



A TOPSIS-Based Approach to Evaluating the Competitiveness of Selected Container Terminals in Northern Vietnam

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ABSTRACT

As global integration accelerates, ports play a pivotal role in economic development, facing increasing competition in the era of containerization. This study examines the key determinants of port competitiveness and evaluates selected container terminals in Northern Vietnam using the TOPSIS methodology. Five primary criteria, comprising 19 sub-criteria, are weighted through the Entropy algorithm, identifying terminal facilities as the most influential factor, followed by throughput, service quality, terminal charges, and location. The TOPSIS ranking provides a comparative assessment of six container terminals, highlighting their respective strengths and weaknesses, with Tan Vu and VIP Greenport emerging as the most competitive. By integrating quantitative and qualitative approaches, this study enhances the understanding of terminal competitiveness and offers strategic insights for terminal management and policy development. The findings contribute to optimizing terminal operations and competitiveness strategies within the evolving maritime landscape, providing a foundation for future research on performance enhancement and regional port development.

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1. Introduction

Ports are widely recognized as critical drivers of economic activity in coastal regions, handling a substantial share of global trade, including exports and imports. Beyond their role in facilitating trade flows, ports serve as vital hubs connecting maritime and inland transport networks, thereby supporting economic activities in hinterland areas [1]. Additionally, ports function as essential nodes in global supply chains, playing a pivotal role in facilitating economic integration at an international scale. Among different types of ports, container ports have become increasingly influential due to their direct impact on trade efficiency and economic competitiveness.

In an era of intensified globalization, competition among container ports has become increasingly fierce. The ability of ports to maintain and enhance their competitive position is crucial for their long-term sustainability and development [2], [3]. Accordingly, a thorough understanding of port competitiveness and the key factors shaping it is essential for both academics and industry practitioners.

Vietnam, as a maritime nation, possesses significant potential for marine economic development. According to the Strategy for Marine Economic Development by 2020 set forth by the Vietnamese government, the country aims to strengthen its position as a leading maritime economy, with the goal of the marine sector contributing approximately 53–55% to the national Gross Domestic Product (GDP) by 2020. Given this strategic direction, the development of the port industry has gained increasing attention. However, while existing research primarily focuses on improving port operational efficiency, limited studies have been conducted on port competitiveness.

To address this research gap, the present study employs a combined approach integrating both quantitative and qualitative methods to assess the competitiveness of six major container ports in Northern Vietnam—one of the fastest-growing regions in the

country, exhibiting an annual growth rate of 18.7%. The selected terminals include three newly developed facilities and three long-established ports, all located in Hai Phong City: Tan Vu (TV), Dinh Vu (DV), Nam Hai Dinh Vu (NHDV), VIP Green (VG), Hai An (HA), and PTSC Dinh Vu (PTSC).

Given the increasing importance of port competitiveness, this study aims to: (1) identify the key determinants of port competitiveness, (2) compare the competitive positioning of six major container terminals in Northern Vietnam using the TOPSIS methodology, and (3) analyze the strengths and weaknesses of each terminal. By employing a structured analytical framework, this research contributes to the literature on port competitiveness and offers practical insights for policymakers and port authorities in optimizing terminal strategies and improving competitiveness in the global maritime industry.

2. Literature Review

This section provides a comprehensive review of existing literature to offer insights into container port competitiveness.

2.1. Port competitiveness

Port competitiveness has been conceptualized in various ways in the maritime literature. Yeo and Lee [4] defined port competition as the ability to develop and implement differentiated strategic approaches to attract customers and gain an advantage over competing ports. Accordingly, the most competitive ports are those that effectively formulate and execute unique strategies, securing a larger market share. Another study [5] suggested that a port's competitive position is determined by its ability to provide superior value to shippers and shipping lines across specific trade routes, geographical regions, and port networks. Despite variations in definitions, a common understanding emerges that port competitiveness encompasses a port's ability to distinguish itself from its competitors by leveraging strategic, operational, and market-driven advantages to achieve competitive objectives,

such as market control and customer attraction.

