The Impact of Integrated Public Transport Modes on Environmental Sustainability in Batam Indonesia

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ABSTRACT

Efficient urban mobility is crucial for supporting economic growth and improving quality of life. In Batam, Indonesia a rapidly growing industrial and urban centre urban mobility faces challenges including fragmented transport systems, traffic congestion, limited modal connectivity, and poor transit coordination. These problems reduce public transport effectiveness and worsen environmental degradation due to high reliance on private vehicles. Integrating public transport modes offers a promising solution to enhance accessibility, travel efficiency, and environmental sustainability. This study examines the impact of transport mode integration on urban mobility in Batam through three key dimensions: physical, operational, and policy-based. Data were collected from 100 public transport users, selected via area random sampling across 12 major transit points. Using Partial Least Squares Structural Equation Modelling, results reveal that all three integration dimensions significantly influence urban mobility, with operational integration being the most dominant. Urban mobility also positively impacts environmental sustainability. The model shows strong validity and reliability.

The study recommends accelerating integrated infrastructure, optimizing technology-based operations, and aligning transport policies. Future research should consider mediating factors such as green technology and broader socio-economic variables.

Keywords: Integrated transport systems, urban mobility, environmental sustainability, partial least squares structural equation modelling

A. Introduction

The rapid pace of urbanisation in metropolitan areas has given rise to complex challenges within transport systems, particularly in developing cities such as Batam. As one of Indonesia's designated special economic zones, Batam has experienced significant population growth, averaging 3.5% annually (BPS Kota Batam, 2023), which has directly contributed to increasing mobility demands. According to data from the Batam City Department of Transportation (2023), the volume of private vehicles has risen by 25% over the past five years, while road capacity has only increased by 8%. This disparity has resulted in chronic traffic congestion in key urban corridors such as Engku Putri Road and Raja Ali Haji Road, with congestion levels reaching level D (approximately 0.75–0.85) during peak hours (Humas Dishub Kota Batam, 2024). These conditions not only hinder the efficient movement of people and goods but also negatively affect economic productivity and quality of life. A study conducted by the World Bank (2022) estimates that congestion in Batam causes annual economic losses amounting to IDR 1.2 trillion, equivalent to 1.8% of the city's GRDP.

Integrated transport systems have become an increasingly prominent solution to urban mobility issues across cities worldwide. The concept involves the coordination of various transport modes such as buses, commuter trains, and micro transit into a unified system (Bokhari & Sharifi, 2024). Internationally, cities like Singapore and Tokyo have successfully implemented integrated transport systems, achieving user satisfaction levels of 85–90% (Nguyen et al., 2023). In Indonesia, however, efforts to achieve transport integration continue to face obstacles, including fragmented governance structures, incoherent policies, and resistance from traditional transport operators (Deng & Nelson, 2012). In Batam, several transport integration initiatives have been introduced such as the development of multimodal transit stops and the implementation of electronic payment systems but these are currently limited to specific corridors. Key challenges include insufficient coordination among government agencies, budget constraints, and the absence of a comprehensive integrated transport master plan.

Efficient urban mobility is a vital component in fostering economic growth and improving residents' quality of life. As noted by Girotti et al, (2024), an effective transport system can reduce travel time by up to 30%, enhance access to employment by 25%, and contribute to local economic growth by approximately 1.5–2% annually. In Batam an industrial and trade-based city smooth mobility is crucial to support economic activities. According to the Batam Chamber of Commerce and Industry (2023), 65% of businesses report that traffic congestion disrupts their supply chains. Furthermore, poor mobility exacerbates social inequality, as low-income groups may spend up to 30% of their income on transportation (BPS Kota Batam, 2023). This situation demands a systemic solution that addresses not only the symptoms (congestion) but also the root causes (overreliance on private vehicles and limited availability of quality public transport alternatives).

