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The Impact of Road Infrastructure Development Policies on Community Quality of Life in Batam City

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ABSTRACT

Road infrastructure is a fundamental driver of economic growth and improved quality of life, especially in rapidly developing urban areas. This study examines the impacts of road infrastructure policies in Batam City, a strategic industrial and trade center in Indonesia. It evaluates their influence on local economic performance, social welfare, and environmental sustainability. Using a quantitative descriptive approach, data were obtained from secondary sources, including government reports, statistical records, and academic literature. The findings reveal that enhanced road infrastructure significantly improves accessibility and mobility, fostering economic opportunities and better access to critical services such as healthcare and education. Furthermore, these improvements contribute to environmental sustainability by reducing traffic congestion and emissions. However, land acquisition disputes, funding constraints, and project management inefficiencies remain obstacles to policy implementation. This study concludes that inclusive planning, robust governance, and active community engagement are essential to maximize the benefits of infrastructure development. The recommendations aim to guide policymakers and serve as a reference for similar urban regions undergoing rapid development, balancing economic, social, and environmental considerations for long-term urban sustainability.

Keywords: *Road infrastructure, Economic growth, Quality of life, Sustainability, Urban Development*

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INTRODUCTION

Samosir & Rajagukguk (2020) and Verico & Qibthiyyah (2023) state that infrastructure development is a key cornerstone for economic growth and social welfare, offering transformational potential connecting regions, accelerating trade, and improving national competitiveness. In Indonesia, road infrastructure has become an important element in the government's strategy, particularly in areas such as Batam City, a strategic center of industry and trade close to international shipping lanes. Batam's rapid urbanization and population growth present an interesting case to examine how the road network addresses the challenges of mobility, accessibility, and sustainability (Choi, 2024; Ma'rifah, 2022).

Bieliatynskyi et al. (2023) and Din et al. (2022) suggest that the theoretical foundations of infrastructure development highlight its multidimensional benefits. In contrast, Public Infrastructure Theory states that investments in infrastructure can reduce transaction costs and increase productivity. Meanwhile, Gjevori & Lako (2024). emphasized through the Accessibility and Mobility Theory that transportation plays a role in improving access to essential services, thus promoting social inclusion. Teodorovici et al. (2021) underline through the Sustainable Development Theory the importance of integrating environmental, economic, and social dimensions in infrastructure planning.

This research aims to assess the impact of road infrastructure development policies on economic growth, social welfare, and environmental sustainability in Batam City. The study aims to provide empirical evidence to guide policy improvements and infrastructure planning processes by analyzing these dimensions. Understanding these impacts is essential for designing infrastructure that drives economic productivity, enhances community well-being, and preserves the environment.

However, these theories must be contextualized in Batam's unique socio-economic landscape, where industrial expansion and urban sprawl often outpace infrastructure development. Kalenyuk et al. (2023) showed that road connectivity can strengthen economic integration, while Choi (2024) linked transportation improvements with improved urban quality of life. However, there are still gaps in understanding the interaction between road infrastructure and quality of life, especially in a rapidly urbanizing city like Batam. Samosir & Rajagukguk (2020) and Siekierski et al. (2018) revealed that challenges such as land acquisition disputes, environmental degradation, and limited funding further complicate policy implementation.

Angelo et al. (2023) highlighted that this study aims to fill the gap by evaluating the impact of road infrastructure policies on economic performance, social equity, and environmental sustainability in Batam. The research relies on quantitative data from government reports, statistical publications, and academic studies to examine how road network improvements can increase industrial productivity, reduce logistics costs, and promote more equitable access to public services. Novel aspects of the research include a focus on sustainable practices, such as green technologies, and an emphasis on participatory approaches in infrastructure planning.

This research has a dual significance: it provides actionable insights for policymakers and enriches the academic discussion on urban infrastructure development. By addressing unresolved issues in the existing literature, the study highlights the importance of strategic road infrastructure investments in promoting sustainable urbanization. Through an in-depth exploration of the economic, social, and environmental dimensions, the study aims to bridge theoretical understanding with practical application, ensuring its relevance to academic and policy discourse.

RESEARCH METHODOLOGY

This study utilizes an explanatory quantitative research design aimed at investigating the causal relationships between road infrastructure policies and the quality of life in Batam City. The design follows a positivist approach, relying on structured data collection and statistical analysis to ensure reliable and measurable outcomes. The independent variable in this research is road infrastructure policy, while the dependent variable is the quality of life in Batam City.

