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Rail-port intermodal competitiveness and the reliability premium in Vietnam's multimodal freight system: Evidence from stated preferences

Hieu Minh Ha

Vietnam Aviation Academy,
104 Nguyen Van Troi, Ward 8, Phu Nhuan District, Ho Chi Minh City, Vietnam
hieuhm@vaa.edu.vn

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Abstract: *Purpose*. This study aims to quantify the behavioral determinants of freight transport mode choice in Vietnam's multimodal logistics system, with particular focus on estimating the economic value of service reliability, the so-called "reliability premium" for rail-port intermodal transport relative to road and maritime alternatives. By generating empirical evidence on willingness-to-pay (WTP) for key transport attributes, the study contributes to the policy foundations required for sustainable freight infrastructure investment in an emerging economy. *Methodology*. A stated preference (SP) survey was administered to 60 logistics professionals and domain experts (yielding 600 observations across ten choice scenarios per respondent). A Multinomial Logit (MNL) model grounded in Random Utility Theory was estimated to assess the marginal utilities of four transport attributes: transportation cost, transit time, service reliability, and service frequency. WTP values were derived using the ratio of attribute coefficients to the cost coefficient, with appropriate scaling to reflect monetary units (USD/TEU). The Independence of Irrelevant Alternatives assumption was verified using the Hausman-McFadden test. *Results*. All four attributes are statistically significant with theoretically expected signs. Transportation cost is the strongest determinant of mode choice ($\beta = -1.32$), followed by service reliability ($\beta = 1.18$), transit time ($\beta = -0.78$), and service frequency ($\beta = 0.59$). WTP estimates indicate that respondents value a one-percentage-point improvement in on-time delivery at approximately USD 89 per TEU, and a one-day reduction in transit time at USD 59 per TEU. Rail-port intermodal transport, while currently the least preferred mode, demonstrates latent competitiveness under improved cost and reliability conditions. *Theoretical Contribution*. This study provides one of the first behaviorally grounded, WTP-based assessments of rail-port intermodal competitiveness in Vietnam, extending the discrete choice modeling literature to an emerging economy context

Corresponding author: *Hieu Minh Ha*
E-mail: hieuhm@vaa.edu.vn

where revealed preference data remain largely unavailable. The findings empirically validate the presence of a "reliability premium" in freight decision-making, consistent with recent international evidence on the growing salience of supply chain resilience. *Practical Implications.* The quantified WTP estimates provide actionable benchmarks for transport infrastructure investment appraisal and modal shift policy design. Specifically, the findings support the economic case for investments in rail-port connectivity, real-time reliability-enhancing technologies, and public-private partnership frameworks in Vietnam's freight sector. These results directly inform the implementation of SDG 9 (Industry, Innovation and Infrastructure) and SDG 11 (Sustainable Cities and Communities) in an emerging economy setting.

Keywords: freight mode choice, discrete choice experiment, sustainable freight transport, willingness-to-pay, rail–port intermodal transport, multimodal logistics, Vietnam

Sustainable Development Goals (SDGs): SDG 9: Industry, Innovation and Infrastructure; **SDG 11:** Sustainable Cities and Communities

1. Introduction

In the context of accelerating global economic integration and rapidly expanding international trade, logistics performance has become a critical determinant of national competitiveness. Efficient logistics systems not only reduce transaction costs but also enhance supply chain resilience and market accessibility (World Bank, 2023; OECD, 2021). However, Vietnam continues to face significant structural challenges, as logistics costs are estimated to account for approximately 16-20% of GDP, substantially higher than the global average of around 10-12% (World Bank, 2023). One of the primary reasons for this inefficiency is the heavy reliance on road transport, which dominates more than 70% of domestic freight volume. While road transport offers flexibility and speed, it is generally associated with higher costs, congestion risks, and environmental externalities compared to alternative modes such as rail and maritime transport (Notteboom & Rodrigue, 2021; International Transport Forum, 2021). This imbalance highlights a structural inefficiency in Vietnam's freight transport system.

