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Risk Analysis Of Bogie Maintenance TB 1014 Using FMEA Method

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ABSTRACT

The bogie is a vital component in the railway system that functions to support the load, maintain stability, and ensure the smooth running of the train. Damage to the bogie can cause safety problems and reduce passenger comfort. This study aims to analyze the risk of failure of the TB 1014 bogie component on the K3 01430 train using the Failure Mode and Effect Analysis (FMEA) method as a case study at the Surabaya Pasar Turi (SBI) Train Depo. Data were collected through field observations, technician interviews, and bogie component inspections. The analysis was carried out by assessing the Severity, Occurrence, and Detection parameters to obtain the Risk Priority Number (RPN) value for each component. The results showed that the shock absorber, block brake sprinkler, and wheels had the highest RPN values of 140, 120, and 108, respectively, which were maintenance priorities. All components had RPNs below 200 so the recommended maintenance strategy was corrective maintenance. The FMEA method has proven effective in helping to identify, assess, and prioritize failure risks, so that it can be used as a basis for developing more targeted maintenance strategies and increasing train operational reliability.

Keywords: Bogie; FMEA; RPN; Corrective Maintenance; Train.

1. INTRODUCTION

Rail transport is a mode of mass transportation that relies on reliable mechanical systems to support travel safety and comfort. One of the main components that plays a vital role in the train operating system is the bogie, namely the undercarriage of the train that supports the train body and is responsible for guiding the wheels and absorbing impact forces and vibrations during travel. The reliability of the bogie significantly affects the stability, speed, and efficiency of braking and acceleration of the train. Important components that make up the bogie system include wheels, axles, bearings, suspension (shock absorbers), couplers, center plates, and the braking system. Each component has its own function but interacts with each other and works simultaneously under severe operational conditions, such as repeated load forces, dynamic vibrations, and extreme environmental conditions. Therefore, regular maintenance and evaluation of the technical condition of bogie components are crucial to prevent functional failures that pose a high risk to travel safety.

Not all potential failures are visible to the naked eye. Therefore, a method is needed that can systematically identify the possibility of failure in each component, its impact on the system, and appropriate handling. One relevant method is Failure Mode and Effect Analysis (FMEA), a risk evaluation method used to identify potential failures based on three main parameters: Severity, Occurrence, and Detection. The result of this analysis is a Risk Priority

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Number (RPN), which is used as the basis for determining maintenance priorities. This research was conducted as a case study on the TB 1014 bogie of K3 Train 01430 at the Surabaya Pasar Turi (SBI) Train Depot. The research aims to identify potential failures of bogie components, evaluate the risk level based on the RPN value, and provide maintenance recommendations based on the results of the FMEA analysis. It is hoped that this research can contribute to the development of more effective and structured maintenance strategies, as well as improve the operational reliability of railway facilities in the future.

2. METHOD

The FMEA-based maintenance risk analysis in this study aims to identify potential failures, evaluate impacts, and determine maintenance priorities for bogie components. This method was applied to the TB 1014 bogie used on the K3 01430 train at the Surabaya Pasar Turi (SBI) Train Depot. The research object was determined based on the importance of the bogie's role in supporting the safety and comfort of train travel. Observations show that the entire series of bogie maintenance processes are carried out based on the standard operating procedures (SOPs) applicable at PT KAI. These SOPs serve as guidelines so that each maintenance stage is carried out correctly and uniformly. When compared to maintenance management theory, structured SOPs can reduce human error, ensure component reliability, and extend asset service life. These specifications serve as the basis for conducting maintenance analysis and risk assessments on bogie reliability, so that operational performance is maintained according to standards as shown in Table 1.