The study targets Batam residents, as they are the direct beneficiaries of road infrastructure improvements. The population consists of urban residents within the city, with a focus on individuals residing in areas most impacted by road development. A stratified random sampling method was employed to ensure a representative sample, covering different districts within Batam. Data were gathered through primary and secondary sources. Primary data were collected via surveys and structured questionnaires, designed to capture residents' perceptions of the current road infrastructure and its influence on their quality of life. These surveys were administered in person and electronically, over a two-month period, ensuring broad coverage of the population. Secondary data were obtained from government reports, policy documents, and publications by Statistics Indonesia, providing context and supplementary information.

For the data analysis, the study uses Partial Least Squares-Structural Equation Modeling (PLS-SEM) to analyze complex hypotheses involving latent constructs. According to Hair et al. (2014) and Purnomo et al. (2022), PLS-SEM is suitable for evaluating models with intricate structural relationships. Analysis includes two stages: evaluating the measurement model (validity and reliability) and the structural model (relationships between variables). Hypotheses were tested using a bootstrapping procedure in Smart-PLS 3.9 software, with significance determined by a t-value above 1.96 and a p-value below 0.05 (Purnomo, 2019). These rigorous methods provide robust evidence for understanding how road infrastructure policies influence quality of life in Batam City.

To ensure the validity and reliability of the study, the questionnaire was pre-tested on a smaller sample before the main survey to identify potential issues and refine the instrument. The data were also subjected to checks for normality, multicollinearity, and outliers to confirm the robustness of the results. Furthermore, the study utilized established scales from prior research, ensuring consistency with previous findings. Statistical tests used in this study included path coefficient analysis and bootstrapping, which are standard procedures in structural equation modeling. The significance of the path coefficients was assessed to determine the strength and direction of the relationships between road infrastructure and quality of life indicators.

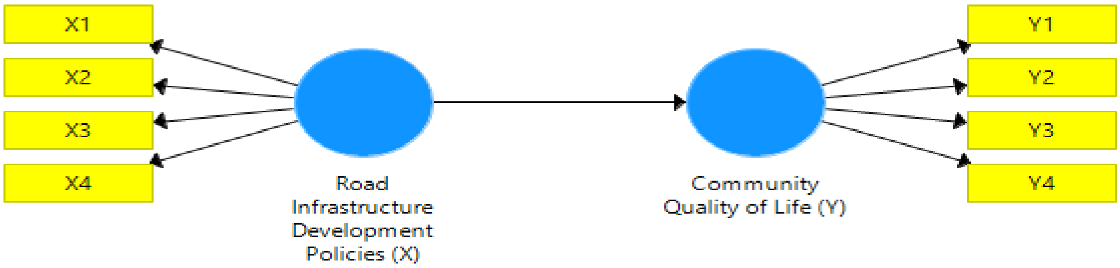

Figure 1. Conceptual framework

RESULT AND DISCUSSION

The measurement model evaluates the validity and reliability of the indicators used to measure latent variables (Purnomo, 2019). This step is critical to ensure that the constructs in the study are accurately captured by their respective indicators. The evaluation focuses on three primary aspects: convergent validity, discriminant validity, and reliability.

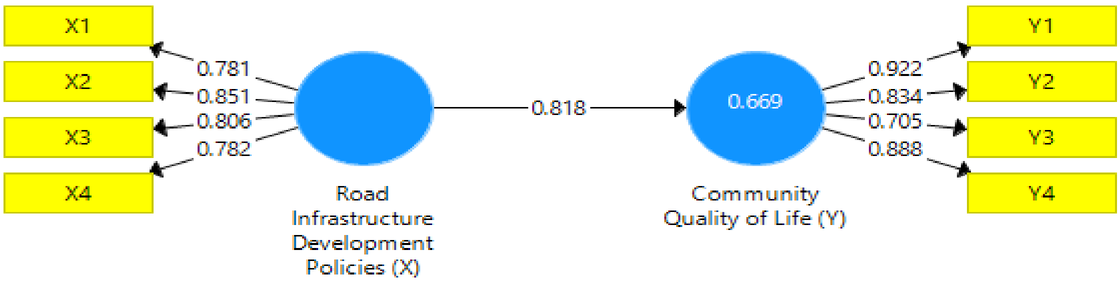

Figure 2. Processed Output From Smart-PLS 3.9

The high loading factor values indicate that the items or indicators used in the measurement model strongly correlate with their respective latent constructs. For instance, the values for “Road Infrastructure Policy” indicators range from 0.781 to 0.851, while those for “Quality of Life” indicators range from 0.705 to 0.922. These results confirm that the selected indicators are appropriate and valid representations of the measured constructs. This level of validity is essential to establish confidence in the measurement instruments used in the study.