The environmental impact of unintegrated transport systems has become a serious concern in urban areas worldwide, including Batam. A recent study by (Li Q et al., 2023) indicates that integrated transport systems can reduce CO_2 emissions by up to 15% within five years. In Batam, the transport sector contributes approximately 35% of total city-wide greenhouse gas emissions (KLHK, 2023), and PM2.5 concentrations in several districts already exceed WHO safety thresholds. Vehicle emissions not only pose public health risks including increased incidences of respiratory and cardiovascular diseases but also undermine Batam's attractiveness as an investment and tourism destination. Some measures have been taken, such as electric bus trials and the construction of dedicated cycling lanes, yet these initiatives remain limited in scale and lack full integration within the city's overall transport system.

This study adopts the Partial Least Squares Structural Equation Modelling (PLS-SEM) method due to its suitability for analysing complex relationships between latent variables. According to Hair et al. (2022), PLS-SEM is well-suited for transport-related research as it accommodates small sample sizes, does not require normal data distribution, and can handle complex models with multiple constructs (J. Hair & Alamer, 2022). Within the scope of this research, PLS-SEM is employed to assess the physical, operational, and policy dimensions of transport integration and their impact on both urban mobility and the environment. Previous studies have successfully applied PLS-SEM to transport-related topics, such as sustainable transport adoption in Malaysia (Nazmi et al., 2025) and Mobility-as-a-Service (MaaS) acceptance factors in Europe (Jittrapirom et al., 2017). Another advantage of PLS-SEM is its predictive power, aligning well with the aim of this study to provide evidence-based policy recommendations. The primary objective of this study is to examine the impact of public transport integration on urban mobility in Batam across three core dimensions. Firstly, physical integration, which includes the development of multimodal infrastructure such as transit hubs and pedestrian access. Secondly, operational integration, involving schedule coordination, unified payment systems, and data exchange between operators. Thirdly, policy integration, which addresses regulatory harmonisation and stakeholder incentives. This study also seeks to measure the socio-economic effects of transport integration, including improved accessibility for low-income populations and reduced logistics costs for businesses. Environmental considerations are equally important, particularly in terms of reducing greenhouse gas emissions and improving urban air quality.

This research is expected to make a meaningful contribution both academically and practically. From an academic standpoint, the findings will enrich the literature on sustainable transport in emerging economic zones an area that remains relatively underexplored. Practically, the study provides valuable insights for local governments in formulating more effective integrated transport policies. Potential recommendations include strengthening institutional frameworks for integrated transport management, developing real-time transport information systems, and enhancing collaboration with the private sector. Moreover, the research model may serve as a reference for other Indonesian cities facing similar urban transport challenges.

B. Research Methodology

This study employs a quantitative approach using Structural Equation Modelling (SEM) to analyse the impact of public transport mode integration on urban mobility in Batam City. The selection of Batam as the research location is based on its unique characteristics as an archipelagic city with a developing transport system. SEM was chosen due to its capacity to examine complex relationships between latent variables, such as physical, operational, and policy integration, and their influence on both urban mobility and the environment (J. Hair & Alamer, 2022; Joseph. F. Hair et al., 2021). The study involved 100 public transport users, selected through area random sampling across 12 major transit points in Batam.

There are three exogenous variables in this study: physical integration (measured through the availability of integrated bus stops and pedestrian access), operational integration (schedule coordination and the reliability of connections), and policy integration (integrated payment systems and government regulations). The endogenous variables include urban mobility (measured by travel time and accessibility) and environmental impact (measured by carbon emissions). This study proposes five main hypotheses to examine the relationship between transport integration and its influence on urban mobility and environmental outcomes. Hypothesis 1 (H1) posits that physical integration, including the availability of integrated transit stops and pedestrian infrastructure, positively affects urban mobility. Hypothesis 2 (H2) suggests that operational integration reflected in coordinated scheduling and real-time information systems enhances the efficiency of urban mobility. Urban mobility itself is hypothesised in Hypothesis 4 (H4) to contribute to reducing environmental impact through the optimisation of transport system performance.

