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FAULT ANALYSIS ON LRT JABODEBEK FACILITIES USING FMEA AND FISHBONE METHODS

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Abstract

The Jabodebek LRT development is part of the government's effort to solve traffic problems in urban areas, especially in Jakarta and its surroundings. The presence of Jabodebek LRT brings many benefits to the community and the government. To maintain all of that, it is necessary to carry out maintenance to maintain the reliability of railway infrastructure or facilities to remain fit for operation. This research method uses the FMEA (Failure mode and effect analysis) method which is used to identify how an equipment, facility, or system fails and the impact it has. From the results of this FMEA calculation, it can be seen that the risk level with the value that has the highest RPN (Risk Priority Number) is brake failure with an RPN value of 100. Based on the analysis conducted using the fishbone diagram on brake failure, 3 failure factors were found, namely, humans, machines, and materials. Suggestions given to Jabodebek LRT are the need for internal and external training from the company so that maintenance runs optimally and according to standard operating procedures (SOP), then the quality of the material is not good which causes the facility to require more maintenance time due to lack of spare parts.

Keyword: LRT Rollingstock Facility Jabodebek, FMEA (Failure Mode and Effect of Analysis), Fishbone

INTRODUCTION

The transport service industry, especially land transport such as trains, is one of the most strategic industries currently. This is because the need for cheap transport services for the lower middle class in Indonesia is an urgent need. As a Badan Usaha Milik Negara (BUMN) PT. Kereta Api Indonesia is required to get the maximum profit possible through its business operations, namely land transportation services, both passenger and goods transportation. (Olfebri, 2016). Rail transport has three characteristics, namely being tied to the track, using a more efficient road area, mass transit. Railway mode has advantages and disadvantages in performing its function as one of the modes of transport for goods and or people (Primadi et al., 2020)

The construction of Jabodebek LRT is part of the government's efforts to solve traffic problems in urban areas, especially in Jakarta and its surroundings. The Jabodebek LRT construction phase 1 consists of several tracks. The details are, first, the cross-service route Cawang - Cibubur along 14.8 kilometres. Second, the cross-service route of Cawang - Dukuh Atas route along 11 kilometres. And, third, the cross-service route of Cawang - East Bekasi along 18.4 kilometres. (Indonesia, 2021)

The presence of Jabodebek LRT brings many benefits to the community and government, including: The availability of alternative modes of mass transportation that are more efficient and modern; Improved performance of the transportation network system; Reduced congestion, emissions, fuel use and travel time savings; Availability of jobs both during project construction and during operation; Potential development of new areas / economic growth around the station; Growing business opportunities, especially UMKM that can cause a multiplier effect; Adding a

positive image of Indonesia as one of the countries in the world that operates LRT based on Grade Of Automation (GOA) level 3 technology; Equitable economic growth in the area around DKI Jakarta and West Java; and Potential state revenue both directly and indirectly (Humas Sekretariat Kabinet Republik Indonesia, 2022). To maintain all of that, it is necessary to do maintenance, where maintenance is an activity carried out to maintain the reliability of railway infrastructure or facilities so that they remain fit for operation (Prasetya et al., 2021).

PT Kereta Api Indonesia, the company responsible for trains has been carrying out train maintenance by means of corrective maintenance, i.e. replacement of components is carried out only when damage occurs. Damage that occurs is only repaired, there is no analysis in the form of evaluation of the causes of damage and there are no steps that can be taken to prevent damage (Mattjik, 2015). Service quality is a must that must be done by the company to be able to survive and still gain customer trust. Service quality is one part of the marketing management strategy (Primadi et al., 2020).

The reference to previous research that has been carried out previously conducted by Masjraul Hidayat & Dewi Indah in 2017 on the Quality of Complete Final Maintenance Results of Trains at Upt Balaiyasa Manggarai using FMEA analysis with the results of the analysis of the priority of interference that must be addressed immediately is wheel interference with an RPN value of 216. The factors that cause interference from the occurrence of these disorders are mostly from the inaccuracy of the workers (manpower), the replacement of new components is not fully implemented (material), the measurements taken are not appropriate (measure), some of the tools used are still manual and not available (tools), the methods used have not been updated so that there are no new studies (method) and the hot and noisy environment disturbs the concentration of workers (environment) (Hidayat et al., 2017).