Table 1. Reliability Test Results

Variable	Cronbach's Alpha	Rho_A	Composite Reliability	Average Variance Extracted (AVE)	Conclusion
Road Infrastructure Policy (X)	0.820	0.827	0.881	0.649	Reliable
Quality of Life (Y)	0.860	0.882	0.906	0.708	Reliable

Source: Processed Output From Smart-PLS 3.9

The Cronbach's Alpha values of 0.820 and 0.860 demonstrate that “Road Infrastructure Policy” and “Quality of Life” have high internal consistencies. Besides, the Composite Reliability values of 0.881 and 0.906 also confirm the high reliability of the constructs. The AVE values of 0.649 and 0.708, which have exceeded the acceptable threshold of 0.50, further support the convergent validity of these constructs.

These findings present evidence of the robustness of results regarding the measurement model of the present study. Adequate results on validity and reliability properties promise representation of the underlying concepts, represented by each latent construct according to their measures. After the assurance of these features, it may confirm appropriate bases that build upon subsequent analysis and enable a practical interpretation that accounts for the nature existing within relationships among latent variables in the structural model. By establishing the appropriateness of the measurement instruments this research has conducted its data collection, it ascertains that its findings ensure appropriate reliability and validity, with conclusions and recommendations included appropriately.

The structural model tests the relationships among latent variables and the extent of the influence of the independent variable on the dependent one. This, on general grounds, emphasizes two types of parameters: first, one of the significant key-value parameters, which usually is R-Square, and also Q^2 Predictive Relevance, as a measurement and an indicator of model predictive power and accuracy. The R-squared refers to the proportion of variance in the dependent variable presented by the independent variable. This study relates that the R-square value of the dependent variable, Quality of Life or Y, is 0.669. Thus, it can be shown herein that the road infrastructure policy variable explains 66.9% of the dispersion in the quality of life. The results are portrayed in Table 2 as follows:

Table 2. R-Square Results

Variable	**R^2**	**Q^2**	**Conclusion**
Quality of Life (Y)	0.669	0.448	Strong

Source: Processed Output From Smart-PLS 3.9

Ghozali (2008) expressed that the R-square value over 0.669 is categorized as strong, showing significant development in people's lives due to road infrastructure policy. Centrally, the immense R-square value represents not only a strong model but, most importantly, supports the important role of infrastructural policy in building one's perceived well-being outcome. The Q^2 value of 0.448 confirms the model's strong predictive relevance. A Q^2 value greater than 0 indicates adequate predictive power, while values approaching 1 suggest excellent accuracy. In this case, the Q^2 value underscores the robustness of the structural model in predicting quality of life-based on road infrastructure policies.

The findings from the structural model reveal a strong and significant relationship between road infrastructure policies and quality of life. The high R-Square value highlights the pivotal role these policies play in enhancing the well-being of Batam's residents. Furthermore, the Q^2 Predictive Relevance supports the model's predictive capability, ensuring the reliability and accuracy of the results. These findings emphasize the critical importance of well-crafted infrastructure policies in promoting sustainable urban development and improving quality of life.