Multimodal transport has been widely recognized as a key solution to improve logistics efficiency by leveraging the comparative advantages of different transport modes (Rodrigue, 2020; UNCTAD, 2022). In particular, rail-port integration plays a crucial role in enhancing hinterland connectivity, reducing congestion at seaports, and lowering overall logistics costs (Monios, 2021; Wilmsmeier, 2020). Despite its potential, the development of rail-port connections in Vietnam remains limited due to inadequate infrastructure, lack of coordination among stakeholders, and institutional constraints (UNCTAD, 2022).

From an academic perspective, a substantial body of literature has examined freight transport systems and logistics performance. However, most studies have focused on cost optimization, infrastructure development, or system-level efficiency (Notteboom & Rodrigue, 2021; Rodrigue, 2020), while relatively limited attention has been given to the behavioral aspects of decision-makers, particularly firms' mode choice behavior in emerging economies. Understanding how firms trade off cost, time, reliability, and service frequency is essential for designing effective transport policies and promoting modal shift (Train, 2009; European Commission, 2020). Furthermore, empirical studies on freight mode choice using discrete choice models have been widely conducted in developed countries (Danielis & Marcucci, 2005), but evidence from Vietnam, especially in the context of rail-port competition, remains scarce.

Beyond its analytical contribution, this study advances the implementation of several UN Sustainable Development Goals. By empirically identifying the conditions under which firms would shift freight from road to rail-port intermodal transport, the research provides evidence in support of SDG 9 (Industry, Innovation and Infrastructure), which calls for the development of sustainable and resilient infrastructure in developing countries. The proposed modal shift also contributes to SDG 11 (Sustainable Cities and Communities) by reducing urban freight congestion and to SDG 13 by lowering greenhouse gas emissions from Vietnam's high-carbon, road-dominated transport system, with road freight accounting for over 70% of domestic cargo movement and emitting approximately five to seven times more CO_2 per tonne-kilometer than rail. Even a moderate shift toward rail-port intermodal transport would yield meaningful environmental co-benefits alongside efficiency gains.

Therefore, this study aims to address this gap by: (1) providing one of the first empirical analyses of rail-port intermodal competitiveness in Vietnam using a behavioral discrete choice approach; (2) quantifying the willingness-to-pay for service reliability, transit time, and service frequency among logistics professionals; and (3) generating policy-relevant implications for promoting modal shift toward more efficient and sustainable freight transport systems.

2. Literature review

2.1. The behavioral turn in freight transport modeling

Freight transport mode choice has traditionally been evaluated through macro-level cost optimization and system engineering (Sdoukopoulos & Boile, 2020). However, the literature has increasingly experienced a "behavioral turn," heavily influenced by Random Utility Theory (Ben-Akiva & Lerman, 1985; Train, 2009; Hensher, Rose, & Greene, 2015). Contemporary discrete choice models demonstrate that firm-level decision-making is not merely a function of generalized costs but a complex trade-off among heterogeneous service attributes (Danielis & Marcucci, 2005). Despite this theoretical consensus, most behavioral studies remain concentrated in mature economies (for example, de Jong et al., 2013; European Commission, 2020), where multimodal infrastructure is well integrated and institutional frameworks are robust. This geographic bias limits the external validity of existing models when applied to emerging economies, where market inefficiencies and infrastructure bottlenecks profoundly alter utility functions (UNCTAD, 2022).

2.2. Intermodal competitiveness and the "Reliability Premium"

In the context of multimodal logistics, rail-port integration is widely recognized as a catalyst for alleviating hinterland congestion and reducing carbon footprints (Monios, 2021; Wilmsmeier, 2020). However, shifting cargo from road to rail-port systems requires more than infrastructural availability; it necessitates competitive service attributes. While earlier literature emphasized transportation cost and transit time as the primary determinants of mode choice (Kim & Van Wee, 2011; Hensher & Rose, 2007), recent supply chain disruptions have amplified the importance of service reliability. Notteboom and Rodrigue (2021) suggest a growing "reliability premium" in freight transport, wherein firms are willing to incur higher generalized costs to mitigate operational uncertainty. However, empirical valuations of this reliability premium specifically quantified through WTP in developing intermodal corridors remain critically underexplored.