There are other reference studies on risk mitigation in the production department using the FMEA method. (Anwar, 2023) Based on the data collection of causes of failure in the auxiliary production department using FMEA conducted on locomotive horns, it can be used to identify the causes of production disruptions, ranging from the nature of locomotive horn defects to the causes of failure. The data for each risk also provides the severity, occurrence value, and detection value, which can be calculated using the Risk Priority Number (RPN) to prioritise and categorise the causes of failure before taking corrective action. Based on several previous research references, the research will discuss the interference of Jabodebek LRT facilities with the method plan that will be taken using the FMEA (Failure Mode and Effect of Analysis) and Fishbone methods. The purpose of using these methods is to identify, find and display various causes that may occur (Prasetya, Atmaja, & Hermawan, 2021).

Jabodebek LRT has been operating for 8 months but its condition has experienced quite a lot of interferences or broken, Jabodebek LRT has experienced 332 disruptions in the cross with the most LRT facility disruptions occurring in June 2024 with 56 facility disruptions occurring in the cross which of course disrupts the performance and reliability of Jabodebek LRT. For this reason, it is necessary to analyze the reliability of the Jabodebek LRT used for daily operations in Jabodebek both in terms of interference or other failure factors in order to maintain the reliability of the Jabodebek LRT, so that what is applied can be adjusted to a state that is feasible to operate. The evaluation is carried out to find out the shortcomings or weaknesses and improvements are made from existing suggestions and proposals, in order to create light rail transportation (LRT) that is safe, comfortable, fast, and besides that it is also profitable both in terms of operators and also does not harm in terms of users of transportation services. In order to improve the optimal light rail transportation (LRT) service in Jabodebek, the title “Fault Analysis on LRT Jabodebek Facilities Using FMEA Method and Fishbone Diagram”.

LITERATURE REVIEW AND HYPOTHESIS FORMULATION

LRT Rollingstock Facility Jabodebek

Light Rail Transit, hereinafter abbreviated as LRT, is railway transport using light railways, electric operating systems, operating on its own track that cannot be accessed by pedestrians and any other vehicles. (Api, 2019)

Cities around the world have implemented or revived light rail transit (LRT) to build compact city strategies and address environmental challenges such as rising CO2 emissions and air pollution. (Kawazoe, 2022). Light rail transit (LRT) systems are a critical component of global efforts to achieve transport sustainability and have played an important role in boosting metropolitan economies. This progressive approach can help alleviate issues including pollution, vehicle accidents, and traffic congestion. (Ahmad Nazrul Hakimi Ibrahim, 2022). Light Rail Transit (LRT) is one of the environmentally friendly transport solutions to solve the traffic congestion problem in Jakarta. This mode of transport is considered useful because land in the capital city is limited for road construction. (Trijeti, 2022)

Train Operational Disruptions

What is meant by railway operational disruption is an unplanned event that results in disrupted, obstructed, or emergency railway journeys. Railway operational disruptions are grouped into two. They are railway accidents or KKA and non-railway accidents or NKKA. Train accidents are events such as collisions between trains, train derailments, train crashes and/or fires. Meanwhile, non-railway accidents are events or operational disturbances other than train accidents that result in damage to railway facilities and / or infrastructure, casualties and / or property losses. (Prasetyo, 2021)

Rail systems can move large volumes of passengers in an efficient manner, thus providing an important means for people mobility in congested urban areas. However, they also suffer frequently from various unexpected operational problems and incidents, which lead to service disruptions. This chapter aims at providing a critical review of the state of knowledge in rail disruption management strategies, modelling, and analysis, with special emphasis placed on unplanned disruptions. (Amer Shalaby, 2021). Likewise, urban rail transit systems are also vulnerable to various risks and disruptions, and therefore, disruption management plays an important role in addressing various disruptions such as system vulnerability, schedule optimisation, and train rescheduling. (Rangaraj, 2013)

Maintenance of Railway Facilities

Maintenance of Railway Facilities is an activity carried out to maintain the reliability of Railway Facilities to remain fit for operation. Maintenance of Railway Facilities as intended is carried out in accordance with the established schedule. Maintenance of Railway Facilities as intended must be carried out by Maintenance Personnel of Railway Facilities. (Perkeretaapian P. M., 2019). Failure management policies generally include maintenance strategy, operational changes, modification of design or other to control due to the mode of failure. (NORDIN, 2015)

Reliability

Reliability is often measured by how often a system or device experiences damage or failure. To ensure the operational feasibility of railway facilities, testing and inspection must be carried out, each type of railway facility that passes the test is marked with a certificate and a test pass mark. Inspection of railway facilities is carried out periodically according to a predetermined schedule.