Table 3. Bootstrapping Test Results

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
Road Infrastructure Development Policies → Community Quality of Life	0.818	0.822	0.036	22.772	0.000

Source: Smart-PLS 3.9 Test Results

Table 3 presents the results of the bootstrapping analysis conducted using Smart-PLS 3.9 software to evaluate the relationship between road infrastructure development policies and the quality of life in the community. The first column, Original Sample (O), represents the initial estimate of the relationship, with a value of 0.818, indicating a strong and positive impact. The Sample Mean (M) column reflects the average value of the bootstrap sample results, which is 0.822, demonstrating consistency with the initial estimate. The Standard Deviation (STDEV) column provides a measure of variability with a value of 0.036. This low value suggests that the estimated relationship is stable. The T Statistics column reports a value of 22.772, significantly exceeding the critical threshold of 1.96 for a 5% significance level. This result provides robust evidence of the statistical significance of the relationship. Lastly, the P Values column shows a probability value 0.000, indicating that the relationship is highly significant at the 99% confidence level. These findings provide compelling empirical evidence that road infrastructure development policies have a meaningful and positive impact on improving people's quality of life. The data supports the hypothesis that effective infrastructure policies can tangibly enhance community welfare.

The findings of this study offer compelling empirical evidence that road infrastructure development policies significantly enhance the quality of life in Batam City. Through bootstrapping analysis using Smart-PLS 3.9 software, an Original Sample (O) value of 0.818 demonstrates these policies' substantial and positive impact on the community's well-being. This result underscores how effective implementation of road infrastructure policies can meaningfully contribute to improving community welfare. The reliability of this result is further reinforced by the Sample Mean (M) value of 0.822, which closely aligns with the initial estimate. Additionally, the low Standard Deviation (STDEV) value of 0.036 reflects the stability of the relationship between road infrastructure policies and quality of life, with minimal variability in the data. A T Statistics value of 22.772, far exceeding the critical threshold of 1.96 at a 5% significance level, confirms the statistical significance of this relationship. Moreover, the probability value (P Values) of 0.000 indicates that the effect is significant at a 99% confidence level, providing strong assurance that road infrastructure development policies positively impact community welfare. These results validate the hypothesis that such policies are vital for enhancing the quality of life, especially in Batam City.

Road infrastructure development in Batam City significantly influences the quality of life, affecting economic, social, and environmental dimensions. Properly designed road networks foster economic growth, improve social welfare, and support ecological sustainability when approached thoughtfully. Economically, road development expands opportunities by facilitating trade and connectivity, boosting local economic activities, and creating employment. Studies have shown that improved road access alleviates poverty, particularly in rural areas, by enhancing access to markets and essential resources, thereby increasing local economic prospects (Hemant Kumar & Shubham Sharma, 2024; Pattiselanno & Krockenberger, 2021). In Batam, expanding road networks invigorates local businesses and attracts new investments, creating a ripple effect on the city's economy (Khanani et al., 2021; Loprencipe et al., 2017).

On a social level, road infrastructure development significantly impacts accessibility and equity. Enhanced road networks reduce travel time and costs, improving mobility and enabling better access to public services like education and healthcare (Teodorovici et al., 2021). However, these changes can also lead to gentrification, where infrastructure improvements displace lower-income residents as wealthier groups move in (Khanani et al., 2021). This phenomenon, if not managed well, could disrupt the social fabric of Batam's communities, necessitating careful policy interventions to ensure equitable benefits (Kambu et al., 2022) (Aceves-González et al., 2020). Involving local communities in planning and implementing infrastructure projects ensures that developments address their needs and fairly distribute benefits (Johar, 2017).

Environmental challenges accompanying road development cannot be overlooked. Poorly planned projects risk habitat destruction, increased pollution, and ecosystem degradation, which negatively affect public health and well-being (Fancello et al., 2013; Sudmeier-rieux et al., 2019). Land clearing often leads to deforestation and soil degradation, exacerbating the risk of natural disasters like floods and landslides. Increased traffic from new roads also contributes to air and noise pollution, creating unhealthy living conditions (Bekele & Ferede, 2016; Jedwab & Moradi, 2016; Johar, 2017; Liu, 2024; Wong & Guggenheim, 2018) Sustainable practices, such as using recycled materials, low-emission asphalt, and green energy, can mitigate these impacts. Preservation of green areas and reforestation are crucial steps to minimize environmental damage and ensure ecological balance (Jedwab & Moradi, 2016; Khusaini et al., 2023).

Road infrastructure development plays a pivotal role in Batam’s economic growth. It enhances logistics efficiency, reduces transport costs, and supports manufacturing productivity. Improved road access facilitates the efficient movement of goods and services, lowering logistics costs by up to 20% (Khanani et al., 2021). This is particularly important for Batam's manufacturing sector, which depends on reliable transportation networks to acquire raw materials and deliver finished products (Pattiselanno & Krockenberger, 2021) Beyond industrial benefits, road development attracts domestic and foreign investment by improving operational efficiency, further driving local economic growth (Kambu et al., 2022). Additionally, improved road infrastructure benefits small and medium-sized enterprises (SMEs) and the informal sector, enabling them to access broader markets and increase household incomes (Sudmeier-rieux et al., 2019).

