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Evaluating the Role of Sustainability in Manufacturing Engineering Project Success: A Case Study of the German Railway Industry

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ABSTRACT: The achievement of manufacturing engineering projects (MEP) in the German railway industry is examined in this study in relation to sustainable practices (SP). A quantitative design was used to determine how the main project performance metrics—cost, time, standards, and operational efficiency—were affected by economic, environmental, and social sustainability measures. A structured questionnaire was sent to project managers, engineers, and sustainability officials; 400 responses were received and analysed in SPSS. To test the proposed hypotheses, the rank correlation test and the Kruskal-Wallis test were used. Environmental sustainability was found to have the strongest association with project performance, and a positive, statistically significant relationship was observed between sustainability integration and overall project success. The findings also support the view that greater emphasis on sustainability enhances the efficiency of long-term operations. The study concludes that integrating sustainability into railway manufacturing projects improves performance, stakeholder outcomes, and strategic value, providing a viable contribution to sustainable project management in highly controlled infrastructure industries.

KEYWORDS: Sustainable Practices, Project Success, Manufacturing Engineering Projects, German Railway Sector, Sustainable Project Management.

INTRODUCTION

Sustainability in project management is a strategy that suggests economic, social, and environmental implication on all stages of project life cycle to ensure long-term value and to be responsible outcomes [1]. Projects in the manufacturing engineering industry can enhance the success of the project and minimize the environmental and societal effects by engaging in green practices that align with Environmental, Social and Governance principles (ESGs) [2]. The paper presents the context and importance of sustainability in railway manufacturing projects and lays the groundwork for its role in the German railway industry's project success.

Much of Europe's rail system was constructed between 100 and 120 years ago, and thus requires constant maintenance in addition to significant modernization and renewal every cycle. Axle loads and speeds have significantly increased as the railway passenger and freight transportation capacity has grown [3], [4]. Unconventional technologies and significant expenses are required to reinforce and rebuild the railway substructure. The need for a novel method to rapidly fortify the substructure beneath preexisting lines without tearing them down originated in Germany and Austria in the latter part of the 1970s [5]. Innovation in track and geotechnical design, to develop the technology for large-scale mechanized formation restoration, engineering control techniques and mechanical innovation were essential. Adapting technology-specific design and technological control processes to local conditions was a need for the machinery systems to be applicable in Hungary [6]. The emphasis on recycling procedures has grown, and mechanical and engineering backgrounds have been further enhanced during the past forty years or more.

The way infrastructures are conceived, developed, negotiated, and evaluated frequently reflects the involvement of several geographical and governance scales. [7] explain how the local towns were consulted in order to get alternate sources of information and to secure political backing, which led to a large number of revisions. Investigating a case study of a new rail line that linked the Netherlands and Germany, they found that while local municipalities participated in the planning of the area around the line, they were not involved in the most critical phases of the project [8] explain the necessity of contingency planning and the inevitable political aspects of infrastructure planning. Furthermore, they offer a range of strategies to address the complexity of future projections and varied interests, such as "qualitative and quantitative planning of scenario impact evaluations, pathway visualization, visioning, back casting, anticipatory gaming, and foresight activities" [9]. Performative stagings, participatory design, and stakeholder input.

Since the adoption of the United Nations Sustainable Development Goals (UNSDGs) in 2015, the concept of sustainability has become essential to global engineering and industrial development. Additionally, corporations are under government and public pressure to reduce their environmental impact without lowering productivity. People's growing worry over resource depletion, environmental degradation, and global warming is the cause of this. Along with conservation of resources and conformity with national and international environmental goals, sustainability in engineering encompasses longer-term system resilience, circularity, strategic alignment, and integration. Using "Renewable Energy" (RE), minimizing waste and emissions, using recyclable or low-impact materials, and doing lifecycle cost analysis are all components of sustainable engineering [10]. These ideas are becoming increasingly significant in today's project planning, design, and implementation, especially in fields where consumer responsibility and infrastructure lifespan are crucial considerations.