2.2. Methodology on assessing port competitiveness

There is no universally accepted methodology for evaluating port competitiveness, leading to the development of multiple approaches in the literature. Manzano et al. [6] categorized these methods into two primary groups: quantitative techniques and Multi-Criteria Decision-Making (MCDM) approaches.

Among quantitative methods, several studies have utilized frameworks such as Data Envelopment Analysis (DEA), cluster analysis, and regression modeling. Wu and Lin [7] applied DEA to assess the performance of Indian ports relative to those in emerging and developed economies. Similarly, Rios and Sousa [8] conducted a cluster analysis to examine the competitiveness of Brazilian container ports based on criteria related to port infrastructure and equipment. Furthermore, Tongzon [2] employed principal component analysis (PCA) and regression techniques to investigate the impact of key factors on port competitiveness.

On the other hand, MCDM methods facilitate the integration of both quantitative and qualitative indicators, making them well-suited for multi-faceted decision-making processes [6]. Yeo [4] applied fuzzy logic to assess port competitiveness using expert opinions from logistics professionals. Kim [9] introduced a hybrid approach combining the TOPSIS algorithm with Entropy weighting to evaluate the competitive potential of ports in Korea and China. Additionally, several studies, have utilized the Analytic Hierarchy Process (AHP) to explore port competition dynamics [10], [11], [12].

2.3. Determinants of port competitiveness

Identifying the factors influencing port competitiveness is essential for developing effective evaluation models. Parola et al. [13] conducted a systematic review of peer-reviewed literature from 1983 to 2014 and identified several key determinants of port

competitiveness, including port costs, hinterland connectivity, geographical location, infrastructure, operational efficiency, service quality, maritime connectivity, nautical accessibility, and port site characteristics.

Recent studies have focused on specific regional contexts, such as Vietnam. Nguyen et al. [14] investigated port competitiveness in Northern Vietnam by analyzing seven quantitative factors: container throughput, number of berths, berth length, maximum berth draft, container yard area, average vessel size, and handling productivity. Their findings provided valuable insights into the competitive advantages of 11 container terminals in the region.

Additionally, the assessment of port competitiveness has been explored from the perspectives of various port stakeholders. Cruz et al. [15] highlighted that perceptions of competitiveness vary between port users and service providers, emphasizing the need to consider multiple viewpoints when evaluating port performance.

Overall, the literature suggests that port competitiveness is influenced by both quantitative and qualitative factors. Quantitative determinants include measurable attributes such as physical infrastructure, container throughput, and port charges, whereas qualitative factors encompass aspects like service quality, operational reliability, flexibility, customer relationships, and marketing efforts. The combination of these factors shapes the competitive standing of container ports in the global maritime industry.

3. Methodology and Selection of Evaluating Criteria

In this study, six container terminals in Northern Vietnam were selected based on three primary criteria: (1) recent container throughput volume, (2) strategic location within the Hai Phong port system and connectivity to hinterland regions, and (3) diversity in ownership structure (including state-owned, joint-venture, and private

ports). These terminals represent the most active and influential ports in the region, ensuring the representativeness of the evaluation.

The development of evaluation criteria followed a two-step approach. First, an extensive literature review was conducted to compile a preliminary list of over 30 potential indicators commonly used in port competitiveness studies [4], [6], [8], [13], [14], [15]. Second, this list was refined and contextualized through expert consultation to identify the most relevant criteria for the Vietnamese port context. As a result, 5 main criteria and 19 sub-criteria were finalized for use in the evaluation framework.

