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Analysis of Maintenance Priority Scale Determination of Permanent Way MRT Jakarta with Reliability Centered Maintenance Method

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ABSTRACT

Inspection and maintenance of infrastructure to maintain service life and to restore the function of railway components to match the replacement plan and ensure the feasibility and reliability of the MRT Jakarta operating system as planned. The priority scale of permanent way maintenance using the Reliability Centered Maintenance (RCM) method, especially on elevated lines, will be obtained for effective and efficient railway maintenance planning. With quartile calculations based on the criticality value of the first priority results, namely the location of the road or the Fatmawati Station - Cipete Raya Station corridor with a value of 41, the second priority on the Lebak Bulus Station - Fatmawati Station corridor with a value of 38, the third priority on the Cipete raya Station - Haji Nawi Station corridor with a value of 37, the fourth priority on the Blok A - Blok M Station corridor with a value of 36, the fifth priority on the haji Nawi - Blok A Station corridor with a value of 34, and on the sixth priority on the Blok M - ASEAN Station corridor with a total value of 29.

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1 INTRODUCTION

Trains are one of the mass land transportation tools that have recently experienced an increase in users. Jabodetabek train passengers were 25.1 million people or 79.58 percent of total train passengers. The increase in the number of passengers occurred in the Jabodetabek and Non Jabodetabek Java regions, up 0.41 percent and 3.85 percent respectively. Large capacity, punctuality, freedom from congestion, relatively affordable prices, and high levels of safety make trains a mainstay of society.

MRT Jakarta is one of the important modes of transportation in an integrated transportation system, with optimal quality and low prices so that the MRT Jakarta company optimizes every stage of the entire process including maintenance methods. PT. MRT Jakarta has a railway line with a total length of 15.7 km with a total of 13 stations which are divided into two sections, namely elevated with 7 stations from Lebak Bulus Station - ASEAN Station and 6 underground stations from Senayan Station - HI Roundabout Station and there is 1 depot located in Lebak Bulus.

In 2023, the MRT Jakarta experienced a thermite rail joint malfunction when an inspection of the rail joint was carried out, a cavity was found in the rail joint which caused a new rail piece to be replaced on the Cipete Raya - Haji Nawi line in August 2023. Regulation of the Minister of Transportation Number 32 concerning Standards and Procedures for Railway Infrastructure Maintenance, every railway infrastructure operator is required to carry out maintenance of the operated infrastructure to maintain the reliability of railway infrastructure so that it remains fit for operation.

Reliability Centered Maintenance (RCM) reliability-based maintenance method for the maintenance of railway components based on priorities per corridor. RCM is a method that includes creating a malfunction which will then look for aspects of damage. With the aspects of damage and the cause of damage will be determined so that the effect of damage can be analyzed on the implementation of maintenance. The priority scale of permanent way maintenance especially on elevated lines, will be obtained from the calculation of criticality values that are reviewed from several aspects ranging from technological aspects to the condition of railway components.

2 RESEARCH METHOD

The primary data and secondary data needed are data from the inspection of the MRT Jakarta railway components from Lebak Bulus Station - ASEAN Station. The data is then processed through the calculation of passing tonnage, quartile calculation, classification of component damage, and calculation of the percentage of component maintenance. Furthermore, data analysis is carried out using the Reliability Centered Maintenance (RCM) method to determine the maintenance priority scale based on the criticality value to planning component maintenance scheduling from the calculation of maintenance priorities per corridor.

According to (Nowlan & Heap, 1978) RCM can be defined as a systematic approach to system functionality, the failure of that functionality, the cause of the damage, and the infrastructure affected by the damage. Once the damage is known, it is classified using safety, reliability, and economic considerations on a priority basis.

