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Decision-Making for Shipping Networks Based on Adaptive Cumulative Prospect Theory: A Case Study in Vietnam

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Abstract

This paper proposes an optimal method designed for use in a real-life situation to deal with port route choice decisions for evaluating and aggregating the daily net profit for liner shipping services to assist shipping lines in making optimal decisions under risk in the choice of the optimal route with the highest average daily profit for container liner shipping under the following un-certain combination factors: Freight rate, shipment demand, and fuel oil price. A cumulative prospect theory approach considers the decision-maker's attitude to describe decision-making under uncertainty applicable for any number of consequences to calculate the daily net profit model for container vessels. The results are compared with benchmark methods such as expected utility theory. This paper includes an application of the proposed approach to Hai An container shipping lines in Vietnam in 2022. Furthermore, adaptive parameters are presented to improve a model's performance when data distribution varies over time or across different contexts. The results show that the larger the adaptive parameter, the higher the daily profit, but the growth rate diminishes. The findings suggest that the Hai Phong-Ho Chi Minh route emerges as the safest with the least effect and the lowest variation in cumulative prospect value of daily profit. The Hai Phong (HP)-Tan Cang Cai Mep (TCIT)-Ho Chi Minh (HCM)-Hai Phong route is recommended as the most effective and economically favorable strategy for managers seeking the highest cumulative daily profit. This paper not only explains that the actual calculated results align with decision makers' behavior, such as risk aversion, decision makers who prioritize stability are inclined to choose options or strategies that offer a higher level of certainty, even if it means foregoing higher profits, but also provides a practical and easy-to-apply method for choosing a shipping network.

Keywords: Adaptive cumulative prospect theory, Cumulative prospect theory, Daily profit model, Decision-making, Shipping network

1. Introduction

For many years, containerized trade has been recognized as the fastest growing and critically important segment of maritime trade. To adapt to the growth of maritime trade, shipping companies are increasingly prioritizing routes to optimize their network, promote higher quality service, profit, and competitive advantage, and meet customer demands. However, decision making in the shipping network is challenging due to a complex operating landscape fraught with risk and uncertainty combined with disruptions and unprecedented problems [1]. These complexities make decision-making in the shipping network necessary to help manage efficiently and choose the optimal network. In addition, container carriers, faced with challenges of increased costs, make a strategic decision to reroute to alternative ports of call to seek greater profitability. Route choice models are essential tools for decision makers to identify the best strategies to improve efficiency and enhance the network's overall sustainability as well as adapt to the rapidly changing maritime industry.

There are a few methods that can be used to support decision making, including cost-benefit analysis (CBA) [2], SWOT analysis [3], multiple criteria decision making [4,5], Pareto analysis [6], Analytical Hierarchy Processes [7,8], TOPSIS [3], and game theory [9]. Programs and algorithms are too complex and difficult for many decision makers [10]. In addition, they often lack a reflection of the complexity of human psychology in decision making when faced with

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choices under risk and uncertainty. Traditional methods, such as expected utility theory (EUT), have numerous applications across a range of fields, including economics, agriculture, finance, psychology, and management [11]. Nevertheless, the EUT has some limitations when assuming that decision makers are rational [12-14]. In contrast, decision-making is a complex process, and decision-makers are influenced by risk and uncertainty factors; involving their past experiences, emotions, and the way choices are framed [13]. Cumulative prospect theory (CPT) overcomes EUT's deficiencies and considers perception bias of diminishing sensitivity, probability weighting, risk-seeking, loss aversion, source dependence, and preference reversals [13,15]. Therefore, this paper proposes an average daily profit model with uncertain combination factors influencing shipping route choice behavior by applying CPT [13].

Many studies have looked into liner shipping network problems from network design and fleet deployment, with the objective being to determine the ports that the ship should call and the sequence in which they should be visited to maximize profits or minimize costs [16]. A set-partitioning approach involves generating all conceivable shipping service routes and consolidating individual shipping routes into multiple routes if possible [17]. A previous paper investigated the influence of the environment on speed and fuel oil consumption; the findings expressed that strategically utilizing ocean currents in routing could decrease the yearly fuel expenses of both the US and global commercial fleets by $10 million and $70 million, respectively [18]. Various sources of uncertainty, such as political factors, international trade volume, bunker price, freight rate, shipbuilding and chartering costs, interest rates, and currency exchange rates, pose significant challenges and should be considered in the decision-making on shipping networks [16].

The main contributions of this paper include the following: first, the development of a daily profit model for container shipping lines based on the fluctuation of the season in shipping market demand from an easier method approach is the decision tree; second, the presentation of a method that is relatively easy to implement in real life for decision-makers in liner shipping when facing selection under uncertainties from the CPT approach in choosing the optimal route to achieve the highest profit; third, bringing an entire horizon about liner shipping company's psychology bias, their preference in decision-making.

The rest of this paper is organized as follows. Section 2 provides a review of the existing literature on shipping network choice. The system modeling and methodology are proposed in section 3 to evaluate the daily business effectiveness in container operation. Section 4 presents an empirical study of Vietnam. Adaptive CPT is then deployed to an empirical study, and the results are analyzed. Finally, section 5 provides the conclusions.

2. Literature Review

2.1. Decision Making for the Shipping Network

Shipping networks have a long research history in the maritime industry and cover a wide range of topics, including network design, route optimization, fleet management, and strategic planning from economic, strategic tactical, and operational perspectives. Decision making in liner shipping can be divided into three different levels: strategic, tactical, and operational planning levels [19]. Liner shipping networks are designed to match the requirements of customers and consider their own operational costs. Several ship routing and scheduling studies have been conducted, and a significant number of comprehensive reviews about ship routing can be found in [16,20,21] that are referred for a review of shipping network problems.

Most of the existing research on shipping networks has considered the network design problem to minimize costs or maximize profits that highlight uncertainty factors such as container shipment demand, uncertain port time, uncertain wait time, and uncertain container handling time [22-25]. Almost all studies concentrated on optimization techniques that are often applied to determine the optimal shipping network for shipping lines. A dynamic cost-based model can assist in choosing the optimal system for serving particular trade routes with known trade requirements for providing liner services, with the goal of minimizing overall expenses [26]. Another study demonstrated the theme of container liner shipping networks, and a mixed-integer linear programing model was proposed to develop the design problem for the intermodal liner shipping service network [27]. A linear programing model to minimize the total operating and lay-up costs for the fleet [28]. A method for scheduling containerships in a liner shipping network was introduced using a mixed-integer linear programing model that can be efficiently solved by CPLEX for real-world shipping activities connecting Asia, Europe, and Oceania [29]. Another study on the liner ship route was designed under the assumption that the container shipment demand was not a precise value but rather a fuzzy number was performed by [30]. However, optimization techniques not only make decision makers encumbered but also psychological factors such as decision makers' behavior can be ignored.

There are not many studies on decision-making for choosing a route, networks, and maritime networks to perform from various approaches including AHP, TOPSIS, CBA, SWOT, Fuzzy Delphi, Fuzzy ELECTRE I method, and game theory [3,5,7,8]. An analytic hierarchy process multi-criteria decision-making methodology that could optimize the supply chain delivery network by considering not only qualitative but also quantitative factors was performed [3,9]. CBA is used to assess the profitability of maritime networks for shipping companies to achieve greater efficiency and sustainability in short shipping networks [31]. Another study developed a game theory model for resolving route choices in intermodal transport networks with the aim of decreasing transport costs for carriers who are adopted as rational players [9]. In these studies, the definition of rational decision making has not been clearly defined [9]. In actuality, as mentioned above, decision making has some limitations. Decision making is a rational view with many limitations and criticisms. Therefore, this study focuses on irrational decision-making to reflect reality in the psychology of decision-making behavior.

2.2. Cumulative Prospect Theory Application to Shipping Networks

Numerous studies have been dedicated to several fields like designing and selecting product concepts [32], location selection of emergency rescue centers [33], charging mode for electric vehicles [34], Grey Multi-attribute Emergency Decision-Making Method for Public Health Emergencies [35], decision-making of investment in navigation safety improving schemes [36], and the path selection model of emergency logistics [37]. Published studies related to the CPT application are presented in Table 1.

