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Analysis of Determinants in the Development of the Medan-Binjai Elevated Railway and Its Contribution to Regional Development

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Abstract

The development of the Medan-Binjai elevated railway is a strategic initiative aimed at enhancing mass transportation efficiency, reducing traffic congestion, and supporting regional development in Medan City. This study identifies key factors influencing the project's success and evaluates its contributions to regional growth. Using quantitative methods, including factor analysis and descriptive statistical evaluations, data were collected through surveys and interviews with 40 respondents comprising government officials, transportation experts, railway operators, and economic stakeholders. The findings reveal that environmental factors (48.57%) and planning human resources (21.14%) are the dominant determinants. Environmental factors emphasize the importance of reducing congestion and promoting eco-friendly transportation, while human resource factors

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highlight the role of competent planners. System, technology, and funding factors also support the project's success. The project has significant social, economic, and environmental impacts, such as improved accessibility, new employment opportunities, and reduced carbon emissions. Aligned with the Regional Spatial Plan (RTRW) 2010–2030, this project enhances connectivity within the Mebidangro metropolitan area and serves as a model for sustainable infrastructure development in Indonesia. Recommendations include strengthening stakeholder collaboration, promoting multimodal integration, and conducting further studies to evaluate the project's long-term impacts after its operation.

Keywords: *Elevated railway, Medan-Binjai, environmental factors, planning human resources, sustainable transportation, regional development*

1. Introduction

Infrastructure development serves as a cornerstone in driving economic growth and regional equity. Adequate infrastructure not only improves interregional connectivity but also accelerates economic activities, reduces regional disparities, and creates new opportunities across various sectors (Adisasmita, 2008; Bappenas, 2021). In Indonesia, the development of transportation infrastructure, particularly mass transit systems like railways, is a national priority as outlined in the 2020–2024 National Medium-Term Development Plan (RPJMN) (Bappenas, 2019). Similarly, in other regions, strategic infrastructure projects such as community empowerment programs and ecotourism initiatives have proven to enhance local welfare and contribute to sustainable development (Lubis et al., 2024; Anisah, 2024).

Mass transit systems such as railways offer advantages over other transportation modes. With higher passenger capacity, energy efficiency, and minimal environmental impact, railways enhance connectivity between urban and rural areas alike (Dwiatmoko, 2019; FAO, 2020). These attributes have also been reflected in regional studies, such as the development of housing projects in Asahan Regency, which emphasize the importance of accessibility and sustainable land use to ensure balanced growth (Suharizki et al., 2024). Similarly, Kisaran City has addressed the challenges of spatial development through improved infrastructure and disaster risk management to align with long-term planning objectives (Abdul et al., 2024).

The Medan-Binjai elevated railway route represents one such strategic project aimed at addressing transportation issues in the region. This route connects two key cities within the Mebidangro metropolitan area (Medan, Binjai, and Deli Serdang), which serves as the main economic center in northern Sumatra (Kementerian Koordinator Perekonomian, 2021; Kementerian Perhubungan, 2022). The project's importance is underscored by its potential to reduce traffic congestion and support urban mobility. This mirrors findings in other sectors, such as sustainable food systems in Medan City, which have improved availability and efficiency in alignment with Sustainable Development Goals (Muliadi et al., 2024).

However, the Medan-Binjai railway development faces significant challenges, particularly in integrating multimodal systems and managing train waiting times, a common public complaint. Train passengers often experience prolonged waiting times and limited strategic station options in certain areas (Adisasmita, 2008; Alkadri et al., 2022). Addressing these issues is critical to ensure the effectiveness of mass transportation systems, similar to the challenges faced in Subulussalam City's housing programs, where improved coordination among stakeholders was essential for success (Masrizal et al., 2024).

Furthermore, mass transportation development is an effective tool to reduce regional disparities. Efficient railway systems provide better access to previously underserved areas, fostering growth not only in metropolitan regions but also in surrounding rural areas that are part of the transportation network (FAO, 2020; Kementerian Pertanian, 2023). This aligns with global practices, such as the processing of Arabica coffee powder in Lintong Nihuta, which has significantly boosted local economies by increasing value-added ratios and fostering rural development (Lubis, S. N., 2023).

The Mebidangro region, encompassing Medan, Binjai, and Deli Serdang, holds substantial potential as North Sumatra's economic center. As one of the most important metropolitan areas in western Indonesia, Mebidangro significantly contributes to logistics and trade activities in Sumatra. However, existing transportation infrastructure limitations hinder further development (Kementerian Koordinator Perekonomian, 2021; Rambey et al., 2022). The Medan-Binjai elevated railway project is expected to address these issues, promoting the region's integration into the regional and national economic systems.