Additionally, the study introduces two direct hypotheses regarding environmental outcomes. Hypothesis 5 (H5) proposes that operational integration not only influences urban mobility through improved coordination, reduced transit waiting times, and enhanced reliability but also contributes to reduced air pollution by optimising routes and minimising fuel consumption. Hypothesis 3 (H3), on the other hand, assumes that policy integration,

Table 1. Variable of Research

Varaibel	Indicators	Code
Physical Integration (X1)	Bus Stop Availability	IF1
	Pedestrian Access	IF2
	Connection between modes	IF3
Operational Integration (X2)	Schedule coordination	IO1
	Transit wait times	IO2
	Connection reliability	IO3
Policy Integration (X3)	Unified payment system (e.g., Card Payment)	IK1
	Government regulations	IK2
	Operator incentives	IK3
Urban Mobility (Y1)	Average travel time	MP1
	Accessibility of the goal	MP2
	Integrated travel expenses	MP3
Environmental Impact (Y2)	Reduction of carbon emissions	DL1
	Air pollution reduction	DL2

in the form of regulations and incentives, encourages the use of environmentally friendly transport options and, in turn, lowers carbon emissions. This research model presents a comprehensive framework by incorporating physical, operational, and policy-related aspects of an integrated urban transport system. The findings are expected to generate practical recommendations for policymakers in developing more efficient and sustainable urban transport systems, while also contributing to the academic discourse on urban mobility through the lens of transport mode integration.

Data analysis was conducted in several stages. First, data quality was assessed using convergent validity (Average Variance Extracted/AVE > 0.5) and reliability (Composite Reliability/CR > 0.7). Subsequently, Confirmatory Factor Analysis (CFA) was applied to validate the measurement model, using fit indices such as chi-square/ degree of freedom ($\chi^2/df < 3$) and Comparative Fit Index (CFI > 0.95). The structural model was then evaluated using bootstrapping with 2,000 subsamples to assess the significance of causal relationships. Mediation analysis was also conducted to examine the intermediary role of urban mobility. The analysis was carried out using Smart PLS 4.0, employing a PLS-SEM approach suitable for data that do not conform to normal distribution assumptions.

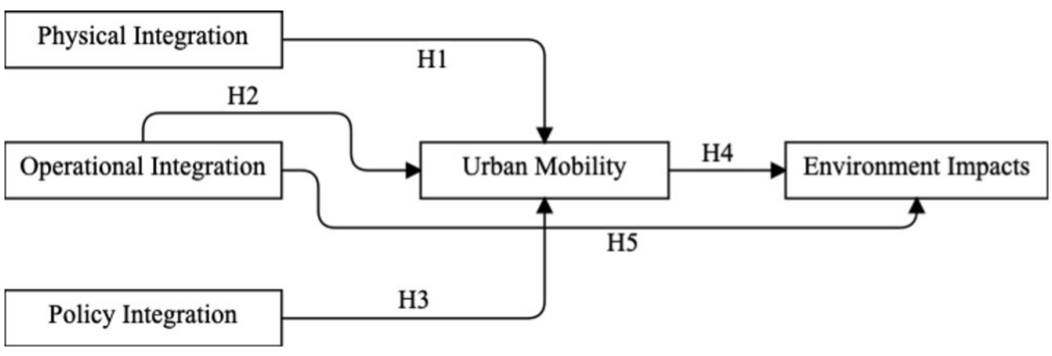

Figure 1. Conceptual Research

C. Results and Discussion

This section discusses the preliminary testing and identification of key attributes regarding the impact of public transport modes on urban mobility, based on the community's perspective on public transport usage in the city of Batam.

1. Preliminary Testing

Based on the results of the Variance Inflation Factor (VIF) test, all indicators within the latent variables recorded VIF values below 5.0. The analysis of VIF results and inter-variable relationships concerning the impact of public transport mode integration on urban mobility revealed that all indicators yielded VIF values ranging from 1.443 to 2.207, clearly indicating the absence of significant multicollinearity issues in the research model. The highest VIF values were observed in the Urban Mobility indicators (MP1 = 2.207 and MP3 = 2.011), reflecting a relatively strong internal correlation between different components of urban mobility. This is a logical outcome, as in an integrated urban system, elements such as average travel time (MP1) and integrated travel costs (MP3) are inherently interconnected and mutually influential in shaping a holistic urban mobility ecosystem.