Expert input was obtained from eight professionals selected through purposive sampling. The selection criteria for the expert panel included: (i) a minimum of 10 years of experience in port operations, logistics, or maritime transport; (ii) current or previous managerial roles in port authorities, shipping lines, or state regulatory bodies; and (iii) in-depth knowledge of the Northern Vietnam port system. While the sample size is limited, the panel reflects both public and private sector expertise, thus providing a balanced and credible basis for validating the evaluation criteria.

Expert opinions were collected through two rounds of structured discussions and follow-up questionnaires. The aggregated input was used to screen, refine, and finalize the evaluation criteria before computing the objective weights using the Entropy method. The Entropy method is utilized to objectively determine the weights of evaluation criteria, while the TOPSIS technique is applied to establish the competitive ranking of each port.

3.1. TOPSIS Methodology

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is a widely used approach for solving Multi-Criteria Decision-Making (MCDM) problems. Initially introduced by Hwang

and Yoon [16], this method is designed to rank alternatives by assessing their relative proximity to an optimal solution.

The core principle of TOPSIS is based on determining the distance of each alternative from two reference points: the Positive Ideal Solution (PIS) and the Negative Ideal Solution (NIS). The PIS represents the best possible values for all considered criteria, whereas the NIS consists of the worst values observed for those criteria [16]. The most favorable alternative is the one that simultaneously exhibits the shortest Euclidean distance from the PIS and the longest Euclidean distance from the NIS [17].

TOPSIS has been extensively applied in decision-making scenarios across various disciplines, particularly for selection and evaluation tasks [18], [19]. This method is well-suited for cases involving numerous attributes and alternatives, especially when dealing with quantitative data, as it eliminates the need for paired comparisons. Moreover, TOPSIS does not require the assumption of attribute independence, making it a flexible and practical approach for complex decision-making problems. Due to its effectiveness in ranking alternatives, TOPSIS has been widely recognized as a reliable decision-making tool [20].

The implementation of the TOPSIS algorithm follows a structured sequence of steps [21], [22].

Step 1: Determine the decision matrix (initial matrix)

A decision matrix X is established, where x_{ij} represents the performance of alternative i on criterion j . m is the number of ports and n is the number of criteria.

$$X = [x_{ij}]_{m \times n} = \begin{pmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{pmatrix} \quad (1)$$

$i = 1, 2, \dots, m, \quad j = 1, 2, \dots, n$

Step 2: Construct the normalized matrix

To ensure comparability, the matrix is normalized using the vector normalization method. The normalized value r_{ij} is obtained by:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^m x_{ij}^2}} \quad (2)$$

Normalized matrix R is as follows:

$$R = [r_{ij}]_{m \times n} = \begin{bmatrix} r_{11} & r_{12} & \dots & r_{1n} \\ r_{21} & r_{22} & \dots & r_{2n} \\ \dots & \dots & \dots & \dots \\ r_{m1} & r_{m2} & \dots & r_{mn} \end{bmatrix} \quad (3)$$

Step 3: Calculate the weighted normalized matrix

The Entropy method objectively determines the weight of each criterion based on its distribution across alternatives.

The Entropy value and Entropy weight of each attribute can be obtained directly from the decision matrix following the procedure below:

Normalize data

The normalized value z_{ij} is obtained by:

$$z_{ij} = \frac{x_{ij} - x_j^{\min}}{x_j^{\max} - x_j^{\min}} \quad (4)$$

Where x_j^{\max} is the maximum performance rating among alternatives for attribute C_j ($j=1,2,\dots,n$) and x_j^{\min} is the minimum performance rating among alternatives for attribute C_j ($j=1,2,\dots,n$); $z_{ij} \in [0,1]$

Calculate the proportion of attribute's value

$$p_{ij} = \frac{z_{ij}}{\sum_{i=1}^m z_{ij}} \quad (5)$$

However, when $p_{ij} = 0$, $\ln(p_{ij})$ has no meaning. It is modified as

$$p_{ij} = \frac{1 + z_{ij}}{\sum_{i=1}^m (1 + z_{ij})} \quad (6)$$

Calculate the Entropy of each attribute

$$e_j = -k \sum_{i=1}^m p_{ij} \ln p_{ij} \quad (7)$$

Where: $k = \frac{1}{\ln m}$ is a constant which guarantees $0 \leq e_j \leq 1$; m: the total number of alternatives