Table 1. The following technical specifications, which are the main reference in defining the system, work processes, and component risk analysis limits:

Parameter	TB 1014
track gauge	1,067 mm
wheel base	2,200 mm
Maximum new/worn wheel diameter	840 / 760 mm
Primary spring center distance	1,600 mm
Secondary spring center distance	2,000 mm
Maximum speed	120 km/h
Train height from rail	1,000 mm

Research data collection was conducted through literature studies and field surveys at the Surabaya Pasar Turi (SBI) Train Depot, involving technicians, maintenance supervisors, and inspectors. The data obtained included the types of bogie component damage, mechanisms and their impacts on operations, detection methods, and maintenance actions. Respondents were asked to complete a structured questionnaire based on FMEA risk assessment standards with a scale of 1–10 for the parameters of Severity, Occurrence, and Detection. This FMEA method was used to identify the main risk parameters in the bogie system according to PT KAI operational standards and relevant literature (Arabian Hoseynabadi et al., 2010; Priharanto et al., 2017; Surya et al., 2017).

- a. The severity of the hazard, indicated by the Severity (S), represents the severity of the hazard when the system is operating. The severity scale is shown in Table 2

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Table 2. Failure severity and hazard level criteria.

Hazard Severity Level (Severity) (S)		
Level	Effect	Criteria
10	Extremely Dangerous	Component damage causes sudden accidents and endangers work safety.
9	Very Dangerous	Component damage causes work accidents and the machine does not operate but there is a warning/early detection
8	Very High	Component damage causes the machine to shut down and lose its primary function.
7	High	Component damage causes the system to shut down, but the machine is still operational.
6	Moderate	Component damage causes a drastic decrease in system performance, but the machine can still operate.
5	Low	Component damage causes a gradual decrease in system performance, but the machine is still operational.
4	Very Low	Component damage has a minor impact on system performance, but the machine is still operating perfectly.
3	Minor	Component performance is degraded, but the fuel system and engine are still operating perfectly.
2	Very Minor	Component is considered poor, but component performance is still good, and the system and engine are still operating perfectly.
1	None	No impact.

- b. Frequency of occurrence shown in Occurrence (O) is the number of occurrences of disturbances in components that cause system failure or can be called the opportunity for disturbances to occur. The Occurrence scale is shown in table 3.

Table 3. Failure rate and number of occurrences.

Frequency of Occurrence (Occurance) (O)		
Level	Probability of Occurrence	The level of occurrence
10	Almost every time, occurs in less than 1-2 surgeries.	Very often, occurs to the point that damage is unavoidable
9	Very high, occurs in less than 3-4 surgeries.	Very often
8	High, occurs in less than 5-8 surgeries.	Frequent (1)
7	Fairly high, occurs in less than 9-20 surgeries.	Frequent (2)
6	Medium, occurs in less than 21-80 surgeries.	Rare (1)
5	Low, occurs in less than 81-400 surgeries.	Rare (2)
4	Rare in less than 401-2000 surgeries.	Rare (3)
3	Very rare, occurs in less than 2001-15000 surgeries.	Very rare (1)
2	Almost never, occurs in more than 15000 surgeries.	Very rare (2)
1	Never Occurs.	Never Occurs

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- c. The Detection Level shown in Detection (D) is how failure can be identified before/just before the incident occurs. The assessment is highly subjective and depends on the experience of the field source. The Detection Scale is shown in Table 4.

Table 4. Failure detection levels and detection level criteria.

Detection Level (Detection) (D)	
Level	Detection Control
10	Impossible to detect
9	Very difficult to detect
8	Difficult to detect
7	Very low to detect
6	Low to detect
5	Moderate to detect
4	Medium to high to detect
3	Easy to detect
2	Very easy to detect
1	Detection can be done very easily

The Risk Priority Number (RPN) is a combination of three variables: Severity (S), Occurrence (O), and Detection (D). The equation can be used: $RPN = S \times O \times D$. The general structure of the risk index parameters and the RPN matrix are used to collect data from assessment results (Balaraju, Govinda, and Murthy, 2019).

The RPN assessment is determined using a quantitative scale based on the interpretation of the qualitative scale. The RPN provides information for prioritizing potential component failures. Component maintenance priority is determined by determining the component's RPN value above the overall RPN threshold. The system RPN threshold is obtained by averaging the RPN values across all components.