One of Germany's railway industries is well positioned to benefit from the adoption of hot, sustainable engineering. The rail network in Germany is among the most developed and extensively utilized in all of Europe, allowing for the cross-border transportation of both people and goods [11]. With the growing focus of the public on environmentally friendly transport and the government actions to reduce emissions and meet climate goals, the industry is adopting green technology such as automated operations, energy efficient rolling stock and electrifying the lines to promote performance and reduce the environmental foot print. Manufacturing engineering, in the railway industry also forms another source of environmentally friendly practices, involving developing trains, their parts along with maintenance of related infrastructure [12]. At project-by-project level though, there is no information or knowledge of the extent to which these tactics are being used and how they are being translated in quantitative terms into project success measures such as scope delivery, cost-reduction, scheduling, and Supply Chain Management (SCM).

With the magnitude and intricacy of the railway engineering projects, it is more crucial than ever to ensure that the sustainability is at least a component of the factory process and that it is reflected on the overall success of the project [13]. On this basis, the paper will explore how the concept of sustainability is incorporated into the German railway sector (GRS) and whether it affects the project's significant results. Since sustainability and the project of management are intertwined, the study will have beneficial information to the academic researchers as well as the professionals in the field. It will also facilitate the development of regulations, guide engineering decisions, and invest in environmentally friendly transportation infrastructure.

Railroads are a significant contributor to the German economy, transportation and environmental policies [14]. With its efficiency, inventiveness, and wide coverage both locally and internationally, the German railway is among the most advanced in Europe. The market is dominated by Deutsche Bahn (DB), a government-owned railway operator that controls a huge percentage of both passenger and freight traffic. Investing heavily on the electrification and modernization of the railways sector, as well as the promotion of rail transport as a less hazardous alternative to roads, Spending a lot of money on updating and electrifying the train industry [15].

Additionally, Sustainable and climate policies in Germany, such as the European Green Deal and the Plan for Climate Action 2050, are based on this sector [16]. Since rail travel is substantially less extremely carbon-intensive than air or road transport, it is believed to be one of the main drivers of the nation's shift to a low-emission economy. Railways are increasingly integrating RE, using energy-efficient rolling equipment, and digitizing their operations. Additionally, As part of its commitment to a sustainable transportation future, Germany is spending money on research and development to make electric and hydrogen trains better [17]. These developments point to a shift in engineering and policy that will make the railway sector the cornerstone of climate-neutral transport in Germany and throughout Europe. About 40% of the industry's entire revenue comes from exports, and new orders increased by 57% from 2022 to USD 23.4 billion. Of the 39,200 km in Germany's rail network, Deutsche Bahn is in charge of about 33,400 kilometres. Since 1994, the DB network has seen passenger rail traffic increase by more than 50% and freight traffic by almost 90%, with over 1 billion train km travelled annually. Regarding transportation performance, regional train carried 59 billion passenger kilometres, an increase of 12%, but long-distance services saw a 10% growth, reaching 47 billion passenger kilometres.

The work overarching goal is to draw conclusions about the impact of incorporating sustainable principles into manufacturing industries' engineering projects in Germany's railway sector. The study's overarching goal is to determine how various sustainability practices—those pertaining to the environment, the economy, and society—influence key project performance indicators like budget, time, quality and stakeholder satisfaction.

A. Motivation and Contribution of the Paper

The primary goal of the study is to raise awareness of the term sustainability in infrastructure-oriented sectors and the lack of empirical data linking sustainable practices to measurable project success outcomes in production engineering projects in the railway industry. Although sustainability is now a strategic priority fuelled by ESG requirements, climate policies, and the demands of the stakeholders, there is still no measurable, project-based analysis of how the practice of environmental, economic and social sustainability can be translated into better performance indicators like cost, time, quality, and operational efficiency especially in environments where there is high regulation like the German railway industry. Based on these, the major contributions of this paper are:

- Provides quantitative empirical evidence on how environmental, economic, and social sustainability practices influence manufacturing engineering project success in the German railway industry.
- Extends sustainable project management literature by integrating sustainability dimensions with core project performance indicators—cost, time, quality, and operational efficiency—in a manufacturing engineering context.
- Provides actionable insights for project managers, sustainability officers, and policymakers to support sustainability-driven decision-making and strategic planning in railway infrastructure projects.