Calculate the Entropy weight of each attribute

$$w_j = \frac{1 - e_j}{\sum_{j=1}^n (1 - e_j)} \quad (8)$$

Step 4: Determine the Positive Ideal and Negative Ideal Solutions

Positive ideal solution (PIS):

$$A^+ = \{v_1^+, v_2^+, \dots, v_n^+\} \quad (9)$$

If the i^{th} criterion is a benefit criterion:

$$v_j^+ = \max v_{ij}$$

If the i^{th} criterion is a cost criterion:

$$v_j^+ = \min v_{ij}$$

Negative ideal solution (NIS):

$$A^- = \{v_1^-, v_2^-, \dots, v_n^-\} \quad (10)$$

If the i^{th} criterion is a benefit criterion:

$$v_j^- = \min v_{ij}$$

If the i^{th} criterion is a cost

criterion: $v_j^- = \max v_{ij}$

Step 5: Calculate the distance measures (Separation from PIS and NIS) for each alternative.

The distance from the PIS is

$$D_i^+ = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^+)^2} \quad (11)$$

$i = 1, 2, \dots, m; j = 1, 2, \dots, n$

The distance from the NIS is

$$D_i^- = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^-)^2} \quad (12)$$

$i = 1, 2, \dots, m; j = 1, 2, \dots, n$

Step 6: Calculate the closeness coefficient (CC_i) to the PIS for each alternative A_i

$$CC_i = \frac{D_i^-}{D_i^+ + D_i^-} \quad (13)$$

$$i = 1, 2, \dots, m, \quad CC_i \in [0,1]$$

Step 7: Rank the preference order

Alternatives are ranked based on their C_i values, with the highest value indicating the most competitive port. This structured approach ensures an objective, data-driven evaluation of port competitiveness using TOPSIS with entropy weighting.

3.2. Selection of evaluating criteria

The extensive literature reviewed in Section 2.3 highlights a diverse set of factors influencing port competitiveness. To refine these factors and ensure their relevance, the following steps were undertaken:

- Narrowing down the number of factors to focus on the most critical determinants;
- Validating and assessing the

factors from the perspective of industry experts, and

- Aligning theoretical foundations with practical industry conditions through expert consensus.

To achieve these objectives, a survey was conducted among a group of eight professionals with extensive experience in container port operations, including individuals from shipping lines, shippers, and freight forwarders. Through discussions and consensus-building, five primary criteria were identified as key determinants of port competitiveness. Additionally, the selection of 19 sub-criteria was determined based on expert insights and corroborated with findings from previous studies. Notably, all identified criteria align closely with the most frequently cited factors in the existing literature.

4. Results and discussion

4.1. Analysis of entropy weights impact on container terminal competitiveness

Using the Entropy weighting method, this study identifies the key determinants of

Table 1. Entropy weights impact on container terminal competitiveness.

Main factor	Weight	Sub-factor	Weight
Throughput (A)	0.217	Container throughput (2023)	0.470
		Increase rate (2023/2022)	0.530
		Berth depth	0.257
Facilities (B)	0.242	Berth length	0.216
		Number of cranes	0.286
		Container yard area	0.241
		Terminal handling charge	0.635
Charges (C)	0.18	Storage charge	0.365
		Pilot boarding position (PS)	0.176
Location (D)	0.151	Cat Bi Airport (AP)	0.167
		Dinh Vu Industrial Zone (IZ1)	0.189
		Chi Linh Industrial Zone (IZ2)	0.158
		Yen Phong Industrial Zone (IZ3)	0.156
		Phu Nghia Industrial Zone (IZ4)	0.154
Service Quality (E)	0.211	Speed of services	0.200
		Reliability of services	0.224
		Safety of services	0.198

appropriateness of the selected port competitiveness by assigning objective

weights to evaluation criteria. The results reveal the relative importance of port throughput, infrastructure, charges, location, and service quality, providing insights into how ports can enhance their competitive advantage. The Table 1 presents Entropy weights impact on container terminal competitiveness.

