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Article

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Asian Journal of Shipping and Logistics (AJSL)

Provided in Cooperation with:

Korean Association of Shipping and Logistics, Seoul

Suggested Citation: Pham Thi Yen; Truong Ngoc Cuong; Phung Hung Nguyen; Kim, Hwan-Seong (2024) : The fuzzy MCDM for container terminal choice in Vietnam from shipping lines' perspective based on cumulative prospect theory, Asian Journal of Shipping and Logistics (AJSL), ISSN 2352-4871, Elsevier, Amsterdam, Vol. 40, Iss. 3, pp. 147-156, <https://doi.org/10.1016/j.ajsl.2024.06.003>

This Version is available at:

<https://hdl.handle.net/10419/329744>

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The fuzzy MCDM for container terminal choice in Vietnam from shipping lines' perspective based on cumulative prospect theory

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ARTICLE INFO

Keywords:

Multi-criteria decision-making (MCDM)
Analytic hierarchy process (AHP)
The technique for order of preference by
similarity to ideal solution (TOPSIS)
Container terminal competitiveness
Cumulative prospect theory (CPT)

ABSTRACT

This study aims to assess the container terminal choice from the perspective of shipping lines. The method incorporates the technique for order of preference by similarity to the ideal solution (TOPSIS) under fuzzy environmental conditions, the analytic hierarchy process (AHP), and cumulative prospect theory (CPT) to address the problem while accounting for both quantitative and qualitative criteria as well as the risk attitude of the decision-makers. This paper evaluates six container terminals in Vietnam as a case study to illustrate the feasibility of the proposed approach. A summary of the assessment of shipping lines shows that operational efficiency is the most crucial criterion for the terminal's choice; the Cat Lai terminal is considered the most appropriate terminal in Vietnam. In addition, prospect parameters have an impact on the best alternative. The findings could offer valuable insights for container terminal operators to enhance their competitiveness. Simultaneously, liner shipping companies stand to benefit by making informed and strategic decisions in their port selection processes.

1. Introduction

In recent times, competition between competing ports has intensified due to the tendencies of globalization and containerization (Pak et al., 2015). With the strong development of the container industry, the maritime industry is still playing an important role and attracting great attention from countries, territories, and shipping companies. Choosing a container terminal is a critical consideration for shipping lines aiming to optimize operational efficiency, fulfill customer requirements, and enhance market competitiveness.

Port selection is considered a key topic to enhance the container industry and is a complex multi-criteria decision process because port selection is influenced by many factors. The determination of criteria from the perspective of different subjects has been presented in many studies over the past decades. Surveyed objects include shipping lines (Wang et al., 2014; Pham & Yeo, 2019; Hsu et al., 2020), carriers (Chou, 2010), shippers (Nir et al., 2003), group experts (van Dyck & Ismael, 2015), or a combination of many of the above objects (Yeo et al., 2008; Aronietis et al., 2010; Lam & Dai, 2012; Yuen et al., 2012; Rosa Pires da Cruz et al., 2013; Nazemzadeh & Vaneslander, 2015; Ha et al., 2017; Phan et al., 2021). In fact, shipping lines are directly subject to port selection based on consideration of cargo flows, expectations of shippers

and forwarders, and consideration of internal and external factors to make decisions. Therefore, this study will focus on a container terminal selection from the perspective of shipping lines.

From the perspective of shipping lines, many scholars have used a combination of criteria for port selection. For example, Yeo et al. (2008) highlighted that Korean and Chinese regional shipping lines base their port selection on factors such as port service, hinterland condition, availability, convenience, logistics cost, regional centrality, and connectivity. Crucial elements in the decision-making process include hinterland-related components such as the size and activity of Free Trade Zones (FTZ), the effectiveness of the inland transport network, and the cost of inland transportation. Hsu et al. proposed four primary factors: port features, operating costs, cargo volume, and port management. They suggested that shipping companies need to give increased consideration to PCF (Port Connectivity Factors), which encompasses local cargo volume, transit cargo volume, domestic multimodal connection, and the balance between import and export goods (Hsu et al., 2020). Another study introduced by Sedat Baştug et al. (2022) emphasized the divergence in evaluating selection criteria between shipping lines and port operators. According to the findings, port location is identified as the foremost criterion for assessing competitiveness by port operators, whereas shipping lines prioritize operational

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<https://doi.org/10.1016/j.ajsl.2024.06.003>

Received 18 March 2024; Accepted 23 June 2024

Available online 3 July 2024

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efficiency as their primary consideration.

Broadly, studies indicated that significant criteria for port selection encompass various technical, infrastructure, economic, and environmental factors. These factors typically involve considerations such as port location, the quantity of wharves, cargo handling equipment, port dues, and service levels. However, a limited number of studies comprehensively integrate technical, economic, environmental, and social factors. Consequently, the port selection process should consider more comprehensive criteria than those previously explored. This paper proposes a more diverse and comprehensive set of primary criteria by dissecting component criteria derived from a synthesis of research history and expert opinions gathered during interviews.

Throughout the history of research, numerous scholars have made significant academic and practical contributions to helping ports worldwide comprehensively improve their capabilities, promoting the maritime industry to become increasingly large-scale, more modern, and associated with sustainable development issues. Case studies on container terminal selection are very active in Southeastern Asia, Korea (Yeo et al., 2008; Kim, 2016; Ha et al., 2017), China (Yeo et al., 2008; Yuen et al., 2012), West Africa (Gohomene et al., 2016; van Dyck & Ismael, 2015), Taiwan (Nir et al., 2003; Chou, 2010; Chou, Kuo et al., 2010; Hsu et al., 2020; Hsu et al., 2021), Australia (Ng et al., 2013), and North European ports (Nazemzadeh & Vanelslander, 2015; Pamucar & Görçün et al., 2022). However, few studies are related to container terminal selection in Vietnam. The Vietnamese government has emphasized the importance of Vietnam's seaports when affirming that the seaport system is the main pillar that plays a motivating, leading role in successfully developing the maritime economy, contributing to bringing Vietnam to become basically industrially developed, high-middle income country in the master plan of Vietnam's seaports by 2030 (Decision No. 886/QĐ-TTg of The Prime Minister 886 (2023)). Vietnam's seaport system has also achieved significant achievements in recent years, with 3 seaports among the top 100 largest container ports for cargo throughout, according to Lloyd (2023), including Hai Phong port, Ho Chi Minh City port, and Cai Mep port. Ho Chi Minh port was ranked 23rd, and Hai Phong port and Cai Mep port held 31st and 32nd positions, respectively. Competitive improvements in more efficient transport and logistics can be key to future productivity gains, propelling the Vietnamese economy to sustainable economic growth. Therefore, this paper evaluates the competitiveness of the top 6 Vietnamese container terminals, including Tan Vu, Tan Cang Hai Phong International Container Terminal (HICT, 2023) in Hai Phong seaport, Cat Lai Terminal represent Ho Chi Minh seaports and Tan Cang – Cai Mep International Terminal (TCIT), SP-SSA International Terminal (SSIT) and Cai Mep International Terminal (CMIT) in Cai Mep port system.