3. RESULT AND DISCUSSION

Based on a case study and field survey conducted on the K3 01430 train with the TB 1014 bogie type at the Surabaya Pasar Turi (SBI) Train Depot, data on the bogie's technical specifications, the actual condition of the components, and the results of interviews with maintenance technicians were obtained. Furthermore, validation was carried out on the actual condition of the bogie components to ensure compliance with the specifications and functions determined by PT KAI standards. The main components analyzed in the bogie system include wheels, shock absorbers, bearings, sprinklers (brake blocks), steerers (steering levers), and center plates. Each component has the potential to fail due to wear, deformation, leakage, or cracking that can affect the safety and comfort of train operations. Field validation and literature review support that the bogie system is a critical subsystem that requires a risk-based maintenance approach. The results of the validation and literature study were further examined using the Failure Mode and Effect Analysis (FMEA) approach. FMEA is used to evaluate the potential risk of failure in each component based on the Severity (S), Occurrence (O), and Detection (D) values. Thus, the use of the FMEA Form method on the TB 1014 bogie system is effective in supporting data-based preventive and predictive maintenance strategies. The results of this approach are shown in table 5 of the FMEA form.

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Table 5. Failure Mode and Effect Analysis (FMEA) Form.

Item	Potential Failure Modes	Potential Effect (S) Of Failure	Current Control & Prevention Process	Recommended Actions	Responsibility & Target Completion Date	Action Given				
						Action Given	Sev	Occ	Det	RPN
Bogie TB 1014 - K3 01430 SBI										
Shock Absorber	Leaking / slow	Hard suspension, unstable train	Shock oil leak check	Corrective Maintenance Performed	Downtime for repair ± 2 hours	Replacing shock absorbers if they leak	7	4	5	140
Sprinkler (brake block)	Uneven wear	Decreased braking effectiveness, risk of accidents	Periodic replacement of brake blocks	Corrective Maintenance Performed	Downtime for repair ± 1 hours	Replacing brake blocks when worn	10	3	4	120
Wheel	Bumps / uneven surface	Shocks, faster wear of rails/wheels	Diameter measurement & profile checking	Corrective Maintenance Performed	Downtime for repair ± 4 days	Reprofiling the wheel on a special lathe	9	3	4	108
Bearing	Leakage in the bearing seal (running)	Grease leaks, worn bearings, vibrations	Direct visual observation	Corrective Maintenance Performed	Downtime for repair ± 5 hours	Regular bearing replacement	8	3	4	96
Steler (Steering Lever)	Loose or bent	Difficulty turning, potential for a crash	Checking bolt tightness	Corrective Maintenance Performed	Downtime for repair ± 3 hours	Tightening and replacing components if necessary	9	2	5	90
Center Plate	Worn or cracked	Change in bogie position, potential for derailment	Wear and crack inspection	Corrective Maintenance Performed	Downtime for repair ± 1 hours	Replace center plate if cracked/worn	4	2	9	72

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The Failure Mode and Effect Analysis (FMEA) form table lists the function of each component, potential failure types, failure mechanisms, the impact of the failure on the bogie system, damage detection methods, and recommended maintenance actions. The Severity value describes the impact of the failure on the system, the Occurrence value indicates the frequency of failure occurrences, and the Detection value reflects the difficulty of detecting the damage. The results of these three parameters produce a Risk Priority Number (RPN) value used to determine component maintenance priorities. The shock absorber has an RPN of 140, followed by the sprinkler (brake block) with an RPN of 120, and the wheel with an RPN of 108. This indicates that these three components have the highest potential for failure that poses the highest risk to train performance and safety. The bearing (RPN 96), the steer (RPN 90), and the center plate (RPN 72) also have significant values, although lower than the three main components.

For example, the RPN value on a shock absorber is influenced by a Severity score of 7, Occurrence 4, and Detection 5, which indicates that the impact of oil leaks on the shock absorber is very large, occurs quite frequently, and is relatively easy to detect. Conversely, although the center plate has a fairly low Severity and Occurrence value, the level of difficulty in detecting cracks makes the Detection value high, so it still requires attention in regular maintenance.

In general, the RPN calculation follows the formula:

$$RPN = S \times O \times D$$

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Where the three parameters (S, O, D) each have a scale of 1–10. The RPN value is then used to prioritize maintenance, so that maintenance activities can be directed to the components with the highest risk first. This finding is in line with previous research, that the RPN value is directly influenced by the interaction of the three main parameters, and is widely used in reliability-based maintenance systems (Reliability Centered Maintenance). Thus, to facilitate understanding of component damage data. In this graphical form, the aim is to make the damage pattern more visible, thus facilitating the analysis process and determining maintenance priorities, as in Figure 1, the RPN (Risk Priority Number) value graph.