Throughput is assigned a weight of 0.217, indicating its strong influence on port competitiveness. Within this category, the increase rate (2023/2022) has a slightly higher weight (0.53) compared to container throughput (2023) (0.47). This suggests that the growth trend of container volume is more critical than the absolute throughput, reflecting the market dynamics and demand shifts. Ports with a rapidly increasing throughput are perceived as more competitive, as they attract more shipping lines and improve economies of scale.

Facilities carry the highest weight among all criteria (0.242), emphasizing the crucial role of infrastructure in port competitiveness. Among the sub-criteria, the number of cranes (0.286) has the highest weight, followed by berth depth (0.257) and container yard area (0.241). This highlights that having sufficient handling equipment and deep berths is vital for improving cargo handling efficiency. Ports with advanced infrastructure can accommodate larger vessels and minimize turnaround times, thereby enhancing their competitive position.

Charges hold a weight of 0.18, signifying their moderate but notable impact on competitiveness. The terminal handling charge (0.635) dominates this category,

showing that high handling costs can significantly affect a port’s attractiveness. In contrast, the storage charge (0.365) has a lower impact. This implies that shipping lines and cargo owners prioritize terminal handling efficiency over storage costs when selecting a port. Ports with competitive pricing structures can gain a competitive edge by reducing overall logistics costs for customers.

Location has a weight of 0.151, reflecting its role in determining a port’s accessibility to key industrial zones and logistics hubs. The Dinh Vu Industrial Zone (0.189) ranks highest among location-based sub-criteria, followed by Pilot boarding position (0.176) and Cat Bi Airport (0.167). This suggests that proximity to major economic zones and transportation hubs is essential for reducing inland transport costs and enhancing supply chain efficiency. Ports strategically located near industrial parks can benefit from increased cargo flow and long-term trade relationships.

Service quality, with a weight of 0.211, plays a vital role in attracting shipping lines and maintaining operational reliability. Among its sub-criteria, reliability of services (0.224) is the most influential, followed by speed of services (0.2) and safety of services (0.198). This highlights that predictable and efficient port operations are key factors in competitiveness. Ports with a reputation for fast, reliable, and safe services are preferred by customers, leading to increased cargo throughput and better long-term partnerships.

4.2. Evaluating the competitiveness of container terminals in Northern Vietnam

The entropy weight analysis highlights

Table 2: Overall ranking of six selected terminals’ competitiveness.

Ranking	Terminal	Total	A	B	C	D	E
1	Tan Vu Terminal	0.747	0.445	0.995	0.724	0.855	0.664
2	VIP GreenPort	0.532	0.737	0.209	0.913	0.681	1.000
3	Dinh Vu Port	0.418	0.232	0.468	0.110	0.749	0.694
4	Nam Hai Dinh Vu Terminal	0.396	0.370	0.261	0.500	0.753	0.716
5	PTSC Dinh Vu Terminal	0.324	0.550	0.093	0.938	0.669	0.049
6	Hai An Terminal	0.260	0.199	0.119	1.000	0.241	0.144

port facilities and throughput growth as the most critical factors in determining port competitiveness, followed by cost efficiency, location accessibility, and service quality. Reflecting these findings, the overall competitiveness ranking in Table 2 identifies Tan Vu and VIP Green as the leading ports. Tan Vu ranks highest due to its superior facility conditions, while VIP Green benefits significantly from high throughput and service quality. As newly developed ports, both are poised for continued growth, playing a pivotal role in regional and national economic development. Their strong performance underscores the importance of infrastructure investment and operational efficiency in enhancing port competitiveness.