There has been limited investigation into the adaptation of optimization techniques in ship routing under uncertainty. Chen (1978) created an adaptive optimization approach called "open-loop feedback", in which a ship's route is changed based on deterministic factors when updated information indicates that environmental conditions are significantly different from the initial estimates. In this study, the method used is primarily deterministic in nature and does not incorporate an explicit representation of uncertainty and does not consider decision-makers' psychological factors [38].

This paper proposes an adaptive approach to CPT in which a decision maker's behavior is irrational for liner shipping that distinguishes itself from previous research. This paper aims to fill the research gaps on decision-making in shipping networks by providing a model to calculate daily voyage profit from the viewpoints of CPT that consider the complexity of psychology when people face an uncertain situation.

3. Methodology

This study proposes a daily profit model based on the cumulative prospect approach of daily profit equal to the resulting daily revenue minus daily cost.

3.1. Model Formulation

3.1.1. Notation

c^t: total cost of the round voyage;

r^t: total revenue of the round voyage;

pr^d: daily profit of the round voyage;

j: index of port: $j = \overline{1,n}$;

gr: vessel gross tonnage in GT;

c^{bun}: total bunker expenses for the round voyage;

d_z: distance between port o and e in leg $z(z \in Z)$ of round route;

v_z^{as}: average sailing speed on a round voyage (knots);

c_z^{hc}: cargo handling cost on the leg $z(z \in Z)$ of round route;

c_z^{ts}: the transshipment service cost on the leg $z(z \in Z)$ of round route;

q_z^{ts}: transshipment volume in TEU via two ports on the leg z $(z \in Z)$;

u_z^{ts}: transshipment unit price in USD via two ports on the leg $z(z \in Z)$;

c_z^{pc}: port charges on the leg $z(z \in Z)$ of round route;

c_z^{inv}: inventory cost on the leg $z(z \in Z)$ of round route;

c_z^{cmm}: commission fees on leg $z(z \in Z)$ of round route;

c_z^{br}: broker fees on the leg $z(z \in Z)$ of round route;

c^{oth}: other cost of the round route (USD)

c^{dv}: daily running cost of a vessel (USD/day)

Table 1. *Summary of the literature review of the cumulative prospect theory approach*

Article	Key finding	Method
[32]	Designing and selecting product concepts	QFD and the cumulative prospect theory
[33]	Location selection of the emergency rescue centers	Pythagorean fuzzy multi-attribute decision-making evaluation method and CPT
[34]	Charging mode for the electric vehicle	CPT
[35]	Grey multi-attribute emergency decision-making method for public health emergencies	Interval gray grey number method, CPT, and AHP
[36]	Decision-making in navigation safety improvement schemes	CPT, linear programing model, and projection method data
[37]	Path selection model of emergency logistics	CPT
CPT: Cumulative prospect theory		

3.1.2. Objective function

This section presents the cumulative prospect value function of the average daily profit as the objective function to support decision making. The average daily profit is calculated by the profit earned from the voyage divided by the total time (days) spent on the round voyage. In this paper, it means that the daily profit is earned before interest and tax. The daily profit function is proposed in Equation (1), and the more detailed components are rewritten in Equation (2).

$$pr^d = \frac{r^t - c^t}{t^{tcv}} \tag{1}$$

$$pr^d = \frac{\sum_{k\in K}\sum_{z\in Z}(fr_z^k q_z^k) - (c^{trc} + c^{bun} + \sum_{z\in Z} c_z^{pc} + \sum_{z\in Z} c_z^{ts} + \sum_{z\in Z} c_z^{cmm} + c^{oth})}{t^{tcv}} \tag{2}$$

Where the first term on the numerator of (2) is the total revenue of the round voyage; the second term is the total cost of the round voyage.

Tversky and Kahneman [13] improved the prospect theory in 1992; the cumulative prospect value (*CPV*) is calculated by accumulating losses and gains. *CPV* values indicate preferences for choices and should be positive. If the value between two choices is negative, the preference for choice is the one that brings the least loss. It is possible to obtain the cumulative prospect values of the average daily profit using Equation (3).

$$CPV(pr^d) = \sum_{i=1}^{m} v^-(pr_i^d)\pi^-(p_i) + \sum_{i=1}^{m} v^+(pr_i^d)\pi^+(p_i) \tag{3}$$

Where $v^-(pr_i^d)$, $v^+(pr_i^d)$ denote prospect value for gains and losses, respectively, which are illustrated by the value function as Equation (4):

$$v(pr_i^d) = \begin{cases} (pr^d)^\alpha \text{ if } pr^d \geq 0 \\ -\lambda(-pr^d)^\beta \text{ if } pr^d < 0 \end{cases} \tag{4}$$

In the above formula, the median exponent of the value function was $\alpha = \beta = 0.88 < 1$ in accordance with diminishing sensitivity; it is convexity in losses and concave in gains. The loss aversion coefficient $\lambda = 2.25 > 1$ could explain individual risk aversion level, which means that an individual perceives loss 2.5 times more than gain, and the graph of losses is steeper than gains. $\pi^+(p_i)$, $\pi^-(p_i)$ are considered crucial elements of prospect theory are the probability weighting function for gains and losses, respectively, by Equations (5), and Equation (6).

$$\pi^+(p_i) = \frac{p_i^\delta}{[p_i^\delta + (1-p_i)^\delta]^{1/\delta}} \tag{5}$$

$$\pi^-(p_i) = \frac{p_i^\theta}{[p_i^\theta + (1-p_i)^\theta]^{1/\theta}} \tag{6}$$

Where δ=0.61, θ = 0.69 are the prospect parameters that indicate the risk-taking attitudes of decision makers [13]. p is the stated probability for the result to i. To improve the performance of a model in situations where the distribution of the data changes over time or across different contexts, a parametric parameter was proposed. In other words, it involves modifying the values of the model's parameters to better fit the new data. This term refers to the process of adjusting the parameters of a mathematical or statistical model based on new data. Therefore, we propose adaptive weighting functions for gains and losses, respectively, as Equations (7), and (8) below:

$$\hat{\pi}^+(p_i) = \frac{p_i^{0.61+\sigma_1}}{[p_i^{0.61+\sigma_1} + (1-p_i)^{0.61+\sigma_1}]^{1/(0.61+\sigma_1)}} \tag{7}$$

$$\hat{\pi}^-(p_i) = \frac{p_i^{0.69+\sigma_2}}{[p_i^{0.69+\sigma_2} + (1-p_i)^{0.69+\sigma_2}]^{1/(0.69+\sigma_2)}} \tag{8}$$

Where $\hat{\pi}^+(p_i)$ and $\hat{\pi}^-(p_i)$ are adaptive parameters that are automatically updated using the gains and loss function. $\sigma_1 = \mu_1 p(fr_i^{sd}) p_i^{FO}$, $\sigma_2 = \mu_2 p(fr_i^{sd}) p_i^{FO}$; μ_1, μ_2 and are the positive parametric adaptation coefficients in gains and losses, respectively, that are used to update parameters for δ and θ.

3.1.3. Revenue function

Now determine the voyage revenue function as resulting from the component sea freight. Revenue is mainly obtained from container transportation. In reality, shipping companies can earn revenue from document, seal, container cleaning, and container repair fees. However, these revenues are considered to be able to cover various costs, including inventory and container repair costs. Assume that the shipment demand in each of the high, medium, and off-seasons accounts for d_1, d_2, and d_3, respectively (noted that $d_1 + d_2 + d_3$ = 100%). Liner shipping companies often re-decide the freight rate depending on the market supply and demand estimated as well as the change in fuel oil price and the change in services tariffs. Assume that the freight rate is adjusted to increase or decrease together for all. When the season comes, if the shipment demand increases, the freight rate also rises, and on the other hand, if the shipment demand decreases, the freight rate will also go down.

Assume that the customer type x has shipment demand probability container type k in season y on the leg z is d_z^{kxy} satisfied with condition $\sum_{x\in X} d_z^{kxy} = 1$. r^t is total revenue obtained from the round voyage and is expressed as Equation (9) below:

$$r^t = \sum_{x\in X}\sum_{y\in Y}\sum_{z\in Z}\sum_{k\in K}(fr_z^{kxy} q_z^{kxy} d_z^{kxy}) \tag{9}$$

Where fr_z^{kxy} the freight rate of k -type container ($k \in K$) is applied for x - type customer ($x \in X$) in the season y $(y \in Y)$ on the leg z ($z \in Z$); q_z^{kxy} indicates volume of container type k ($k \in K$) is transported for customer type x ($x \in X$) in the season y $(y \in Y)$ on the z ($z \in Z$).

