the results of the possibility of CC201 locomotives in good condition are 0.432, the possibility of light damage 0.290, the possibility of medium damage 0.206 and the possibility of heavy damage 0.069.

The results based on the steady state probability of the CC201 locomotive will be used to determine the appropriate maintenance time, with the following discussion.

a. Probability Comparison
   P0: Good (0.321), Heavy (0.207)
   P1: Good (0.139), Heavy (0.089)
   P2: Good (0.609), Heavy (0.021)
   P3: Good (0.561), Heavy (0.019)
   P4: Good (0.432), Heavy (0.069)
b. Analysis
   1) P2 has the highest probability for good condition at 0.609 and a very low probability for severe condition at 0.021.
   2) P3 also showed good results with a high good condition probability of 0.561 and the lowest severe probability of 0.019.
   3) P1 showed the worst results with the lowest probability of good condition and the highest probability of severe condition.
c. Interpretation
   1) P2 represents the optimal point where the locomotive engine is in the best condition with a low risk of severe damage.
   2) The interval between P2 and P3 is the period when the engine has the best performance.
d. Recommendation
   The bestmaintenance should be done at interval P2, because this is the point where the probability of the engine being in good condition is highest. The risk of heavy damage is lowest, but has not yet reached the low point that occurs at P3. Performing maintenance at P2 will help to maintain the optimal condition of the locomotive engine and prevent deterioration to a worse condition.

From the results of the steady state probability of locomotive CC201, the best maintenance time is obtained at interval P2. This will maximize the operating time of the locomotive engine under optimal conditions and minimize the risk of heavy damage. P2 intervals are corrective maintenance in states 3 and 4, and prevention in state 2 every 1 month.

To determine the best maintenance schedule in the context of time based on steady state probability data that has been obtained, the total results of the probability of heavy conditions from P1 to P4 are taken. From the total results of heavy conditions P1 to P4, 0.198 is obtained. The solution is as follows.

0.198 × 60 days = 11.88. This result is rounded to 0.1188 × 60 days = 7.128. Then the CC201 locomotive is recommended to perform maintenance on the 7,128th day of each month.

B. CC203 Locomotive

Fig. 2 showing the frequency of the locomotive CC203 operational for past 1 year. After analyze the probability of proposal I and proposal II on locomotive CC201 according to the data, the steady state probability results are obtained as in the following table.

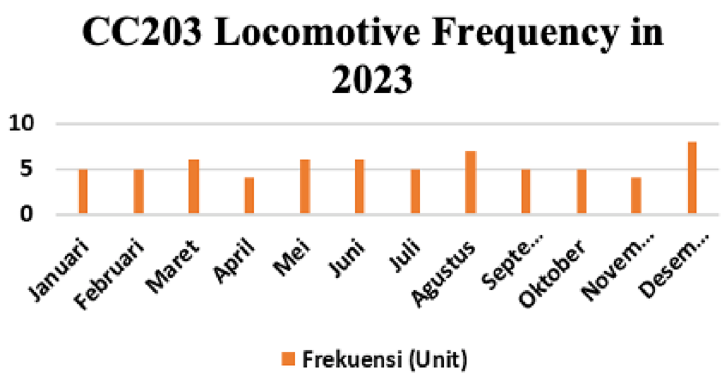

Figure 2. CC203 Locomotive Frequency

Table 4. Steady State Probability of Locomotive CC203

Maintenance Activities	**Probability of Proposal**			
	Good	**Lightweight**	**Medium**	**Weight**
P0	0,432	0,178	0,076	0,232
	Probability of Proposal II			
Maintenance Activities	**Good**	**Lightweight**	**Medium**	**Weight**
P1	0,371	0,330	0,097	0,199
P2	0,619	0,190	0,047	0,142
P3	0,592	0,226	0,044	0,136
P4	0,425	0,307	0,071	0,204