B. Structure of the Paper

This is how the rest of the paper is organized. To lay the theoretical groundwork for the study, Section II examines pertinent literature on manufacturing projects, railway engineering, sustainability, and project management. The research design, gathering data methods, sample criteria, and the statistical analysis methodologies used are all covered in Section III. The empirical data are presented in Section IV, together with a discussion of the findings in light of the current literature and the suggested hypotheses. Section V, which wraps up the work, summarizes the main conclusions, emphasizes the management and policy ramifications, and suggests future research paths.

LITERATURE REVIEW

This literature review section synthesizes prior research on railway technology, sustainability, manufacturing engineering, and project management, with particular emphasis on how sustainable practices influence project outcomes. The reviewed studies provide technological, managerial, economic, and environmental perspectives that collectively establish the theoretical foundation for examining sustainability-driven project success in the railway manufacturing sector.

Cascino, Meli and Rindi (2026) explores the interplay between material choice, constraints on manufacture, and a stress constraint function that is dynamic in nature to ascertain the ultimate distribution of materials that structural optimization produces, all the while guaranteeing conformity with the applicable European evaluation criteria for railway bogies. By creating a thorough finite element simulation of the complete bogie system, the study was able to accurately replicate the operational stresses and structural interactions between the motor support and its surrounding components. The suggested methodology systematically assesses the effects of material quality, drawing orientation, and minimum feature size on the optimal design by combining topology optimisation with a manufacturability-oriented framework. Here, an adaptive stress coefficient was used to improve the optimized design's material distribution and resulting stress levels. The coefficient was obtained from the original component's performance. The outcomes show that a production-feasible and structurally efficient design is achieved when manufacturing restrictions, adaptive stress control, and material selection are all taken into account simultaneously. The results of the mass savings and distribution of stress tests on the three different materials were consistent with each other. While keeping acceptable stress levels, the novel optimized arrangement reduced mass by more than 16%. The suggested method offers a framework for future topology optimization applications in railway engineering that is both standard-compliant and generalizable [18].

Railway transit is crucial to a nation's economic growth. However, there are certain difficulties with railway project management. To optimize railway transit, this paper examines existing issues and proposes solutions. In a study Petrova (2024) looked at European development policy of railway transit and the part played by the government in building, maintaining, and repairing railway infrastructure. An outline of the options for funding railway projects with state budget and EU monies is provided. The article offers analysis and recommendations for enhancing railway project management and attaining more effective and sustainable railway transportation [19].

In a study, Loizaga, Losada and Amorrortu (2023) Innovations in the rail industry is largely driven by technologies, which address important issues such freight transportation, efficiency, sustainability, and passenger experience. Along with the use of smart operation and modern manufacturing, to reduce environmental impact and maximize resource utilization, cutting-edge propulsion systems and materials are being used in the quest for sustainability. Predictive maintenance and safety, enhanced service dependability and safety, and more efficient operation management are all made possible by data and analytics-based solutions. Furthermore, the user experience is enhanced by passenger-focused apps and services including digital ticketing and real-time information. Additionally, technology is transforming freight transportation by improving infrastructure and operations for more sustainable and effective cargo transit. A more sophisticated and effective future for the rail industry is being shaped by these technologies taken together.

As mentioned by, Milewicz, Mokrzan and Szymański (2023), the advent of railroads was a watershed moment in transportation history; they altered the course of human events and the flow of commodities and people around the globe. Without the emergence of railways that began as simple track systems and have since gone on to become more complex and interconnected networks, economic growth, globalisation, and the formation of modern communities would not have been possible. The importance of railways has just increased as the world scurries to find ways of addressing the dire need to cut down on the emission of greenhouse gases and adopt more environmentally friendly means of transport. Public transport Railways have historically been considered as one of the most environmentally friendly, since it has lower carbon footprints, higher energy efficiency, and reduced traffic. Conversely, species and habitats protection is not the only barrier which should be encountered on the way to the environmental sustainability in the long term. This study attempts to explore the concept of sustainability in the rail industry by providing an in-depth analysis of the environmental effects of the railway industry [20].

Braun and Franke (2022) takes a look at the average and varied impacts of railway access on industrialization, incomes, and population in Württemberg while the Industrial Revolution, on a parish level. Specifically, they have shown that larger and more industrialized parishes from the outset felt the growth-promoting effects of the railway to a far greater extent. But in the comparatively impoverished German state, such early industrial parishes were uncommon. This could help to explain why average growth effects are minor and only start to increase around the 19th century ending. As a result, the railway's varied effects widened economic gaps within Württemberg and contributed to the state's comparatively slow growth [21].