Routing depends on the strategies of shipping lines and the shipment demand of shippers for specific seasons. To respond to these fluctuations in demand, tactical decision making is necessary, and it typically involves planning every 3-4 months. This ensures that companies can adapt to changes in demand and make informed decisions accordingly [39]. Therefore, accept the argument that the shipment demand is determined in a year and is divided into three ranges with different probabilities: off-season, high season, and medium season. Off-season refers to the period of lowest demand, during which the freight rate is lower than in other seasons. Relating to the high season, the shipment demand surges to higher levels, and the container freight rates also increase and events escalate and reach highs. Various factors can cause high demand, including container shortages, port congestion, and delays. The length of this high-demand period can vary and is dependent on a range of factors [40]. Assume that the shipment demand in each of the high, medium, and off-seasons accounts for d_1, d_2, and d_3, respectively (noted that $d_1 + d_2 + d_3 = 100\%$). Liner shipping companies often re-decide the freight rate depending on the market supply and demand estimated as well as the change in fuel oil price and the change in services tariffs. Assume that the freight rate is adjusted to increase or decrease together for all. When the season comes, if the shipment demand increases, the freight rate also rises, and on the other hand, if the shipment demand decreases, the freight rate will also go down.

Normally, in liner shipping companies, sea freight rates are classified into several customer groups depending on the shipment volume and frequency of service use. It can be called customer policy, price policy, or price strategy and can be adjusted flexibly by surcharges. Adopt the assumption that there are three groups of customers, meaning that the liner shipping company has three ranges of the freight rate. The probability of shipment volume is estimated including occasional customers is r_1 (%), the regular customer is r_2 (%), and the contractual customers is r_3 (%), in where $r_1 + r_2 + r_3 = 100\%$. Note that in each season, the probability of shipment for each customer group is stable. In addition, it should be noted that this work mainly concentrates on the method to support decision making; hence, it assumes that the weight of shipment demand d_1 $(i = \overline{1,3})$ and r_i $(i = \overline{1,3})$ is fixed for each voyage and season. Therefore, in the case where shipment demand is d_1, obtained revenue equals the sum of revenue from group customer 1 in which freight rate is fr_{11}, group customer 2 with freight rate is fr_{12}, and customer 3 with freight fr_{13}. A decision tree is proposed to select the optimal route from the planned set of alternatives.

The decision tree is deployed as shown in Figure 1. As mentioned above, the sea freight rate is also arranged by clusters of seasons and customers. From n scenarios of total cost and three probabilities of shipment demand. This study presents $3n$ probabilities of average daily profit called consequences.

3.1.4. Cost function

Total cost components are proposed, including [41]: Vessel running costs, bunker costs; port dues; liners costs such as administration, agency fees, brokerage, and other costs. In this study, terminal handling charges (THC) are considered to be the responsibility of payment by the shipper; therefore, in this study, terminal handling costs will not be considered and were eliminated from the shipping line's cost model in Equation (10).

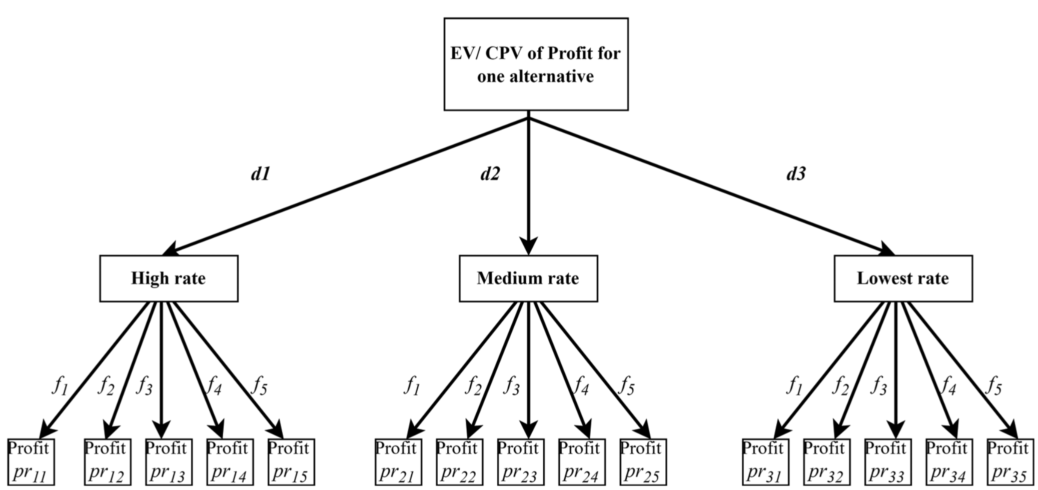


Figure 1. *Decision tree for one alternative in a case study*

$$c^{t} = c^{trc} + c^{bun} + \sum_{z\in Z} c_{z}^{pc} + \sum_{z\in Z} c_{z}^{ts} + \sum_{z\in Z} c_{z}^{cmm} + c^{oth} \quad (10)$$

Port dues include tonnage, navigation, pilotage, berth, tugboat, mooring/unmooring, quarantine, anchorage, customs declaration, clearance, and canal tolls, if any. Port dues in port *j* is described as Equations (11) and (12).

$$c_{j}^{pc} = c_{j}^{ton} + c_{j}^{nav} + c_{j}^{plt} + c_{j}^{ber} + c_{j}^{tug} + c_{j}^{m/u} + c_{j}^{qrt} + c_{j}^{anc} + c_{j}^{d} + c_{j}^{c} \quad (11)$$

$$= r_{j}^{ton} gr + r_{j}^{nav} d_{j}^{nav} gr + d_{j}^{plt} r_{j}^{plt} gr + r_{j}^{ber} d_{j}^{ber} gr + n^{tug} hp_{j}^{tug} r_{j}^{tug} + c_{j}^{m/u} + c_{j}^{qrt} + c_{j}^{anc} + c_{j}^{d} + c_{j}^{oc} + c_{j}^{cl} + c_{j}^{c} \quad (12)$$

The above addition notations are explained as follows:

r_j^{ton}: tonnage due rate in USD/GT in port *j* is built for each tonnage group of vessels and at the berth or at the lifebuoy;

r_j^{nav}: navigation rate in USD/GT is calculated on the basis of gross tonnage for each nautical mile;

d_j^{nav}: the distance in nautical miles when the vessel travels through the navigable port *j*;

r_j^{plt}: pilot rate in USD per ton per nautical mile in port *j*;

d_j^{plt}: the distance in nautical when the vessel is assisted in navigating through a complex waterway by port authority service when a vessel enters or leaves the port *j*;

r_j^{ber}: daily berth rate in USD per day is charged per day for the use of the berth;

d_j^{ber}: number of days in the berth;

n^{tug}: number of tugboats used to support the ship in entering and leaving the port *j* safety;

hp^{tug}: tugboat measurement of power in horse power;

r^{tug}: tugboat rate in USD per hour charged on the basis of the vessel's gross tonnage per hour;

$c_j^{m/u}$: mooring/unmooring price in USD in port *j*;

c_j^{qrt}: quarantine, disinfection fees in USD port *j*;

c_j^{anc}: anchorage dues in USD charged by port authorities for the use of anchorage facilities in port *j*;

c_j^{d}: customs declaration fees in USD that are charged by custom authorities for processing the declaration of goods being imported or exported in port *j*;

c_j^{cl} : clearance fees in USD in port *j*;

The total running cost (USD) is determined by multiplying the total number of days spent on the round voyage by the average daily running cost (c^{dv}). It includes wage and insurance expenses incurred by crews and administration; maintenance costs (inspections, repairs…); cost of insurance like hull and machinery insurance; protection and indemnity insurance (P&I insurance); and war risk insurance. Equation (13) is used to calculate the total running cost per voyage:

$$c^{trc} = c^{dv} t^{tcv} \quad (13)$$

Now consider the bunker cost in USD for the round voyage. Bunker cost is the expense of consumption that is spent on vessels at sea and in port. Bunker cost is influenced by various factors, including the vessel's speed, the duration of time the vessel is in port or at sea, the distance of the voyage leg, the price of the bunker, and the exchange rate if purchasing bunker fuel using foreign currency. For simplification, this paper only considers two major bunkers: diesel and fuel oil cost, and other factors are neglected and given by Equation (14):

$$c^{bun} = s^{tcv} \sum_{i=1}^{n} f_i^{fo} c_i^{fo} + t^{tcv} f^{do} c^{do} \quad (14)$$

Where: s^{tcv} indicates sailing time at sea, f^{fo} presents average daily fuel oil consumption in tons per day; f^{do} shows average diesel oil consumption per day in tons per day; c^{fo} is fuel oil price in USD/ton; and c^{do}: diesel oil price in USD/ton. As mentioned above, the range of fuel oil prices is divided into n clusters with the probabilities are f_i^{fo} and the fuel oil cost is, $\sum f_i = 1, (i = \overline{1,n}$, nis the number of range fuel oil price).

