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Study on Technical Challenges of Maintenance Vehicle Trains (MVTs) for Construction Phase in ECRL Project

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Abstract

The East Coast Rail Link (ECRL) project in Malaysia involves the deployment of various Maintenance Vehicle Trains (MVTs), including tamping machines, ballast regulators, and dynamic stabilizers, to support track construction. However, these machines face significant technical challenges during the construction phase, particularly due to Malaysia's tropical environment, prolonged operational hours, and dependence on imported spare parts. This study aims to identify the key technical challenges faced by MVTs, evaluate their impact on operational performance and project timelines, and propose effective mitigation strategies. A structured questionnaire was distributed to 50 technical personnel from Malaysia Rail Link (MRL) and China Communications Construction Company (CCCC), who are directly involved in MVT operations. The findings reveal that environmental factors such as heavy rainfall and dust significantly contribute to wear and tear, while mechanical fatigue and supply chain delays further disrupt operations. The study also highlights the importance of preventive maintenance, frequent lubrication, and the development of local spare part suppliers as critical strategies to improve MVT reliability. These insights provide practical recommendations for enhancing equipment performance and ensuring timely project delivery in large-scale railway construction projects like the ECRL.

1. Introduction

Maintenance Vehicle Trains (MVTs), including tamping machines, ballast regulators, and dynamic stabilizers, are vital to track construction in the ECRL project. However, Malaysia's tropical climate—with frequent rainfall, high humidity, and dry-season dust—accelerates wear on components, especially air filters and moving parts. Continuous operation under these harsh conditions further contributes to mechanical deterioration and increases the risk of equipment failure. Delays in spare part procurement, primarily due to dependence on suppliers from China, add to operational challenges by disrupting maintenance schedules. These environmental, mechanical, and supply chain issues pose significant risks to MVT reliability and project timelines. Addressing them is essential to reduce downtime and ensure the successful delivery of the ECRL project.

Dust generated from construction activities—such as soil preparation, concrete pouring, and heavy machinery operation—can compromise engine performance if not properly managed (Manzhilevskaya, 2024). Air filters play a crucial role by preventing these contaminants from entering the combustion chamber, ensuring a stable air-to-fuel ratio for efficient engine function (Abdullah et al., 2014). Unfiltered dust can damage components like pistons and valves, leading to reduced compression, higher oil consumption, and eventual engine failure. Proper air filtration is essential to maintain engine reliability and reduce emissions. Inefficient air filters can allow dust and impurities to enter diesel engines, leading to excessive wear, costly repairs, and component failure (Dziubak & Dziubak, 2022). Contaminants also degrade engine oil quality, reducing its lubrication capability and increasing corrosion risks (Thermal Control Magazine, 2023). This promotes sludge buildup, clogging oil passages and accelerating engine wear. Proper air filter maintenance is essential for protecting engine health and performance.

Mechanical components such as shafts, axles, bearings, and gears are highly susceptible to fatigue-related wear due to repeated cyclic loading in railway applications (Hou et al., 2022b). Shafts, which transmit torque and motion, are particularly critical and prone to fatigue fractures—defined as delayed failures caused by cyclic stress well below the material's yield strength (Xu et al., 2023b). These failures originate from microscopic cracks in high-stress areas, often near surface defects or corrosion pits (Lindley et al., 1982b). Over time, these cracks propagate, reducing the shaft's cross-section and leading to catastrophic failure. Fatigue damage is cumulative and not the result of a single overload event. In the context of Maintenance Vehicle Trains (MVTs), such deterioration is common due to the extended operational hours under harsh site conditions. Understanding fatigue behavior is essential for designing effective maintenance routines and preventing unplanned breakdowns in railway construction.