Inspection of railway facilities as intended is carried out in accordance with the instruction manual issued by the manufacturer of the facility. (Perkeretaapian P. M., 2015)

Today the railway transport sector is assessed as an especially important segment of economy, which mostly determines the movement of goods within the country and their transportation abroad. (Leonas Povilas Lingaitis, 2014) Railways play a pivotal role in transportation systems worldwide. Effective maintenance policies are crucial to guarantee the reliability and availability of such systems inserted in a challenging and competitive environment. (Manuel Leite, 2022). To analyze the reliability of the train control system, we first need to understand the working principle of the train control system. (Lijuan Shi and Jian Wang, 2020). During the operation process, the performance degradation of the system caused by environmental interference, component wear, equipment aging, etc., will lead to system reliability degradation, causing failures, and creating hidden dangers to the safety of the HSR. (Bin Chen 1, Baigen Cai,2019). Reliability plays an important role in the production of the system and its normal and efficient operation. (MAN LI, 2019)

Research Method

FMEA (*Failure Mode and Effect Analysis*)

FMEA (Failure Mode and Effect Analysis) is a method that aims to evaluate system design by considering various failure modes of a system consisting of components and analysing their effects on the reliability of the system. (Syarifudin & Putra, 2021) (Andiyanto & Sutrisno, 2017) In this study, FMEA was conducted to look at the risks that might occur in maintenance operations and company operations. In this case there are three things that help determine the interference among others:

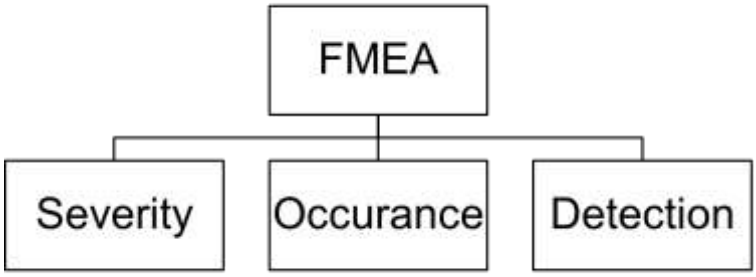

Figure 1. Schematic of FMEA parameters

Severity Level

In determining the level of damage (severity) it can be determined how serious the damage produced by the occurrence of process failures in terms of maintenance operations and plant operational activities. (Andiyanto & Sutrisno, 2017)

Table 1. Scale number of severity

Scale	Effect	Criteria: Severity of Effect
1	Never	Failure has no effect
2	Rarely	Failure has little effect

3	Quite Frequently	Failure has impact and is quite critical
4	Frequently	Failure is very impactful and critical
5	Very Frequently	Failure is very costly and critical

(Sumasto, et al., 2023)

Occurance Level

In determining the Occurrence value, it can be determined how many disturbances occur that can cause a failure in maintenance operations and company operations. (Andiyanto & Sutrisno, 2017)

Table 2. Scale number of Occurance

Scale	Effect	Criteria: Severity of Occurance
1	Never	Minor or avoidable failures
2	Rarely	A failure that can be overcome and has no effect
3	Quite Frequently	Failures are not a significant amount
4	Frequently	Significant failure
5	Very Frequently	Unavoidable failure

(Sumasto, et al., 2023)

Detection Level

In determining this detection rate, it can be determined how the failure can be known before it occurs. the detection rate can also be influenced by the number of controls that regulate the process. the more controls and procedures that regulate the maintenance operational handling system and plant operational activities, it is expected that the detection rate of failures can be higher. (Andiyanto & Sutrisno, 2017)

Table 3. Scale number of Detection

Scale	Effect	Criteria: Detection of Effect
1	Certain	Problems can be detected immediately
2	Easy	Problems are detected after they occur
3	Quite difficult	Problems that occur are unlikely to be detected and resolved
4	Difficult	Problems that occur may not be detected and resolved
5	Very difficult	Problems that occur cannot be detected and resolved

(Sumasto, et al., 2023)