If there is no direct route from the origin to the destination, containers can be transshipped. The total transshipment cost is illustrated in Equation (15).

$$\sum_{z\in Z} c_z^{ts} = \sum_{z\in Z} (q_z^{ts} u_z^{ts}) \quad (15)$$

In this paper, "other cost" refers to other cost components such as equipment charges, liner management charges, and carrier insurance and claims that are estimated as a percentage of revenue or sea freight.

3.1.5. Total time function

Total time (days) spent on a round voyage includes total sailing time and total port time spent on the round voyage and can be expressed as the following equation:

$$t^{tcv} = \frac{\sum_{z\in Z} d_z}{24 v^{as}} + 2\sum_{j=1}^{n} m_j^t + \sum_{j=1}^{n} \left(\frac{q_j^l}{r_j^l} + \frac{q_j^d}{r_j^d}\right) \quad (16)$$

The initial value on the right side of Equation (16) is the total sailing time at sea on the round voyage; the second term shows the total maneuver time in all ports of call of the round voyage, including the time spent on embarking and disembarking port; the third term indicates the total time for cargo handling works on the round voyage consisting of loading and unloading in all ports of call of the round voyage. Where: 24 is the number of hours per day; r_j^l is rate of loading in port *j* (TEU/day); and r_j^d represents the rate of discharging in port *j* (TEU/day); q_j^l shows the volume of cargo in TEU loaded in port j; and q_j^d indicates volume of cargo discharged in port j (TEU).

3.2. Methodology

This paper focuses on the route decision-making problem for container liner shipping facing uncertain shipment demand, fuel oil price, and freight rate. In the framework of this paper, we assumed that the variable factors affecting the results of daily average profit are divided into ranges of probabilities. The round route between port m and n consists of predetermined and unchanging sailing distances and sailing times for each leg. The daily vessel cost of containerships is established and remains constant. Other periodic and unexpected costs are disregarded. Moreover, the vessel is assumed to be parallel, to follow the same route, and to have a capacity that is adapted to transport demand. This work aims to consider a container transportation network that involves not only direct routes but also combines with transshipment, which may help shipping lines save time and increase their ability to turn around. For simplicity, the carrier's empty containers are not considered in this study. To simplify the process by assuming that does not consider other variation factors. Argue that the Break Even Point is the reference point in the model. This means that at the reference point, total revenues equal total costs, and on the other hand, in the case of the model, the outcome is the average daily profit, and the reference point at a daily profit equals zero (0). If the average daily profit is better than 0, then gains and vice versa are losses.

This paper refers to the calculation steps introduced by Gungor and Barlas [10]. Table 2 shows a visual representation of the calculation sequence. First, fill in the column "pr_i^d" vessel's daily profit (consequences) and arrange from the top to the bottom in ascending order. The consequences are arranged in ascending order from top to bottom to adhere to the CPT. The lowest value of the outcome is listed at the top of the column, and the highest value is listed at the bottom. An average daily profit less than 0 is distinguished by the column number "no" marking the sequence number with a negative sign. In this table, assume that there are five values of daily profit that are negative. Group the freight rate and estimate the probability $p(fr_i^{sd})$, next, classify and estimate the probability of fuel oil price p_i^{FO} can be referenced in Table 3 for a case study. On the table of order of operation, assume that there are three probability clusters of freight rate and five probability clusters of fuel oil price. The probability of each scenario is calculated by $p_i = p(fr_i^{sd})\, p_i^{FO}$. The expected values of the consequences of each alternative are calculated using: $EV = \sum_{i=1}^{n}[p_i(\frac{r_i{}^t - c_i{}^t}{t^{tcv}})]$ and recorded in the column labeled "$EV(pr_i^d)$". The sum of all values of consequences is shown in the row labeled "Total". The prospect value of outcomes is recorded in the column labeled $v(pr_i^d)$ by using Equation (4). The probabilities of gains and losses are shown in the column labeled "cp_i" which is calculated cumulatively p_i from top to bottom for losses and from bottom to top for gains. Then, we demonstrate the probability transformation of cumulated probabilities by Equation (7) for gains and Equation (8) for losses. The column labeled "dcp_i^{trf}" is described by multiplying the accumulated probabilities. The obtained results from $v(pr_i^d)dcp_i^{trf}$ is referred to as the cumulative prospect value, which is recorded in the "*CPV*" column. The sum of all CPT values for the consequences of each alternative is given in the row labelled "Total".

4. A Case Study in Vietnam

4.1. Current Status of the Shipping Network in Vietnam

In Vietnam, the form of container transport began to develop in the early 1990s. There are some shipowners who have many years of experience, such as Gemadept, Vinafco, Vinalines. Others have just been established in recent years, including Viet Sun, Viconship, Hai An, and GLS. In where, Hai Phong to Ho Chi Minh and vice versa is well-known as the bustle and dynamic container shipping route that attracted almost all container shipping lines. Other operating routes include Hai Phong - Da Nang - Ho Chi Minh - Hai Phong and Hai Phong - Ho Chi Minh - Tan Cang Cai Mep - Hai Phong. Several companies, such as East Sea, Gemadept, and Vinalines, operate feeder routes to transshipment ports located in the region, such as Singapore, Hong Kong, and Port Klang. At present, Vietnam has approximately 10 domestic container shipping companies, which primarily operate on the North Central South route, as well as some short routes within Southeast Asia and Northeast Asia.

The most popular Vietnam sea freight destinations are Hai Phong, Da Nang, Sai Gon, and Vung Tau ports. TCIT and VICT are two of the five largest terminals in the Ho Chi Minh - Ba Ria Vung Tau port. VICT is authorized to operate as a 40-year joint venture, which involves Southern Waterborne Transport Corporation (SOWATCO) of Vietnam and MITORIENT, a Singaporean company. MITORIENT holds a majority stake of 63% as part of a partnership with Japan's Mitsui & Co and the CMA CGM Group, while SOWATCO holds the remaining 37% of the company's shares [42]. Tan Cang-Cai Mep International Terminal Co., Ltd (TCIT) is a company formed through a partnership between Saigon Newport Corporation and Mitsui O.S.K. Lines (Japan), Wan Hai Lines (Taiwan), and Hanjin Transportation (Korea) [43]. The percentage of cargo throughput in Vietnam's major ports in 2022 is presented in Figure 2.