Spare parts are essential to maintaining the operational efficiency of Maintenance Vehicle Trains (MVTs) in railway construction, as they support both routine maintenance and emergency repairs (Sareminia & Amini, 2022). Effective spare parts management directly impacts maintenance duration, system reliability, and cost efficiency (Gao et al., 2024). In the ECRL project, the reliance on Chinese-manufactured MVTs—such as the DC-32 Tamping Machine and SPZ-200 Ballast Regulator—makes China a primary source for critical spare components. China's dominance in railway equipment manufacturing and export strengthens its position as a key supplier (Briefing, 2024). However, this dependency poses logistical and operational risks due to shipping delays, long lead times, and limited local availability. Disruptions in the supply chain can lead to extended downtimes, affecting project progress. Therefore, robust procurement planning and exploring local supplier alternatives are crucial for enhancing supply chain resilience in large-scale rail projects.

The performance and reliability of Maintenance Vehicle Trains (MVTs) in the ECRL project are significantly challenged by Malaysia's harsh environmental conditions, mechanical fatigue from prolonged usage, and a high dependency on foreign spare parts. Issues such as dust-induced engine wear, fatigue failures in key components, and delays in part procurement can lead to costly downtime and project delays. Addressing these challenges through preventive maintenance, proper filtration systems, and improved spare parts management—particularly through local sourcing—is critical to ensuring uninterrupted MVT operations and the timely delivery of the ECRL project.

2. Methodology

This study adopted a structured research methodology to systematically explore the technical challenges faced by Maintenance Vehicle Trains (MVTs) during the construction phase of the East Coast Rail Link (ECRL) project. Figure 2.1 illustrates the detailed workflow adopted in this study. The methodology begins with clearly defining the research objectives, which focused on identifying the technical issues affecting MVTs and proposing effective mitigation strategies. This was followed by a comprehensive literature review to establish the background and theoretical framework related to MVT operations, environmental conditions, mechanical reliability, and supply chain vulnerabilities.

Once the literature was reviewed, a structured questionnaire was developed based on gaps and insights identified in the literature. A pilot test was then conducted to evaluate the clarity, reliability, and relevance of the questionnaire items. Feedback from pilot respondents was used to refine the instrument. If the pilot feedback was not satisfactory, revisions were made, and the questionnaire was retested until it met the desired standard. Upon acceptance of the final version of the questionnaire, data collection was carried out involving 50 technical personnel from Malaysia Rail Link (MRLSB) and China Communications Construction Company (CCCC), all of whom had direct experience with MVT operations.

The collected data were then subjected to descriptive analysis using Microsoft Excel to summarize response patterns and identify significant trends. These findings were used to develop mitigation strategies addressing the most critical issues, particularly those involving environmental impacts, mechanical fatigue, and supply chain limitations. The process concluded with a summary of findings and recommendations, aiming to support stakeholders in enhancing the reliability and efficiency of MVTs in large-scale rail infrastructure projects.

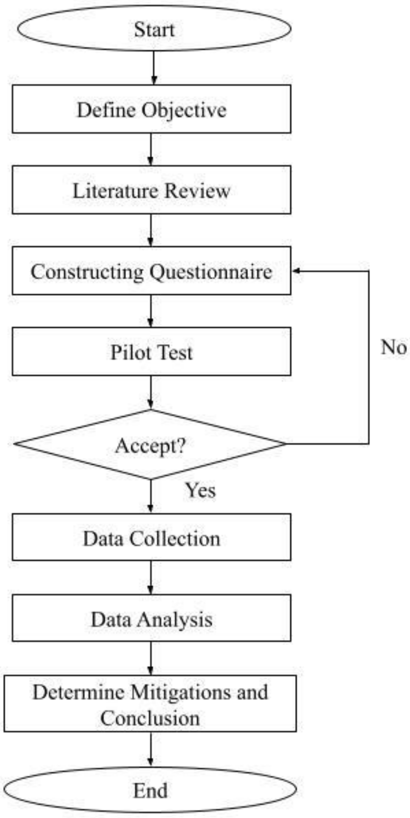

Figure 2.1 Research methodology flowchart

2.1 Data Collection

This study utilized both primary and secondary data to ensure a comprehensive understanding of the technical challenges faced by Maintenance Vehicle Trains (MVTs) during the ECRL construction phase. Primary data were gathered through a structured questionnaire, which was distributed to 50 technical personnel from Malaysia Rail Link Sdn Bhd (MRLSB) and China Communications Construction Company (CCCC). All respondents had direct experience in MVT operations, ensuring the relevance and reliability of the data collected.