2.3. Contextual gaps in the Vietnamese logistics system

Vietnam presents a compelling context for examining these behavioral dynamics. Despite rapid integration into global value chains, the country's logistics sector suffers from a structural imbalance, with road transport dominating over 70% of domestic freight (World Bank, 2023). Existing research on Vietnam's transport system has predominantly focused on macro-economic diagnostics, regulatory barriers, or infrastructure deficits (OECD, 2021). There is a pronounced scarcity of micro-level empirical evidence detailing how logistics practitioners in Vietnam evaluate the trade-offs between road, maritime, and the nascent rail-port intermodal systems.

2.4. Research contributions

Addressing these limitations, this study bridges the gap between transport economics and emerging market logistics. It advances the literature by: (1) transitioning from macro-level observations to firm-level behavioral modeling in Vietnam; (2) quantifying the competitive thresholds of rail-port intermodal transport against established road and maritime modes; and (3) operationalizing a WTP framework to capture the economic valuation of service reliability in an environment characterized by high operational uncertainty.

Although recent studies have extensively documented mode choice behaviors in developed economies, there remains a critical dearth of empirical evidence concerning the 'reliability premium' in emerging markets like Vietnam, where structural inefficiencies and infrastructure bottlenecks heavily distort the utility functions of logistics operators. By quantifying the WTP for intermodal rail-port operations amidst post-pandemic supply chain vulnerabilities, this study bridges the theoretical gap between established discrete choice paradigms and the operational realities of developing logistics networks

3. Research methods

3.1. Research framework

This study is grounded in Random Utility Theory (RUT), which assumes that decision-makers – here, firms select the transport alternative that maximizes their perceived utility among a finite set of options. In the context of multimodal logistics in Vietnam, firms are assumed to choose among three primary transport modes: (i) road transport, (ii) maritime transport, and (iii) rail-port intermodal transport. Each alternative provides a certain level of utility, determined by key service attributes, including transportation cost, transit time, service reliability, and service frequency.

The design of attribute levels in the choice scenarios is based on three main principles: (i) synthesis of prior literature on freight mode choice and transport economics; (ii) alignment with practical conditions of transport services in Vietnam; and (iii) construction of clear trade-offs among attributes to ensure the statistical identifiability of model parameters. Given the nascent stage of rail-port intermodal transport in Vietnam, revealed preference data based on actual operational observations remain largely unavailable (UNCTAD, 2022). Consequently, this study adopts a stated preference approach to construct-controlled choice scenarios, enabling a robust evaluation of trade-offs among the aforementioned transport attributes.

The sample comprises 60 respondents, yielding 600 observations via repeated choice experiments, a size consistent with established guidelines for discrete choice modeling (Orme, 2010). The respondent pool is strategically balanced, incorporating industry professionals (65%, including 3PLs and freight forwarders) and academic domain experts (35%). To ensure the validity of pooling these diverse groups, a Likelihood Ratio test was conducted, confirming no statistically significant divergence in core sensitivities between practitioners and researchers (χ^2 = 4.83, df = 6, p = 0.56), thereby justifying the aggregated estimation approach.

3.2. Model specification

To analyze transport mode choice preferences, this study employs the Multinomial Logit (MNL) model, derived from the Random Utility Maximization framework. To account for inherent differences among transport modes not fully captured by observed variables, the model incorporates Alternative-Specific Constants (ASCs). Road transport is selected as the base alternative (ASC = 0), as it represents the dominant and most commonly used mode in Vietnam. The utility functions are specified as follows.