While road development supports economic and social progress, it poses environmental challenges. Habitat destruction, ecosystem disruption, and carbon emissions threaten biodiversity and public health. Land clearing for road construction exacerbates environmental degradation and increases disaster risks. These challenges underscore the importance of adopting sustainable practices in infrastructure projects. Recyclable materials, low-emission asphalt, and green energy can significantly reduce environmental impacts (Forman & Alexander, 1998). Comprehensive environmental impact assessments (EIAs) at every project stage are essential to meet sustainability standards. Community participation in planning can also enhance environmental preservation efforts, aligning development goals with local priorities.

Analysis of similar research findings highlights consistent patterns in the impact of road infrastructure on urban sustainability (Wanume et al., 2023). Studies in other rapidly developing regions, such as Surabaya and Medan, demonstrate that well-planned road networks reduce travel time, boost local economies, and facilitate access to essential services (Ziter, 2016). However, researchers also observe that the ecological consequences of unchecked development often counterbalance these benefits if sustainability measures are not integrated early in the planning phase (Zhao & Pan, 2023).

In Surabaya, for instance, public-private partnerships (PPP) have effectively balanced development speed with environmental accountability. The involvement of local stakeholders in decision-making has ensured that infrastructure expansion aligns with community needs, minimizing displacement and promoting social equity (Wang et al., 2019). Similarly, Medan's experience using recycled construction materials and renewable energy sources illustrates the practical feasibility of sustainable practices, reinforcing the need for continuous innovation in infrastructure technology (Shafique & Kim, 2018).

Achieving sustainable road infrastructure development in Batam requires a holistic approach encompassing innovative financing, community participation, and environmentally friendly technologies. Public-private partnerships (PPP) offer a viable solution to funding constraints, reducing the government's financial burden while improving efficiency and innovation (Samosir & Rajagukguk, 2020; Verico & Qibthiyyah, 2023). In Batam, adopting PPP models can attract private investment to accelerate the construction of quality road networks. Meaningful community participation is equally critical, ensuring that infrastructure projects address local needs and foster a sense of ownership among residents World Bank (2019). Using ecological technologies like recycled asphalt, local materials, and green energy further enhances sustainability and reduces costs (O'Born et al., 2016). This comparative analysis underscores that sustainable road infrastructure is an aspirational goal and a tangible outcome achievable through collaborative governance, adaptive policy frameworks, and technological innovation. Lessons from other urban areas provide a valuable blueprint for Batam, guiding policymakers toward infrastructure solutions that balance development with environmental preservation, ultimately enhancing the city's long-term resilience and livability.

CONCLUSION

This research highlights the critical role of road infrastructure development in supporting economic growth and improving the quality of life in Batam City. Good road infrastructure significantly enhances accessibility, boosts economic activities, and improves public services like education and health. By increasing connectivity, rural areas can benefit equally as urban counterparts, reducing social inequalities and promoting inclusion. Improved logistics efficiency and reduced transportation costs bolster the manufacturing sector's productivity, while adequate road networks attract domestic and foreign investment, further contributing to local economic growth and supporting the formal and informal sectors.

The study also addresses environmental challenges accompanying road construction, such as habitat disruption, increased carbon emissions, and ecosystem degradation. Implementing sustainable practices, including environmentally friendly technologies, green energy, and preservation of green spaces, can mitigate these adverse impacts. Integrating sustainability into infrastructure projects ensures that road construction aligns with nature conservation while meeting developmental goals. Community participation is emphasized as a crucial element in planning and implementing road infrastructure projects. Engaging the community not only legitimizes projects but also ensures that diverse needs are addressed. Combining inclusive policies, sustainable technologies, and innovative financing strategies, such as public-private partnerships, can drive Batam's road infrastructure development toward long-term sustainability. This holistic approach, encompassing economic, social, and environmental dimensions, provides a strategic pathway for improving the quality of life while promoting sustainable socio-economic progress in Batam City.

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