In addition to firsthand input, secondary data were also examined to support and contextualize the findings. These included technical documents such as the SPZ-200 Ballast Regulator Operation Manual, maintenance logs accessed during an internship at MRLSB, and relevant academic publications. These sources provided critical background on equipment specifications, typical operational issues, and current maintenance practices, helping to frame the questionnaire and support the interpretation of the results.

2.2 Questionnaire Design and Pilot Test

According to Greenhalgh et al. (2004), a questionnaire is a research instrument that consists of a series of questions and prompts designed to collect information from respondents. The questionnaire was constructed based on an extensive review of related literature, equipment manuals, and technical reports to ensure it captured all relevant aspects of MVT operations. A structured questionnaire depicted in Table 2.1 was developed to gather insights on the technical challenges affecting Maintenance Vehicle Trains (MVTs) during the ECRL construction phase. It consisted of four parts: Part A collected respondent demographics; Part B assessed the presence and impact of technical challenges using a 5-point Likert scale; Part C focused on how these challenges influenced project timelines; and Part D collected suggestions for mitigation strategies through close-ended responses.

Table 2.1 Questionnaire's Structure

Section	Focus	Details
A	Demographic Information	Collected respondent's backgrounds and biographic details to assess diversity and relevance to MVTs
B	Validating Technical Challenges and Determining The Impact	Evaluated the impact of technical challenges of MVTs using a Likert scale (1 Strongly Disagree to 5 Strongly Agree)

C	Determining the Impact of Technical Challenges	Provided data on the severity of how these issues influence to MVTs
D	Suggestion for Mitigations	Provided data on the severity of how these issues influence to MVTs

A pilot test was conducted to evaluate the clarity and effectiveness of the questionnaire prior to full distribution. Five individuals—one academic lecturer and four professional engineers from MRLSB—reviewed the instrument and provided feedback on sentence structure, wording, and clarity. Based on their input, necessary modifications were made to improve alignment with the research objectives. Following this, the questionnaire was reviewed and validated by a senior engineer from the Operations & Maintenance (O&M) department of MRLSB, who confirmed that the items were appropriate and aligned with field practices and technical realities. Complete feedback were show below in the Table 2.2

Table 2.2 Pilot Test's Feedback and Actions

Position	Comment	Actions to be taken
Lecturers	• Suggests a modification to the original sentence • A change in wording	• Improve the sentence • Clarify the question
Engineers	• Suggest a modification to the original sentence	• Improve the sentence
Engineers	• Suggests a modification to the Likert Scale	• Improve the Likert Scale
Engineers	• Confusion about which specific objectives the question is referring to	• Clarify the question
Engineers	• Need for clarification	• Clarify the questions

2.3 Reliability Test

A reliability test using Cronbach's Alpha was conducted to assess the internal consistency of the questionnaire. This statistical measure evaluates how well a set of items measures a single construct. The computed Cronbach's Alpha value was 0.716 by using Cronbach's Alpha formula below, indicating acceptable reliability based on common research standards. This suggests that the questionnaire items were consistent and suitable for analyzing the technical challenges related to MVT operations.

$$a = \frac{k}{k-1}\left(1 - \frac{\sum si^2}{st^2}\right) \tag{1}$$

Based on Table 3.3, a Cronbach's Alpha score above 0.7 is generally deemed satisfactory in social science research. The obtained value of 0.716 indicates that the questionnaire responses are consistent and reliable, providing a solid foundation for data analysis.