In Uygun and Ahsan (2021) focused on the railway network, which has six main corridors, within the latter. They offered a high-level representation of the Chinese-German rail freight market. within the limits of the Any Logic (Version 8) program at the present time's border control points. Using a geographic information system (GIS), this discrete-event model sorts routes and countries according to their criticality index before giving a high-level summary of their classification. A criticality index is calculated by multiplying the index of logistics performance by the time variance. The former is achieved by employing various set-up studies within the constraints of the shortest way and the existing border check locations, accounting for both a fixed capacity and a variable number of trains each day. The analysis also found that to get the most out of this transcontinental rail system, processing capacity at border control stations must be increased in an effort to comprehend the network under stress. The findings demonstrate that trains take longer to reach their destination when border control points have less capacity. Stakeholders that are actively looking to increase their investment in the Belt and Road Initiative or who use rail transit may be able to predict when the network will operate at its best and what steps could be taken to achieve optimal efficiency [22].

TABLE I. SUMMARY OF SELECTED STUDIES ON RAILWAY TECHNOLOGY, SUSTAINABILITY, AND PROJECT MANAGEMENT

Reference	Study Focus	Methodology / Approach	Key Findings	Relevance to Present Study
Cascino, Meli & Rindi (2026)	Structural optimisation of railway bogies	Finite element modelling and topology optimisation	Achieved over 16% mass reduction while maintaining structural integrity and compliance	Illustrates advanced manufacturing engineering practices enhancing efficiency and sustainability
Petrova (2024)	Railway project management and policy	Policy analysis and review of European railway frameworks	Highlights challenges in railway project management and emphasizes state and EU funding, policy support, and management optimisation	Supports discussion on regulatory and managerial factors influencing project success
Loizaga, Losada & Amorrortu (2023)	Role of technology in railway innovation	Conceptual and analytical review of rail technologies	Advanced propulsion systems, smart operations, data analytics, and digital services enhance sustainability, efficiency, passenger experience, and freight transport	Provides a generalized technological context supporting sustainability integration in railway projects
Milewicz, Mokrzan & Szymański (2023)	Sustainability in railway transport	Conceptual analysis of environmental impacts	Railways are environmentally efficient but face challenges related to habitat and wildlife protection	Provides foundational sustainability perspective relevant to environmental dimensions of SP
Braun & Franke (2022)	Economic impact of railway access	Historical economic analysis using parish-level data	Railway access had heterogeneous growth effects, increasing regional disparities during industrialisation	Demonstrates the broader economic implications of railway infrastructure development
Uygun & Ahsan (2021)	Rail freight efficiency between Asia and Europe	GIS-based discrete-event simulation using AnyLogic	Border control capacity significantly affects transit time and network efficiency	Relevant to operational efficiency and infrastructure planning in railway systems

Table I provides a brief overview of the selected empirical and conceptual studies that are related to the technology, sustainability, and project management of railroads. It brings to light important methodologies, findings and their applicability to the current study.

METHODOLOGY

In this section, the methodological methodology that will be employed in researching the relationship between sustainable practices and project success in manufacturing engineering projects in the German railway industry is detailed. To ensure methodological rigour, dependability as well as compliance with the research aims of the study, it outlines the research design, data collection methods, sampling criteria, and statistical methods applied.

C. Research Design

This paper is based on the Research Onion paradigm by [23] that will be used to organize the research process systematically. The framework provides a logical and precise method of structuring the different methodological decisions which are involved in the research process. It shows research as a chain of interrelated levels, the first one being research philosophy and research approach. These are then succeeded by research design aspects, such as methodology selection, research plan, and period. The last layer is the innermost and is concerned with the data collection and data analysis techniques. In such an organized way, the research can be taken to be rather methodologically rigorous, coherent and consistent with the research goals.

The study adopted a mixed-methods research design, using both quantitative and qualitative methods. A structured questionnaire was used to collect the quantitative data, which was analyzed using SPSS to test the relationships between sustainable practices and the project success indicators. At the same time, the qualitative data were gathered through the responses of the open-ended questionnaires and practitioner reflections, which were thematically analyzed to provide the contextual depth and supportive meaning to the interpretation of the statistical findings[24].

