ANALYZING KEY FACTORS AND STRATEGIC SOLUTIONS FOR RAILWAY INFRASTRUCTURE MAINTENANCE IN VIETNAM: A CASE STUDY APPROACH

Nguyen Quang Trung[1], Truong Quynh Chau[1]*, Nguyen Vu Ngoc Hoang[2]

[1]The University of Danang - University of Science and Technology, Vietnam
[2]Quang Nam – Da Nang Railway Joint Stock Company, Vietnam

*Corresponding author: tqchau@dut.udn.vn

(Received: May 05, 2025; Revised: June 18, 2025; Accepted: June 22, 2025)

DOI: 10.31130/ud-jst.2025.23(10C).658E

Abstract - The study examines the factors affecting the quality of railway infrastructure maintenance at Quang Nam – Da Nang Railway Joint Stock Company (QNDN Railway). Through a survey and SWOT analysis, it identifies key factors such as management issues, economicand technical challenges, and the effects of terrain and weather on maintenance operations. The analysis outlines the company's internal strengths and weaknesses, as well as external opportunities and threats. Based on these findings, the study proposes several improvement strategies, including strengthening management capacity, modernizing maintenance technology, and fostering international cooperation. These solutions aim to enhance the effectiveness and sustainability of railway infrastructure maintenance at QNĐN Railway and could be applied to other railway companies in Vietnam, contributing to the overall efficiency of the national rail system.

Key words - Railway infrastructure maintenance; SWOT analysis; management capacity; technology improvement; international cooperation

1. Introduction

Railway infrastructure plays a fundamental role in the transportation of goods and passengers, contributing to national economic development and regional connectivity. In Vietnam, the railway system is largely based on narrow-gauge tracks (1,000 mm), originally constructed during the colonial period. Over decades of operation, this infrastructure has undergone limited upgrades and inconsistent maintenance, resulting in widespread deterioration of critical components such as tracks, bridges, tunnels, and signaling systems [1]. These conditions not only compromise transportation safety but also reduce operational efficiency and increase the long-term costs of infrastructure renewal.

Quang Nam – Da Nang Railway Joint Stock Company (QNĐN Railway) is responsible for maintaining a 146.568 km section of the national North–South railway line, encompassing 79 stations, 137 signal points, and various engineering structures. Despite the company's adherence to standard maintenance procedures issued by the Ministry of Transport, many sections of the infrastructure remain below acceptable quality levels [2] - [4]. Budget constraints, aging equipment, and an insufficient number of technically trained personnel are among the persistent challenges. Although the maintenance budget has increased over recent years, there is limited evidence that these investments have led to proportionate improvements in infrastructure quality [5].

While infrastructure maintenance has been extensively studied in other developing countries such as India, Indonesia, and China [6], [7], limited academic research exists on maintenance practices in Vietnam, especially at the enterprise level. Most existing studies focus on macro-level policy or infrastructure investment, without addressing company-specific operational and managerial factors [8], [9]. Moreover, few studies have applied structured strategic frameworks to identify practical solutions in this sector. This gap limits the ability of managers and policymakers to make informed decisions regarding maintenance strategies.

To address this limitation, this study employs a two-stage methodological approach. First, a structured survey is conducted among railway maintenance personnel and managers at QNĐN Railway to identify and evaluate the key factors influencing maintenance quality. This includes examining issues related to management capacity, technical conditions, human resources, and financial constraints. The survey results provide empirical data to assess the severity and frequency of these factors. Second, the findings are integrated into a SWOT (Strengths–Weaknesses–Opportunities–Threats) analysis framework. Compared to other diagnostic tools, SWOT is well-suited for identifying and integrating both internal constraints (e.g., technical capacity, budget limitations) and external conditions (e.g., regulatory policies, environmental impacts). Previous studies in emerging economies have demonstrated that SWOT can effectively support infrastructure planning and strategic decision-making under resource constraints [10] - [12]. Its application in this study provides a practical and holistic approach to formulating targeted maintenance strategies for QNĐN Railway. The case of the QNĐN railroad was chosen because it is representative of many other segments of Vietnam's railway network - both in terms of infrastructure features and operational constraints. It also serves as a critical node in the national railway network, making it a revealing case for broader policy and management insights

The objective of this study is to identify the main factors affecting the quality of railway infrastructure maintenance at QNĐN Railway and to propose strategic solutions based on survey findings and SWOT analysis. The results aim to support the company in improving maintenance performance and provide reference points for other railway enterprises facing similar challenges in Vietnam's railway sector.