Additionally, the Medan-Binjai railway has a strategic dimension of supporting sustainability agendas. Rail-based transportation is recognized as being more environmentally friendly compared to motor vehicle-based systems. By reducing carbon emissions and utilizing land more efficiently, railways provide a long-term solution for better urban environmental management (Dwiatmoko, 2019; Wahyudi et al., 2020). These benefits align with findings on sustainable oil palm cultivation, which emphasize the need for technical and institutional improvements to ensure balanced development (Arga et al., 2024).

Given the significance of this railway development, this study aims to analyze the determinants influencing the success of the Medan-Binjai elevated railway project. Additionally, it evaluates the project's impact on regional development in Medan City. Understanding the dynamics of these factors is expected to contribute to the development of more effective and sustainable transportation infrastructure policies (FAO, 2020; Monica, 2020).

2. Research Methodology

2.1 Research Location

This study was conducted along the development route of the Medan-Binjai elevated railway. The research area encompasses a corridor with a delineation of 25 meters on both sides of the railway line. The location was selected based on its potential direct impact on surrounding communities and economic activities. The railway is a strategic segment of the Mebidangro metropolitan area, comprising Medan City, Binjai City, and Deli Serdang Regency, which serves as a regional economic hub in North Sumatra.

2.2 Population and Sample

The study population includes all residents of Medan City with direct or indirect connections to the elevated railway project. A purposive sampling technique was employed to ensure the sample's relevance to the research objectives.

The sample comprised 40 individuals, including:

1. The Head of the Medan Class I Railway Technical Center.
2. Operators from PT KAI (Persero) Divre I SU.
3. Project contractors and consultants.
4. Representatives from the Transportation Agency and Regional Development Planning Agency (Bappeda) of Medan City and Binjai City.
5. Train users on the Medan-Binjai route.
6. Economic actors located near the railway development.

These participants were chosen for their knowledge of the project and its impacts on the surrounding area. The sample selection aimed to gather insights from diverse perspectives, spanning technical to socioeconomic dimensions.

2.3 Data Types and Collection Techniques

The study utilized two main data types: primary and secondary data.

1. **Primary Data**
    - Primary data were collected through surveys, in-depth interviews, and field observations.
    - Structured questionnaires were designed to evaluate respondents' perceptions of factors influencing the project and its impact on the surrounding region.

- In-depth interviews with key stakeholders provided detailed information.

2. **Secondary Data**
   - Secondary data were obtained from official documents, such as the Medan City Spatial Plan (RTRW) 2010–2030, reports from relevant institutions, and previous research.
   - These data provided additional context to support the research analysis.

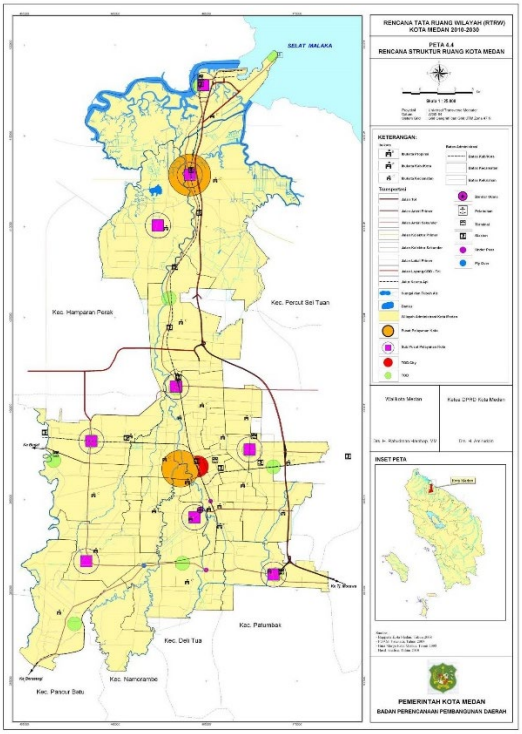

Figure 1. City Spatial Plan (RTRW) 2010-2030 of Medan

2.4 Data Analysis Techniques

The collected data were analyzed using quantitative descriptive methods through the following steps:

1. **Validity and Reliability Testing**
   - The research instruments were tested for validity and reliability to ensure data quality.
   - Validity was assessed using the Pearson Product Moment correlation technique, while reliability was tested using Cronbach's Alpha.
2. **Factor Analysis**
   - Factor analysis was employed to identify the primary factors influencing the railway project.
   - This technique simplifies complex research variables into interrelated dimensions.
3. **Descriptive Analysis**
   - Survey and interview results were processed to provide an overview of community perceptions, stakeholder opinions, and economic actors' views on the elevated railway project.
   - Descriptive analysis also evaluated the project's impact on regional development in Medan City.