Multi-criteria decision-making (MCDM) is an effective method to solve complex problems and is also used in container terminal selection such as Data Envelopment Analysis (DEA) (Nguyen & Kim, 2015; Nguyen et al., 2016; Kuo et al., 2020), AHP (Song & Yeo, 2004; Chou, 2015; Gohomene et al., 2015; Nazemzadeh & Vanelslander, 2015; van Dyck & Ismael, 2015), Fuzzy Analytic Hierarchy Process (FAHP), Fuzzy LBWA and fuzzy CoCoSo'B techniques (Pamucar & Görçün, 2022), Exploratory Factor Analysis (EFA) (Hsu et al., 2020; Le et al., 2020), a hybrid Fuzzy-Delphi–TOPSIS (Wang et al., 2014), Consistent Fuzzy Preference Relation (CFPR) (Pham & Yeo, 2019). Some researchers proposed using Data Envelopment Analysis (DEA) to study the competitiveness of Vietnamese seaports (Nguyen & Kim, 2015; Nguyen et al., 2016; Kuo et al., 2020). The DEA technique is solely designed for assessing effectiveness, providing evaluations of either effectiveness or ineffectiveness. Notably, it does not consider the decision-makers' preferences in the evaluation process and overlooks uncertainties in the data (Omran et al., 2021). As a result, the capability of this technique to compare alternative decisions is limited (Pamucar & Görçün, 2022).

The TOPSIS technique is a well-known MCDM approach established by Hwang et al. (1981) and was widely applied in port selection (Wang et al., 2014; Nguyen & Kim, 2015; Nguyen et al., 2016; Pham & Yeo,

2019; Kuo et al., 2020). The traditional TOPSIS method operates under the assumption that the decision-makers are totally rational. These papers frequently integrate numerous criteria encompassing qualitative and quantitative factors, yet their applicability to most practical decision-making problems is limited. Fuzzy-based methods excel in quantifying the ambiguity inherent in decision-maker assessments, thereby improving subjective evaluations in terminal selection. However, it lacks a mechanism to dynamically capture the variations in judgments among different decision-makers (Fang et al., 2018). Kahneman and Tversky (1992) formulated prospect theory, revealing that human judgments and decisions often depart from the expectations of the rational choice model. Therefore, this paper fills the research gap by evaluating the competitiveness of the top six Vietnamese container terminals with the largest throughput in 2022 from the shipping lines' perspective based on a combination of qualitative and quantitative criteria using the AHP method and the fuzzy TOPSIS method based on cumulative prospect theory to consider the decision-makers' bias.

This paper is organized as follows: Section 2 is presented by summarizing the combined method of AHP, Fuzzy TOPSIS, and CPT to select container terminals. A case study in Vietnam will be presented in Section 3. Finally, some important discussion and conclusions are presented in Section 4.

2. Methodology

The procedures for identifying the optimal alternative are given in this section (Wu et al., 2018). This process integrates the analytic hierarchy process (AHP) method, the fuzzy TOPSIS, and cumulative prospect theory. The decision framework and detailed steps are illustrated in Fig. 1 below:

2.1. Initial data

2.1.1. Data collection

The nine main criteria and twenty-seven sub-criteria are selected from the literature review and expert survey on container terminal selection from the perspective of shipping lines, including port infrastructure and capacity, geographical location and connectivity, port costs and tariffs, quality and reputation, operational efficiency, port safety and security, port information system, port ownership, and corporate social responsibility. Studies spanning two decades were selected. Table 1 shows the criteria selected for this study.

The input data types for evaluation are classified into quantitative and qualitative values. Quantitative criteria related to container terminals, such as port infrastructure, port costs, and tariffs, are compiled from public data on the official terminals' websites. Other qualitative criteria are expressed by linguistics values that were obtained from expert interviews, including seven levels: very poor, poor, medium poor, fair, medium good, good, and very good. Experts were invited to evaluate the level of implementation of each criterion at each container terminal and compare the weights between pairs of criteria. Calculating the weight of each criterion and sub-criteria follows the AHP method developed by Saaty (1990). This paper uses a scale from one to nine to compare criteria; the linguistics scale is defined in Table 2. The respondents could express their preferences between every two criteria and translate these preferences into numerical ratings of 1, 3, 5, 7, and 9 and 2, 4, 6, and 8 as intermediate values.

After the weight of criteria and sub-criteria y are determined, the subsequent phase involves performing a consistency assessment to ascertain the comparisons' reasonableness. Therefore, only responses with a Consistency Index (CI) and a Consistent Ratio (CR) below 10 % were selected to compute the important weight of the elements. In addition, alternatives are also evaluated by this group of experts. Assume that the decision-maker group includes k experts ($D_t, t = 1, 2, \dots, k$) that have responsibility for assessment m alternative ($A_i, i = 1, 2, \dots, m$) based on n performances ($C_j, j = 1, 2, \dots, n$). A multi-criteria decision-

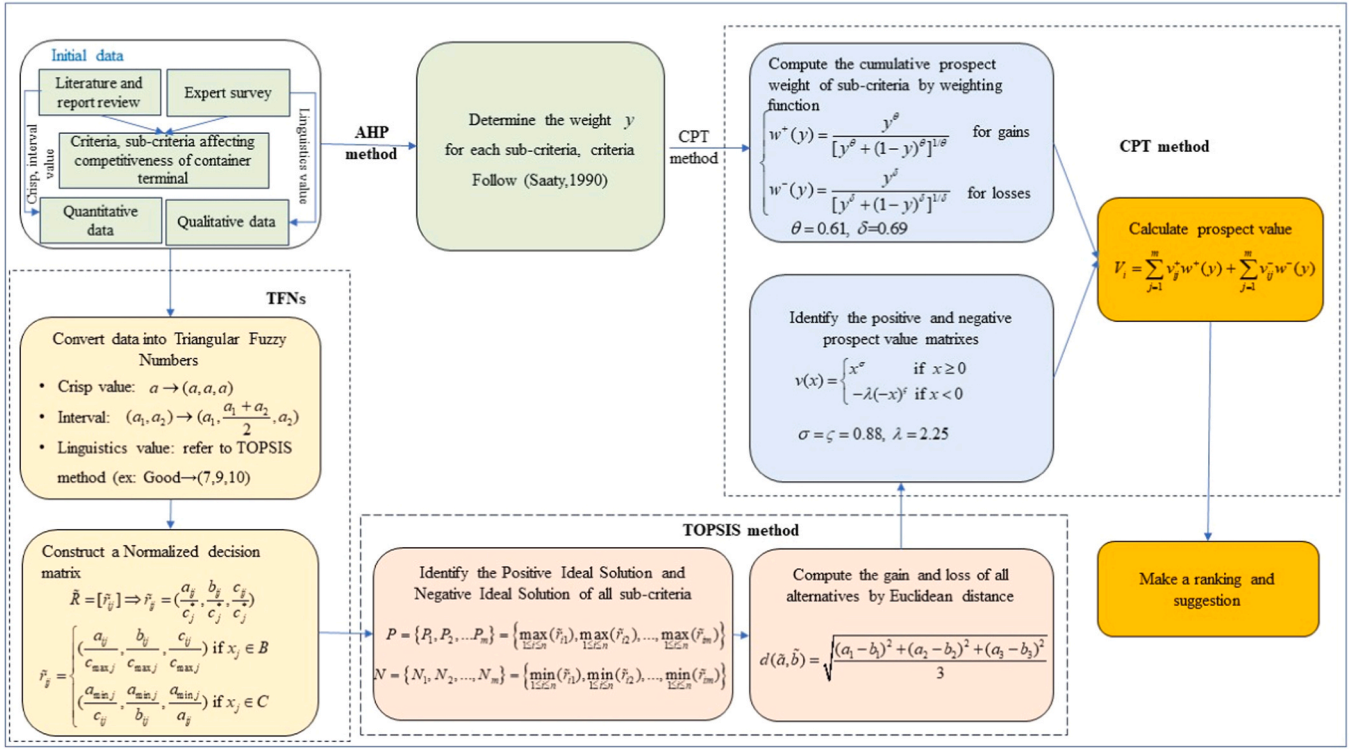


Fig. 1. Flow chart for the proposed hybrid method.

making can be expressed in the following matrix (Chen, 2000).

$$D_t = \begin{matrix} & C_1 & C_2 & \dots & C_n \\ \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} & \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \end{matrix} \quad (1)$$

Where

$$x_{ij} = \frac{1}{k} (x_{ij}^1 + x_{ij}^2 + \dots + x_{ij}^k) \quad (2)$$

x_{ij} is the average point value of A_i corresponding to C_j is evaluated.