The Environmental Impact variable (DL) also demonstrated a relatively high VIF value (1.846), suggesting a reciprocal relationship between urban mobility and environmental factors. In the context of sustainable urban development, well-designed mobility policies can directly contribute to reductions in emissions (DL1) and air pollution (DL2), and conversely, environmental pressures may influence the planning of mobility infrastructure. Meanwhile, the integration variables Physical Integration (IF), Operational Integration (IO), and Policy Integration (IK) recorded lower VIF values (between 1.4 and 1.7), indicating that while each of these dimensions plays an important role in urban systems, they contribute independently and specifically to the model.

A more intricate relationship is observed between Urban Mobility (MP) and the three integration variables. Sound Physical Integration (IF) supports improvements in urban mobility (MP), with a VIF of 1.940, while Operational Integration (IO) contributes to effective coordination in mobility implementation, with a VIF of 1.736. In contrast, Policy Integration (IK) functions as a regulatory framework governing the relationship between MP and DL, with a VIF of 1.699. Operational Integration (IO) is also linked to Environmental Impact (DL) in the context of urban transport operations, particularly through aspects such as fuel consumption and pollution impact, with a VIF of 1.823. Clearly, urban transport mobility exerts considerable influence on urban development, particularly with regard to environmental impacts (DL) recorded at a similar VIF value of 1.823. This pattern of relationships highlights the need for synergy among four key pillars in establishing an ideal urban system: efficient mobility, environmental sustainability, fiscal alignment, and coordinated policy. The collinearity test conducted on the external variables also confirmed that all values were below 3.3 (see

Table 2. Multicollinearity Test Results

Correlation	Result
Physical Integration ✍ of Urban Mobility	1,940
Urban Mobility ✍Operational Integration	1,736
Urban Mobility ✍Policy Integration	1,699
Environmental Impact ✍Operational Integration	1,823
Urban Mobility ✍ Environmental Impact	1,823

Table 2), indicating the absence of data bias in this study (Kock, 2015).

2. Measurement *Model Assessment*

The validation process of the research instrument was conducted by applying Composite Reliability (CR), which incorporates two key indicators: Cronbach's Alpha and Rho A. These indicators are employed to measure the internal consistency of the instrument, with a minimum recommended threshold of 0.70. Additionally, to assess the convergent validity of each construct, the Average Variance Extracted (AVE) was used, where the recommended cut-off value is greater than 0.50. The results obtained for Cronbach's Alpha (CA), Composite Reliability (CR), and AVE are as follows: (X1) "Physical Integration" (CA = 0.731, CR = 0.847, AVE = 0.649); (X2) "Operational Integration" (CA = 0.760, CR = 0.862, AVE = 0.675); (X3) "Policy Integration" (CA = 0.755, CR = 0.859, AVE = 0.670); (Y1) "Urban Mobility" (CA = 0.825, CR = 0.896, AVE = 0.741); and (Y2) "Environmental Impact" (CA = 0.807, CR = 0.912, AVE = 0.838). Based on the results of the analysis, all indicators demonstrated factor loadings above 0.70, indicating an acceptable level of data reliability. Cronbach's Alpha values exceeding 0.70 for all constructs confirm the strong internal consistency of the measurement items. Moreover, AVE values greater than 0.50 for each construct affirm that the requirement for convergent validity has been fully satisfied. These findings align with the research instrument testing standards established by J. F. Hair et al, (2019), confirming that the instruments employed in this study fulfil rigorous reliability and validity criteria. Further validation was carried out using the Fornell-Larcker criterion to assess discriminant validity. This approach compares the square root of each construct's AVE (as shown on the diagonal of the matrix) to the inter-construct correlations (Wong Kay, 2015). The evaluation results showed that all values along the main diagonal exceeded the threshold of 0.5, confirming that each construct is distinct and significantly different from the others. This demonstrates that the measurement instruments are capable of effectively distinguishing between different latent variables within the model. The discriminant validity scores were as follows: X1 = 0.805, X2 = 0.822, X3 = 0.819, Y1 = 0.861, and Y2 = 0.916. All of these measurements meet the required standards of construct reliability.