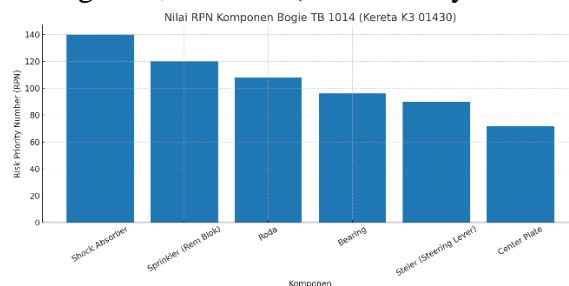


Figure 1. RPN (Risk Priority Number) value graph

Table 6 explains the appropriate maintenance selection strategy for each component, namely corrective maintenance (RPN ≥ 200).

Table 6. Selection criteria for maintenance strategies.

Treatment Strategy	
Predictive Maintenance	RPN > 300
Preventive Maintenance	200 < RPN < 300
Corrective Maintenance	RPN < 200

Based on the results of the FMEA analysis of the main components of the TB 1014 bogie on the K3 01430 train at the Surabaya Pasar Turi (SBI) Train Depot, it was found that all Risk Priority Number (RPN) values were still below the threshold of 200. Therefore, the recommended maintenance strategy for all components is corrective maintenance, which is maintenance actions taken if indications of damage are found during routine inspections or when components experience problems during operation. The component with the highest RPN value is the shock absorber, at 140. Shock absorber failure is generally caused by oil leaks due to seal wear, which can reduce suspension performance and cause shaking in the train. Although in the corrective category, the shock absorber still requires more attention with regular monitoring of its condition. Furthermore, the sprinkler (brake block) has an RPN value of 120. Uneven wear on the brake block can reduce braking effectiveness and pose a safety risk. Damage detection is carried out through visual inspection and measuring the thickness of the brake pads. The recommended action is to replace the brake block periodically if signs of significant wear are found. The wheel component received an RPN of 108, with potential failures in the form of uneven surfaces or flat spots due to friction and sudden braking. Wheels experiencing this condition can cause shocks during travel and accelerate rail wear. Recommended maintenance is corrective wheel reprofiling or re-lathing when signs of damage are detected.

Other components, such as bearings, had an RPN of 96, with potential failures in the form of seal leaks or runny conditions, which could result in suboptimal lubrication and potential further damage to the axle. The steering lever had an RPN of 90, typically experiencing looseness or deformation due to impact and wear. Meanwhile, the center plate had the lowest RPN of 72, with potential failures in the form of wear or cracks that could affect bogie stability. Based on the overall RPN calculation, no components met the criteria for preventive (RPN > 200) or predictive maintenance (RPN > 300). Thus, a corrective approach is the most appropriate and efficient strategic choice for current conditions, while maintaining a regular inspection and evaluation schedule so that potential damage can be detected early before disrupting train operations.

4. CONCLUSION

Based on the results of the risk analysis using the Failure Mode and Effect Analysis (FMEA) method on the TB 1014 bogie components on the K3 01430 train at the Surabaya Pasar Turi (SBI) Train Depot, it can be concluded that all components analyzed have a Risk Priority Number (RPN) value below 200. This indicates that the most appropriate maintenance strategy is corrective maintenance, which is maintenance carried out after indications of damage or decreased function are found during inspection. The component with the highest RPN value is the shock absorber (RPN 140), followed by the block brake sprinkler (RPN 120), and the wheel (RPN 108). Other components such as bearings, stellers, and center plates also show potential failures, but are at a lower risk level. Although all components are included in the corrective category, routine monitoring and periodic inspections are necessary to detect potential damage early. The FMEA method has proven effective in identifying and prioritizing potential failures based on severity, occurrence, and detection parameters. With this approach, maintenance strategies can be formulated more systematically and efficiently to improve the safety, reliability and operational efficiency of railway facilities.

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