2.1.2. Data transformation

Because of the ambiguous decision-making environment, data is transformed using triangular fuzzy numbers (TFNs). The following techniques can be used to convert the three representations into TFNs. The crisp value is a unique TFN that can degenerate into a specific crisp value when all three TFN parameters are equal. If a is called a crisp value, then the triangular fuzzy number is generalized by (a, a, a) (Wu et al., 2018). For the case of interval values case, the TFN is obtained by determining the average of the upper and lower bound values. Consider (a_1, a_2) as a known interval value, then the TFN is determined as $(a_1, \frac{a_1+a_2}{2}, a_2)$ (Wu et al., 2018). Transformation of the linguistic value to the TFN is followed by the rules illustrated in Table 3.

In order to remove data redundancy, maintain atomicity, and remove data inconsistency in the database table, a normalization approach is useful and will be used in the next step.

2.2. Construct a normalized decision matrix

Criteria are divided into a subset of benefit criteria (B) and a subset of cost criteria (C). While the cost criterion suggests that a lower value is

better, the benefit criterion suggests a higher value. Assume $r_{ij} = (a_{ij}, b_{ij}, c_{ij})$ is the performance of alternative ion criteria j . The linear scale transformation is used to obtain a normalized fuzzy decision matrix

denoted by \tilde{R} , and $\tilde{R} = [\tilde{r}_{ij}] \Rightarrow \tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^+}, \frac{b_{ij}}{c_j^+}, \frac{c_{ij}}{c_j^+} \right)$ and

$$\tilde{r}_{ij} = \begin{cases} \left(\frac{a_{ij}}{c_{\max j}}, \frac{b_{ij}}{c_{\max j}}, \frac{c_{ij}}{c_{\max j}} \right) & \text{if } x_j \in B \\ \left(\frac{a_{\min j}}{c_{ij}}, \frac{a_{\min j}}{b_{ij}}, \frac{a_{\min j}}{a_{ij}} \right) & \text{if } x_j \in C \end{cases} \quad (3)$$

Where $c_{\max j} = \max\{c_{ij} | i = 1, 2, 3, \dots, m\}$, $a_{\min j} = \min\{c_{ij} | i = 1, 2, \dots, m\}$. B , C are the subsets of benefit criteria and cost criteria, respectively.

2.3. Identify the positive and negative ideal solutions of all sub-criteria using the TOPSIS method

This paper uses the positive ideal solution (PIS) and the negative ideal solution (NIS) as benchmarks for describing how decision-makers perceive risks. When the reference point is PIS, decision-makers tend to exhibit risk-seeking behavior as they face potential losses. Conversely, decision-makers tend to lean towards risk aversion when the reference point is NIS due to the potential benefits involved. The PIS and NIS of all alternatives under each sub-criterion are determined as

$$P = \{P_1, P_2, \dots, P_m\} = \left\{ \max_{1 \leq i \leq n} (\tilde{r}_{i1}), \max_{1 \leq i \leq n} (\tilde{r}_{i2}), \dots, \max_{1 \leq i \leq n} (\tilde{r}_{im}) \right\} \quad (4)$$

$$N = \{N_1, N_2, \dots, N_m\} = \left\{ \min_{1 \leq i \leq n} (\tilde{r}_{i1}), \min_{1 \leq i \leq n} (\tilde{r}_{i2}), \dots, \min_{1 \leq i \leq n} (\tilde{r}_{im}) \right\} \quad (5)$$

Let $\tilde{A}_1 = (a_1, b_1, c_1)$ and $\tilde{A}_2 = (a_2, b_2, c_2)$ be two TFNs. The gain and loss values can be depicted by the distance between alternative and NIS and PIS by the Euclidean distance between two TFNs is represented in Eq. (6) (Manakandan et al., 2017; Wu et al., 2018).

Table 1
Criteria and sub-criteria for assessment.

Criteria		Sub-criteria and sources		Sources
C1	Port Infrastructure and Capacity	C11	Number of berths	(Chou, 2010; Pham & Yeo, 2019)
		C12	Depth alongside	(Chou, 2010; Yeo et al., 2014; van Dyck & Ismael, 2015; Pham & Yeo, 2019)
		C13	Length of berth	(van Dyck & Ismael, 2015; Pham & Yeo, 2019)
		C14	Storage of space	(De Martino & Morvillo, 2008; Chou, 2010; van Dyck & Ismael, 2015; Thai, 2016)
		C15	Number of equipment	(Murphy & Daley, 1994; Chou, Kuo et al., 2010; Chou, 2010)
C2	Geographical location and connectivity	C21	Land distance and connectivity to major shippers	(Yeo et al., 2014; Nazemzadeh & Vanelislander, 2015; Parola et al., 2017; Kaliszewski et al., 2020)
		C22	Hinterland proximity	(Yuen et al., 2012; Kim, 2014; Nazemzadeh & Vanelislander, 2015; van Dyck & Ismael, 2015; Parola et al., 2017)
		C23	Efficient inland transport network	(Yeo et al., 2014; Nazemzadeh & Vanelislander, 2015; Pham & Yeo, 2019; Hsu et al., 2021;)
		C24	Maritime connectivity	(Tongzon, 2009; van Dyck & Ismael, 2015; Kaliszewski et al., 2020)
C3	Port cost and tariffs	C31	Port authority charges (berth dues, tug boat fees, navigation dues)	(Chou, 2010; Nazemzadeh & Vanelislander, 2015; Hsu et al., 2021; Yeo et al., 2014; Kaliszewski et al., 2020)
		C32	Handling charges	(Chou, 2010; Nazemzadeh & Vanelislander, 2015; van Dyck & Ismael, 2015; Pham & Yeo, 2019)
		C33	Pricing strategies, rebates, and financial incentives	(Kaliszewski et al., 2020; Hsu et al., 2021;)
C4	Quality and reputation	C41	24/7 service	(Yeo et al., 2014)
		C42	Waiting time	(Yeo et al., 2014; Nazemzadeh & Vanelislander, 2015; van Dyck & Ismael, 2015)
		C43	Professional and skilled labors in port operation	(Yeo et al., 2014)
C5	Operational efficiency	C51	Congestion	(Tiwari et al., 2003; Yeo et al., 2014; Pham & Yeo, 2019)
		C52	Flexible operation process	Experts survey.
		C53	Stability of terminal's labor (no strikes, conflicts, and others)	(van Dyck & Ismael, 2015; Kaliszewski et al., 2020)
C6	Port safety and security	C61	Port safety	(Chou, 2010; van Dyck & Ismael, 2015; Ha et al., 2017; Kannika et al., 2019)
		C62	Port security	(van Dyck & Ismael, 2015; Ha et al., 2017;)
C7	Port information system	C71	Electronic information availability	(Yeo et al., 2014; Ha et al., 2017; Pham &

Table 1 (continued)

Criteria		Sub-criteria and sources		Sources
		C72	Electronic information accessibility	(Yeo, 2019; Kaliszewski et al., 2020)
C8	Port ownership	C81	Private ownership of a terminal	(Yeo et al., 2014; Ha et al., 2017; Pham & Yeo, 2019; Kaliszewski et al., 2020)
		C82	Private ownership of a terminal by shipping lines	(van Dyck & Ismael, 2015; Kaliszewski et al., 2020; Baştuğ et al., 2022)
C9	Corporate Social responsibility	C91	Business ethics	(van Dyck & Ismael, 2015; Kaliszewski et al., 2020; Baştuğ et al., 2022)
		C92	Respect of the natural environment	(Kaliszewski et al., 2020)
		C93	Involvement with local communities	(Kaliszewski et al., 2020)

Table 2
The ratio scale and definition of AHP (Saaty, 1990).