Table 2.3 Cronbach's Alpha range value

Cronbach's Alpha Score	Level of Reliability
0.0 – 0.2	Less Reliable
0.2 – 0.4	Somewhat Reliable
0.4 – 0.6	Reliable Enough
0.6 – 0.8	Reliable
0.8 - 1	Excellent Reliable

2.4 Data Analysis and Descriptive Analysis

Data analysis was conducted after collecting questionnaire responses to extract key insights aligned with the study's objectives. A descriptive analysis approach was applied using Microsoft Excel to summarize demographic data, identify response trends, and highlight technical challenges and proposed solutions. Visual tools such as bar graphs and pie charts were used to enhance data interpretation.

3. Data Analysis and Discussion

3.1 Respondent's Profile and Familiarity of MVT Operations

This section presents findings from a structured questionnaire distributed to 50 technical staff involved in the ECRL construction phase, specifically those with direct engagement in Maintenance Vehicle Trains (MVTs). The responses were analyzed using Microsoft Excel, focusing on key trends and challenges.Most respondents were engineers (56%), followed by technicians (26%), managers (10%), supervisors (4%), and executives (4%). This indicates broad representation from both technical operators and decision-makers directly responsible for MVT upkeep.

In terms of organizational affiliation, 62% of respondents were from Malaysia Rail Link (MRLSB), while 38% were from China Communications Construction Company (CCCC). This balance reflects input from both client and contractor sides of the project. Regarding railway maintenance experience, 50% of participants had 0–3 years of experience, 40% had 4–7 years, and 10% had more than 8 years. This mix captures perspectives from both newer engineers and experienced professionals, offering a well-rounded understanding of on-ground challenges. Additionally, 84% of respondents reported familiarity with MVT operations, confirming that the data came from personnel who are directly involved with the equipment. This ensures the responses are grounded in hands-on knowledge of the issues affecting MVT performance and reliability.

Table 3.1 Summary of Respondent's Profile

Item	Category	Frequency	Percentage (%)
1	Role in Project		
	Engineer	28	56
	Manager	5	10
	Supervisor	2	4
	Technician	13	26
	Senior Executive	1	2
	Technical Executive	1	2
2	Organizations		
	MRLSB	31	62
	CCCC	19	38
3	Experience		
	0 – 3 years	25	50
	4 – 7 years	20	40
	8 years and above	5	10
4	Familiarity		
	Yes	42	84
	No	8	16

3.2 Analysis of Respondent's Perceptions of Technical Challenges of MVTs for the Construction Phase in ECRL Project

This section presents an analysis of respondents' perceptions regarding key technical challenges affecting MVT operations during the ECRL construction phase. Using Likert scale responses (1 = Totally Disagree to 5 = Totally Agree), the results highlight the impact of environmental conditions, mechanical wear, and supply chain issues. These findings validate earlier observations and offer practical insight into the severity and frequency of these challenges in real-world operations. A majority of respondents (64%) agreed that environmental conditions such as high rainfall and humidity significantly contribute to the wear and tear of MVT components. These tropical conditions accelerate corrosion and degradation of machinery, especially during the monsoon season.
About 70% of the respondents indicated that dust accumulation during dry seasons causes clogging of air filters, which directly reduces engine performance. This finding emphasizes the importance of frequent inspection and cleaning to avoid engine failures in dusty environments.

Respondents (68%) agreed that long-term use of MVTs leads to frequent fatigue fractures and mechanical issues. This points to the need for periodic overhauls and timely replacement of worn-out parts to prevent breakdowns. A strong 80% of participants agreed that repeated loading and continuous operation cause frequent failures in critical components such as tamping tines and brushes. This highlights the importance of robust maintenance planning and high-durability materials. The majority (84%) acknowledged that reliance on foreign suppliers, especially from China, introduces weaknesses into the supply chain. Any delays in shipping or customs can hinder MVT availability and performance. Approximately 70% of respondents agreed that delays in receiving imported spare parts often lead to operational downtime. This emphasizes the need to diversify suppliers, improve procurement planning, and consider local sourcing for essential components.