2.5 Research Procedure

The study was conducted in several stages:

1. **Preparation:** Identification of research locations, development of questionnaires, and coordination with respondents.

2. **Data Collection:** Field surveys, in-depth interviews, and secondary data collection.
3. **Data Analysis:** Data processing using statistical software, interpreting factor analysis results, and synthesizing key findings.
4. **Reporting:** Compiling research findings into a comprehensive report based on the analyses.

The methodology used in this study was designed to provide a robust scientific foundation for addressing the research questions. This approach ensures that the findings contribute significantly to transportation infrastructure policy development and regional planning in Medan City.

3. Results and Discussion

3.1 Overview of the Study Area

Medan City, the capital of North Sumatra Province, covers an area of 265.10 km² and is situated between 3°27'–3°47' North Latitude and 98°35'–98°44' East Longitude. As a strategic regional economic hub, it plays a critical role in supporting the Mebidangro metropolitan area. With an elevation of 2.5–37.5 meters above sea level, most of Medan is a lowland area, offering high potential for infrastructure development.

In 2023, Medan City had a population of 2,474,166, reflecting a 1.45% increase compared to 2020. The average population density reached 9,333 people/km², with Medan Perjuangan as the most densely populated district (25,750 people/km²) and Medan Labuhan as the least (3,698 people/km²). These figures highlight the urgent need for mass transportation development to alleviate traffic pressure and enhance mobility.

3.2 Data Processing Results

1. Validity Testing

Validity tests using Pearson Correlation revealed that all research indicators had correlation values (r) exceeding the table value (0.304) at a 5% significance level. All indicator significance values were < 0.05, confirming the validity of the instruments. For instance:

- Environmental Factors (X1): Correlation values ranged from 0.821 to 0.882.
- Planning Human Resources Factors (X2): The correlation value for X2_2 was 0.954, indicating a very strong relationship between the statement and the total variable score.

2. Reliability Testing

Cronbach's Alpha values for all factors exceeded 0.60, demonstrating good instrument consistency. Reliability test results included:

- Environment: Cronbach's Alpha = 0.879
- Planning Human Resources: Cronbach's Alpha = 0.765
- Systems Used: Cronbach's Alpha = 0.871

3. Factor Analysis

Factor analysis identified the main determinants influencing the development of the Medan-Binjai elevated railway. The Kaiser-Meyer-Olkin (KMO) value of 0.577 and Bartlett's Test of Sphericity with Sig. 0.000 confirmed the data's suitability for factor analysis.
The factor analysis revealed two dominant factors with eigenvalues > 1:

a. First Factor: Environmental Factors (eigenvalue = 2.428; contribution = 48.57%).
b. Second Factor: Planning Human Resources (eigenvalue = 1.057; contribution = 21.14%).

Rotated factor loading (Varimax) supported these results, with factor loadings > 0.60. For example:

- Environmental Factors (X1): Highest loading on component 2 = 0.840.
- Planning Human Resources (X2): Highest loading on component 1 = 0.897.

4. Determinants of the Medan-Binjai Elevated Railway Development

a. Environmental Factors
Environmental factors emerged as the most dominant determinant, contributing 48.57%. Significant correlations were found between this variable and the need to reduce congestion and carbon emissions. Correlation coefficients for the statements within this factor ranged from 0.821 to 0.882, indicating strong support for the main findings.

Figure 2. Elevation Ballast Data Collection and Thermite Welding Refinement

b. Planning Human Resources
Planning Human Resources ranked as the second most significant factor, with an eigenvalue of 1.057 (contribution = 21.14%). A strong correlation (r = 0.954) was observed in statements highlighting the importance of skilled planners in ensuring project quality and safety.

c. Other Factors
Although their contributions were lower, factors such as Systems Used, Technological Advances, and Funding were still relevant. Correlations for these factors ranged from 0.581 to 0.889, reflecting their supporting role in project success.