Subsequently, the Heterotrait-Monotrait Ratio (HTMT) was calculated to further examine discriminant validity. According to established guidelines, acceptable HTMT values must fall below 0.90 for each pair of constructs. In this study, all HTMT values were below the threshold, confirming the discriminant validity of the constructs and demonstrating that each variable is empirically distinct. The HTMT values obtained were: X1 = 0.708, X2 = 0.713, X3 = 0.824, and Y1 = 0.849. The results thus affirm that all instruments used in the study satisfy the criteria for discriminant validity, convergent validity, and reliability. These findings indicate that the measurement model adheres to psychometric standards, ensuring that each construct is both clearly distinguishable and measured consistently. Consequently, the model is deemed appropriate for further analysis.

3. Structural Models

After verifying the validity and reliability of the instrument, the study proceeded to test the structural model using the bootstrapping technique with 500 subsamples to achieve a more accurate estimate. This method generates an average geometric correlation between constructs, which must exceed the threshold of 0.90, while also revealing the statistical significance and the magnitude of the influence (β) between variables. The bootstrapping analysis enabled the researchers to validate the causal relationships between exogenous and endogenous variables, assess the strength of the influence of each pathway, and ensure the overall stability of the model. Consequently, this approach not only strengthens the research

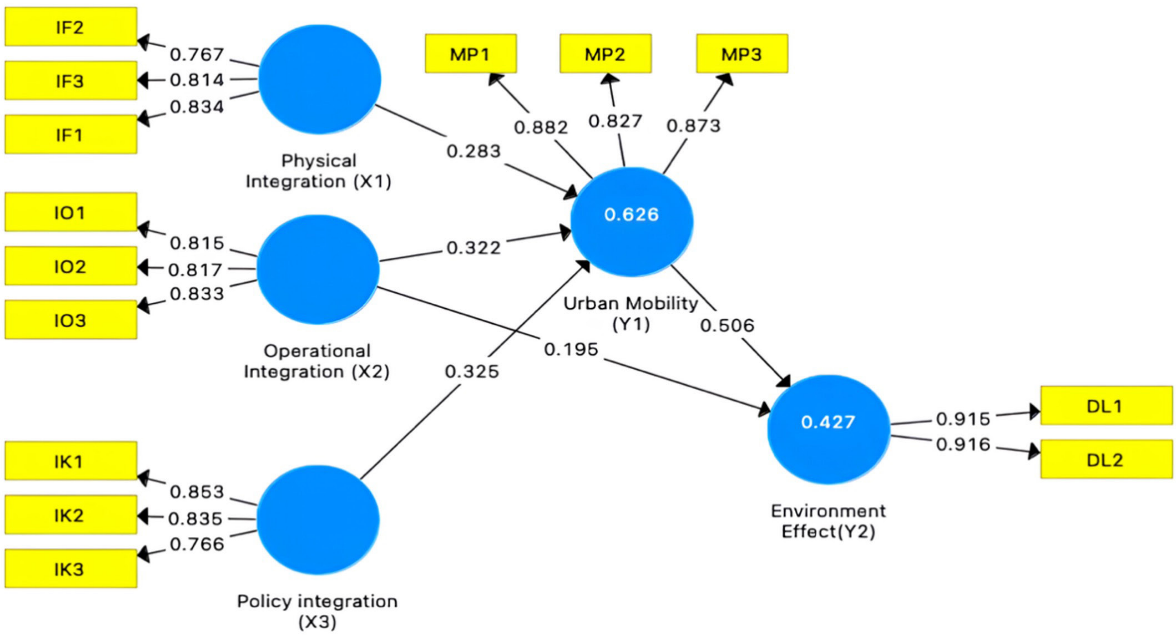

Figure 2 Structural Models

findings but also provides a robust empirical foundation for understanding the dynamics of relationships between variables within the proposed structural model.