Fishbone diagram

Fishbone diagram often called Cause and Effect diagram is a diagram that resembles a fishbone that can show the cause and effect of a problem. Fishbone diagram is also one of the 7 basic quality tools. (Julianto & Nugroho, 2021)

A fishbone diagram will identify various potential causes of a single effect or problem and analyse the problem through a brainstorming session. The problem will be broken down into a few related categories, including people, materials, machines, and methods. (Zulkarnain, 2019)

Results and discussion

FMEA Analysis (*Failure Modes and Effect Analysis*)

FMEA (Failure Mode and Effect Analysis) is a method that aims to evaluate system design by considering various failure modes of the system consisting of components and analysing their effects on the reliability of the system. Risk Priority Number (RPN) is a measurement of relative risk, RPN is obtained through the multiplication of Severity, Occurence and Detection ratings. The RPN is determined before implementing the recommended corrective actions, and it is used to determine which part is the top priority based on the highest RPN value. (Syarifudin & Putra, 2021).

Table 4. Results of Failure Analysis of LRT facilities using FMEA Method (Failure Mode and Effect Analysis)

Variabel	Potential Failure Mode	Potential Effects of Failure	Severity (S) (1 - 5)	Potential Causes (s) of Failure	Occurrence (O) (1 - 5)	Current Process Control	Detection (D) (1 - 5)	RPN (S x O x D)
	1	2	3	4	5	6	7	8
Traction	Traction Failure	Traction cannot work	5	Traction failure	4	HSCB open on traction interruption	4	80
	Brake failure	Brake works continuously	5	Brake Disc and EBCU Card for braking sensor must be replaced	5	Ground braking on faulty trains	4	100
SIV	AC failure	AC not working on 3 cars	4	The voltage entering the SIV is excessive or even not entering	4	SIV trains must be forced to continue operating	4	64
	lights out	3 trains or the whole train lights out	4	The voltage entering the SIV is excessive or even not entering	4	SIV trains must be forced to continue operating	3	48
Door System	Door limit switch is not working properly	indication that the door sensor has not closed the train cannot operation	4	Door close sensor failure	5	the door sensor has not closed but the door is physically closed	2	40

Variabel	Potential Failure Mode	Potential Effects of Failure	Severity (S) (1 - 5)	Potential Causes (s) of Failure	Occurrence (O) (1 - 5)	Current Process Control	Detection (D) (1 - 5)	RPN (S x O x D)
	1	2	3	4	5	6	7	8
	leaks in door hoses	the door cannot be used to detraintment passengers (isolate the door)	3	Leaky/broken wind hose	5	no follow-up can be done when passenger conditions are crowded	2	30

Based on table 4, it can be seen that the highest Severity value is 5 which is the value of Traction Failure and Brake Failure, then the Severity 4 value is in the form of air conditioning interference, passenger light interference, Door limit switch does not work perfectly. Furthermore, Severity 3 value is a leak in the door hose.

Meanwhile, the Occurrence value, the highest value is Brake Failure and the crossing system, these problems occur most often causing delays in Jabodebek LRT travel. While the highest Detection value also occurs when brake failure.

Next step is to calculate the risk priority number or risk priority by multiplying the severity value, number of events and detection value. The results of this multiplication know the causes of production failures that can be prioritised for handling. (Anwar, 2023)

Table 5. Results of RPN value analysis with FMEA method

No.	Causes of Failure	RPN	%	Rounding %
1	Traction failure	80	0,240964	24%
2	EBCU card for braking sensor must be replaced	100	0,301205	30%
3	The voltage entering the SIV is excessive or even not entering	64	0,192771	20%
4	Door close sensor failure	48	0,144578	14%
5	Leaky/broken wind hose	40	0,120482	12%

The results of table 5 above are the calculation of the FMEA method where the value that has the highest RPN is brake failure which is known to come from the ebcu card factor with an RPN value of 100 with a failure frequency of 30%.

Facility Rollingstock Failure/Disruption Data

This failure data is the final data or annual data from the Jabodebek lrt facility unit, this data is taken from September 2023 - July 2024.