Table 2. *Order of operations*

No	pr_i^d	$v(pr_i^d)$	$p(fr_i^{sd})$ (%)	p_i^{FO} (%)	p_i (%)	cp_i (%)	cp_i^{trf} (%)	dcp_i^{trf} (%)	CPV	EUV(pr_i^d)
-1	pr_1^d	$-2.25(-pr_1^d)^{0.88}$	$p(fr_1^{sd})$	p_1^{FO}	$p(fr_1^{sd})*p_1^{FO}$	p_1	$\frac{cp_1^{0.69}}{[cp_1^{0.69}+(1-cp_1)^{0.69}]^{0.69^{-1}}}+\hat{\sigma}_1$	cp_1^{trf}	$v(pr_1^d)*dcp_1^{trf}$	$pr_1^d*p_1$
-2	pr_2^d	$-2.25(-pr_2^d)^{0.88}$	$p(fr_1^{sd})$	p_2^{FO}	$p(fr_1^{sd})*p_2^{FO}$	p_1+p_2	$\frac{cp_2^{0.69}}{[cp_2^{0.69}+(1\text{-}cp_2)^{0.69}]^{0.69^{-1}}}+\hat{\sigma}_2$	$cp_2^{trf}-cp_1^{trf}$	$v(pr_2^d)*dcp_2^{trf}$	$pr_2^d*p_2$
-3	pr_3^d	$-2.25(-pr_3^d)^{0.88}$	$p(fr_1^{sd})$	p_3^{FO}	$p(fr_1^{sd})*p_3^{FO}$	$p_1+p_2+p_3$	$\frac{cp_3^{0.69}}{[cp_3^{0.69}+(1\text{-}cp_3)^{0.69}]^{0.69^{-1}}}+\hat{\sigma}_3$	$cp_3^{trf}-cp_2^{trf}$	$v(pr_3^d)*dcp_3^{trf}$	$pr_3^d*p_3$
-4	pr_4^d	$-2.25(-pr_4^d)^{0.88}$	$p(fr_1^{sd})$	p_4^{FO}	$p(fr_1^{sd})*p_4^{FO}$	$p_1+p_2+\ldots+p_4$	$\frac{cp_4^{0.69}}{[cp_4^{0.69}+(1-cp_4)^{0.69}]^{0.69^{-1}}}+\hat{\sigma}_4$	$cp_4^{trf}-cp_3^{trf}$	$v(pr_4^d)*dcp_4^{trf}$	$pr_4^d*p_4$
-5	pr_5^d	$-2.25(-pr_5^d)^{0.88}$	$p(fr_1^{sd})$	p_5^{FO}	$p(fr_1^{sd})*p_5^{FO}$	$p_1+p_2+\ldots+p_5$	$\frac{cp_5^{0.69}}{[cp_5^{0.69}+(1-cp_5)^{0.69}]^{0.69^{-1}}}+\hat{\sigma}_5$	$cp_5^{trf}-cp_4^{trf}$	$v(pr_5^d)*dcp_5^{trf}$	$pr_5^d*p_5$
6	pr_6^d	$(pr_6^d)^{0.88}$	$p(fr_2^{sd})$	p_1^{FO}	$p(fr_2^{sd})*p_1^{FO}$	$p_{15}+p_{14}+\ldots+p_6$	$\frac{cp_6^{0.61}}{[cp_6^{0.61}+(1\text{-}cp_6)^{0.61}]^{0.61^{-1}}}+\hat{\sigma}_6$	$cp_6^{trf}-cp_7^{trf}$	$v(pr_6^d)*dcp_6^{trf}$	$pr_6^d*p_6$
7	pr_7^d	$(pr_7^d)^{0.88}$	$p(fr_2^{sd})$	p_2^{FO}	$p(fr_2^{sd})*p_2^{FO}$	$p_{15}+p_{14}+\ldots+p_7$	$\frac{cp_7^{0.61}}{[cp_7^{0.61}+(1\text{-}cp_7)^{0.61}]^{0.61^{-1}}}+\hat{\sigma}_7$	$cp_7^{trf}-cp_8^{trf}$	$v(pr_7^d)*dcp_7^{trf}$	$pr_7^d*p_7$
8	pr_8^d	$(pr_8^d)^{0.88}$	$p(fr_2^{sd})$	p_3^{FO}	$p(fr_2^{sd})*p_3^{FO}$	$p_{15}+p_{14}+\ldots+p_8$	$\frac{cp_8^{0.61}}{[cp_8^{0.61}+(1\text{-}cp_8)^{0.61}]^{0.61^{-1}}}+\hat{\sigma}_8$	$cp_8^{trf}-cp_9^{trf}$	$v(pr_8^d)*dcp_8^{trf}$	$pr_8^d*p_8$
9	pr_9^d	$(pr_9^d)^{0.88}$	$p(fr_2^{sd})$	p_4^{FO}	$p(fr_2^{sd})*p_4^{FO}$	$p_{15}+p_{14}+\ldots+p_9$	$\frac{cp_9^{0.61}}{[cp_9^{0.61}+(1\text{-}cp_9)^{0.61}]^{0.61^{-1}}}+\hat{\sigma}_9$	$cp_9^{trf}-cp_{10}^{trf}$	$v(pr_9^d)*dcp_9^{trf}$	$pr_9^d*p_9$
10	pr_{10}^d	$(pr_{10}^d)^{0.88}$	$p(fr_2^{sd})$	p_5^{FO}	$p(fr_2^{sd})*p_5^{FO}$	$p_{15}+p_{14}+\ldots+p_{10}$	$\frac{cp_{10}^{0.61}}{[cp_{10}^{0.61}+(1-cp_{10})^{0.61}]^{0.61^{-1}}}+\hat{\sigma}_{10}$	$cp_{10}^{trf}-cp_{11}^{trf}$	$v(pr_{10}^d)*dcp_{10}^{trf}$	$pr_{10}^d*p_{10}$
11	pr_{11}^d	$(pr_{11}^d)^{0.88}$	$p(fr_3^{sd})$	p_1^{FO}	$p(fr_3^{sd})*p_1^{FO}$	$p_{15}+p_{14}+\ldots+p_{11}$	$\frac{cp_{11}^{0.61}}{[cp_{11}^{0.61}+(1-cp_{11})^{0.61}]^{0.61^{-1}}}+\hat{\sigma}_{11}$	$cp_{11}^{trf}-cp_{12}^{trf}$	$v(pr_{11}^d)*dcp_{11}^{trf}$	$pr_{11}^d*p_{11}$
12	pr_{12}^d	$(pr_{12}^d)^{0.88}$	$p(fr_3^{sd})$	p_2^{FO}	$p(fr_3^{sd})*p_2^{FO}$	$p_{15}+p_{14}+\ldots+p_{12}$	$\frac{cp_{12}^{0.61}}{[cp_{12}^{0.61}+(1-cp_{12})^{0.61}]^{0.61^{-1}}}+\hat{\sigma}_{12}$	$cp_{12}^{trf}-cp_{13}^{trf}$	$v(pr_{12}^d)*dcp_{12}^{trf}$	$pr_{12}^d*p_{12}$
13	pr_{13}^d	$(pr_{13}^d)^{0.88}$	$p(fr_3^{sd})$	p_3^{FO}	$p(fr_3^{sd})*p_3^{FO}$	$p_{15}+p_{14}+p_{13}$	$\frac{cp_{13}^{0.61}}{[cp_{13}^{0.61}+(1-cp_{13})^{0.61}]^{0.61^{-1}}}+\hat{\sigma}_{13}$	$cp_{13}^{trf}-cp_{14}^{trf}$	$v(pr_{13}^d)*dcp_{13}^{trf}$	$pr_{13}^d*p_{13}$
14	pr_{14}^d	$(pr_{14}^d)^{0.88}$	$p(fr_3^{sd})$	p_4^{FO}	$p(fr_3^{sd})*p_4^{FO}$	$p_{15}+p_{14}$	$\frac{cp_1^{0.61}}{[cp_{14}^{0.61}+(1-cp_{14})^{0.61}]^{0.61^{-1}}}+\hat{\sigma}_{14}$	$cp_{14}^{trf}-cp_{15}^{trf}$	$v(pr_{14}^d)*dcp_{14}^{trf}$	$pr_{14}^d*p_{14}$
15	pr_{15}^d	$(pr_{15}^d)^{0.88}$	$p(fr_3^{sd})$	p_5^{FO}	$p(fr_3^{sd})*p_5^{FO}$	p_{15}	$\frac{cp_{15}^{0.61}}{[cp_{15}^{0.61}+(1-cp_{15})^{0.61}]^{0.61^{-1}}}+\hat{\sigma}_{15}$	cp_{15}^{trf}	$v(pr_{15}^d)*dcp_{15}^{trf}$	$pr_{15}^d*p_{15}$
Total					100			100	$\sum_{i=1}^{15}v(pr_i^d)*dcp_i^{trf}$	$\sum_{i=1}^{15}pr_i^d*p_i$

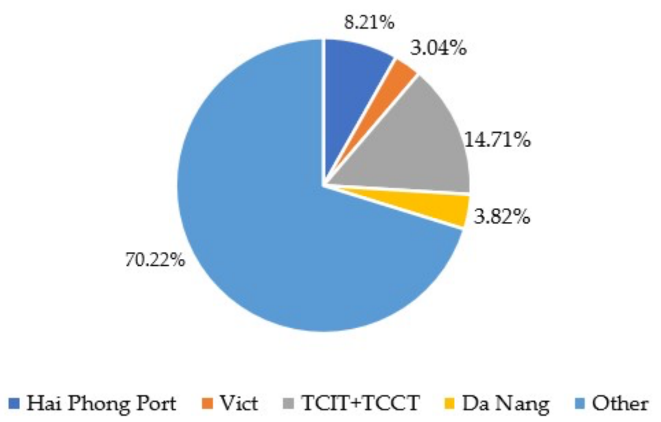


Figure 2. Percentage of cargo throughput in Vietnam's major ports by 2022

4.2. Alternative Shipping Network

This study evaluates three alternatives to networking for shipping lines. Shipment demand is estimated using data obtained from the final freight reports for 144 voyages in 2022 of Hai An shipping line on Bravo software, and interview results of marketing department manager and commercial team leader. Furthermore, port dues and transshipment costs by barge are collected from "vessel cost reports" of the Hai An shipping line, which are managed by vessel management, the commercial department, and the ports' official website. In addition, other relevant costs also use data obtained from vessel cost reports of the Hai An container transport company.