Based on the results of the structural model analysis presented in Figure 3, it can be concluded that several significant causal relationships between variables were identified from the data in the accompanying table. Firstly, "Physical Integration" (X1) demonstrated a positive and statistically significant effect on "Urban Mobility" (Y1), with a path coefficient of 0.283 (t-value = 3.154, p-value = 0.002). The p-value, being well below the 0.05 threshold, indicates a high level of statistical significance. Similarly, "Operational Integration" (X2) exerted a stronger influence on "Urban Mobility" (Y1), with a coefficient of 0.322 (t-value = 4.456, p-value = 0.000), suggesting that a one-unit increase in operational integration is associated with a 32.2% improvement in urban mobility.

In addition, "Policy Integration" (X3) was also found to significantly influence "Urban Mobility" (Y1), albeit to a slightly more moderate extent (β = 0.325, t-value = 3.190, p-value = 0.002). With respect to the dependent variable "Environmental Impact" (Y2), "Urban Mobility" (Y1) exhibited a particularly strong influence, with a path coefficient of 0.506 (t-value = 5.171, p-value = 0.000). Although "Operational Integration" (X2) had a comparatively weaker effect on "Environmental Impact" (Y2), the relationship remained statistically significant (β = 0.195, t-value = 2.052, p-value = 0.041). All reported relationships met the critical thresholds, with t-values exceeding 1.96 and p-values remaining below 0.05, thereby confirming the statistical validity and overall reliability of the structural model.

4. Predictive Analysis Evaluation

Based on the results of the predictive relevance analysis, the model demonstrates adequate predictive capability for each endogenous construct. "Urban Mobility" (Y1) recorded the highest Q^2 value of 0.453, signifying excellent predictive power and a relatively low error rate (SSE/SSO = 164,004/300,000). "Environmental Impact" (Y2) also exhibited satisfactory predictive performance, with a Q^2 value of 0.348, which is categorised as a large predictive effect. It is important to note that the exogenous variables "Physical Integration" (X1), "Operational Integration" (X2), and "Policy Integration" (X3) do not yield Q^2 values, as they function as independent variables within the model.

These findings suggest that the model possesses sufficient predictive relevance, particularly in forecasting outcomes related to "Urban Mobility" (Y1) and "Environmental Impact" (Y2). This conclusion aligns with the previously reported R^2 values, wherein "Urban Mobility" (Y1) demonstrated strong explanatory power. The combination of positive Q^2 values and substantial R^2 estimates reinforces the overall empirical robustness and validity of the structural model.

5. Good of Fit (GoF) Analysis

Goodness of Fit (GoF) serves as a critical metric for evaluating the overall adequacy of a research model. While the implementation of GoF differs between covariance-based SEM (CB-SEM) and partial least squares SEM (PLS-SEM), the PLS-SEM approach is often regarded as more advantageous, particularly for theory testing and confirmation. Despite ongoing debates, numerous scholars advocate for the use of GoF in PLS-SEM, provided that key indicators such as cut-off values, the Standardised Root Mean Square Residual (SRMR), and chi-square statistics are duly considered.

Technically, the GoF value is computed by integrating the Average Variance Extracted (AVE) and the average coefficient of determination (R^2), following the formula: $GoF = \sqrt{(AVE \times R^2)}$. According to established standards, GoF values are interpreted within three categories: 0.10 (small), 0.25 (medium), and 0.36 (large). In the present study, the calculation of the GoF index adheres to these parameters, yielding an overall GoF value of 0.607. This figure significantly exceeds the 0.36 threshold, thereby suggesting a strong model fit. The GoF value was derived from a mean AVE of 0.715 and a mean R^2 of 0.515, reflecting a robust combination of convergent validity and predictive capability.