Table 6. Number of failures/disruptions of lrt facilities

No	Month	Year	Traction	Door Failure	Static Inverter (SIV)	Total
1	September	2023	10	38		48
2	Oktober	2023	4	26		30
3	November	2023	3	13		16
4	Desember	2023	12	17		29
5	January	2024	9	19	6	34
6	February	2024	4	12	8	24
7	March	2024	5	21	7	33
8	April	2024	5	17	11	33
9	May	2024	5	6	5	16
10	June	2024	13	26	17	56
11	July	2024	4	7	2	13
	TOTAL		74	202	56	332

Source: Rollingstock Unit LRT Jabodebek

From the data above, the highest number of disturbances of lrt facilities from September 2023 to July 2024, for the greatest frequency of disturbance of LRT facilities is in June with a frequency of 56 failures.

Data on Number of Rollingstock

Data on the number of facilities ready for operation (SO) and not ready for operation (TSO) is data from the Jabodebek LRT facilities unit, this data is taken from January 2024- July 2024.

Table 7. Number of LRT Rollingstock facilities in 2024

Month	TOTAL (1)	SGO (2)	SO (3)	TSO (4)	TSGO (5)	CAD (6)
January	31	29	21	8	2	5
February	31	29	23	6	2	6
March	31	29	23	6	2	5
April	31	29	22	7	2	4
May	31	29	24	5	2	4
June	31	29	24	5	2	3
July	31	29	23	6	2	1

Source: Rollingstock Unit LRT Jabodebek

Keterangan:

1. TOTAL = Jumlah armada
2. SGO = Siap Guna Operasi

3. SO = Siap Operasi
4. TSO = Tidak Siap Operasi
5. TSGO = Tidak Siap Guna Operasi
6. CAD = Cadangan

Fishbone Diagram

In previous research conducted by Masjraul Hidayat & Dewi Indah, (2017) a fishbone diagram analysis was then carried out to find out what were the causes of frequent disruptions to trains in the Balaiyasa coverage period in February 2015 - August 2016. Data from the cause of this disturbance is obtained from Balaiyasa Manggarai expert judgment. After the fishbone diagram instrument was made by the Balaiyasa Manggarai expert judgment team, the following is one of the problem analyses, namely Train Wheels. In the analysis of the FMEA method that has been carried out above, we can find out several factors that cause damage or disruption of LRT facilities as follows:

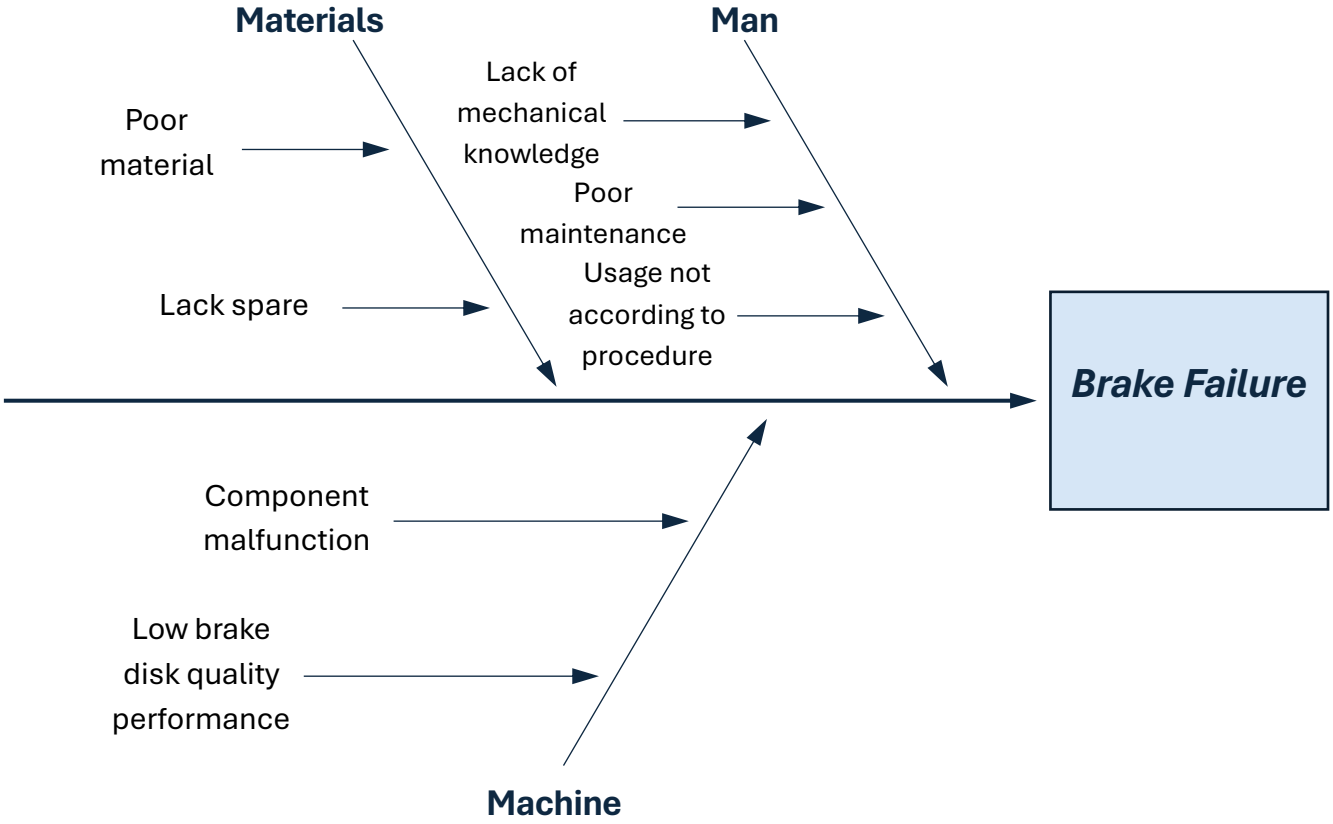

Figure 2. Fishbone Diagram

The results of the Fishbone diagram are obtained based on the results of interviews with several technicians of light maintenance and heavy maintenance unit facilities, based on the results of identifying the factors that cause brake failure, which are known to come from material, human and machine factors. The following is an explanation of the factors causing the failure:

a. Man

The human factor is one of the causes of failure because there are still technicians who have not received internal or external training from the company, resulting in less-than-optimal maintenance coupled with the use of lrt facilities that are not in accordance with procedures.

b. Machine
Machine factors are one of the causes of failure due to low brake disk quality performance and malfunctions in braking components such as ebcu cards.

c. Materials
Material factors are one of the causes of failure, namely poor-quality materials which cause facilities to require more maintenance time due to lack of spare parts.

Conclusion and Suggestion

Conclusion

Based on the results of the research that has been carried out, the following conclusions are obtained:

1. Known disturbances that often occur and affect the reliability of lrt facilities include:
   a. Traction and braking failure that cause interference with the acceleration and deceleration of lrt means, either from the condition of traction performance or malfunctions in braking components.
   b. Disturbance to the static inverter (SIV) which causes disturbances to Air Conditioning (AC), lighting, line flow fan which affects passenger comfort.
   c. Disturbances in the door system either from the door limit switch control system or leaks in the door hoses that cause the train to not be able to run which requires the doors to be isolated first.

   Based on the results of research that has been carried out using the FMEA (Failure Mode and Effect Analysis) method, the RPN (Risk Priority Number) value is determined from the analysis of severity, occurrence, and detection calculations with the results of the highest RPN value found in interference with braking traction with an RPN value of 100 where the causal factor is brake failure which is known to come from the card ebcu factor and brake discs that must be replaced.
2. From the results of the identification of factors causing brake failure, it is known to come from material, human and machine factors with the following explanation:
   a. Man
      The human factor is one of the causes of failure because there are still technicians who have not received internal or external training from the company, resulting in less-than-optimal maintenance.
   b. Machine
      Machine factors are one of the causes of failure due to low brake disk quality performance and malfunctions in braking components such as ebcu cards.
   c. Materials
      Material factors are one of the causes of failure, namely poor-quality materials which cause facilities to require more maintenance time due to lack of spare parts.

Suggestion

Based on the results of the Failure Mode and Effect Analysis (FMEA) analysis conducted, it is known that there are 3 types of disturbances that cause LRT facilities to fail to perform their functions both from traction, static inverters (SIV) and doors that cause the condition of the facility to be not

ready for operation (TSO). Therefore, the company needs to evaluate by paying attention to maintenance activities and checking the condition of spare parts of LRT facilities directly from the manufacturer of LRT facilities components so that when LRT facilities experience direct interference, repairs can be made without having to wait for spare parts first, because if the component is sufficient, the reliability of LRT facilities will also always be reliable and ready for operation (SO) so as not to interfere with the comfort of Jabodebek LRT passengers and not cause large losses for the company.

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