From the Table 4, where P0 or proposal I with the action taken is a monthly check (MC) in status 4 results in the possibility of locomotive CC203 in a good state of 0.432, the possibility of light damage 0.178, the possibility of medium damage 0.076, and the possibility of heavy damage 0.232. As for P1, P2, P3, and P4 in proposal II, the policy carried out in P1 is to conduct monthly checks in status 4 and daily checks in status 3, 4 resulting in the possibility of CC203 locomotives in good condition 0.371, the possibility of light damage 0.330, the possibility of medium damage 0.097 and the possibility of heavy damage 0.199. Furthermore, the policy carried out in P2 is to carry out monthly checks in status 3, 4 and daily checks in status 2 obtained the results of the possibility of the CC203 locomotive being in good condition CC203 locomotive in good condition 0.619, the possibility of light damage 0.190, the possibility of medium damage 0.047 and the possibility of heavy damage 0.142. The policy carried out in P3 is to conduct monthly checks in status 4 and daily checks in status 2, 3 with the results of the possibility of CC203 locomotives in good condition 0.592, the possibility of minor damage 0.226, the possibility of moderate damage 0.044 and the possibility of heavy damage 0.136. Furthermore, the last policy carried out in P4 is to conduct a monthly check in status 4 3, the results obtained are the possibility of CC203 locomotives in good condition 0.425, the possibility of minor damage 0.307, the possibility of moderate damage 0.071 and the possibility of heavy damage 0.204.

The results through the steady state probability of the CC201 locomotive will be used to determine the right maintenance time, with the following discussion.

a. Probability Comparison

P0: Good (0.432), Heavy (0.232)
P1: Good (0.371), Heavy (0.199)
P2: Good (0.619), Heavy (0.142)

P3: Good (0.592), Heavy (0.136)
P4: Good (0.425), Heavy (0.204)

b. Analysis of
   1) P2 has the highest probability for good condition at 0.619 and a very low probability for severe condition at 0.142.
   2) P3 also shows good results with a high good condition probability of 0.592 and the lowest severe probability of 0.136.
   3) P1 and P4 showed a decrease in condition compared to P2 and P3.
c. Recommendations
   The bestmaintenance should be done at interval P2, because P2 has the highest probability of locomotives being in good condition, although the probability of heavy conditions at P2 is slightly higher than P3, but the difference is not significant. Performing maintenance at the P2 interval will maximize locomotive operating time in optimal conditions.

CC203 locomotive obtained the best maintenance time at interval P2. This will maximize the operating time of the locomotive engine under optimal conditions and minimize the risk of heavy damage. P2 intervals are corrective maintenance in status 3 and 4, and prevention in status 2 every 1 month. In determining the best maintenance schedule in the context of time based on steady state probability data that has been obtained, the total results of the probability of heavy conditions from P1 to P4 are taken. From the total results of heavy conditions P1 to P4, 0.681 is obtained. This result is rounded up to 0.4086 x 60 days = 24.516. Then the CC203 locomotive is recommended to perform maintenance on the 24.516th day of each month.

4. Conclusion

The results of the research carried out and based on the discussion that has been presented, it can be concluded that can be concluded that:

The right periodic maintenance implementation time for CC201 locomotive maintenance is proposal II at the P2 interval, namely monthly check (MC) maintenance in status 3, 4 and daily check (DC) in status 2. This is because P2 has the highest probability of good condition of 0.609 and a very low probability of severe condition of 0.021. Performing maintenance on P2 will help to maintain the optimal condition of the CC 201 locomotive engine and prevent a decline to a worse condition. For the maintenance scheduling policy for each month, it is determined that using proposal II at interval P2 provides scheduling for CC201 locomotives every 1 month to perform periodic maintenance on days 7,128 each month.

The right periodic maintenance implementation time for CC203 locomotive maintenance is proposal II at interval P2, namely monthly check (MC) maintenance in status 3, 4 and daily check (DC) in status 2. This is because P2 has the highest probability for good conditions, which is 0.619 and a very low probability for severe conditions, which is 0.142. Performing maintenance at the P2 interval will maximize locomotive operating time under optimal conditions. For the maintenance scheduling policy for each month, it is determined that using proposal II at interval P2 provides scheduling for locomotive CC203 every 1 month to perform periodic maintenance on day 24,516 each month.

Conflict of interest

The authors declare no conflict of interest.

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