More specifically, the construct "Urban Mobility" recorded a GoF value of 0.675, supported by an AVE of 0.741 and an R^2 of 0.614, indicating a particularly strong model fit. In comparison, "Environmental Impact" achieved a GoF of 0.590, with an exceptionally high AVE of 0.838, despite a more modest R^2 value of 0.415. The AVE scores across all constructs exceeded 0.6, further affirming the excellent reliability and validity of the measurement items employed. However, it is worth noting that there remains potential to enhance the explanatory power of the "Environmental Impact" construct by incorporating additional mediating or moderating variables that may capture unaccounted variance.

Furthermore, the SRMR value obtained in this study was 0.085, situating the model within an acceptable range. According to Hair et al. (2019), SRMR values between 0.08 and 0.10 are considered moderately good, albeit requiring further scrutiny. Thus, while the model exhibits satisfactory fit indicators including a high GoF, strong AVE values, and tolerable SRMR ongoing evaluation and refinement are recommended to optimise model precision and explanatory capacity.

6. Discussion

The findings of this study provide compelling empirical evidence regarding the influence of public transport integration on urban mobility in Batam City, as perceived by the community. Structural model analysis reveals that all three dimensions physical, operational, and policy integration contribute significantly to the enhancement of urban mobility. "Physical integration" ($\beta = 0.283$, $p = 0.002$) demonstrates a positive effect through the provision of integrated infrastructure, such as transit stops and unified payment systems, corroborating previous research that emphasises the importance of physical connectivity in transport systems (Suleiman et al., 2023; Zhang & Lu, 2024). A low Variance Inflation Factor (VIF) value (1.940) confirms that this construct contributes uniquely to the model without multicollinearity issues. Additionally, the measures of convergent validity (Average Variance Extracted, AVE = 0.649) and reliability (Composite Reliability, CR = 0.847) affirm the precision and consistency of the indicators used to assess physical integration. These results strengthen the argument that well-connected infrastructure is a fundamental prerequisite for establishing an efficient transport system. However, while the effect is statistically significant, the moderate path coefficient (0.283) suggests that physical integration alone is insufficient to achieve optimal mobility outcomes without the support of other critical dimensions, such as operational coordination and coherent policy frameworks.

"Operational integration" ($\beta = 0.322$, $p < 0.001$) emerged as the most influential factor in enhancing urban mobility, underpinned by the effective coordination of routes and schedules. This aligns with findings from studies in other Southeast Asian cities, which underscore the importance of operational efficiency (Ibrahim et al., 2023). High values of Cronbach's Alpha (0.760) and Composite Reliability (0.862) demonstrate the internal consistency of this construct, while an AVE of 0.675 indicates that the indicators account for a substantial portion of the variance in operational integration. Moreover, a Heterotrait-Monotrait Ratio (HTMT) of 0.713 confirms its discriminant validity within the model. Notably, operational integration not only directly enhances mobility but also indirectly influences "environmental impact" ($\beta = 0.195$, $p = 0.041$), highlighting its role in promoting sustainable transport by reducing emissions through better-coordinated services (Montes et al., 2023).

"Policy integration" ($\beta = 0.325$, $p = 0.002$) demonstrated an almost equivalent impact to operational integration, reflecting the vital role of regulatory frameworks in fostering an integrated transport ecosystem. The construct's reliability and validity are supported by its Composite Reliability value (0.859) and AVE (0.670). Furthermore, the Fornell–Larcker criterion ($\sqrt{AVE} = 0.819$) and HTMT ratio (0.824) validate the discriminant uniqueness of the policy integration construct. These findings are consistent with prior research emphasising the necessity of a clear, enforceable policy framework to guide integration across transport modes (El Amrani et al., 2024; Litman, 2024). Nonetheless, there remains scope for enhancing policy effectiveness through cross-sectoral collaboration and periodic regulatory evaluation.