Data for the three main routes are gathered to benefit from the decision-making issue. Three main routes including Hai Phong to Ho Chi Minh and vice versa are called alternative 1; alternative 2 is the journey Hai Phong - TCIT - Ho Chi Minh - Hai Phong (directly) and the sailing Hai Phong - Ho Chi Minh - TCIT - Ho Chi Minh - Hai Phong (transshipment between Ho Chi Minh and TCIT) is considered alternative 3. The three alternatives are described further in Figure 3. Note that there is no revenue for the leg from Tan Cang - Cai Mep International Terminal (TCIT) to Ho Chi Minh port. Containers from TCIT are transported to Vietnam International Container Terminals (HCM) and continue to be transported to the Hai Phong port (HP). The goods operated in this leg belong to main lines such as MOL lines, Hapag-Lloyd, and OOCL, meaning that in this situation, the vessel acts as a feeder for the main lines.

In this work, IFO 380 (used for the main engine) is the only fuel type considered, and its price is calculated in 1 year according to the live fuel oil price. Three hundred sixty-five days in 2022 of statistics for Singapore oil prices are determined fuel oil probabilities (Table 3) [44].

"Probability" is calculated by the number of days that the price levels in each interval appear divided by 365, which is the number of days in a year. Fuel consumption during operation is assumed to stabilize. Thus, the fuel costs of

***Table 3.** Fuel oil price probabilities*

Price range (USD)	Average value of IFO 380 price (USD)	Probability $p(FO)$ (%)
300-400	385	15
400-500	440	29
500-600	529	25
600-700	651	22
700-800	745	9

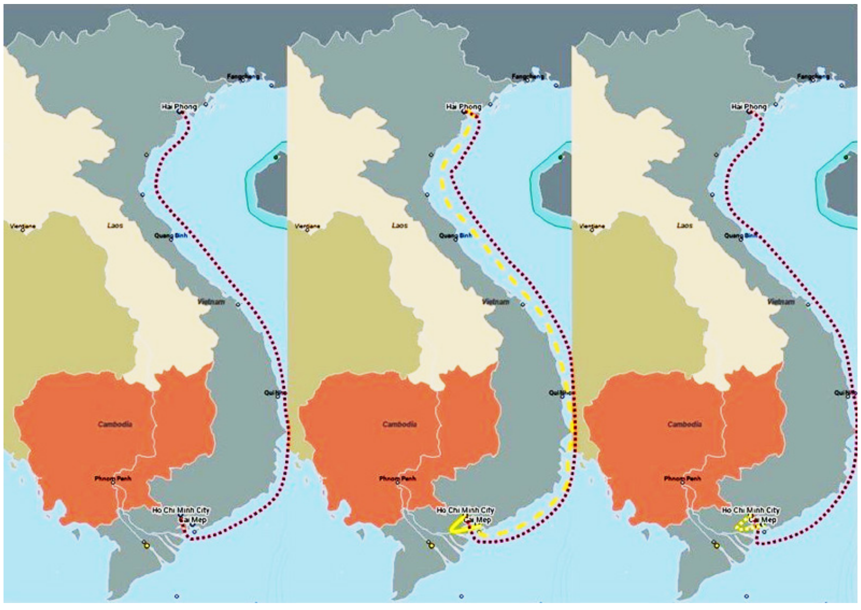


Figure 3. Networks for a case study

the containerships depend on the price of fuel oil for each voyage leg.

The average loading factor of 20-foot dry container (20'DC) and 40-foot dry container (40'DC) for each way of the round voyages of main and feeder containerships is different and according to the booking confirmation and not over vessel capacity and suitable with the vessel's stable, considering the light and heavy legs of the container transportation line. For this study, marketing manager and commercial manager interviews were also conducted. The ship's specifications are listed in Table 4.

Data output from the software for peak, low, and medium seasons account for 18%, 23%, and 59% of the total annual transport volume, respectively. All voyages in each season are counted, and the average number of containers per voyage for each season is calculated and filled in the corresponding "volume" column for 20, and 40 feet containers. Hai An shipping line reserves 15% of slot booking for contractual customers who sign dead-slot contracts and enjoy the best rates; 55% of slot booking for regular customers; and 30% for occasional customers. Data are arranged by season, each customer group, and the average value of the freight in the "freight rate" column. The average container volume and freight rate in each dimension of alternative 1 are illustrated in Table 5. Table 6 summarizes the average container volume in each dimension of alternatives 2, 3.

For simplicity of calculation, assume that the average daily running cost is 137,920,300 VND/day; an average FO consumption is 16 MTs/day; an average DO consumption is 0.25 MT/day. DO is usually used when the machine is in the maintenance mode. DO consumption when maneuvering

Table 4. *Ship's specifications*

Vessel's criteria	Specifications
Gross tonnage due	1728
IMO number Call sign	9245158 XVLV9
Flag	Vietnam
Average speed	13.5 NM
Sources: Author's computation	

the machine forward and backward. Using DO mainly to run the channel and mannequin in and out of the port; DO unit price is unchanged, taken as 20,825,000 VND/MT; marine and port expense in each port of call is similar; other costs include vessel husbanding agency fees, general operations agency fees, booking commissions, management and operation consultant fees, the vessel on/off hire survey (if any), and others. The average of additional agency fees gathered on various voyages is used to calculate other agency costs. The characteristics of all networks are shown in Table 7.

Table 8 expresses the CPV and EUV of Alternative 1 when the parametric adaptation coefficient $\mu_1 = 0$.

4.3. Comparison with the Traditional Method

TTo examine how behavioral biases impact decisions made on shipping networks, this paper calculates voyage daily profit from the CPT approach and compares the obtained results to EUT, according to which decision makers are irrational. Many previous studies have compared CPT and EUT [45-50]. Results reveal that many barriers identified in the literature have potential explanations offered through CPT. According to the EUT, decision makers choose the

Table 5. *Average container volume and freight rate in each dimension of alternative 1*

	HP-HCM				HCM-HP			
Season	Volume 20'	Freight rate/ probability (USD/%)	Volume 40'	Freight rate/ probability (USD/%)	Volume 20'	Freight rate/ probability (USD/%)	Volume 40'	Freight rate/ probability (USD/%)
High season (18%)	371	242/30	343	279/30	317	166/30	352	229/30
		271/55		313/55		179/55		242/55
		296/15		346/15		187/15		254/15
Off-season (23%)	283	226/30	258	263/30	230	150/30	255	221/30
		255/55		297/55		163/55		234/55
		280/15		330/15		171/15		246/15
Medium season (59%)	320	234/30	291	271/30	260	158/30	288	221/30
		263/55		305/55		171/55		234/55
		288/15		338/15		179/15		246/15
Types of goods	Bricks, lime, stone powder, food, plastic pellets, plywood, automobiles, motor vehicles, electronics				Plastic granules, aluminum, building materials, rice, coffee, bran, and paper			
Sources: Author's computation								