2. Research process

The research followed a structured four-step process, as illustrated in the conceptual framework. Each stage is described below, including the procedures for data analysis and quality control (see Figure 1)

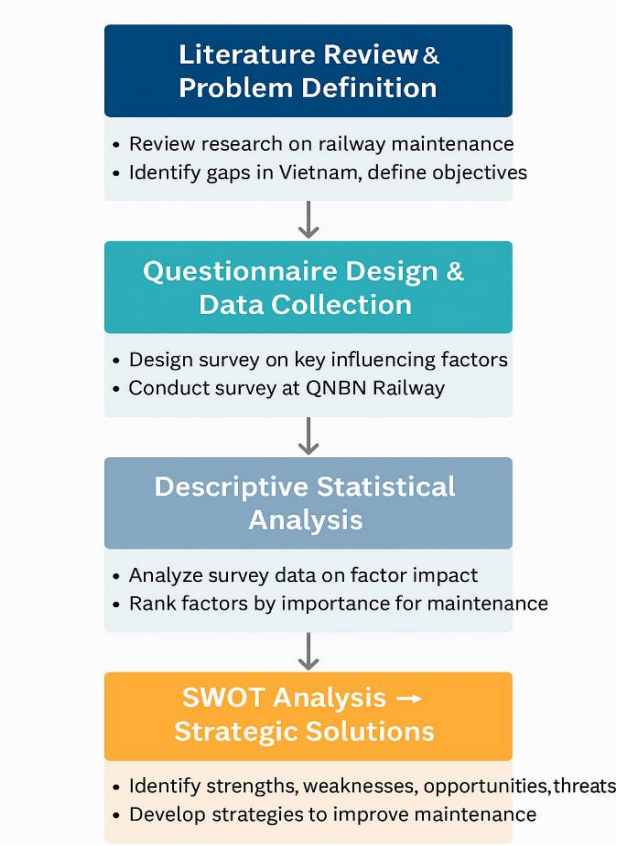

Figure 1. *Research design framework*

Step 1: Literature Review and Problem Definition

The study began with a comprehensive literature review to understand theoretical and empirical work related to railway infrastructure maintenance. This step helped identify existing knowledge gaps in the Vietnamese context and informed the selection of factor groups to be investigated. Based on this review, the research questions were formulated, and the overall direction of the study was determined.

Step 2: Questionnaire Design and Data Collection

A structured questionnaire was developed to assess the extent to which different factors influence the quality of railway infrastructure maintenance at QNĐN Railway. The questionnaire comprised items categorized into four factor groups:

- Technical factors;
- Economic factors;
- Organizational and managerial factors;
- Other factors (weather, policy, international support…).

Each item was rated using a 5-point Likert scale (1 = Not influential, 5 = Extremely influential). The questionnaire was reviewed and refined based on expert input before being distributed to a sample of relevant staff, including engineers, team leaders, and middle-level managers involved in railway maintenance.

Step 3: Data Analysis

Data collected through the questionnaire were analyzed using the following methods:

- Reliability testing using Cronbach's Alpha: Cronbach's Alpha was used to assess internal consistency, with $\alpha \geq 0.7$ considered acceptable [13]. Items with corrected item-total correlations below 0.3 were removed to ensure scale validity. The EFA loading matrix was later used to confirm and refine factor groupings based on empirical patterns [14].

- Descriptive statistics: Mean scores and standard deviations were calculated for each item and factor group. These results were used to rank the factors by their perceived influence on maintenance quality, helping to identify priority areas for improvement.

Step 4: SWOT analysis and strategic recommendations

The final stage involved synthesizing the validated findings from the quantitative analysis into a SWOT framework:

- Strengths and weaknesses reflected internal factors such as staff capacity, technical resources, and management effectiveness.