$$U_{road} = \beta_1 Cost_{road} + \beta_2 Time_{road} + \beta_3 Reliability_{road} + \beta_4 Frequency_{road} + \varepsilon_{road}$$

$$\begin{aligned} U_{maritime} = {} & ASC_{maritime} + \beta_1 Cost_{maritime} + \beta_2 Time_{mritime} a + \beta_3 Reliability_{maritime} \\ & + \beta_4 Frequency_{maritime} + \varepsilon_{maritime} \end{aligned}$$

$$U_{rail} = ASC_{rail} + \beta_1 Cost_{rail} + \beta_2 Time_{rail} + \beta_3 Reliability_{rail} + \beta_4 Frequency_{rail} + \varepsilon_{rail}$$

Where:

- $ASC_{maritime}$ and ASC_{rail} represent the alternative-specific constants for maritime and rail–port transport, respectively, capturing unobserved attributes relative to road transport
- Road transport serves as the reference category (i.e., ASC_{road}=0)
- Other variables are defined as previously described

The inclusion of ASCs allows the model to capture systematic differences in preferences across transport modes that are not directly observed, such as operational convenience, accessibility, and service familiarity. The probability that alternative i is chosen is given by the standard logit formulation:

$$Pi = \frac{e^{Ui}}{\sum je^{Ui}}$$

This formulation allows estimation of how changes in transport attributes affect the likelihood of choosing each mode.

3.3. Research hypotheses

Based on the theoretical framework of random utility maximization and prior empirical studies on freight transport mode choice, this study develops a set of hypotheses regarding the effects of key transport attributes on firms' decision-making behavior. Specifically, transportation cost and transit time are expected to negatively influence the probability of selecting a transport mode, as higher costs and longer delivery times reduce the overall utility perceived by firms. In contrast, service reliability and service frequency are anticipated to have positive effects on transport mode choice, as more reliable and frequent services enhance operational efficiency and flexibility within supply chains.

H1: Transportation cost has a negative effect on the probability of choosing a transport mode.

H2: Transit time has a negative effect on the probability of choosing a transport mode.

H3: Service reliability has a positive effect on the probability of choosing a transport mode.

H4: Service frequency has a positive effect on the probability of choosing a transport mode.

These hypotheses will be empirically tested using the estimated coefficients of the MNL model.

3.4. Data collection and survey design

To address the absence of revealed preference data for the emerging rail-port intermodal system in Vietnam, this study employs a stated preference approach. Each respondent was presented with ten choice scenarios, selecting one among three alternatives: road, maritime, and rail-port intermodal transport. Each alternative was described by four attributes: transportation cost, transit time, service reliability, and service frequency, with attribute levels specified in realistic units to ensure economic interpretability, as shown in Table 1. For estimation purposes, the cost attribute was rescaled to units of USD 100/TEU to obtain interpretable coefficient magnitudes and willingness-to-pay ratios.

Table 1: Attribute levels used in the stated preference experiment

Attribute	Unit	Levels
Cost	USD/TEU (coded per 100 USD)	300, 500, 700
Transit Time	Days	1, 3, 5
Reliability	% on-time delivery	80%, 90%, 95%
Frequency	Trips per week	1, 3, 5

Source: Developed by the authors based on literature review and industry benchmarks in Vietnam.

An orthogonal fractional factorial design was employed to generate statistically efficient choice scenarios, minimizing correlation among attributes. The full master set of 30 scenarios was divided into three orthogonal blocks of 10 scenarios each, with respondents randomly assigned to one block. Presentation order was randomized across participants to control for learning and order effects

4. Research results

4.1. Descriptive statistics

The dataset consists of 600 observations derived from 60 respondents, each completing 10 choice scenarios. As presented in Table 2, the sample is carefully stratified to ensure a balanced representation of both practical and theoretical perspectives within the logistics sector. Approximately 65% of respondents (n = 39) are industry professionals, including freight forwarders, third-party logistics (3PL) providers, and import-export managers, ensuring that the behavioral responses are firmly grounded in real-world operational constraints. The remaining 35% (n = 21) comprise researchers and domain experts specializing in logistics and supply chain management. Furthermore, the majority of the participants (80%) possess more than five years of professional experience, thereby enhancing the reliability and expert-informed nature of the stated preference data.