Furthermore, based on the analysis results of each criterion, the strengths and weaknesses of each port are discovered and summarized in Table 3.

Tan Vu terminal holds the highest ranking in port competitiveness among the six evaluated ports. As the only state-owned port under VINALINES (Vietnam National Shipping Lines), it serves as a strategic terminal within the Hai Phong port network. This ownership advantage has enabled Tan Vu to surpass its competitors in infrastructure, equipment, and container yard capacity. Additionally, its favorable location further strengthens its competitive

adopt a more competitive pricing strategy to attract a larger customer base. Accordingly, Tan Vu should invest in customer service training, digitalize operational procedures, and apply flexible pricing schemes tailored to strategic clients.

VIP Green Port, operated by VICONSHIP (Vietnam Container Shipping Corporation), is the most recently established dedicated container terminal in the region. Since its launch in 2015, the port has undergone continuous innovation and infrastructure upgrades, leading to a significant increase in container throughput. A key competitive advantage of VIP Greenport is its exclusive service to renowned international shipping lines, ensuring a steady and high-volume container flow. Additionally, the terminal's operators have prioritized service excellence, positioning it as a strong future competitor in the regional port industry. To sustain this momentum, VIP Green Port should expand connections to inland container depots (ICDs) and implement automation technologies to streamline handling operations.

In operation since 2005, Dinh Vu Port is partially state-owned, with 51% of its charter capital held by Hai Phong Port JSC. This ownership structure has contributed to its strong facility conditions, ranking second only to Tan Vu terminal. However, similar to Tan Vu, Dinh Vu Port faces challenges

Table 3. Strength and weakness of each terminal.

Terminal	Strength	Weakness
Tan Vu Terminal	Facility, Location	Charge, Services
VIP GreenPort	Throughput, Services	Location
Dinh Vu Port	Facility	Charge
Nam Hai Dinh Vu Terminal	Services, Location	Charge
PTSC Dinh Vu Terminal	Throughput, Charge	Facility, Service,
Hai An Terminal	Charge	Throughput, Location

position. However, despite these advantages, its service quality does not yet fully align with its potential. To enhance its competitiveness, Tan Vu terminal should focus on service quality improvements and

related to pricing policies. The terminal currently has the least competitive charges, which may impact customer satisfaction and retention. To address this, Dinh Vu Port should consider redesigning its pricing models based on cargo volume tiers and

introducing loyalty programs to incentivize long-term partnerships.

Nam Hai Dinh Vu Port has been operated terminal by VICONSHIP, a company with extensive experience in the port industry. The terminal benefits from a strategic location and high-quality service offerings, making it a preferred choice for major shipping lines such as Maersk Line, MSC, and Yang Ming. Nonetheless, the terminal's pricing remains less competitive compared to other options in the region. To strengthen its market position, Nam Hai Dinh Vu should offer bundled service packages (e.g., handling and storage) and apply discounts for long-term or high-volume clients.

PTSC Dinh Vu terminal is a small-scale terminal that has been in operation for over a decade. While it benefits from low port charges, this alone is insufficient to sustain its competitiveness. The terminal faces significant operational constraints, including a single short berth, which poses challenges in ship maneuvering. Additionally, the lack of specialized handling equipment limits service efficiency and competitiveness. To improve its overall competitiveness, PTSC Dinh Vu should prioritize infrastructure upgrades, including berth extension and investment in mobile cranes or RTGs to enhance operational flexibility.

Hai An terminal is a small private terminal known for its low-cost pricing strategy. However, it faces major limitations in location and throughput capacity. Situated upstream on the Cam River, behind the Bach Dang Bridge, the terminal is inaccessible to large vessels, creating a significant disadvantage in attracting international shipping lines. Given these constraints, Hai An should consider repositioning its strategy toward domestic feeder services and focus on developing value-added logistics such as warehousing and distribution hubs to maintain market relevance.