- Opportunities and threats related to external conditions including regulatory support, funding environments, and physical risks from climate or geography.

Based on this structured analysis, strategic solutions were developed to address weaknesses, capitalize on opportunities, and mitigate risks. These strategies were designed to align with the practical capabilities and constraints of QNĐN Railway, offering a pathway to improve the effectiveness and sustainability of its maintenance practices.

3. Results and discussion

3.1. Characteristics of the survey population

The survey sample was designed to reflect diversity in education, organizational roles, and work experience to ensure a well-rounded perspective on the effectiveness of railway infrastructure maintenance. The descriptive statistics for the 104 valid responses are shown in Figures 2, 3 and 4.

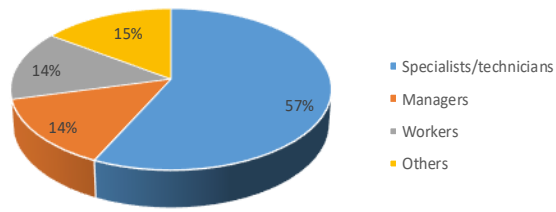

Figure 2. *Professional positions of survey respondents*

57% of respondents were specialists/technicians, 14% were managers, 14% were workers and the remainder held positions in administration, accounting and support units. This distribution confirms the involvement of the main actors directly involved in maintenance activities (Figure 2).

In terms of experience, 72.1% of respondents had more than 5 years of professional experience, and 28.8% had more than 15 years. This reflects a high level of practical knowledge among the participants (Figure 3).

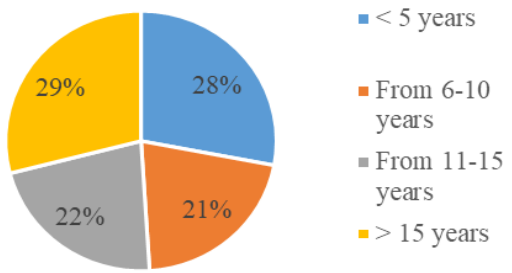

Figure 3. *Experience of survey respondents*

In terms of education, 79.8% of respondents had a university degree or higher, indicating a solid technical and theoretical understanding of infrastructure maintenance (Figure 4).

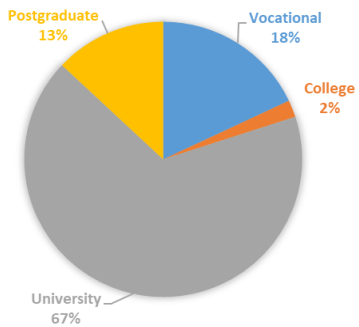

Figure 4. *Educational background of survey respondents*

3.2. Scale reliability evaluation

To assess the internal consistency of the measurement scale, Cronbach's alpha was used to evaluate the reliability of the 14 observed variables grouped into four factor categories: technical factors (4 items), economic factors (3 items), organizational/managerial factors (3 items), and other factors (4 items).

The analysis yielded a Cronbach's alpha of 0.868 for the overall 14-item scale, indicating a high level of internal consistency and suitability for further statistical analysis [13]. Cronbach's alpha values were also computed separately for each factor group (Table 1). The technical (α = 0.722) and organizational/managerial groups (α = 0.766) exceeded the 0.7 threshold, indicating acceptable reliability. Although the economic (α = 0.698) and other factors group (α = 0.693) were slightly below 0.7, these values are still considered acceptable for exploratory research [16]. The corrected item-total correlations within each group were all greater than 0.3, further supporting the internal consistency of the scales.