Symbol	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extremely strong importance
2,4,6,8	Intermediate values

Table 3
Linguistic value for the rating of all alternative.

Symbol	Definition	Scale of triangular fuzzy number
VP	Very Poor	(0, 0, 1)
P	Poor	(0, 1, 3)
MP	Medium Poor	(1, 3, 5)
F	Fair	(3, 5, 7)
MG	Medium Good	(5, 7, 9)
G	Good	(7, 9, 10)
VG	Very Good	(9, 10, 10)

$$d\left(\tilde{a}, \tilde{b}\right)=\sqrt{\frac{\left(a_1-b_1\right)^2+\left(a_2-b_2\right)^2+\left(a_3-b_3\right)^2}{3}} \quad (6)$$

This paper uses the averaging operator as a defuzzification method to convert a triangular fuzzy number into a crisp value (Ezhilarasan Natarajan et al., 2023). It is necessary step to facilitate comparison and make recommendations for each criterion between alternatives. Hence, the defuzzification of \tilde{A}_1 be determined as Eq. (7).

$$d^f\left(\tilde{A}_1\right)=\frac{a_1+a_2+a_3}{3} \quad (7)$$

2.4. Analytic by Cumulative Prospect Theory Method

To explain how people make decisions in uncertain circumstances, Tversky and Kahneman (1992) proposed the cumulative prospect theory, which is the more extensive version of prospect theory. The weighting function of probability is a crucial part of prospect theory, and they are divided into weighting functions for gains and losses, respectively by Eq. (8).

$$\begin{cases} w^+(y) = \frac{y^\theta}{[y^\theta + (1-y)^\theta]^{1/\theta}} \\ w^-(y) = \frac{y^\delta}{[y^\delta + (1-y)^\delta]^{1/\delta}} \end{cases} \quad (8)$$

where $\theta = 0.61, \delta = 0.69$ the parameters reflect decision-makers' attitudes to risk (Tversky & Kahneman, 1992). In this step, positive and negative prospect value matrixes are determined by value function as illustrated in Eq. (9).

$$v(x) = \begin{cases} x^\sigma \text{ if } x \geq 0 \\ -\lambda(-x)^\zeta \text{ if } x < 0 \end{cases} \quad (9)$$

Where x denotes the gains or losses; $x \geq 0$ represents the gains and $x < 0$ represents the losses. Exponential parameters σ, ζ related to gains and losses, respectively satisfy the condition $0 \leq \sigma \leq \zeta \leq 1$. The risk aversion degree represents the characteristic of steeper for losses than gains, and $\lambda > 1$. Generally, $\sigma = \zeta = 0.88, \lambda = 2.25$ (Tversky & Kahneman, 1992). The cumulative prospect theory values can be deducted as Eq. (10).

$$V_i = \sum_{j=1}^m v_{ij}^+ w^+(y) + \sum_{j=1}^m v_{ij}^- w^-(y) \quad (10)$$

3. A case study in Vietnam

3.1. Survey design

Interviews are conducted, and a pre-designed survey is sent to interview respondents at the same time. The survey period is from August 12th to December 15th, 2023. Instructions and interviews are conducted through face-to-face meetings and calls via the popular social media platforms and applications in Vietnam: zalo and Google Meet. Although the survey has been translated into English and Vietnamese for the convenience of experts, calls are conducted to guide and ensure respondents will understand more clearly as well as ensure consistency when conducting assessments. The survey forms were sent to managers of shipping lines in Vietnam. The shipping lines were conducted survey consisting of domestic as well as worldwide shipping companies: GLS, Vosco, TS. Line, Yangming, Bien Dong shipping lines, Gemandep, Saigon Newport shipping company, Hai An container transportation, Evergreen, Namsung, ONE, etc. Fifteen experts who participated in this survey are vice directors, section managers, and department managers with more than seven years of working in shipping lines to ensure that they have enough knowledge and experience in the shipping industry and understand the current container terminals in Vietnam. Detailed information about respondents is summarized in Table 4.

Following the steps of the AHP method, the importance weights of the criteria under the evaluation of shipping lines are presented in

Table 4
Respondent's profile.

Characteristics	Range	N	%
Type of company	Shipping lines/ Agent	15	100
Size of company (number of employees in Vietnam)	Under 100 employees	0	0
	Upper 100 employees	15	100
Position in company	Director/ Vice director	2	13.3
	Department manager	13	86.7
Years of experience	5-10	4	26.7
	10-15	6	40
	15-20	3	20
	Upper 20 years	2	13.3

Table 5.

Table 5 shows the important weight of all criteria under liner shipping companies' judgment. For the first level hierarchy, the most important criterion was operational efficiency, followed by port safety and security, geographical location, port infrastructure, quality and reputation, port information system port ownership, and corporate social responsibility. The flexible operation process was considered the most important criterion at the sub-hierarchy level. Four other criteria, including port security, port safety, stability of terminal labor, electronic information availability, and maritime connectivity, were the top five most influential factors in shipping companies' decision to choose a container terminal. Three factors that had the least influence were respect of the natural environment, storage space, and involvement with local communities.

3.2. Performance evaluation of six container terminals

Data on objective factors is shown in Table 6, including the number of berths, length of berths, storage space, and port authority charge (berth dues), handling charges (for 20'empty, handling charges for 40'laden) were collected from the official websites of Tan Vu terminal (Tan Vu terminal, 2023), HICT (Hai Phong Port, 2023), Cat Lai (Cat Lai Port, 2023), CMIT (Cai Mep International Terminal, 2023), SSIT (SP-SSA International Terminal, 2023), and Tan Cang - Cai Mep International Terminal (2023)), and the support of sales departments and operations departments of container terminals. This study uses container throughput as a reference indicator for terminals' ability to connect with major shippers (Vietnam Seaports Association, 2022); Liner Shipping Connectivity Index (LSCI) data collected from the first quarter of 2021 to the third quarter of 2022 was used to assess maritime connectivity (United Nations Conference on Trade and Development, 2022), congestion (The World Bank, 2014), efficient inland transport network by number of transport mode for all alternative include road and inland waterway (Pham & Yeo, 2019). The remaining data were collected through a survey. Following the conversion to numbers TFNs, fuzzy TOPSIS, and normalization rules, Table 7 shows the fuzzy decision matrix, and the normalized fuzzy decision matrix is presented in Table 8 below.