5. The Role of Elevated Railway Infrastructure in Regional Development

The Medan-Binjai elevated railway significantly impacts Medan's regional development across three primary dimensions:

a. Social
Improved accessibility reduces waiting times (15–30 minutes per trip), encouraging more people to use the railway.
This alleviates congestion, enhances social mobility, and creates new employment opportunities, particularly at stations like Sunggal and Helvetia.

b. Economic
The project generates direct and indirect employment opportunities and fosters new businesses near stations.
With an investment exceeding IDR 1 trillion, the project significantly supports regional economic growth.

c. Environmental
The project aligns with sustainable development concepts by significantly reducing carbon emissions. Studies show that railways produce 41 grams of CO_2 per passenger-km, far lower than cars (192 grams per passenger-km).

3.3 Discussion

The findings of this study reveal that environmental and planning human resource factors are the dominant determinants influencing the success of the Medan-Binjai elevated railway project. These findings align with and expand upon insights from previous studies on infrastructure development.

Environmental Factors

Environmental factors emerged as the most significant determinant, contributing 48.57% to project success. Key variables included reducing congestion, controlling carbon emissions, and promoting eco-friendly transportation. This is consistent with the findings of Norhaliza, Siti (2020), who identified financial constraints, particularly delays in material supply due to natural conditions, as a major barrier to infrastructure development in rural areas like Desa Tanjung Kedabu. While Norhaliza focused on rural infrastructure, this study highlights similar challenges in urban contexts but emphasizes environmental benefits like carbon emission reductions, aligning with broader sustainability goals.

Planning Human Resources

Planning human resource factors were the second most significant determinant, contributing 21.14%. The role of skilled planners is critical for ensuring the project meets technical and community requirements. This finding complements Iles Sinta Lestari's (2015) study, which identified a lack of political will and insufficient government support as major barriers to road and bridge infrastructure development in Kampar Kiri Hulu. In contrast, this research underscores the importance of strategic planning expertise, highlighting how effective human resource planning can overcome administrative and technical challenges in large-scale infrastructure projects.

Challenges in Infrastructure Projects

Beyond these dominant factors, this study identified additional challenges such as system integration, technology implementation, and funding. These findings resonate with the research by Yurianto, Kadri Trihono (2020), which analyzed delays in the Jakarta-Bandung high-speed rail project. Similar to the Jakarta-Bandung project, where land acquisition, tight project schedules, and poor coordination were significant issues, this study highlights the need for synchronized planning and stakeholder coordination in the Medan-Binjai railway project. However, while Yurianto emphasized procedural and design challenges, this study focuses on integrating environmental and human resource factors to ensure long-term project sustainability.

Implications for Regional Development

The Medan-Binjai elevated railway project demonstrates significant social, economic, and environmental benefits, such as improved accessibility, reduced waiting times, and decreased carbon emissions. These findings echo the importance of sustainable infrastructure in regional development, as emphasized in studies like Muliadi et al. (2024), which advocate for sustainable food systems and efficient transportation to achieve Sustainable Development Goals.

By comparing findings with previous studies, this research highlights both shared challenges and unique aspects of urban railway infrastructure development. It offers actionable insights into overcoming barriers and leveraging key determinants to achieve project success, positioning the Medan-Binjai elevated railway as a model for sustainable urban infrastructure in Indonesia.

4. Conclusion and Recommendations

The Medan-Binjai elevated railway project is a strategic initiative designed to enhance transportation efficiency, reduce congestion, and support sustainable regional development in the Mebidangro metropolitan area. This study identified environmental factors, such as reducing carbon emissions and mitigating traffic congestion, as the most significant determinant, contributing 48.57% to project success. Planning human

resources, contributing 21.14%, emerged as the second key factor, underscoring the importance of skilled planners in ensuring effective implementation. Additional determinants, including system integration, technological innovation, and funding, also play supportive roles. The project's contributions to social, economic, and environmental dimensions—such as improved accessibility, job creation, and reduced carbon emissions—highlight its alignment with the Sustainable Development Goals (SDGs) and its potential as a model for urban infrastructure development in Indonesia.

To ensure the success and sustainability of the Medan-Binjai elevated railway project, it is recommended that stakeholders strengthen collaboration among government agencies, private sector partners, and community representatives to improve planning and implementation processes. Emphasis should be placed on integrating multimodal transportation systems, adopting eco-friendly technologies, and optimizing resource allocation. Public awareness campaigns are essential to educate communities about the benefits of sustainable transportation and encourage greater adoption. Furthermore, ongoing monitoring and evaluation should be conducted post-completion to assess the project's long-term social, economic, and environmental impacts. These efforts will not only enhance the project's effectiveness but also provide valuable insights for future infrastructure planning and regional development strategies across Indonesia.

Competing Interests Disclaimer:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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