Table 1. *Item-total statistics by factor groups*

No.	Factors	Corrected item-total correlation	Cronbach's Alpha if Item Deleted
I	Technical factors (*Cronbach's Alpha* = 0.722 - *N of Items* = 4))		
KT1	Outdated maintenance technology	0.465	0.736
KT2	Insufficient or outdated maintenance equipment	0.499	0.725
KT3	Shortage of skilled maintenance engineers	0.587	0.677
KT4	Non-compliance with procedures and standards	0.672	0.646
II	Economic factors (*Cronbach's Alpha* = 0.698 - *N of Items* = 3)		
KTE1	Insufficient maintenance funding	0.512	0.614
KTE2	Unreasonable allocation of maintenance budget	0.589	0.513
KTE3	Cost and quality of materials and equipment	0.451	0.682
III	Organizational and managerial factors (*Cronbach's Alpha = 0.766 - N of Items = 3)*		
QL1	Poor coordination among departments	0.550	0.745
QL2	Ineffective maintenance planning	0.638	0.646
QL3	Lack of managerial competence	0.614	0.669
IV	Other factors (*Cronbach's Alpha = 0.693 - N of Items = 4)*		
YTK1	Adverse weather and climate conditions (e.g., storms, heat)	0.585	0.570
YTK2	Complex terrain, weak soil, landslide- or flood-prone areas	0.446	0.648
YTK3	Unclear or inappropriate policies	0.514	0.605
YTK4	Limited access to international expertise	0.389	0.692

3.3. Exploratory factor analysis results

Although the specific EFA procedures are not presented in detail in this paper, the analysis was conducted after confirming the internal consistency of the measurement scales. The results indicate that the data were suitable for factor analysis, as shown by a KMO coefficient of 0.755 and a significant Bartlett's test of sphericity (Sig. = 0.000). The extracted factors explain 60.499% of the total variance, which demonstrates good explanatory power.

Based on the results, three principal components were identified:

Management-related factors – accounting for 37.774% of the total variance, this is the most dominant factor group. It includes variables associated with management practices, human resources, coordination, and policy implementation. Notably, two items initially categorized under "Other factors" (unclear policies and lack of

international support) were statistically grouped into this component, indicating their close alignment with managerial dimensions.

Economic–Technical factors – explaining 13.825% of the variance, this component integrates both technical and economic aspects. The strong correlation between these variables suggests that in practice, technical limitations and financial constraints often interact and jointly affect maintenance performance.

Topographical and climatic factors – accounting for 8.899% of the variance, this group encompasses environmental and geographical challenges. It includes variables related to complex terrain and adverse weather conditions, which were originally classified as "Other factors".

The reclassification of variables based on empirical data provides a clearer structure for subsequent strategic analysis and reinforces the practical interdependence among technical, managerial, and environmental dimensions in railway infrastructure maintenance.

3.4. Descriptive statistical analysis of factors affecting infrastructure maintenance at QNĐN Railway

Descriptive statistics were used to evaluate the perceived influence of individual factors on infrastructure maintenance quality. The analysis focused on mean scores, derived from responses on a five-point Likert scale (1 = Not influential to 5 = Extremely influential). The result is shown in Table 2 as follows.

Table 2. *Summary of criteria by level of importance*

STT	Criterion	Importance	Mean	Standard Deviation
1	QL3	**1**	4.31	0.904
2	YTK2	**2**	4.26	0.848
3	YTK4	**3**	4.04	0.924
4	KT1	**4**	4.04	0.847
5	KTE1	5	3.9	1.066
6	KTE3	6	3.7	0.944
7	KT2	7	3.56	1.05
8	YTK3	8	3.48	0.995
9	YTK1	9	3.42	1.012
10	KT3	10	3.39	1.092
11	KTE2	11	3.26	0.975
12	QL2	12	3.24	0.96
13	KT4	13	3.22	1.07
14	QL1	14	3.22	1.07

Based on the survey results, several key factors with high mean scores were identified, reflecting their significant influence on maintenance quality:

- *Lack of managerial competence* (QL3) received the highest mean score (mean = 4.31), highlighting that the quality of human resources, especially in management positions, plays a central role in the organization and execution of effective maintenance activities.

- *Complex terrain, weak soil, landslide- or flood-prone areas* (YTK2) were also rated highly (mean = 4.26), indicating that harsh natural conditions are a major obstacle to planning and carrying out maintenance work.

- *Limited access to international expertise* (YTK4) and *outdated maintenance technology* (KT1) both received an average score of 4.04. These figures highlight the company's limited access to modern maintenance methods and global best practices, which has a direct impact on the efficiency and durability of maintenance work.

In summary, three main conclusions can be drawn from the descriptive analysis:

1. Managerial human resources, natural conditions, limited access to international expertise and outdated technology emerged as the most influential factors affecting maintenance quality.