The score of sub-criteria of all alternatives be shown in Table 9. Results show that Cat Lai terminal leads in competitiveness in criteria such as the number of berths, storage space, number of equipment, land distance and connection with major shippers, port cost, and tariffs. In addition, Cat Lai terminal was also highly appreciated for 24/7 service, professional and skilled labor in port operation, electronic information availability and accessibility, and business ethics. Cat Lai terminal has emerged as the port with the largest throughput nationwide for many consecutive years with large investments in infrastructure facilities. With the advantage of being located in Ho Chi Minh, the largest economic center in Vietnam, about 20 industrial zones have been developed to operate in various fields and industries, in addition to being located near southern industrial parks such as Truong Tho complex, Phung Long ICD 3, Tay Nam, Transimec, Sotrans, Phuc Long Port and convenient transportation to key economic regions of the country. However, according to the proposed calculations, maritime connection and length of berth were the least competitive criteria of Cat Lai port. If these criteria can be improved, competitiveness can be enhanced. The results of expert interviews show that shipping lines still prioritize choosing Cat Lai terminal instead of neighboring terminals because of the flexibility in organizing professional operations and customs work.

Terminals in the South were highly appreciated for their competitiveness in criteria such as respect for the natural environment, involvement with local communication, port information system, port safety, and security. Three ports in Vung Tau, including TCIT, SSIT, and CMIT, recorded better control of waiting times as well as port congestion. The two Northern terminals have advantages in terms of length of berth and more competitive port tariffs, but their pricing policies are less

Table 5

Importance weight of the competitiveness for container terminals from shipping lines' perspective.

Upper Hierarchy		Sub-Hierarchy						
Criteria	Rank	Sub-criteria	Weight	Priority	Global weight	Rank	$w^+(y)$	$w^-(y)$
Weight								
C1 (0.123)	4	C11	0.181	3	0.022	21	0.089	0.067
		C12	0.335	1	0.041	9	0.125	0.099
		C13	0.242	2	0.030	15	0.105	0.080
		C14	0.072	5	0.009	26	0.053	0.036
		C15	0.171	4	0.021	23	0.087	0.064
C2 (0.128)	3	C21	0.231	2	0.030	16	0.105	0.080
		C22	0.190	4	0.024	20	0.094	0.071
		C23	0.206	3	0.026	18	0.099	0.075
		C24	0.373	1	0.048	6	0.136	0.108
C3 (0.078)	7	C31	0.281	2	0.022	22	0.089	0.066
		C32	0.239	3	0.019	24	0.081	0.060
		C33	0.480	1	0.037	11	0.119	0.093
C4 (0.100)	5	C41	0.348	2	0.035	13	0.115	0.089
		C42	0.244	3	0.025	19	0.095	0.071
		C43	0.407	1	0.041	10	0.125	0.098
C5 (0.188)	1	C51	0.146	3	0.027	17	0.101	0.076
		C52	0.544	1	0.102	1	0.201	0.172
		C53	0.311	2	0.058	4	0.151	0.123
C6 (0.152)	2	C61	0.483	2	0.073	3	0.170	0.141
		C62	0.517	1	0.078	2	0.176	0.147
C7 (0.098)	6	C71	0.528	1	0.052	5	0.142	0.114
		C72	0.472	2	0.046	7	0.134	0.106
C8 (0.078)	8	C81	0.59	1	0.046	8	0.133	0.105
		C82	0.41	2	0.032	14	0.109	0.084
C9 (0.056)	9	C91	0.65	1	0.036	12	0.117	0.091
		C92	0.221	2	0.012	25	0.064	0.045
		C93	0.129	3	0.007	27	0.047	0.032
Total			1.000		1.000			

Table 6

Data for objective factors.

Factors	Unit	Tan Vu	HICT	Cat Lai	CMIT	SSIT	TCIT
Number of berths		5	8	9	3	2	3
Depth alongside	m	9.4	16.0	12.5	16.5	16.5	16.8
Length of berth	m	980.6	750	216	600	600	890
Storage space	ha	51	41	62	48	60	55
Number of equipment	Crane	4	8	10	5	4	10
Connectivity to major shipper	10 ⁶ TEU	1.37	1.181	5.482	0.7974	0.7025	0.5341
Port authority charge (berth dues)	USD/GT/hour	15	15	15	16.2	16.5	15
Handling charges for 20'empty	10 ³ VND/time	218	218	218	227	239.8	218
Handling charges for 40'laden	10 ³ VND/time	627	627	627	670	689.7	627
Waiting time	Day	7.3	8.2	5.3	3.5	4.0	3.5

flexible. In addition, Northern terminals can improve their operational flexibility as well as their responsibility to participate in local activities to improve their competitiveness. Shipping lines believe that although the degree of partial ownership by other influential shipping lines does not account for a high proportion of their port selection decisions if the remaining conditions are the same, a shipping line will be given equal priority if the terminal is private ownership by terminal because the terminal gives priority to its members first.

Follow the steps of decision framework presented in the above sections, each alternative's cumulative prospect values are computed and are shown in Table 10.

The results show that Cat Lai terminal held the highest competitiveness, followed by TCIT, SSIT, CMIT, HICT, and Tan Vu. Interestingly, the priority order in choosing container terminals was ranked by region. Cat Lai terminal is located in Ho Chi Minh port was ranked as the first best choice, the next preference port group along the Cai Mep Thi Vai River, and the last priority were two terminals located in Northern Vietnam.

3.3. Comparison analysis with existing methods

To clarify the influence of risk attitude on decision-makers in multi-criteria decision-making, the ranking results of the integrated AHP method and Fuzzy TOPSIS based on CPT are compared with two traditional methods. The others are fuzzy SAW and CODAS. Scores of CODAS and SAW methods are shown in Table 11.

The specific calculation steps of the SAW and CODAS methods are referred to in (Fishburn, 1967; Keshavarz Ghorabae et al., 2016). The ranking results are calculated and shown in Fig. 2 below.

Fig. 2 shows that the methods share the same optimal alternative, but the ranking orders are not entirely consistent. In the approach from the fuzzy SAW method, the ranking order is Cat Lai > HICT > TCIT > CMIT > SSIT > Tan Vu. The CODAS method's output ranking order is Cat Lai > HICT > TCIT > Tan Vu > CMIT > SSIT. From the results of comparing the integrated method between AHP, fuzzy TOPSIS, and CPT with two classical methods, fuzzy SAW and CODAS, it can be concluded that the methods have a positive correlation with each other. The correlation level between the proposed method and SAW is higher at 0.6, and with CODAS, it is 0.314. Compared with SAW, we can see that there are three priority positions, first, fourth, and sixth, which are homogeneous.

Table 7

Fuzzy decision matrix.