D. Data Gathering Procedure

The research strategy that was used in this study was a comprehensive data collection method involving both primary and secondary data to investigate how sustainable practices are integrated in the manufacturing of railway projects and their effect on the success of project in Germany. More than 500 respondents were to be targeted with an aim of improving reliability, as well as to consider non-response bias. Four hundred of these were received and considered enough to carry out a powerful statistical analysis. The structured questionnaire was a measure that had 41 measurement items and was used to collect data. Cronbach's alpha was used to check the reliability of the instrument, and the data obtained was 0.734, which was satisfactory internal consistency. The survey included some open-ended questions, which introduced some qualitative backdrop to lead a supplemental thematic analysis.

E. Primary Data

The data on the primary level were gathered using the structured questionnaire, those were distributed to the railway managers of projects, engineers, and sustainability officers using Google Forms. The tool included the demographic information, nature of the project, and how the environmental, economic, and social (EES) sustainability practices impacted the project results.

F. Secondary Data

Published sources were used as the source of secondary data, examples include yearly reports on the sustainability and performance of German railway businesses, official documents regarding transportation and environmental laws, industry benchmarks and other European Union directives on the green transportation.

G. Inclusion and exclusion criteria

Data relevance and quality were primary concerns in developing the inclusion and exclusion criteria. Participants included sustainability officials, project managers, and engineers from with the completed railway projects in Germany in the last five years and administrative personnel, non-technical staff, and off-country professionals were not included in the study.

H. Data Analysis Guide

The data collected were analyzed in a systematic way using Statistical Package for Social Science (SPSS) in order to come up with a meaningful interpretation of the research findings. SPSS is a popular statistical program that helps to manage the data efficiently, conduct further statistical analysis, and visualize without the necessity to learn the programming language. It is usually used in social sciences and market research to conduct descriptive and inferential statistical tests and detect trends in large data [25]. In this research, the proper statistical tests were used depending on the research objectives and hypothesis to achieve accuracy and reliability of the analysis.

- The use of a correlation analysis through Spearman rho is used to determine the strength and direction of relationships among ranked or ordinal variables. This non-parametric correlation coefficient is specially applicable in the case of data that is not normally distributed. It looks at how a change in one variable correlates with increases or decreases in another variable hence showing the nature and strength of their association without the assumption that they are linear or that they are normally distributed [26].
- Kruskal-Wallis test is an alternative to one-way ANOVA and is non-parametric and is applied when a researcher wants to test variations between more than two independent groups. It is especially relevant in cases where the normality and homogeneity of variance assumptions are broken. The test is based on ranked data to test whether there are significant differences in distributions of the groups under consideration that are statistically significant [27].

RESULT ANALYSIS AND DISCUSSION

To assess the validity of the proposed study hypotheses, this section employs statistical methods. It helps identify key connections and derive insightful conclusions from the data.

TABLE II. DEMOGRAPHIC PROFILE OF RESPONDENTS

Demographic Variable	Category	Frequency	Percentage (%)
Gender	Male	249	62.3
	Female	151	37.7
Age (Years)	18–28	69	17.3
	29–39	76	31.3
	40–50	125	32.0
	Above 50	128	19.3
Education Level	Diploma or Lower	13	3.3
	Bachelor's Degree	123	30.7
	Master's Degree / Project Management Certification	160	40.0
	Doctorate	104	26.0
Years of Experience in Engineering Projects	Less than 5 Years	82	20.7
	5–10 Years	136	34.0
	11–20 Years	107	26.7
	Over 20 Years	75	18.7

Table II based on the demographic profile, the respondents are well-balanced and experienced and can be successfully analyzed in the project-based manner. The majority of the respondents are males (62.3 percent), but there is also an increasing number of females (37.7 percent) in engineering positions. The majority of the respondents are between the 29-50 age group, which implies a mature workforce with minimal decision-making roles. Majority of the people are highly qualified, with 40% having a masters degree or project management certificate and 26% having a doctorate, which means that they are very competent technically and at the managerial level. The level of experience is high with more than 60 percent of the respondents having an experience of more than five years in engineering projects, which adds credibility and usability to the study results.