The influence of "urban mobility" on "environmental impact" ($\beta = 0.506$, $p < 0.001$) presents a significant insight into the sustainability of integrated transport systems. A predictive relevance (Q^2) value of 0.348 for environmental impact denotes strong predictive capability, suggesting that improvements in mobility integration are associated with reductions in air pollution and emissions. This reinforces sustainable transport principles (Litman, 2024), although the moderate R^2 value (0.415) indicates potential gains from the inclusion of mediating factors such as clean vehicle technologies. The construct of environmental impact also demonstrated exceptional convergent validity (AVE = 0.838) and reliability (CR = 0.912), confirming the robustness of the indicators used. Methodologically, the overall model exhibits high quality, with a Goodness of Fit (GoF) value of 0.607 and a Standardised Root Mean Square Residual (SRMR) of 0.085. HTMT values for all constructs remained below the 0.85 threshold (X3 = 0.824; Y1 = 0.849), indicating acceptable discriminant validity. Interestingly, the dual influence of operational integration on both mobility ($\beta = 0.322$) and environmental outcomes ($\beta = 0.195$) highlights the need for a more holistic and coordinated policy approach.

The practical implications of these findings are manifold. Firstly, they underscore the urgency of accelerating the development of integrated physical infrastructure. Secondly, they highlight the value of enhancing operational coordination through digital platforms and real-time data management. Thirdly, the findings advocate for policy harmonisation across government departments and transport operators. For future research, it would be beneficial to explore potential moderating variables such as user demographic characteristics and the economic impact of integration measures (Gutiérrez et al., 2021).

In conclusion, this study makes both academic and policy-relevant contributions to the discourse on sustainable urban transport. It offers concrete recommendations for policymakers in Batam City, demonstrating how optimising physical, operational, and policy integration can lead to a transport system that is not only efficient but also inclusive and environmentally sustainable. Future research may expand this scope by incorporating additional dimensions such as green technologies and socio-economic outcomes, thereby yielding a more comprehensive understanding of urban transport integration.

D. Conclusion

This study provides conclusive evidence that the integration of public transportation modes in Batam City has a significantly positive effect on urban mobility through three key dimensions: physical, operational, and policy integration. Physical integration, supported by the development of connected infrastructure, operational integration through improved coordination of schedules and routes, and policy integration via coherent regulations collectively contribute to a more efficient, accessible, and sustainable urban transport system. Moreover, enhanced urban mobility is associated with better environmental outcomes, reinforcing the importance of integrated transport planning in promoting ecological sustainability. The findings offer valuable contributions to both the academic and practical domains. For society, the study highlights the potential for creating more inclusive and equitable mobility options, particularly benefiting low-income and transit-dependent populations. For industry and government, the research provides a strategic framework for developing integrated transport systems that improve service efficiency, reduce operational costs, and support environmental goals. These insights are especially relevant for rapidly developing cities seeking to modernize their transportation networks while addressing sustainability challenges. Future research is encouraged to explore additional mediating variables, such as the adoption of green technologies and consideration of socio-economic factors, to further enhance the effectiveness of integrated urban mobility strategies.

To advance future research, several key developments are recommended. First, a more detailed investigation into potential mediating and moderating variables such as electric vehicle technologies or user demographic characteristics is warranted. Second, the research scope should be broadened to include comparative analyses with other Indonesian cities and incorporate cost–benefit assessments to evaluate the economic viability of integration strategies. Third, methodological refinement is encouraged through the application of real-time data and social network analysis to provide a more comprehensive understanding of systemic interactions. Fourth, more nuanced policy-oriented research is needed to explore sustainable business models and the socio-economic implications of integrated transport systems.

Overall, the findings offer a robust foundation for the Batam City government to accelerate the development of integrated transport infrastructure, enhance operational efficiency through digital innovation, and promote greater policy harmonisation among relevant agencies. The implementation of these recommendations is expected to foster an urban transportation system that is not only efficient but also environmentally sustainable and socially equitable for all residents of Batam.

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