Criterion	TAN VU	HICT	CAT LAI	CMIT	SSIT	TCIT
C11	(5,5,5)	(8,8,8)	(9,9,9)	(3,3,3)	(2,2,2)	(3,3,3)
C12	(9.4,9.4,9.4)	(16,16,16)	(12.5,12.5,12.5)	(16.5,16.5,16.5)	(16.5,16.5,16.5)	(16.8,16.8,16.8)
C13	(980.6980.6,980.6)	(750,750,750)	(216,216,216)	(600,600,600)	(600,600,600)	(890,890,890)
C14	(51,51,51)	(41,41,41)	(62,62,62)	(48,48,48)	(60,60,60)	(890,890,890)
C15	(4,4,4)	(8,8,8)	(10,10,10)	(5,5,5)	(4,4,4)	(10,10,10)
C21	(1.37,1.37,1.37)	(1.18,1.18,1.18)	(5.49,5.49,5.49)	(0.797,0.797,0.797)	(0.703,0.703,0.703)	(0.54,0.54,0.54)
C22	(12,12,12)	(17,17,17)	(12.6,12.6,12.6)	(8.7,8.7,8.7)	(9.7,9.7,9.7)	(4.8,4.8,4.8)
C23	(2,2,2)	(2,2,2)	(2,2,2)	(2,2,2)	(2,2,2)	(2,2,2)
C24	(46.75,46.75,46.75)	(46.75,46.75,46.75)	(40.29,40.29,40.29)	(56.09,56.09,56.09)	(56.09,56.09,56.09)	(56.09,56.09,56.09)
C31	(15,15,15)	(15,15,15)	(15,15,15)	(16.2,16.2,16.2)	(16.5,16.5,16.5)	(15,15,15)
C32	(218,422.5627)	(218,422.5627)	(218,422.5627)	(227,448.5670)	(239.8464.75,689.7)	(218,423,627)
C33	(2.33,4.33,6.27)	(3.93,5.93,7.73)	(3.53,5.53,7.27)	(4.33,6.27,8.07)	(3.8,5.8,7.67)	(4.47,6.33,8)
C41	(4.33,6.33,8.13)	(5.67,7.67,9.13)	(6.33,8.33,9.6)	(6.07,8.07,9.47)	(5.8,7.8,9.33)	(5.4,7.33,8.87)
C42	(7.3,7.3,7.3)	(8.2,8.2,8.2)	(5.3,5.3,5.3)	(3.5,3.5,3.5)	(4,4,4)	(3.5,3.5,3.5)
C43	(5.93,7.93,9.27)	(6.6,8.6,9.73)	(7.8,9.3,9.93)	(6.73,8.67,9.73)	(6.6,8.6,9.73)	(6.73,8.67,9.8)
C51	(6.6,6.6,6.6)	(6.6,6.6,6.6)	(6.6,6.6,6.6)	(7.9,7.9,7.9)	(7.9,7.9,7.9)	(7.9,7.9,7.9)
C52	(5,7,8.73)	(5.67,7.67,9.13)	(6.6,8.47,9.53)	(6.2,8.2,9.6)	(5.93,9.73,9.47)	(6.6,8.6,9.8)
C53	(6.73,8.73,9.87)	(6.33,8.33,9.53)	(6.87,8.73,9.73)	(6.87,8.8,9.8)	(6.73,8.73,9.87)	(6.87,8.87,9.93)
C61	(6.33,8.33,9.67)	(6.73,8.73,9.2)	(7.8,8.9,8)	(7.13,9.07,10)	(6.6,8.6,9.8)	(7.13,9.07,10)
C62	(7.4,9.2,10)	(7.53,9.13,9.8)	(7.93,9.47,10)	(7.8,9.4,10)	(7.67,9.33,10)	(8.2,9.6,10)
C71	(4.87,6.87,8.67)	(5.53,7.53,9.13)	(6.6,8.53,9.67)	(6.47,8.4,9.67)	(5.67,7.67,9.2)	(6.47,8.4,9.07)
C72	(5.13,7.13,9)	(5.4,7.4,9)	(6.47,8.4,9.53)	(5.93,7.87,9.4)	(5.53,7.53,9.07)	(5.93,7.87,9.27)
C81	(9,9,9)	(9,9,9)	(9,9,9)	(7,7,7)	(7,7,7)	(6,6,6)
C82	(1,1,1)	(1,1,1)	(1,1,1)	(3,3,3)	(3,3,3)	(4,4,4)
C91	(6.6,8.6,9.73)	(6.47,8.47,9.6)	(7.27,9.13,10)	(6.87,8.87,9.93)	(7,9,10)	(7.13,9.07,10)
C92	(4.73,6.73,8.47)	(5.53,7.53,9.13)	(6.07,8.9,47)	(6.2,8.2,9.6)	(6.07,8.07,9.47)	(6.33,8.27,9.6)
C93	(6.07,8.07,9.47)	(6.47,8.47,9.67)	(7.27,9.13,10)	(7,9,10)	(7,9,10)	(7.27,9.13,10)

Table 8

Normalized fuzzy decision matrix.

Criterion	TAN VU	HICT	CAT LAI	CMIT	SSIT	TCIT
C11	(0.56,0.56,0.56)	(0.89,0.89,0.89)	(1,1,1)	(0.33,0.33,0.33)	(0.22,0.22,0.22)	(0.33,0.33,0.33)
C12	(0.56,0.56,0.56)	(0.95,0.95,0.95)	(0.74,0.74,0.74)	(0.98,0.98,0.98)	(0.98,0.98,0.98)	(1,1,1)
C13	(1,1,1)	(0.76,0.76,0.76)	(0.22,0.22,0.22)	(0.61,0.61,0.61)	(0.61,0.61,0.61)	(0.91,0.91,0.91)
C14	(0.82,0.82,0.82)	(0.66,0.66,0.66)	(1,1,1)	(0.77,0.77,0.77)	(0.97,0.97,0.97)	(0.89,0.89,0.89)
C15	(0.4,0.4,0.4)	(0.8,0.8,0.8)	(1,1,1)	(0.5,0.5,0.5)	(0.4,0.4,0.4)	(1,1,1)
C21	(0.25,0.25,0.25)	(0.22,0.22,0.22)	(1,1,1)	(0.15,0.15,0.15)	(0.13,0.13,0.13)	(0.1,0.1,0.1)
C22	(0.4,0.4,0.4)	(0.28,0.28,0.28)	(0.38,0.38,0.38)	(0.55,0.55,0.55)	(0.49,0.49,0.49)	(1,1,1)
C23	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)
C24	(0.83,0.83,0.83)	(0.83,0.83,0.83)	(0.72,0.72,0.72)	(1,1,1)	(1,1,1)	(1,1,1)
C31	(1,1,1)	(1,1,1)	(1,1,1)	(0.93,0.93,0.93)	(0.91,0.91,0.91)	(1,1,1)
C32	(0.35,0.52,1.00)	(0.35,0.52,1.00)	(0.35,0.52,1.00)	(0.33,0.49,0.96)	(0.32,0.47,0.91)	(0.35,0.52,0.1)
C33	(0.29,0.54,0.78)	(0.49,0.74,0.96)	(0.44,0.69,0.9)	(0.54,0.78,1)	(0.47,0.72,0.95)	(0.55,0.79,0.99)
C41	(0.45,0.66,0.85)	(0.59,0.8,0.95)	(0.66,0.87,1)	(0.63,0.84,0.99)	(0.6,0.81,0.97)	(0.56,0.76,0.92)
C42	(0.48,0.48,0.48)	(0.43,0.43,0.43)	(0.66,0.66,0.66)	(1,1,1)	(0.88,0.88,0.88)	(1,1,1)
C43	(0.6,0.8,0.93)	(0.66,0.87,0.98)	(0.7,0.9,1.0)	(0.68,0.87,0.98)	(0.66,0.87,0.98)	(0.68,0.87,0.99)
C51	(0.84,0.84,0.84)	(0.84,0.84,0.84)	(0.84,0.84,0.84)	(1,1,1)	(1,1,1)	(1,1,1)
C52	(0.51,0.71,0.89)	(0.58,0.78,0.93)	(0.67,0.86,0.97)	(0.63,0.84,0.98)	(0.61,0.81,0.97)	(0.67,0.88,1.00)
C53	(0.68,0.88,0.99)	(0.64,0.84,0.96)	(0.69,0.88,0.98)	(0.69,0.89,0.99)	(0.68,0.88,0.99)	(0.69,0.89,1.00)
C61	(0.63,0.83,0.97)	(0.67,0.87,0.92)	(0.7,0.88,0.98)	(0.71,0.91,1.00)	(0.66,0.86,0.98)	(0.71,0.91,1.0)
C62	(0.74,0.92,1)	(0.75,0.91,0.98)	(0.79,0.95,1)	(0.78,0.94,1)	(0.77,0.93,1)	(0.82,0.96,1)
C71	(0.5,0.71,0.9)	(0.57,0.78,0.94)	(0.68,0.88,1)	(0.67,0.87,1)	(0.59,0.79,0.95)	(0.67,0.87,0.94)
C72	(0.54,0.75,0.94)	(0.57,0.78,0.94)	(0.68,0.88,1)	(0.62,0.83,0.99)	(0.58,0.79,0.95)	(0.62,0.83,0.97)
C81	(1,1,1)	(1,1,1)	(1,1,1)	(0.78,0.78,0.78)	(0.78,0.78,0.78)	(0.67,0.67,0.67)
C82	(1,1,1)	(1,1,1)	(1,1,1)	(0.33,0.33,0.33)	(0.33,0.33,0.33)	(0.25,0.25,0.25)
C91	(0.66,0.86,0.97)	(0.65,0.85,0.96)	(0.73,0.91,1)	(0.69,0.89,0.99)	(0.7,0.9,1)	(0.71,0.91,1)
C92	(0.49,0.7,0.88)	(0.58,0.78,0.95)	(0.63,0.86,0.99)	(0.65,0.85,1)	(0.63,0.84,0.99)	(0.66,0.86,1)
C93	(0.61,0.81,0.95)	(0.65,0.85,0.97)	(0.73,0.91,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.73,0.91,1)