I. Impact of Sustainable Practices on Project Success

This section explores the connection between sustainability issues and the success of project in the manufacturing engineering projects in the railway industry of Germany. The performance of the key project metrics regarding the effect of the social, environmental, and economic sustainability policies is assessed by the rank correlation analysis of Spearman

TABLE III. CORRELATION BETWEEN SUSTAINABILITY PRACTICES AND STAKEHOLDER MOTIVATION

Variables	Economic Sustainability	Environmental Sustainability	Social Sustainability	Project Performance	Significance ($p < 0.01$)
Economic Sustainability	1.00	0.41	0.40	0.31	Significant
Environmental Sustainability	0.41	1.00	0.46	0.41	Significant
Social Sustainability	0.40	0.46	1.00	0.39	Significant
Project Performance	0.31	0.41	0.39	1.00	Significant

According to Table III the correlation between prioritizing the sustainable practices and the degree of happiness and motivation experienced by the stakeholders is observed. According to the results, there is a strong and favorable relationship (ρ =.175, p =.002). Although the correlation is weak, it is statistically significant at the 0.01% level, indicating that stakeholders are more likely to be pleased and driven by projects that priorities sustainability. they can accept the alternative hypothesis because the p-value is smaller than 0.05. According to Table III, stakeholders are more satisfied with initiatives that incorporate sustainability, even if it's just a little.

J. Effect of Sustainability Investment on Long-Term Operational Efficiency

This section evaluates whether varying levels of investment in sustainable practices lead to differences in long-term operational efficiency in German railway projects. The Kruskal–Wallis test is employed to identify statistically significant variations in operational performance based on the prioritization of sustainability initiatives.

TABLE IV. FINDING OF KRUSKAL–WALLIS TEST

Variable Tested	H Statistic	df	Sig.
Sustainability Practices Priority	22.517	2	0.000

The findings of the Kruskal-Wallis test, which compares the relationship between operational efficiency and prioritization of the sustainable practices, are shown in Table IV. The two degrees of freedom are perceived as statistically significant with Chi-Square value of 22.517 and p-value of.000. The organizations do not collaborate much because they are all in the agreement that environmental friendly strategies should be prioritized. Having a lower p-value below 0.05, it may accept the alternative hypothesis and reject the null. Table IV shows that prioritization of sustainable practices can make a project considerably more efficient in terms of its operations.

K. Qualitative Insights Supporting Quantitative Results

Thematic analysis was performed on the qualitative insights from the open-ended questionnaire responses, which were summarised in Table V to support the quantitative analysis.

TABLE V. SUMMARY OF QUALITATIVE INSIGHTS SUPPORTING QUANTITATIVE FINDINGS

Qualitative Theme	Practitioner Observations	Interpretive Meaning	Alignment With Quantitative Results
Strategic role of environmental sustainability	Participants indicated that environmental sustainability practices, including energy-efficient rolling stock, lifecycle-based material selection, and waste minimisation, were treated as strategic priorities rather than regulatory obligations. Projects incorporating these practices experienced smoother regulatory approvals, reduced rework, and improved operational reliability.	Environmental sustainability functioned as a value-creating mechanism that enhanced project efficiency and stakeholder confidence.	Supported the regression analysis, where environmental sustainability emerged as the strongest predictor of project success.

Implementation challenges and organisational learning	Practitioners reported short-term challenges such as higher initial costs of sustainable materials, limited supplier readiness, and the need for additional staff training. These challenges were observed to decrease across successive projects as organisational sustainability capabilities matured.	Sustainability integration was interpreted as an organisational learning process that improved over time.	Explained the moderate yet statistically significant relationships observed between economic and social sustainability practices and project success.

The qualitative results in Table V did not only provide an added dimension to the quantitative findings by capturing the practitioner views on the aspect of sustainability implementation in railway manufacturing engineering projects, but also pointed out the significant contribution of environmental sustainability in a strategic perspective. The insights also revealed the immediate challenges of implementation and impacts of organizational learning. The qualitative analysis as a whole substantiated the statistical results and further emboldened the mixed-method approach adopted in this research.