Table 6. *Average container volume in each dimension of alternatives 2, 3*

HP-HCM					HCM-HP			
Season (Probability)	**Volume 20'**	**Freight rate/ probability (USD/%)**	**Volume 40'**	**Freight rate/ probability (USD/%)**	**Volume 20'**	**Freight rate/ probability (USD/%)**	**Volume 40'**	**Freight rate/ probability (USD/%)**
High season (18%)	264	242/30	240	279/30	241	166/30	268	229/30
		271/55		313/55		179/55		242/55
		296/15		346/15		187/15		254/15
Off-season (23%)	176	226/30	160	263/30	170	150/30	155	221/30
		255/55		297/55		163/55		234/55
		280/15		330/15		171/15		246/15
Medium season (59%)	220	234/30	200	271/30	220	158/30	200	221/30
		263/55		305/55		171/55		234/55
		288/15		223/15		176/15		246/15
	HP-TCIT				**TCIT-HP**			
High season (18%)	91	251	182	290	72	230	144	280
		292		332		272		320
		324		355		305		345
Off-season (23%)	60	235	120	273	47	214	94	264
		276		316		256		310
		308		339		289		331
Medium season (59%)	76	243	152	281	60	222	120	272
		284		324		264		318
		312		347		297		337
Types of goods	Main line goods (Empty container and other)				Main line goods (Empty container and other)			
Sources: Author's computation								

Table 7. *Characteristics of all networks*

Parameters	Alternative 1	Alternative 2	Alternative 3
Tonnage dues (GT)	17280	17280	17280
Sailing time (day)	4.94	5.02	4.94
Time in port (day)	2.44	2.89	2.89
Total time	7.38	7.91	7.38
Navigation aid dues (VND)	16,588,800	16,588,800	16,588,800
Clearance fees	320,000	480,000	320,000
Pilot dues (VND)	61,344,000	86,227,200	61,344,000
Berth dues (VND)	9,720,000	12,485,664	9,720,000
Mooring/unmooring (VND)	4,441,500	5,541,500	4,441,500
Tugboat charges	69,200,000	100,109,090	69,200,000
Quarantine fees	0	0	0
Customs others (VND)	54,200,000	39,151,200	54,200,000
DO expenses (VND)	20,825,000	38,432,248	41,160,709
Daily fixed cost (VND/day)	137,920,300	137,920,300	137,920,300
Agency others	312,138,000	367,090,000	367,090,000
Average value of revenue in one voyage	Rev1	Rev2	Rev3
Equipment charge (est.)	0.058 Rev1	0.058 Rev2	0.058 Rev3
Liner management fees	0.035 Rev1	0.035 Rev2	0.035 Rev3
Obtained revenue from sea freight	TR^1_{SF}	TR^2_{SF}	TR^3_{SF}
Carrier insurance and claim	$0.01TR^1_{SF}$	$0.01\ TR^2_{SF}$	$0.01TR^3_{SF}$
Source: Author's computation			

option that will result in the highest expected utility value. The expected utility value of each alternative is expressed as follows:

$$EV(pr^d) = \sum_{i=1}^{n} p_i pr_i^d \qquad (17)$$

Where: $\sum_{i=1}^{n} p_i = 1$, i is indicates alternative, n is the number of alternative payoffs, p_i presents the probability of alternative and pr_i^d indicates the payoff of an alternative.

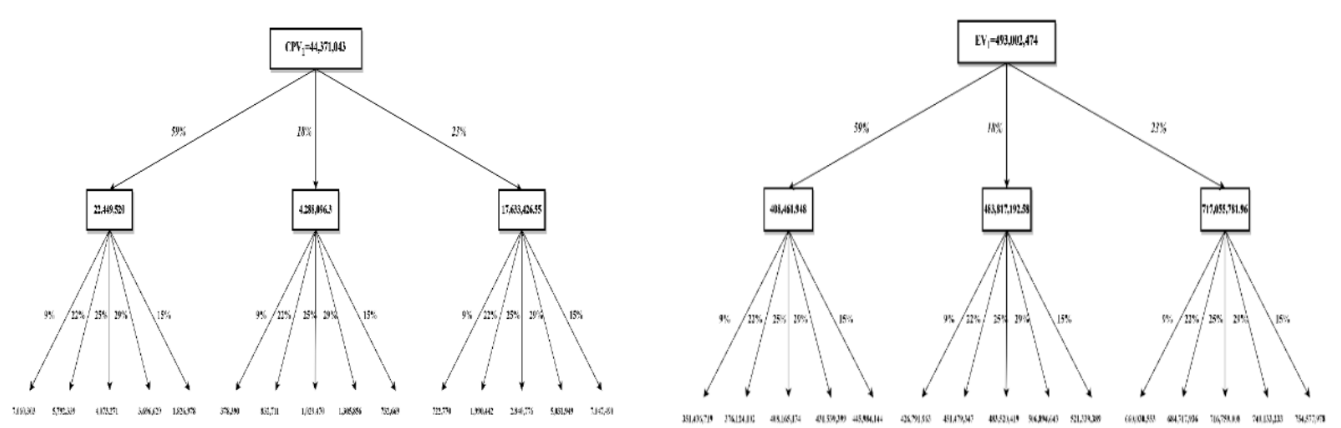
In this section, perform the same steps of the operation for alternatives 1, 2, and 3; then, the CPV and EUV values of all alternatives are summarized in the decision tree of Figures 4, 5, and 6, respectively.

The results obtained from the two methods are depicted in Figure 7. The results from the two methods indicate that the preference in decision-making for Hai An shipping lines is the same and greater than 0. Based on the given information, it can be argued that the Hai An company is operating efficiently. In this case, daily profit cumulative prospect values of alternatives 42,694,100 < 44,371,043 < 44,470,292 show that the prescriptive approach prefers alternative 2 as the first best economical route, with the order of preference being alternative 3 $\prec$ alternative 1 $\prec$ alternative 2. The daily profit expected values of alternatives also have the same prescriptive preference as cumulative prospect values.

Focusing on ratios rather than absolute values is one of the important fundamentals of CPT. Hence, this study investigates the relative comparison between alternatives

Table 8. *CPV and EUV calculation of alternative 1*

No	pr_i^d	$v(pr_i^d)$	$p(fr_i^{sd})$ (%)	p_i^{FO} (%)	p_i (%)	cp_i (%)	cp_i^{trf} (%)	dcp_i^{trf} (%)	CPV	$EUV(pr_i^d)$
1	351,436,719	33,139,464	59	9	5.31	100.00	100.00	21.30	7,060,303	18,661,290
2	376,124,102	35,179,643	59	22	12.98	94.69	78.70	16.47	5,792,339	48,820,908
3	408,165,174	37,803,815	59	25	14.75	81.71	62.23	10.77	4,073,271	60,204,363
4	426,791,963	39,317,897	18	9	1.62	66.96	51.46	0.99	387,390	6,914,030
5	431,539,399	39,702,513	59	29	17.11	65.34	50.47	9.31	3,696,629	73,836,391
6	445,984,144	40,869,666	59	15	8.85	48.23	41.16	4.47	1,826,978	39,469,597
7	451,479,347	41,312,487	18	22	3.96	39.38	36.69	2.02	832,711	17,878,582
8	483,520,419	43,881,861	18	25	4.50	35.42	34.67	2.35	1,029,470	21,758,419
9	506,894,643	45,743,309	18	29	5.22	30.92	32.33	2.85	1,305,856	26,459,900
10	521,339,389	46,888,471	18	15	2.70	25.70	29.47	1.56	732,669	14,076,164
11	660,030,553	57,705,387	23	9	2.07	23.00	27.91	1.25	722,770	13,662,632
12	684,717,936	59,600,554	23	22	5.06	20.93	26.66	3.34	1,990,442	34,646,728
13	716,759,008	62,048,085	23	25	5.75	15.87	23.32	4.58	2,840,776	41,213,643
14	740,133,233	63,825,278	23	29	6.67	10.12	18.74	7.88	5,031,949	49,366,887
15	754,577,978	64,920,167	23	15	3.45	3.45	10.86	10.86	7,047,490	26,032,940
Total						**100**		**100**	**44,371,043**	**493,002,474**



(a) (b)