Table 1 Parameters of Reliability Centered Maintenance Method

Factors Calculation	Supporting Factors	Description	Critical Classification			
			Score 1	**Score 2**	**Score 3**	**Score 4**
Technology	-	Type of operational technology used	Mecha-nical	Electro-mechanical	Electricity	Electronic
Traffic density	-	Number of train circulation asset use in day	1 – 20	20 – 60	60 – 200	> 200
Return	-	Modelled return on asset use	Low	Medium	High	Very High
Train Operations	Operating hours	Legth of train operating	6 hours	12 hours	18 hours	24 hours
	Speed Facility	Operating Speed	Low	Medium	High	Very High
Users	-	Number of passengers passing through the road patch	Low	Medium	High	Very high
Reliability	Railway Class Reliability	Passing Tonnage	IV – V	III	II	I
	Track Quality Index (TQI)	Geometric assessment using *track master*	0 – 20	21 – 40	41–60	> 60
Maintenance	Joint	Number of rail joint failures fish plate, thermit	Low	Medium	High	Very high
	Fastening	Number of fastening failures	Low	Medium	High	Very high
	Sleeper	Number of sleeper failures	Low	Medium	High	Very high
	Track Bed	Number of track bed failures	Low	Medium	High	Very high
Cost	-	Maintenance cost in a year	Low	Medium	High	Very high
Environmental Impact	-	Noise generated	Low	Medium	High	Very high
Safety	Number of curve	Number of curve in a corridor	Low	Medium	High	Very high
	Small radius curved length	Arch length < 800m	Low	Medium	High	Very high

3 RESULT AND DISCUSSION

3.1 Condition of the MRT Jakarta Line

The MRT Jakarta line construction is an elevated structure that stretches 8.73 km from the Lebak Bulus area to ASEAN. The MRT Jakarta line is a double track or double track with the term uptrack for train travel from Lebak Bulus Station - Bundaran HI Station (small kilometer to large kilometer), and for downtrack for train travel from Bundaran HI Station - Lebak Bulus Station (large kilometer to small kilometer). The seven elevated stations of this construction are as follows:

a. Lebak Bulus (LBB)
b. Fatmawati (FTM)
c. Cipete Raya (CPR)
d. Haji Nawi (HJN)
e. Blok A (BLA)
f. Blok M (BLM)
g. ASEAN (ASN).

3.2 Inspection Results of the MRT Jakarta Railway

The results of the MRT Jakarta railway component inspection from the results of primary and secondary findings. For secondary findings, damage is reported on the exodus application accompanied by images and a brief description of the component damage. From the damage to the railway components, it is previously necessary to know the number of assets owned by the MRT Jakarta line as follows:

Table 2 Total Sleeper and Fastening System Assets

No.	Koridor	Rail Line Leght (meter)	Number of *Sleeper* (pcs)	Number of Fastening System (pcs)
1.	LBB-FTM	2018	3363	13453
2.	FTM-CPR	1811	3018	12073
3.	CPR-HJN	1292	2153	8613
4.	HJN-BLA	1217	2028	8113
5.	BLA-BLM	1267	2112	8447
6.	BLM-ASN	631	1052	4207

3.3 Passing Tonnage

The load of a known train set crossing the Lebak Bulus Station to ASEAN Station roadbed is calculated according to its formation. A train set consists of several trains equipped with drives. The MRT Jakarta has a total of 16 train sets with 6 trains in one train set.

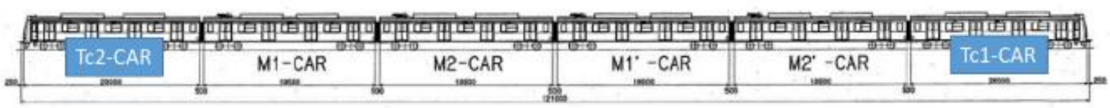

Figure 1 General Specification of MRT Jakarta Train Set

The calculation of passing tonnage includes the weight of the facilities and the number of train trips. The number of train trips in one day in 2023 is 131 trips/day and the weight of the facilities is as follows:

Table 3 Weight of MRT Jakarta Train Set

No.	Type of Train	Weight (kg)
1.	Tc2 Car	49.682
2.	M1 Car	55.292
3.	M2 Car	55.593
4.	M1' Car	55.292
5.	M2' Car	55.543
6.	Tc1 Car	49.683