CONCLUSION AND FUTURE WORK

Using the German rail sector as an example, this article demonstrates how green practices can boost engineering project success rates. Key performance indicators for projects include: cost-effectiveness, timeliness, quality, and stakeholder happiness, are positively affected by environmental, economic, and social sustainability, according to the results. Although there were issues connected to regulatory compliance, technological adoption, and coordination among stakeholders of the project, sustainability-oriented strategies help to ensure better operational efficiency, innovation ability, and long-term value creation. Thematic analysis was performed on the qualitative insights obtained from the open-ended questionnaire responses, and these insights were summarized in Table V, to support the quantitative analysis. All in all, it is possible to state that the implementation of sustainable practices into project planning and execution is the key to the acquisition of competitive advantage and contributing to the responsible development of the sphere of railway industry that is highly controlled and that is of strategic significance.

The current study can be developed in the future by investigating the enduring effects of sustainable practices on post-project performance and life cycle results of assets in the rail industry. Further research on comparative studies in various countries or modes of transport would have given a wider perspective regarding contextual and regulatory factors on sustainability implementation. More advanced approaches to analysis, including structural equation modelling or longitudinal research designs, can also be included in further work to underpin causal relationships in a more compelling manner. Another possible future research might focus on the contributions of emergent digital technologies, green innovations, and policy incentives to the improvement of sustainability outcomes. Qualitative research with inputs on the stakeholder views can also give more insight on the organizational and cultural issues that lead to the implementation of sustainable projects.

REFERENCES

1. I. T. Addison and Y. M. Cudjoe-Mensah, "The Impact of Agile Project Management on Sustainability Initiatives in the U.S. Corporate Sector," Sarcouncil J. Entrep. Bus. Manag., vol. 4, no. 9, pp. 1–12, 2025, doi: 10.5281/zenodo.17217920.
2. E. R. Ahmed, T. T. Y. Alabdullah, and M. Akyürek, "Management of innovations in the environmental, social, and governance scores and sustainability performance through esg disclosure: Evidence from emerging Marketing," Mark. Manag. Innov., vol. 14, no. 4, pp. 69–83, 2023, doi: 10.21272/mmi.2023.4-05.
3. B. Lichtberger, The Comprehensive Manual of Track Maintenance, New Construction and Renewal. tredition Verlag GmbH, 2024.
4. S. Fischer et al., "Investigation of Heat-Affected Zones of Thermite Rail Weldings," Facta Univ. Ser. Mech. Eng., p. 689, Dec. 2024, doi: 10.22190/FUME221217008F.
5. S. Fischer and S. K. Szurke, "Detection Process of Energy Loss in Electric Railway Vehicles," Facta Univ. Ser. Mech. Eng., vol. 21, no. 1, p. 081, Apr. 2023, doi: 10.22190/FUME221104046F.
6. L. Ézsiás, R. Tompa, and S. Fischer, "Investigation of the Possible Correlations between Specific Characteristics of Crushed Stone Aggregates," Spectr. Mech. Eng. Oper. Res., vol. 1, no. 1, pp. 10–26, Apr. 2024, doi: 10.31181/smeor1120242.
7. J. Oomen, J. Hoffman, and M. A. Hajer, "Techniques of futuring: On how imagined futures become socially performative," Eur. J. Soc. Theory, vol. 25, no. 2, pp. 252–270, May 2022, doi: 10.1177/1368431020988826.
8. J. Monstadt, J. Colen Ladeia Torrens, M. Jain, R. M. Macrorie, and S. R. Smith, "Rethinking the governance of urban infrastructural transformations: a synthesis of emerging approaches," Curr. Opin. Environ. Sustain., vol. 55, p. 101157, Apr. 2022, doi: 10.1016/j.cosust.2022.101157.
9. K. Muiderman, A. Gupta, J. Vervoort, and F. Biermann, "Four approaches to anticipatory climate governance: Different conceptions of the future and implications for the present," WIREs Clim. Chang.,

vol. 11, no. 6, Nov. 2020, doi: 10.1002/wcc.673.