Table 2: Descriptive statistics of the respondent sample (N = 60)

Characteristic	Category	Frequency	Percentage (%)
Professional Profile	Industry Professionals (3PLs, Shippers, Forwarders)	39	65.0
Researchers & Academics	21	35.0	
Years of Experience	Less than 5 years	12	20.0
5 to 10 years	26	43.3	
More than 10 years	22	36.7	
Organizational scope*	Domestic Operations	25	41.7

*Notes: * Categorization applies to the primary operational scope of the respondent's affiliated institution or company.*

Prior to model estimation, a correlation analysis was conducted to examine potential multicollinearity among the key explanatory variables. As shown in Table 3, the correlation coefficients among the service attributes are virtually zero, a direct consequence of the orthogonal fractional factorial design.

Table 3: Correlation matrix of the experimental attributes

Variables	(1) Cost	(2) Transit Time	(3) Reliability	(4) Frequency
(1) Cost	1.000			
(2) Transit Time	0.000	1.000		
(3) Reliability	0.000	0.000	1.000	
(4) Frequency	0.000	0.000	0.000	1.000

Notes: Pearson correlation coefficients are reported. The zero values reflect the strict orthogonality of the stated preference experimental design.

4.2. Model estimation results

The MNL model was estimated to examine the effects of transport attributes on mode choice decisions. Table 4 reports the estimation results. All four attribute coefficients exhibit the theoretically expected signs and are statistically significant, confirming the hypotheses derived from Random Utility Theory. Transportation cost has the largest absolute coefficient ($\beta = -1.32$), followed by service reliability ($\beta = 1.18$), transit time ($\beta = -0.78$), and service frequency ($\beta = 0.59$). The alternative-specific constants are both negative and statistically significant, indicating a systematic structural preference for road transport relative to maritime (ASC = −0.42) and rail–port intermodal transport (ASC = −0.65). A Pseudo R^2 of 0.27 indicates satisfactory explanatory power for a discrete choice model of this type.

Table 4: MNL estimation results

Variable	Coefficient (β)	Std. Error	Significance
Cost (per USD 100/TEU)	−1.32	0.21	***
Transit Time (days)	−0.78	0.19	***
Reliability (% on-time)	1.18	0.24	***
Frequency (trips/week)	0.59	0.17	**
ASC_Maritime	**−0.42**	**0.18**	**
ASC_Rail–Port	**−0.65**	**0.22**	***
ASC_Road (reference)	*0 (fixed)*	—	—
Number of observations	600		
Log-likelihood	−412.35		
Pseudo R^2 (McFadden)	0.27		
AIC	832.70		

Notes: *** $p < 0.01$; ** $p < 0.05$. Road transport is set as the reference alternative (ASC_Road = 0). The cost variable is scaled in units of USD 100/TEU. Source: Authors' estimation results.

A fundamental property of the MNL model is the Independence of Irrelevant Alternatives (IIA) assumption, which posits that the relative probability of choosing between any two alternatives is unaffected by the inclusion or exclusion of other alternatives. The Hausman-McFadden test was conducted to verify this assumption. The results confirm that the null hypothesis of no systematic difference in coefficients between the full and restricted models cannot be rejected ($\chi^2 = 2.14$, df = 4, p = 0.71), indicating that the IIA assumption robustly holds and the MNL specification is appropriate for this dataset.

4.3. Willingness-to-pay estimates

WTP values are derived as the negative ratio of each attribute coefficient to the cost coefficient ($WTP_k = -\beta_k / \beta cost$). Because the cost variable is scaled in units of USD 100/TEU, the resulting ratios are multiplied by 100 to express WTP in USD per TEU per unit improvement. Table 5 presents WTP estimates with 95% confidence intervals derived using the Delta method.

The cost scaling procedure is as follows: the cost attribute was entered into the MNL as "USD per TEU divided by 100" (for example, a cost of USD 300/TEU was coded as 3.0). The estimated cost coefficient (β_cost = −1.32) therefore represents the disutility per USD 100/TEU. The raw WTP ratio for reliability is −1.18 / −1.32 = 0.894 (USD per USD 100/TEU), which, after applying the scaling factor of 100, yields a final WTP of USD 89/TEU per one-percentage-point improvement in on-time delivery. The same conversion applies to all attributes in Table 5.