T_E = total weight of train set

$$T_E = Tc1 + M1 + M2 + M1' + M2' + Tc2$$

$$T_E = 49.682 + 55.292 + 55.593 + 55.292 + 55.543 + 49.683$$

$$T_E = 321{,}085 \ ^{ton}/_{day}$$

$T_E total = T_E \text{ x trip}$
$T_E total = 321{,}085 \text{ x } 131$
$T_E total = 38.089{,}784\ ^{ton}/_{day}$
Then if converted to T based on the T equation as follows:
$T = 360 \text{ x S x } T_E$
$T = 360 \text{ x } 1{,}1 \text{ x } 38.089{,}784$
$T = 16.667.554{,}46\ ^{ton}/_{year}$

3.4 Prioritization Based on Criticality Value

The examination data is then subjected to quartile calculations to determine the weighting assessment boundaries from the lowest value of 1 to the highest value of 4 and means the most priority. Example of determining the weighting value with quartile calculation:

Table 4 Environmental impact of noise

No.	Corridor	Limit of Noise (dB)	Actual Noise (dB)
1.	LBB-FTM	75	80,15
2.	FTM-CPR	75	84
3.	CPR-HJN	75	81,6
4.	HJN-BLA	75	83,25
5.	BLA-BLM	75	79,35
6.	BLM-ASN	75	76,2

The data obtained is then sorted based on the smallest to largest results.

Table 5 Sorting of Environmental Impact Data

No.	Corridor	Limit of Noise (dB)	Actual Noise (dB)
1	BLM-ASN	75	76,2
2	BLA-BLM	75	79,35
3	LBB-FTM	75	80,15
4	CPR-HJN	75	81,6
5	HJN-BLA	75	83,25
6	FTM-CPR	75	84

Calculation of quartile boundary values using the formula:
Q_1 = 76,2 + 0,25 (79,35 – 76,2) = 76,99
Q_2 = 80,15 + 0,5 (81,6 – 80,15) = 80,88
Q_3 = 83,25 + 0,75 (84 – 83,25) = 83,81

Table 6 Environmental Impact Limitation Value

No.	Score	Interval
1.	4	> 83,81
2.	3	80,88 - 83,81
3.	2	76,99 - 80,88
4.	1	< 76,99

Table 7 Environmental Impact Criticality Value

No.	Corridor	*Actual Noise* (dB)	Criticality Value
1.	LBB-FTM	80,15	2
2.	FTM-CPR	84	4
3.	CPR-HJN	81,6	3
4.	HJN-BLA	83,25	3
5.	BLA-BLM	79,35	2
6.	BLM-ASN	76,2	1

a) Technology
The signaling and operational technology used by the MRT Jakarta is electric signaling on all corridors using Electricity Overflow and an operational system that uses the Operational Control Center (OCC).

Table 8 Criticality Value of Technology

No.	Corridor	Technology	Criticality Value
1.	LBB – FTM	Electricity	3
2.	FTM – CPR	Electricity	3
3.	CPR – HJN	Electricity	3
4.	HJN – BLA	Electricity	3
5.	BLA – BLM	Electricity	3
6.	BLM – ASN	Electricity	3

b) Traffic Density
Traffic density is characterized by the amount of circulation in a corridor.

Table 9 Traffic Density Criticality Value

No.	Corridor	Trip 2022	Trip 2023	Criticality Value
1.	LBB-FTM	558	611	4
2.	FTM-CPR	558	611	4
3.	CPR-HJN	558	611	4
4.	HJN-BLA	558	611	4
5.	BLA-BLM	558	611	4
6.	BLM-ASN	558	611	4

c) Train Operation
1. Operational Time
The length of train operations in one corridor can be seen in the MRT Jakarta Train schedule diagram/GAPEKA and Timetable. The MRT Jakarta operating hours start from 05.00 - 24.00 so the operating hours of the MRT Jakarta facilities are 19 hours.

Table 10 Operational Time Criticality Value

No.	Corridor	Operational Time (hour/day)	Criticality Value
1.	LBB-FTM	19	3
2.	FTM-CPR	19	3
3.	CPR-HJN	19	3
4.	HJN-BLA	19	3
5.	BLA-BLM	19	3
6.	BLM-ASN	19	3

2. Speed of Train
At the MRT Jakarta, the operational speed of the facility has been set by the OCC team according to the headway and railway conditions. Data obtained from visual observations of the driver's speedometer during cabin ride activities as follows:

Table 11 Train Speed Criticality Value

No.	Corridor	Operational Speed (km/hour)	Criticality Value
1.	LBB-FTM	75	3
2.	FTM-CPR	75	3
3.	CPR-HJN	84	4
4.	HJN-BLA	52	1
5.	BLA-BLM	81	3
6.	BLM-ASN	49	1

d) Passenger
The number of passengers served by a corridor is calculated by dividing the total passengers on all passing trains by the total length of the corridor.