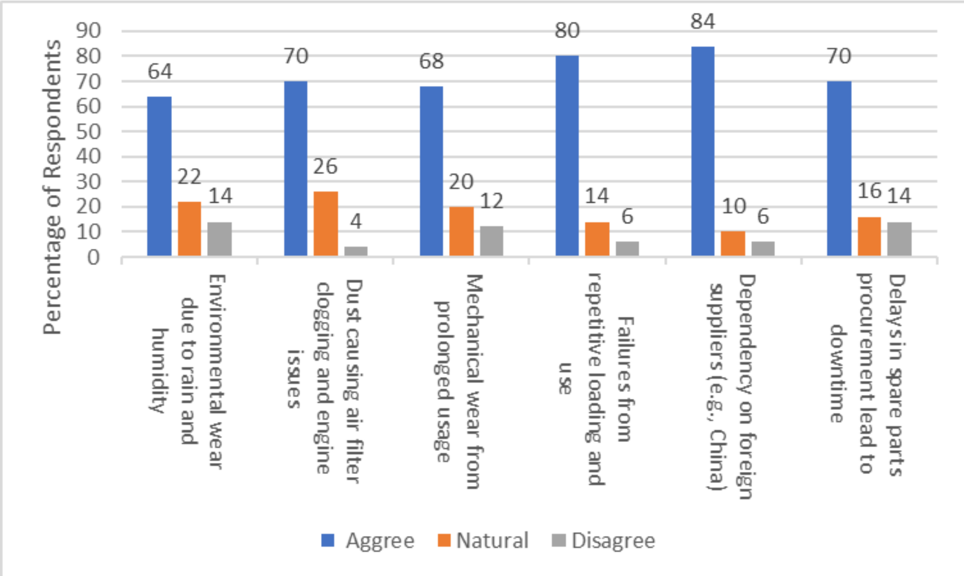

Figure 3.1 Summary of Respondent's Agreement on MVT Technical Challenges

3.3 Evaluation of the Impact of Technical Challenges on MVT Performances and Project Timeline

This section evaluates the perceived impact of technical challenges on the performance of Maintenance Vehicle Trains (MVTs) and the timely execution of the ECRL construction phase. Based on the responses gathered, several critical insights emerged. Firstly, in assessing the influence of environmental conditions such as humidity and dust, 48% of respondents affirmed that these factors adversely affect MVT operational reliability—particularly through issues like engine inefficiency and air filter clogging. These findings suggest the urgent need for climate-adapted maintenance protocols and the integration of protective systems suited to Malaysia's tropical construction environments. Secondly, when asked to what extent technical challenges affect project timelines, 56% of participants agreed that such issues frequently result in construction delays. This implies that mechanical degradation, unplanned maintenance events, and equipment unavailability due to technical failures have a direct influence on schedule adherence and productivity.

Lastly, 82% of respondents reported that delays in the procurement of spare parts—primarily due to international supply chain dependencies, substantially hinder project progress. This reflects the systemic vulnerability associated with sourcing critical components from foreign suppliers and reinforces the necessity of establishing diversified procurement strategies and improving local supply chain resilience. Collectively, the data underscore the significance of addressing technical, environmental, and logistical challenges to ensure the continuous, efficient operation of MVTs and to minimize disruptions to construction timelines.