10. L. Chen et al., “Conversion of waste into sustainable construction materials: A review of recent developments and prospects,” Mater. Today Sustain., vol. 27, p. 100930, Sep. 2024, doi: 10.1016/j.mtsust.2024.100930.
11. M. Gleser and R. Elbert, “Combined rail-road transport in Europe – A practice-oriented research agenda,” Res. Transp. Bus. Manag., 2024, doi: 10.1016/j.rtbm.2024.101101.
12. G. Peira, A. Lo Giudice, and S. Miraglia, “Railway and Tourism: A Systematic Literature Review,” Tour. Hosp., vol. 3, no. 1, pp. 69–79, Jan. 2022, doi: 10.3390/tourhosp3010005.
13. M. Giunta, “Trends and Challenges in Railway Sustainability: The State of the Art regarding Measures, Strategies, and Assessment Tools,” Sustainability, vol. 15, no. 24, p. 16632, Dec. 2023, doi: 10.3390/su152416632.
14. S. Ehrenberger, S. Seum, T. Pregger, S. Simon, G. Knitschky, and U. Kugler, “Land transport development in three integrated scenarios for Germany – Technology options, energy demand and emissions,” Transp. Res. Part D Transp. Environ., vol. 90, p. 102669, Jan. 2021, doi: 10.1016/j.trd.2020.102669.
15. D. da Fonseca-Soares, S. A. Eliziário, J. D. Galvincio, and A. F. Ramos-Ridao, “Greenhouse Gas Emissions in Railways: Systematic Review of Research Progress,” Buildings, vol. 14, no. 2, p. 539, Feb. 2024, doi: 10.3390/buildings14020539.
16. L. Verbeek et al., “One Health: Eine Sichtweise des informellen ministeriellen Netzwerkes,” Bundesgesundheitsblatt - Gesundheitsforsch. - Gesundheitsschutz, vol. 66, no. 6, pp. 593–598, Jun. 2023, doi: 10.1007/s00103-023-03706-3.
17. M. M. Hossain Bhuiyan and Z. Siddique, “Hydrogen as an alternative fuel: A comprehensive review of challenges and opportunities in production, storage, and transportation,” Int. J. Hydrogen Energy, vol. 102, pp. 1026–1044, Feb. 2025, doi: 10.1016/j.ijhydene.2025.01.033.
18. A. Cascino, E. Meli, and A. Rindi, “Lightweight Design and Topology Optimization of a Railway Motor Support Under Manufacturing and Adaptive Stress Constraints,” Vehicles, vol. 8, no. 1, p. 3, Jan. 2026, doi: 10.3390/vehicles8010003.
19. [19] I. Petrova, “Railway project management: Contemporary issues and solutions,” in Proceeding of scientific-expert Conference on Railway Railcon ’24 - zbornik radova, University of Niš - Faculty of Mechanical Engineering, Niš, 2024, pp. 145–147. doi: 10.5937/Railcon24147P.
20. [20] J. Milewicz, D. Mokrzan, and G. M. Szymański, “Environmental Impact Evaluation as a Key Element in Ensuring Sustainable Development of Rail Transport,” 2023. doi: 10.3390/su151813754.
21. [21] S. T. Braun and R. Franke, “Railways, Growth, and Industrialization in a Developing German Economy, 1829–1910,” J. Econ. Hist., vol. 82, no. 4, pp. 1183–1221, Dec. 2022, doi: 10.1017/S0022050722000377.
22. [22] Y. Uygun and J. Ahsan, “Analyzing the Railway Network of the Belt and Road Initiative,” Cogent Bus. Manag., vol. 8, no. 1, pp. 145–147, Jan. 2021, doi: 10.1080/23311975.2021.1932066.
23. [23] M. Saunders, P. Lewis, and a. Thornhill, Research Methods for Business Students. 2009.
24. [24] H. S. R. Rosairo, “Thematic Analysis in Qualitative Research,” J. Agric. Sci. – Sri Lanka, vol. 18, no. 3, Sep. 2023, doi: 10.4038/jas.v18i3.10526.
25. [25] A. Alili and D. Krstev, “USING SPSS FOR RESEARCH AND DATA ANALYSIS,” Knowl. Int. J., 2019, doi: 10.35120/kij3203363a.
26. [26] W. Huang, K. Chen, W. Wei, J. Xiong, and W. Liu, “Fast and Robust Digital Image Spearman’s Rho Correlation for Displacement Measurement,” Inf. Technol. Control, 2022, doi: 10.5755/j01.itc.51.4.30866.
27. [27] I. Ahmed and A. K. Jena, “Using non-parametric Kruskal-Wallis H test for assessing mean differences in the opinion of environmental sustainability,” Int. J. Geogr. Geol. Environ., 2023, doi: 10.22271/27067483.2023.v5.i1a.146.