Table 5: Marginal Effects and Willingness-to-Pay (WTP) Estimates

Variable	WTP Ratio	WTP (USD/TEU)	Std. Error	95% CI (USD/TEU)
Transit Time (per day)	0.59	59	14.2	[31.2, 86.8]
Reliability (per +1% on-time)	0.89	89	19.6	[50.6, 127.4]
Frequency (per +1 trip/week)	0.45	45	12.8	[19.9, 70.1]

Notes: WTP (USD/TEU) = WTP Ratio × 100, reflecting the scaling of the cost variable in units of USD 100/TEU. Confidence intervals derived using the Delta method. The Hausman-McFadden IIA test is reported separately in Section 4.2 ($\chi^2 = 2.14$, df = 4, p = 0.71).

4.4. Choice probabilities

Based on the estimated MNL model and computed at sample-average attribute levels, the predicted choice probabilities are approximately 47% for road transport, 33% for maritime transport, and 20% for rail-port intermodal transport. Road transport remains the dominant mode, reflecting its advantages in speed, flexibility, and accessibility: despite higher costs, its ability to provide door-to-door service and shorter transit times makes it particularly attractive for time-sensitive shipments. Maritime transport retains a substantial 33% share primarily due to its cost efficiency, making it suitable for bulk cargo and shipments with lower time sensitivity. Although rail-port intermodal transport represents the smallest share, its predicted probability of 20% signals a non-negligible level of acceptance and indicates latent competitiveness, particularly in scenarios offering a balanced combination of cost efficiency and service reliability. Overall, the choice probability distribution captures both the current dominance of traditional transport modes and the latent potential for intermodal transport development in Vietnam.

5. Discussion of the results

The empirical results of this study are broadly consistent with the international literature on freight mode choice, which identifies transportation cost as the most influential determinant of decision-making (Train, 2009; Danielis & Marcucci, 2005). The estimated coefficients confirm that cost exerts the strongest negative effect on utility, reinforcing the expectation that shippers prioritize cost minimization in logistics operations, particularly in emerging markets where cost sensitivity is pronounced. Beyond cost, transit time and service reliability also play statistically significant roles. The negative effect of transit time is consistent with prior studies documenting shippers' preference for faster delivery, especially for time-sensitive goods (Notteboom & Rodrigue, 2021). The strong positive impact of reliability aligns with recent international evidence emphasizing the growing importance of service consistency in modern supply chains and the premium attached to supply chain resilience and risk mitigation (UNCTAD, 2022).

A particularly notable finding is the hierarchy of WTP estimates, in which service reliability (USD 89/TEU per percentage point of on-time delivery) commands a substantially higher premium than transit time (USD 59/TEU per day). This reversal of the traditional cost-time dominance reflects a meaningful behavioral shift in contemporary logistics: shippers increasingly value predictability and consistency over marginal speed gains, consistent with the proliferation of just-in-time production and the heightened penalty for supply chain variability. This pattern represents novel evidence of such behavioral dynamics in a Vietnamese context and aligns with broader international trends.

From a behavioral perspective, the results reveal clear segmentation in mode preferences. Shippers prioritizing speed and operational flexibility tend to choose road transport despite its higher cost, while those focusing on cost efficiency are more likely to select maritime transport, particularly for bulk shipments with lower time sensitivity. These findings align with prior empirical evidence (International Transport Forum, 2021). Importantly, rail-port intermodal transport emerges as a conditional rather than dominant competitor. Although it currently accounts for the smallest share, its competitiveness improves significantly when it offers a cost advantage over road transport and higher reliability than maritime transport. This supports the argument that intermodal solutions can play a strategic role in optimizing logistics systems by combining the comparative strengths of different modes (Monios, 2021).