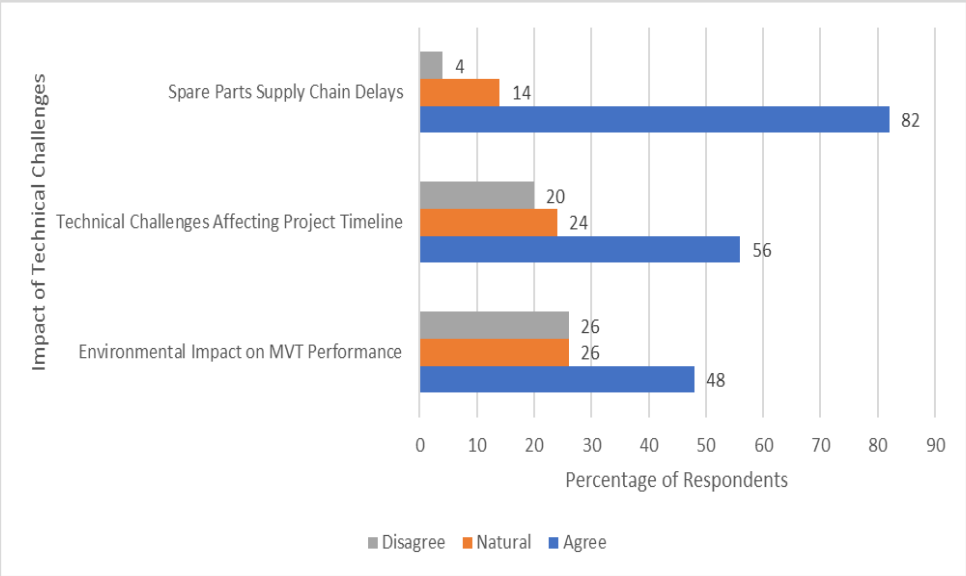

Figure 3.2 Summary of Impacts from Technical Challenges on MVTS Operations and Project Timeline

3.4 Respondent's Recommendations for Addressing MVT Technical Challenges

Part D of the questionnaire was designed to elicit expert-driven recommendations from technical personnel directly involved in MVT operations. The responses focused on three critical areas—environmental exposure, mechanical degradation, and spare parts supply chain inefficiencies. The findings offer practical, experience-based strategies intended to improve MVT operational reliability and reduce unplanned downtime. These industry-informed insights contribute to the development of targeted and actionable mitigation measures, supporting more resilient and efficient maintenance practices throughout the ECRL construction phase.

Firstly, when asked about measures to address environmental challenges, the majority of respondents (64%) identified regular maintenance of components exposed to environmental stressors such as corrosion prevention and frequent air filter cleaning as the most practical and effective approach. This highlights the importance of preventive maintenance routines in preserving MVT performance under harsh field conditions. Meanwhile, 20% recommend the use of advanced materials that resist environmental degradation, such as rust proof alloys. This response suggests a moderate interest in long term material innovation as part of the solution. A smaller group (12%) supported installing weather resistant enclosures for sensitive components like electronics, while only 4% opted for modifying MVT designs to better handle uneven terrain and gradients. Overall, the findings indicate that respondents prioritize immediate, routine maintenance solutions over more costly or design-intensive modifications when it comes to combating environmental impacts on MVTs.