Table 12 Passenger Criticality Value

No.	Corridor	Passenger (human/m)	Criticality Value
1.	LBB - FTM	76	2
2.	FTM - CPR	82	3
3.	CPR - HJN	83	3
4.	HJN - BLA	61	1
5.	BLA - BLM	62	2
6.	BLM - ASN	502	4

e) Reliability
1. Railway Class Reliability
The class of railway is influenced by the traffic load of a corridor. The MRT Jakarta has the same traffic load because the facilities used are all the same according to the calculations in the following subchapters 3.3

Table 13 Railway Class Reliability Criticality Value

No.	Corridor	Passing Tonnage (ton/year)	Criticality Value
1	LBB-FTM	16.667.554,46	3
2	FTM-CPR	16.667.554,46	3
3	CPR-HJN	16.667.554,46	3
4	HJN-BLA	16.667.554,46	3
5	BLA-BLM	16.667.554,46	3
6	BLM-ASN	16.667.554,46	3

2. Track Quality Index (TQI)
The TQI value is a value that represents the condition of the railway geometry horizontally and vertically which is important to take into account because it is one of the biggest contributors to the decline in railway quality. the results of the TQI calculation are as follows:

Table 14 Track Quality Index (TQI) Criticality Value

No.	Corridor	TQI Total	Criticality Value
1.	LBB-FTM	5,2	1
2.	FTM-CPR	4,7	1
3.	CPR-HJN	3,6	1
4.	HJN-BLA	5,6	1
5.	BLA-BLM	4,4	1
6.	BLM-ASN	5,9	1

f) Maintenance
Maintenance is carried out on components that affect the operation of the facility. Analysis of railway component damage data is carried out to obtain maintenance weighting values.
1. Rail Joint
There are several types of rail joints used in the MRT Jakarta, namely welding, fishplate / normal joint, insulated rail joint (IRJ) and glue insulated joint (GIJ).

Table 15 Rail Joint Criticality Value

No.	Corridor	Failures of Rail Joint (point)	Criticality Value
1.	LBB-FTM	6	4
2.	FTM-CPR	1	2
3.	CPR-HJN	0	1
4.	HJN-BLA	3	3
5.	BLA-BLM	3	3
6.	BLM-ASN	0	1

2. Fastening System
   The damage to the fastening system has several aspects to its components.

Table 16 Fastening System Criticality Value

No.	Corridor	Failures of Fastening System (set)	Criticality Value
1.	LBB-FTM	2	2
2.	FTM-CPR	1	2
3.	CPR-HJN	1	2
4.	HJN-BLA	-	1
5.	BLA-BLM	4	4
6.	BLM-ASN	2	3

3. Sleeper
   Sleeper damage includes cracking, spalling, and the Anti Vibration System is out or loose.

Table 17 Sleeper Criticality Value

No	Corridor	Failures of Sleeper (pcs)	Criticality Value
1	LBB-FTM	21	3
2	FTM-CPR	8	2
3	CPR-HJN	8	2
4	HJN-BLA	60	4
5	BLA-BLM	33	3
6	BLM-ASN	2	1

4. Trackbed
   The track bed is a concrete-based component with damage such as cracking and spalling.

Table 18 Track Bed Criticality Value

No.	Corridor	Failures of Track Bed (point)	Criticality Value
1	LBB-FTM	14	2
2	FTM-CPR	42	4
3	CPR-HJN	31	3
4	HJN-BLA	11	2
5	BLA-BLM	15	3
6	BLM-ASN	7	1

g) Environmental Impact
   The environmental impact criticality score focuses on noise that impacts passengers and the surrounding environment.