2. Financial resources, while important, were rated slightly lower in priority than the core issues above.

3. Several technical and internal management issues, though relevant, were perceived as less urgent compared to the more pressing challenges identified.

4. SWOT analysis and strategic solutions

4.1. SWOT Analysis

To propose strategic solutions for improving maintenance quality at QNĐN Railway, a SWOT analysis was conducted based on the results of survey data. This framework helped identify the company's internal strengths and weaknesses, as well as external opportunities and threats, as shown in Figure 5. The intersection of these elements enables the formulation of appropriate strategic directions.

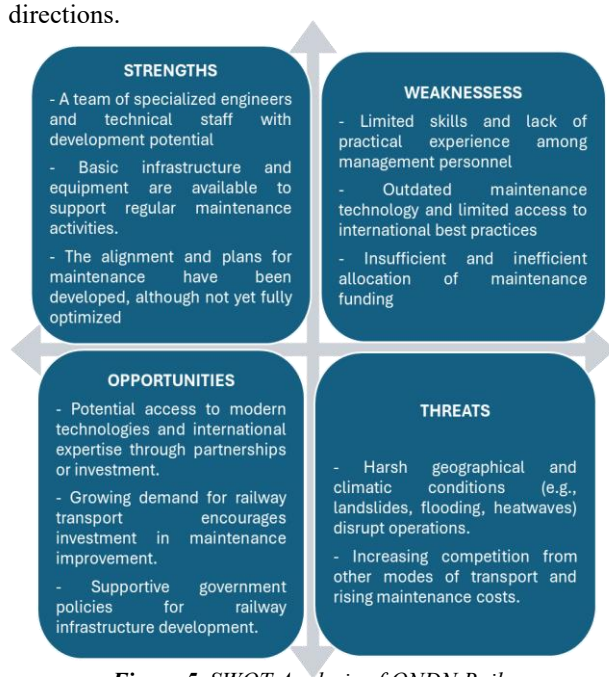

Figure 5. *SWOT Analysis of QNĐN Railway*

4.2. Strategic Implications

SO strategies (Use strengths to exploit opportunities)

- Use the existing team of trained engineers and technical staff to absorb and apply international expertise through partnerships or training programs.

- Use available infrastructure and maintenance capacity to quickly adapt modern technologies aligned with the growing demands of the railway sector.

- Take advantage of government support policies to upgrade and optimize current maintenance plans.

WO strategies (Overcoming weaknesses by exploiting opportunities)

- Address the lack of international maintenance practices by initiating cooperation with international agencies or donor-funded projects.

- Invest in capacity-building programs to upskill the management team by leveraging opportunities for training and global collaboration.

- Prioritize funding improvement projects by aligning them with national railway infrastructure initiatives and policy incentives.

ST strategies (Using strengths to counteract threats)

- Strengthen response capabilities to climate-related risks by using the existing technical team to develop contingency plans for infrastructure in flood- or landslide-prone areas.

- Improve planning systems using current infrastructure to enhance operational flexibility and resilience to extreme weather conditions.

WT strategies (Minimizing weaknesses and avoiding threats)

- Seek external funding or government subsidies to reduce dependence on limited internal financial resources.

- Develop a structured management improvement program to minimize the impact of leadership capacity gaps when facing external shocks such as rising costs or climate disruptions.

- Conduct regular risk assessments to align limited resources with the most vulnerable infrastructure segments.

The proposed strategic directions derived from the SWOT analysis provide a practical roadmap for QNĐN Railway to enhance maintenance performance. By leveraging internal strengths and external opportunities while addressing critical weaknesses and mitigating external threats, the company can move toward more effective, resilient, and sustainable infrastructure maintenance practices

5. Conclusion

This study identified key factors affecting railway infrastructure maintenance at QNĐN Railway using quantitative methods including reliability testing, factor analysis, and descriptive statistics. The main challenges include limited managerial capacity, outdated technology, limited access to international expertise, and harsh natural conditions. A SWOT analysis was conducted to structure these findings and propose strategic directions tailored to the company's internal and external conditions. Moving forward, the company is advised to implement targeted training programs, seek partnerships for technological transfer, and align internal improvements with external opportunities such as government support and market demand. These strategies will help strengthen the company's ability to maintain infrastructure more effectively and sustainably.