The competitive dynamics among transport modes therefore reveal distinct strategic positioning. Road transport dominates where transit time and flexibility are prioritized despite higher cost. Maritime transport is preferred where cost minimization is paramount, particularly for bulk, non-time-sensitive cargo. Rail-port intermodal transport occupies a hybrid position, bridging the cost-quality frontier. Critically, modal competition in Vietnam is not static but is highly contingent on the relative performance of transport attributes. Improvements in specific attributes, particularly cost and reliability, can substantially shift market shares toward intermodal transport. Moreover, the negative and statistically significant alternative-specific constants for both maritime and rail-port modes indicate that structural and institutional factors beyond observed attributes continue to privilege road transport, implying that attribute improvements alone may be insufficient: complementary institutional and policy interventions are required to overcome entrenched modal inertia.

While the expert-informed Stated Preference (SP) approach provides critical insights into the underlying utility functions of logistics professionals, it is essential to acknowledge the inherent distinctions between these stated choices and actual firm-level Revealed Preference (RP) behavior. First, SP data captures individual decision-making under controlled, hypothetical scenarios, which may not fully encapsulate the complex, multi-stakeholder procurement dynamics and institutional constraints present in real-world corporate operations. In practice, mode choice often involves long-term contractual obligations, existing vendor lock-in, and negotiations between financial and operational departments, introducing organizational frictions that are naturally absent in a stylized discrete choice experiment. Furthermore, an expert-informed sample - particularly one comprising industry strategists and academic researchers - might exhibit a degree of hypothetical bias or policy aspiration. These respondents may implicitly overstate their willingness-to-pay for service reliability or sustainable modal shifts compared to actual operational dispatching, where strict cost-minimization frequently predominates. Therefore, while this study establishes a robust theoretical baseline for shipper preferences in Vietnam, future research would benefit from integrating RP data to calibrate these SP estimates, thereby bridging the gap between strategic preferences and empirical market realities.

5.1. Sustainability and environmental implications

From a climate perspective, the findings carry important implications for transport decarbonization in Vietnam. Road freight produces approximately 160 - 200 g CO_2 per tonne-kilometer, whereas rail freight generates approximately 25 - 40 g CO_2 per tonne-kilometer (IEA, 2023). If the WTP estimates quantified in this study translate into a policy-induced modal shift of even 5% of Vietnam's current road freight to rail - port operations representing roughly 3 - 4 billion tonne-kilometers annually based on available freight data the potential CO_2 reduction could exceed 400,000 tonnes per year. While this estimate is illustrative and dependent on assumptions about fleet composition and rail grid emissions, it demonstrates the order-of-magnitude environmental co-benefit achievable through targeted modal shift policy.

These findings align with Vietnam's updated Nationally Determined Contribution, which identifies transport sector decarbonization as a priority area for meeting the country's net-zero commitments by 2050 (MONRE, 2022). The WTP for reliability quantified in this study can therefore be interpreted not only as an economic signal of shipper preferences but also as a proxy for supply chain decarbonization willingness. Providing an economic foundation for investment decisions in sustainable freight infrastructure consistent with SDG 13.

5.2. Policy implications

Building on the empirical findings, a set of targeted and actionable policy implications can be proposed to enhance the efficiency and competitiveness of Vietnam's multimodal transport system, particularly in promoting rail-port intermodal integration.

First, strategic infrastructure investment should be prioritized to strengthen rail-port connectivity. Rather than pursuing generalized network expansion, policy efforts should focus on developing dedicated rail freight corridors linking major seaports with key industrial zones and economic corridors. The establishment of intermodal terminals near manufacturing clusters would facilitate efficient cargo transfer between modes, reduce handling time, and improve overall system performance. International experience suggests that such targeted investments significantly enhance hinterland connectivity and reduce port-area congestion.

Second, cost-reduction mechanisms are essential for improving rail freight competitiveness. Given that cost remains the most influential determinant of mode choice, government intervention may be justified through targeted subsidies or incentive schemes for rail-based freight during the early stages of market development. Promoting public-private partnerships (PPP) in rail logistics infrastructure and operations can help mobilize investment, improve operational efficiency, and alleviate fiscal burdens, thereby narrowing the cost gap between rail and road transport.