Table 19 Environmental Impact Criticality Value

No.	Corridor	*Actual Noise* (dB)	Criticality Value
1.	LBB-FTM	80,15	2
2.	FTM-CPR	84	4
3.	CPR-HJN	81,6	3
4.	HJN-BLA	83,25	3
5.	BLA-BLM	79,35	2
6.	BLM-ASN	76,2	1

h) Safety
   1. Number of curve
      The safety factor is assessed through the number of risks that can endanger passengers, one of which is the number of curves.

Table 20 Number of Curve Criticality Value

No.	Corridor	Number of curves (pcs)	Criticality Value
1.	LBB-FTM	3	3
2.	FTM-CPR	6	4
3.	CPR-HJN	1	1
4.	HJN-BLA	2	2
5.	BLA-BLM	1	1
6.	BLM-ASN	1	1

2. Small radius curved length
   A small curved radius will affect the safety of train operations because it affects the centrifugal force and speed of the train.

Table 21 Small Radius Curve Length Criticality Value

No.	Corridor	Curve Length (km)	Criticality Value
1.	LBB-FTM	0,157	2
2.	FTM-CPR	0,164	3
3.	CPR-HJN	0,357	4
4.	HJN-BLA	0,368	2
5.	BLA-BLM	0,892	1
6.	BLM-ASN	1,126	2

From all existing parameters from technology to safety, the total value is obtained as follows:

Table 22 Total Criticality Value

No.	Corridor	Total Critical Value	Priority
1.	LBB-FTM	38	2
2.	FTM-CPR	41	1
3.	CPR-HJN	37	3
4.	HJN-BLA	34	5
5.	BLA-BLM	36	4
6.	BLM-ASN	29	6

3.5 Maintenance Planning

The railway maintenance carried out in this plan is maintenance on the upper structural components of the railway such as joints, tethers, sleepers and track beds. The priority of track bed maintenance is ignored because damage to the track bed has no effect on operations. The maintenance procedure carried out is based on PM 32 of 2012 concerning Standards and Procedures for Railway Infrastructure Maintenance which is then implemented by PT. MRT Jakarta in the MRT Jakarta Railway Inspection and Maintenance Manual.

Table 23 Component Maintenance Time Estimation

Location (Corridor)	Component	Estimated Time
FTM - CPR	Rail Joint	1 day
	Sleeper	2 day
	Fastening	1 day
	Track Bed	optional
LBB - FTM	Rail Joint	2 day
	Sleeper	5 day
	Fastening	1 day
	Track Bed	optional
CPR - HJN	Sleeper	2 day
	Fastening	1 day
	Rail Joint	0 day

Location (Corridor)	**Component**	**Estimated Time**
BLA - BLM	Track Bed	optional
	Rail Joint	1 day
	Sleeper	8 day
	Fastening	1 day
	Track Bed	optional
HJN - BLA	Sleeper	15 day
	Rail Joint	1 day
	Fastening	0 day
	Track Bed	optional
BLM - ASN	Sleeper	1 day
	Fastening	1 day
	Rail Joint	0 day
	Track Bed	optional

4 CONCLUSION

1. The condition of the existing line of the MRT Jakarta on the elevated line has many findings of damage to railway components starting from January 2024 with an open status or no maintenance has been carried out. Some of these components are joints, fastening systems, bearings / sleepers, and track beds.
2. Based on the calculation of determining the priority scale of the condition data of the MRT Jakarta elevated line with the Reliability Centered Maintenance (RCM) method from the results of the summation based on the criticality value and the component condition value, the first priority is obtained in the road patch / corridor of Fatmawati Station - Cipete Raya Station, then Lebak Bulus Station - Fatmawati Station, third priority at Cipete Raya Station - Haji Nawi Station, fourth priority in the Blok A - Blok M Station corridor, fifth priority in the Haji Nawi - Blok A Station corridor, and in the sixth priority Blok M - ASEAN Station corridor.
3. To determine the maintenance planning of railway components refers to PM 32 of 2012 which is then implemented by PT MRT Jakarta into the Railway Inspection and Maintenance Manual. In determining the time of implementation, it refers to annual schedule planning or annual planning based on maintenance priorities based on the condition of the MRT Jakarta line and its damage.

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