5. Conclusions

In an increasingly competitive maritime industry, particularly in the containerization era, understanding port competitiveness and its key influencing factors is essential. This study integrates quantitative and qualitative approaches to evaluate six major container ports in Northern Vietnam, identifying port facilities, throughput, service quality, port charges, and location as the primary determinants of competitiveness. Based on Entropy weighting, port facilities emerge as the most critical factor, underscoring the importance of infrastructure investment and operational efficiency. The ranking derived from the TOPSIS method further reveals that Tan Vu and VIP Green lead the competition, benefiting from modern facilities, increasing throughput, and high service quality. These findings highlight that competitive advantages are primarily driven by infrastructure capabilities, cargo-handling efficiency, and service excellence rather than cost advantages alone.

The Entropy-TOPSIS analysis provides deeper insights into the performance of individual ports. Tan Vu terminal ranks highest due to its state ownership, strategic location, and advanced infrastructure, yet it must enhance service quality and pricing strategies to maximize its potential. VIP GreenPort, benefiting from rapid throughput growth and strong service quality, has established itself as a major player in the market. Dinh Vu Port, with significant state capital investment, maintains a strong infrastructure base but struggles with less competitive tariff structures. Nam Hai Dinh Vu terminal, a privately operated terminal, effectively leverages its location and service offerings, yet further pricing competitiveness is required. PTSC Dinh Vu terminal faces operational limitations due to its small berth size and limited handling equipment, making it less competitive despite its low charges. Lastly, Hai An terminal, constrained by geographical disadvantages,

may need to shift focus towards domestic logistics services rather than international container handling.

From a strategic perspective, the findings suggest that infrastructure investment, throughput expansion, and service quality enhancements are the key areas for strengthening port competitiveness. Port with superior infrastructure can accommodate larger vessels, reduce turnaround times, and improve operational efficiency, thereby attracting shipping lines and cargo owners. Additionally, service digitalization, automation, and streamlined customs processes can enhance customer satisfaction and reliability, further reinforcing a port's market position. Pricing strategies should be carefully managed, as cost advantages alone do not sustain long-term competitiveness. Moreover, ports facing locational constraints should adapt by diversifying their logistics services or focusing on specialized cargo operations to maintain relevance in the evolving market.

While this study provides valuable insights, future research should focus on developing practical improvement strategies, incorporating emerging deep-water ports such as Lach Huyen International Gateway Port, Nam Dinh Vu Port, and Hai Phong International Container Terminal. They are expected to reshape the competitive landscape in Northern Vietnam. Furthermore, integrating additional evaluation methods, such as DEA (Data Envelopment Analysis) or AHP (Analytic Hierarchy Process), could provide a more comprehensive assessment.

Several limitations should also be acknowledged. First, the current study focuses only on ports in Northern Vietnam, which limits the generalizability of the findings. Comparative analyses with major ASEAN ports such as Singapore, Laem Chabang, or Tanjung Pelepas would offer broader regional perspectives. Second, while the Entropy-TOPSIS method provides objective weighting, it lacks sensitivity analysis due to the fixed nature of entropy-

derived weights. Future research could explore hybrid models, such as Entropy-CRITIC or fuzzy TOPSIS, to assess the robustness of results under varying data structures. Third, the evaluation criteria mainly reflect traditional port performance metrics. Incorporating modern indicators—such as automation levels, digital port management systems (TOS), and sustainability commitments - will help align future assessments with current global port development trends.

Ultimately, the results of this study serve as a strategic guide for port authorities, policymakers, and logistics stakeholders, ensuring data-driven decision-making in enhancing port efficiency, competitiveness, and long-term sustainability.

Declaration of competing interest and dedication to copyright

The authors declare the absence of any potential conflicts of interest from this study and affirm that the paper has not been previously published.

Data available

Data will not be provided upon request.

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