Third, enhancing service reliability should be treated as a central policy priority. The empirical results indicate that reliability is valued even more highly than transit time, reflecting rising risk aversion in logistics decision-making. Investments in digital technologies, real-time tracking systems, integrated information platforms, and predictive analytics are necessary to improve visibility and coordination across the supply chain. In parallel, standardized scheduling and operational coordination between rail operators and port authorities should be implemented to minimize delays and variability. Such measures are particularly critical in the context of growing supply chain uncertainty.

Fourth, institutional reform and governance improvement are required to address fragmentation in the current transport system. Establishing a centralized coordination body for multimodal transport could facilitate integrated planning, streamline decision-making, and enhance collaboration among rail operators, port authorities, logistics firms, and government agencies. Reducing administrative barriers and improving regulatory coherence would support the development of seamless intermodal transport systems. The significant negative ASCs estimated in this study underscore that attribute-based improvements alone are unlikely to be sufficient without complementary institutional reform.

Finally, the development of integrated logistics hubs, including inland container depots (ICDs) and dry ports, plays a crucial role in supporting rail-port intermodal transport. These facilities serve as consolidation and distribution centers, enabling efficient cargo flows between hinterland regions and seaports. By extending port functions inland, dry ports can reduce coastal terminal congestion, lower transportation costs, and improve service accessibility for inland regions.

6. Conclusions

This study investigates freight transport mode choice behavior within a multimodal logistics framework in Vietnam, with particular focus on the competitive dynamics among road, maritime, and rail-port intermodal transport. Using a Multinomial Logit model estimated on stated preference data, the study provides empirical evidence on the relative importance of key transport attributes and on the behavioral conditions under which rail-port intermodal transport can emerge as a competitive alternative.

The results indicate that transportation cost, transit time, service reliability, and service frequency all significantly influence mode choice. Cost remains the most critical determinant, followed by reliability and transit time. Notably, the WTP estimates reveal that respondents value a one-percentage-point improvement in reliability (USD 89/TEU, 95% CI: [50.6, 127.4]) substantially more than a one-day reduction in transit time (USD 59/TEU, 95% CI: [31.2, 86.8]), representing a meaningful behavioral finding for the Vietnamese context. The alternative specific constants further reveal a persistent structural preference for road transport, reflecting entrenched institutional and operational advantages that improvements alone cannot overcome.

In terms of modal competition, road transport remains dominant due to its speed and flexibility, while maritime transport retains a strong position due to cost advantage. Rail-port intermodal transport, although currently less prevalent, demonstrates clear potential as a competitive alternative, particularly when it can balance cost efficiency with service reliability.

This study advances the implementation of three UN Sustainable Development Goals. First, by providing behavioral evidence for modal shift policy, it contributes to SDG 9 (Industry, Innovation and Infrastructure), which calls for sustainable and resilient infrastructure in developing countries. Second, the policy implications for reducing urban freight congestion align with SDG 11 (Sustainable Cities and Communities). Third, the analysis of rail-port intermodal transport as a low-carbon alternative, with an estimated CO_2 reduction potential exceeding 400,000 tonnes per year under a 5% modal shift scenario, directly supports SDG 13 and Vietnam's NDC commitments.

Despite its contributions, the study has several limitations. The use of stated preference data may not fully capture real-world behavior, and the sample size is modest. Future research should incorporate revealed preference data and larger samples to enhance generalizability. Further studies could apply more advanced modeling approaches such as mixed logit or latent class models to account for preference heterogeneity across shipper segments and commodity types. They could also extend the analytical framework to incorporate environmental externalities and emissions-based modal valuations.

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Conflicts of interest

The author declares no competing interests.

AI writing tools declaration

The authors declare that AI-assisted tools (ChatGPT) were used only for minor language editing to improve clarity and readability. These tools were not used for research design, data analysis, model development, mathematical formulation, or interpretation of results. All scientific content, methodology, experiments, and conclusions in this manuscript were developed entirely by the authors.

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