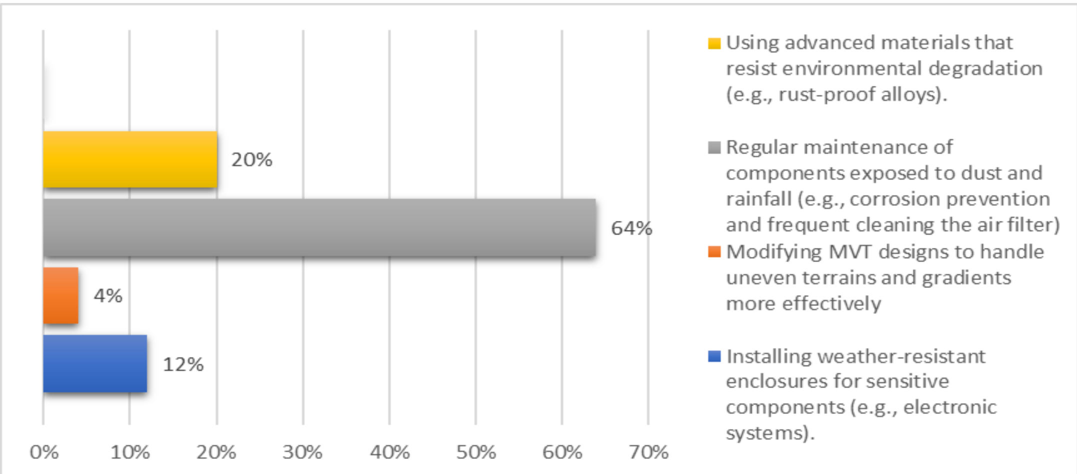

Figure 3.3 Preferred strategis to address environmental challenges affecting MVTs

Secondly, regarding critical routine maintenance to reduce wear and tear on MVT components, the goal of the question is to identify the most effective maintenance strategies for preventing mechanical deterioration, especially under challenging construction site conditions. A significant majority of respondents, comprising 54%

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underscored the critical nature of routinely lubricating moving parts as the most vital maintenance practice. Lubricating fluids play a crucial role in minimizing friction and wear between moving parts, which ensures smooth operation and prolongs the life of machinery and equipment. In industrial settings, the use of these fluids significantly enhances operational efficiency, lowers maintenance costs, reduce energy consumption, and helps prevent expensive equipment failure (Owunna & Ikpe, 2023).

Regular inspection and replacement of hydraulic systems came in second, as the data indicates that 26% of respondents reported concerns related to the components. These components often face significant challenges as they operate under high pressure and fluctuating loads, making them susceptible to failure and wear. This highlights the critical nature of understanding the stresses and strains they endure in their operational environments. A smaller proportion of respondents, specifically 12%, indicated a preference for upgrading critical components using more durable materials. This suggests a clear trend towards investing in long-term and more durable solutions, although this approach is not widely adopted overall. In contrast, the concept of implementing real-time monitoring of vibration and stress levels garnered the least support, at just 8%. This data may be attributed to the perception of high costs or technological challenges.

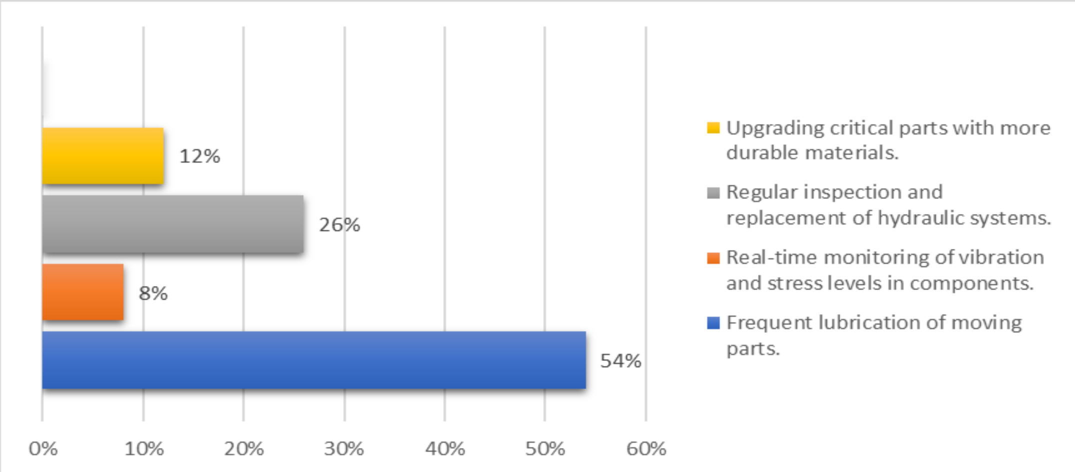

Figure 3.4 Most critical routine maintenance practices to reduce wear and tear on MVTS components