The study contributes to the limited literature on maintenance in developing railway systems and provides practical guidance for data-driven decision-making. However, this study is not without limitations. The data were collected from a single regional railway company and may not fully represent the broader Vietnamese railway context. Additionally, the analysis relied on cross-sectional survey data, which may be subject to respondent bias and temporal limitations. Future research could expand the sample size and geographic scope, incorporate longitudinal data, and integrate qualitative insights to deepen the understanding of institutional, technical, and policy-related barriers in railway maintenance practices.

REFERENCES

[1] ALMEC Corporation, Pacific International Corporation, Nippon Koei Corporation Japan International Cooperation Agency, "*Nghien cuu toan dien ve phat trien ben vung he thong giao thong van tai o Viet Nam (VITRANSS 2)*", Japan International Cooperation Agency, Tokyo, Japan, 2010.

[2] *National Technical Regulation on Railway Operation*, QCVN 08:2018/BGTVT, 2018.

[3] Ministry of Transport, *Regulation on Railway Infrastructure Maintenance Procedures*, Decision No. 2320/QĐ-BGTVT, 2015.

[4] Ministry of Transport, *Prescribing criteria for surveillance and acceptance testing of maintenance performance of national railway infrastructure in terms of maintenance quality, regime and* procedures, Circular No. 06/2019/TT-BGTVT, 2019.

[5] Japan International Cooperation Agency, "*Data Collection Survey for Sustainable and Resilient Urban Development of Da Nang City. Final Report*", Da Nang People's Committee, Vietnam, 2022.

[6] R. Gangwar, *Handbook on Railway Regulation - Chapter 11: Railways in India: challenges and opportunities*. Cheltenham, UK: Edward Elgar Publishing, 2020.

[7] M. Su, G. Dai, S. Marx, W. Liu, and S. Zhang, "A brief review of developments and challenges for high-speed rail bridges in China and Germany", *Structural Engineering International*, vol. 29, pp. 160–166, 2019. https://doi.org/10.1080/10168664.2018.1456892.

[8] V. Chakraborty and S. Dutta, "Indian railway infrastructure systems: global comparison, challenges and opportunities", *Proceedings of the Institution of Civil Engineers – Smart Infrastructure and Construction*, vol 175, pp. 127–140, 2022. https://doi.org/10.1680/jsmic.22.00014

[9] I. W Hatta, A. A Samudra, and E. Satispi, "Challenges and opportunities for improving management and regulation of the rail transport sector in Indonesia: perspective from the industry 4.0 concept", *Journal of Law and Sustainable Development*, vol 12, pp. e3037, 2024. https://doi.org/10.55908/sdgs.v12i2.3037

[10] S. Stoilova and N. Munier, "Analysis of Policies of Railway Operators Using SWOT Criteria and the SIMUS Method: A Case for the Bulgarian Railway Network", *Sustainability*, vol. 13, pp. 6948, 2021. https://doi.org/10.3390/su13126948

[11] M. B Bouraima, Y. Qiu, B. Yusupov, and C. M Ndjegwes, "A study on the development strategy of the railway transportation system in the West African Economic and Monetary Union (WAEMU) based on the SWOT/AHP technique", *Scientific african*, vol. 8, pp. e00388, 2020. https://www.sciencedirect.com/science/article/pii/S2468227620301265

[12] M. T Ahi and K. Yildiz, "Determining performance criteria of railway market: A case study", *Journal of Open Innovation: Technology, Market, and Complexity*, vol 4, pp. 1-15, 2018. https://jopeninnovation.springeropen.com/articles/10.1186/s40852-018-0084-5

[13] J. F Hair, W. C Black, B. J Babin, and R. E Anderson, *Multivariate Data Analysis. 7th Edition*, Pearson, New York, 2010.

[14] B. D Haig, "Exploratory Factor Analysis, Theory Generation, and Scientific Method", *Multivariate Behavioral Research*, vol. 40, pp. 303–329, 2005. https://doi.org/10.1207/s15327906mbr4003_2