Although, the SAW and CODAS methods achieve a fairly high correlation level of up to 0.83, they are limited because these methods assume that decision-makers are rational, opposite to the reality that the decision process is complex. Therefore, fuzzy SAW and CODAS methods do not comprehensively consider human bias and behavioral psychology, so they cannot fully assess decision-makers' sensitivity when factors fluctuate.

3.4. Sensitivity analysis

Prospect parameters reflect decision-makers' attitudes when facing risk and describe how people evaluate and respond to uncertainty and risk. To shed more light on the impact of the decision maker's risk avoidance factor in the multi-criteria decision-making process, this part will consider the effect of parameters on the order of priority (Wu et al., 2018; Pham & Yeo, 2019). For this purpose, three prospect parameters will be assumed to change, and the next responsibility is to calculate

Table 9
Score of sub-criteria of all alternative.

Criteria	Sub-criteria	TAN VU	HICT	CAT LAI	CMIT	SSIT	TCIT
C1	C11	0.56	0.89	1.00	0.33	0.22	0.33
	C12	0.56	0.95	0.74	0.98	0.98	1.00
	C13	1.00	0.76	0.22	0.61	0.61	0.91
	C14	0.82	0.66	1.00	0.77	0.97	0.89
C2	C15	0.40	0.80	1.00	0.50	0.40	1.00
	C21	0.25	0.22	1.00	0.15	0.13	0.10
	C22	0.40	0.28	0.38	0.55	0.49	1.00
	C23	1.00	1.00	1.00	1.00	1.00	1.00
C3	C24	0.83	0.83	0.72	1.00	1.00	1.00
	C31	1.00	1.00	1.00	0.93	0.91	1.00
	C32	0.62	0.62	0.62	0.59	0.56	0.62
	C33	0.53	0.73	0.67	0.77	0.71	0.78
C4	C41	0.65	0.78	0.84	0.82	0.80	0.75
	C42	0.48	0.43	0.66	1.00	0.88	1.00
	C43	0.78	0.84	0.87	0.84	0.84	0.85
	C51	0.84	0.84	0.84	1.00	1.00	1.00
C5	C52	0.71	0.76	0.84	0.82	0.79	0.85
	C53	0.85	0.81	0.85	0.85	0.85	0.86
	C61	0.81	0.82	0.85	0.87	0.83	0.87
	C62	0.89	0.88	0.91	0.91	0.90	0.93
C7	C71	0.70	0.77	0.86	0.85	0.78	0.83
	C72	0.74	0.76	0.85	0.81	0.77	0.81
C8	C81	1.00	1.00	1.00	0.78	0.78	0.67
	C82	1.00	1.00	1.00	0.33	0.33	0.25
C9	C91	0.83	0.82	0.88	0.86	0.87	0.87
	C92	0.69	0.77	0.82	0.83	0.82	0.84
	C93	0.79	0.82	0.88	0.87	0.87	0.88

Table 10
The order of priority for results obtained is below.

Rank	Scale	Terminal
1	0.04	Cat Lai
2	-0.05	TCIT
3	-0.12	SSIT
4	-0.35	CMIT
5	-0.40	HICT
6	-0.81	Tan Vu

Table 11
Comparison analysis with existing methods.

Terminal	CODAS		SAW		AHP+Fuzzy TOSIS+CPT	
	Score	Rank	Score	Rank	Score	Rank
Tan Vu	-0.00175181	4	0.8235	6	-0.81	6
HICT	0.001897691	2	0.8802	2	-0.40	5
Cat Lai	0.005773457	1	0.9121	1	0.04	1
CMIT	-0.00280582	5	0.8615	4	-0.35	4
SSIT	-0.0043229	6	0.8426	5	-0.12	3
TCIT	0.001229211	3	0.8779	3	-0.05	2

how the preference will change. The results are given in Fig. 3 and Fig. 4.

Fig. 3 shows that λ affects CPV and can change the optimal alternative. In case $\lambda = 1$, the optimal alternative is SSIT. In the remaining cases, Cat Lai is a best choice, Tan Vu is the last option; HICT, CMIT, and TCIT were sensitive, and their rankings were changed slightly when the parameters changed greatly. All alternatives were insensitive when prospecting parameters $\sigma = \zeta = 0.88$, and λ in the range from 2 to 5. The higher the λ coefficient, the lower the cumulative prospect value and the faster the decrease rate. It means that shipping lines tend to avoid risk, the more risk-averse the decision maker becomes, the lower the cumulative prospective value.

Fig. 4 shows that the fluctuating of parameters σ, ζ affect the decision-making result. $0.6 \leq \sigma = \zeta < 1$ alternatives were insensitive in which Cat Lai terminal was ranked at the highest competitiveness, TCIT was

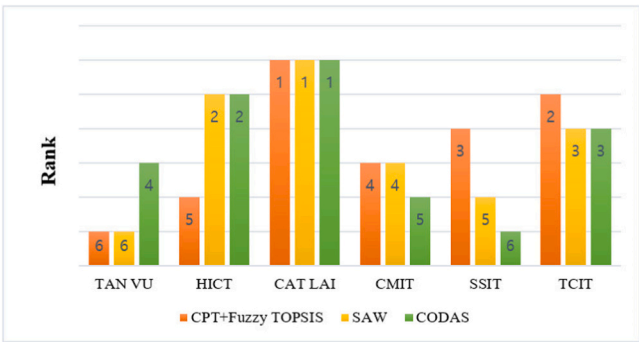


Fig. 2. Rank comparison between methods.