Lastly, as illustrated in Figure 3.5, a majority of the respondents (56%) identified the development of local suppliers for critical components as their primary strategy. This preferences reflects a strong believe that local sourcing can greatly enhance the reliability and responsiveness of spare part availability. This strategy is particularly crucial in high stakes infrastructure projects like the ECRL, where timely access to vital materials can be very important for project success in timely completion. Other preferred strategies emphasized by the respondents include establishing long-term agreements with multiple suppliers and utilizing standardized components that are compatible across various vendors, each receiving 16% of the responses. These methods illustrate as strong awareness among respondents of the essential need for diversification and flexibility within the supply chain. In contrast, the practice of stockpiling commonly used spare parts on-site received support from only 12% of respondents. This data reflects concerns about over-storage costs, inventory management, and the risk of parts becoming obsolete before use.

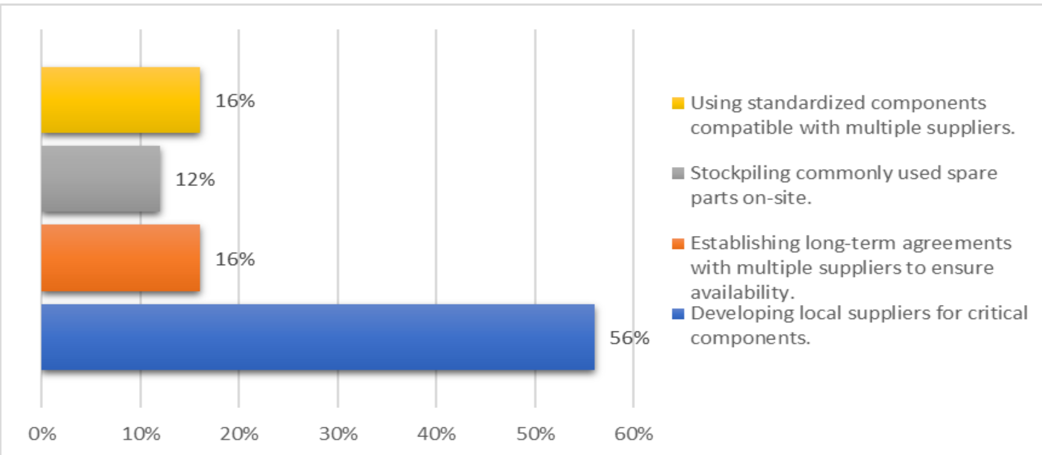

Figure 3.5 Prefered strategies to reduce dependency on imported spare parts

4. Conclusion

This study systematically identified and evaluated the key technical challenges affecting Maintenance Vehicle Trains (MVTs) during the ECRL construction phase. Using structured questionnaires involving 50 experienced technical personnel, three major problem areas were highlighted: environmental conditions, mechanical fatigue, and supply chain limitations. Specifically, 67% of respondents agreed that environmental factors, such as high humidity and dust accumulation, can negatively affect component durability and lead to air filter clogging. Additionally, 74% confirmed that prolonged usage and repetitive loadings contributed to mechanical fatigue and failure in critical components such as tamping tines and shafts. The issue of spare parts dependency was also prominent, with 77% of respondents indicating that delays in procurement especially from China, significantly contributed to downtime and disrupted project timelines. In response, the majority of participants recommended proactive mitigation strategies, including regular lubrication of moving parts, preventive maintenance in dusty conditions, and the development of local spare parts suppliers. These data-driven insights not only validate the real-world challenges faced in MVT operations but also provide practical recommendations to improve performance and ensure timely completion of infrastructure projects like the ECRL.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: **Study On Technical Challenges Of Maintenance Vehicle Trains (MVTs) For Construction Phase In ECRL Project**: Fadhlan Syakirin Bin Ahmad Shukri. Corresponding Authors: Musli Nizam Bin Yahya, Siti Nina Nadia Binti Nazaruddin. All authors reviewed the results and approved the final version of the manuscript.

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