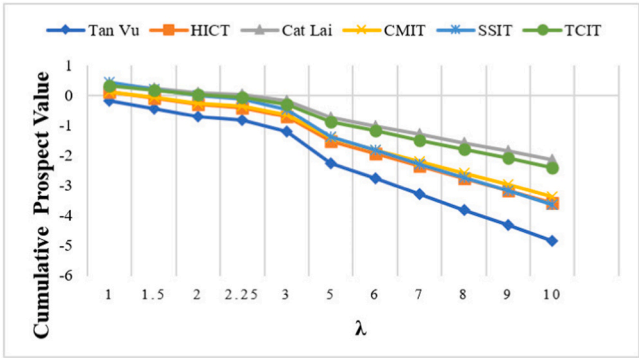


Fig. 3. Sensitivity analysis when changing the λ coefficient.

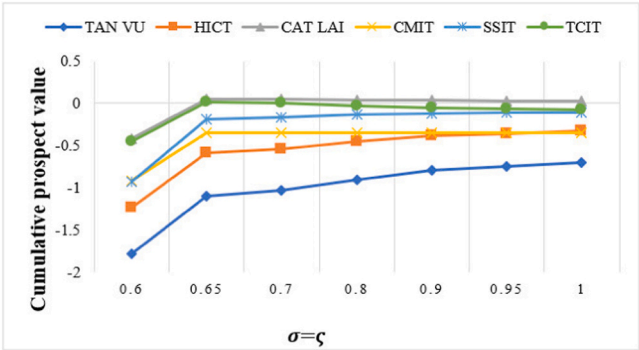


Fig. 4. Sensitivity analysis when changing σ and ζ .

the second priority, and Tan Vu terminal held the worst rank in competitiveness. They were indicated to keep the most stability priority in decision-makers' judgment.

Another sensitivity was also conducted by adjusting the weight of each criterion. This study chooses a 10 % adjustment to the priority as believed to be acceptable (Leenders et al., 2017; Wang & Yeo, 2018; Pham & Yeo, 2019). To consider the effect of changing the important weight of main factors, assume eight scenarios in which four factors have the highest weight variable 10 %. The result of this analysis is illustrated in Fig. 5.

Tan Vu terminal remained the last priority for all scenarios, and Cat Lai terminal held the first best priority. It means they were insensitive when changing the importance weight. The remaining alternative terminals all have a very slight sensitivity to changes in the important weights of the main criteria when choosing a terminal. Specifically, three of the eight container terminals were presented; HICT and CMIT terminals have changed the priority order for each other, changed one level, HICT increased the priority order from fifth to fourth, and CMIT

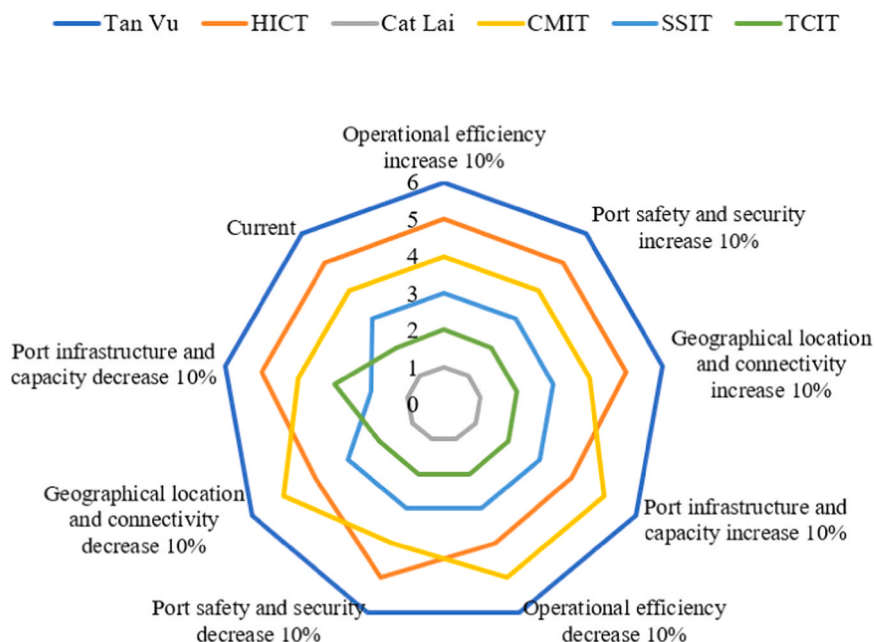


Fig. 5. Correlation between rank and criterion weights change.

decreased one level. Priority is from fourth to fifth as the importance of port infrastructure increases, operation efficiency decreases, and geographical location decreases. The decrease in the importance weight of port infrastructure has affected the priority order of shipping lines for the SSIT and TCIT terminals. SSIT terminal priority level was increased from third to second priority, while TCIT's priority level was lowered from second to third. The sensitivity analysis suggests that the multi-criteria decision-making approach, incorporating triangular fuzzy numbers, TOPSIS, AHP, and CPT for container terminal selection, remained robust against variations in crucial weights and prospect parameters, thus yielding precise outcomes.

4. Discussion and conclusion

Choosing a suitable port is an important issue that shipping lines must always consider before opening routes and even during operations to make appropriate adjustments according to business strategies for each stage to respond promptly to the fluctuations of many internal and external factors. This paper has examined many issues and contributed both academically and practically. Academically, the paper has fully synthesized the main criteria and sub-criteria when selecting ports according to hierarchy.

This paper presented the AHP combined with the Fuzzy TOPSIS method based on prospect theory to solve the problem of selecting the most suitable container terminal. The case study conducted an analysis of the six container terminals with the largest throughput in Vietnam in terms of shipping lines and port operators. Accordingly, from the perspective of shipping lines, Cat Lai terminal held the highest priority position, followed by TCIT, CMIT, SSIT, HICT, and Tan Vu terminals. The most important criteria for choosing a terminal in terms of shipping lines are operational efficiency, port safety, and security. These findings help port operators identify the main factors that their customers value so that the port can take measures to focus and improve further to increase competitiveness.

Human decisions are extremely complex, sometimes inconsistent, and uncertain when faced with multiple, interwoven criteria. Classical MCDM techniques do not fully consider the decision maker's risk attitude, and the inherently uncertain decision-making environment has not been comprehensively evaluated. Therefore, this paper has applied a more complete method that fully evaluates the decision-making

environmental factors as ambiguous and uncertain and considers the decision maker's behavior and attitude toward decisions under risk. This method is believed to be appropriate and feasible. Sensitivity comparisons and comparative analysis were performed in the above section to demonstrate and imply that risk aversion factors have an influence on the decision maker's ranking of port choices.

This paper will assist decision-makers in decreasing mistakes in decision-making because it considers fully weighing the benefits and drawbacks of substitute container terminals by offering the ranking of options for each criterion as well as the alternatives under the overall goal. The decision maker's judgments are considered to estimate the importance of each criterion. Moreover, both quantitative and qualitative criteria can be used with the approach. Decision-makers could easily recognize which criteria are more crucial in their judgment by comparing the importance of the criteria. Another benefit is that the procedure lessens bias in decision-making by checking that decisions are consistent.

Funding

The authors declare that no funds, grants, or other support were received during the prepare of this manuscript.

Authorship contributions

Concept design: T.Y. Pham, and H. Kim, Data collection or Processing: T.Y. Pham, and P.H. Nguyen, Analysis or Interpretation: T.Y. Pham, N.C. Truong, and P.H. Nguyen, Literature Review: T.Y. Pham, and N.C. Truong, Writing, Reviewing and Editing: T.Y. Pham, N.C. Truong, P.H. Nguyen, and H. Kim.

Acknowledgements

This research was supported by the 4th Educational Training Program for the Shipping, Port, and Logistics from the Ministry of Oceans and Fisheries.

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