Figure 4. *Decision tree analysis for alternative 1. (a) CPV; (b) EV*

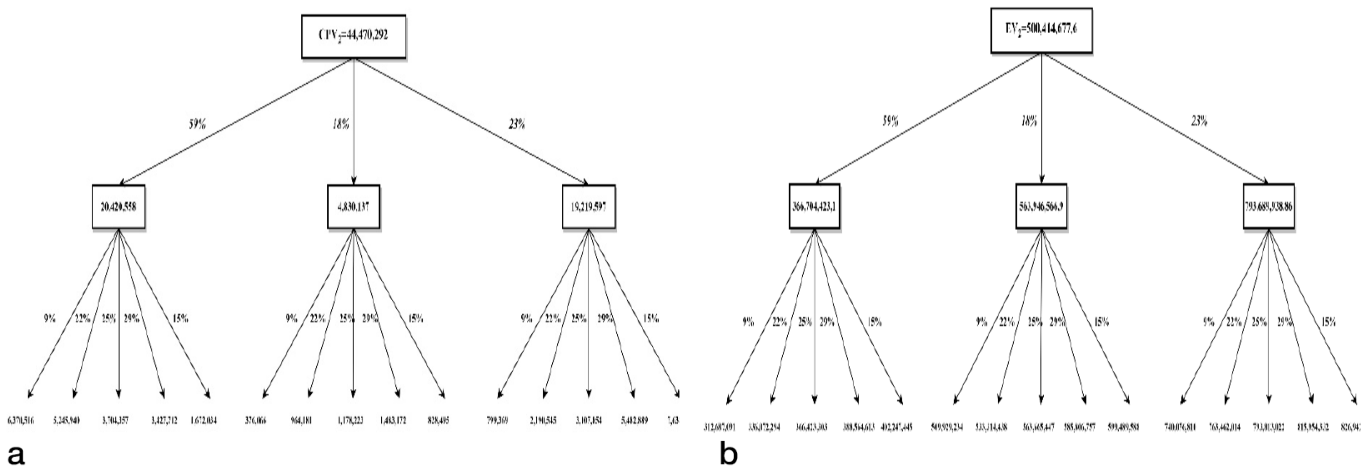


Figure 5. Decision tree analysis for alternative 2. (a) CPV; (b) EV

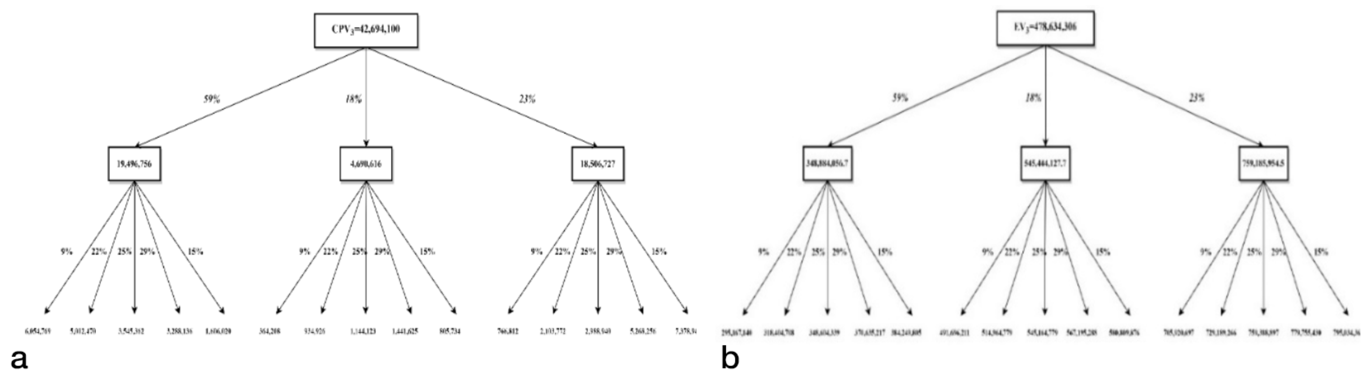


Figure 6. Decision tree analysis for alternative 3. (a) CPV; (b) EV

and grasp the decision-making behavior, as listed in Table 9. In this case study, assume that the obtained results from alternative 3 are indicated as the reference point. The following table illustrates the relative comparison.

From the above comparison results, if access is obtained from the EUT approach, the shipping company would choose alternative 2 as the optimal option and would ignore alternatives 1 and 3. Nevertheless, from the CPT method, options 1 and 2 are both worthy options because they are both profitable compared to the reference point. In addition, the profit gap between the two options equal to 0.22% is negligible. In contrast, the profit gap between the two options is higher and equals 1.55% from the EUT approach. Therefore, decision makers will consider additional factors such as the stability of goods to deploy the shipping route. Alternative 1 is the busiest and most dynamic route in Vietnam's domestic shipping market and is of interest to many major Vietnam shipping lines. Even though the shipping line's selection does not follow EUT, their decisions are consistent with the concept of CPT.

The next step will investigate the relationship between the change of parametric adaptation coefficient $\mu_1$and the variation of CPV and EUV of each alternative by assigning a value to the coefficient ensuring that $\mu_1$is greater than 0, starting from 0.1 to 2.0 under the rule of arithmetic progression with a common difference of 0.1. The results are shown in Table 10.

It is interesting to observe that the EUV remains unaffected by modifying the model's parameters. As a result, EUV does

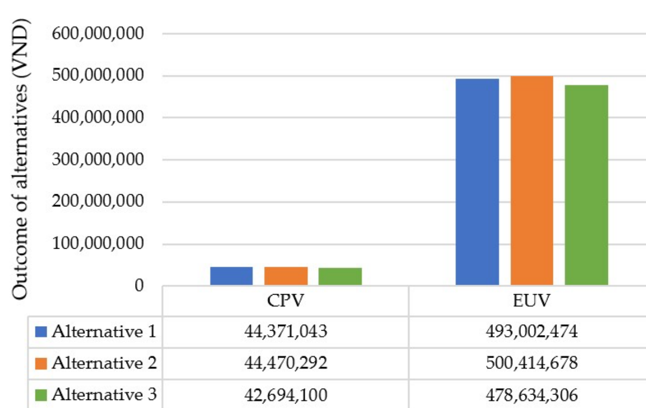


Figure 7. CPV and EUV of the alternatives

not consider complexity factors that can influence decision making, such as prejudices and cognitive biases, which may not adequately reflect the complexities inherent in decision making under uncertainty. Figure 8 depicts the relationship between the parametric adaptation coefficient and the variation of CPV of the three alternatives.

It is possible to realize the peculiarity of the effect of the parameter on the variation of the cumulative prospect value. The higher the parametric adaptation coefficient value, the higher the cumulative prospect of daily profit, but the growth rate diminishes. This means a greater emphasis on risk aversion, demonstrating that prioritizing risk aversion leads to diminishing growth rates despite higher daily profits. Furthermore, alternative 1 is least affected by the adaptive parameters. Under the influence of the adaptive parameter, the CPV of alternative 3 has the highest and fastest variation growth rate compared to the other two options, although it has the lowest CPV. It can be concluded that alternative 1, which is considered a safer choice due to its stability and minimal susceptibility to changes in the uncertainty factor. While alternative 3 may offer a higher potential for CPV, it also carries a greater risk. Similarly, alternative 2 also has a higher possibility of achieving a higher CPV than alternative 1. These findings underscore the importance of risk aversion, safety, and stability in the decision-making process. Combined with the aforementioned arguments, domestic carriers in Vietnam, who prefer certainty, are willing to sacrifice higher profits for stable profits, which aligns with the concept of CPT.

5. Conclusion

This paper proposes a quantitative method that uses econometric cognitive parameters to calculate the round voyage efficiency of shipping network decisions. This paper has demonstrated and compared values from two backbone methods for decision analysis: EUT, in which decision-makers following the EUT are rational, and CPT, in which decision-makers are irrational. This work will be useful and easier for strategy makers of liner shipping companies to consider when making decisions in an uncertain environment. This paper adds to the literature by improving comprehension of the demand for transport, cost, and revenue components by analyzing both shipment demand and clusters of customer and freight rates in the comparison between route scenarios. Networks are constructed, and daily profit formulation is introduced to choose the best optimal shipping network.

For the case study, the results are obtained as follows. Alternative 2 was investigated as the best route. Furthermore, the decision-maker's behavior is not consistent with the fundamentals of EUT, but it was explained from the CPT approach. The preference results from the CPT and the EUT approach are the same. Based on the comparison results mentioned earlier, according to the EUT approach, the relative comparison of average daily profit between alternatives 2 and 1 equal to 1.55% is greater than this gap from the CPT approach in that the difference is only 0.22%, which is very small. The shipping company would choose alternative 2 as the first best option if approached from the EUT perspective and would disregard both alternatives 1 and 3. From the CPT perspective, alternatives 1 and 2 can be considered efficient options. Shipping lines will consider other factors besides the average cumulative profit when choosing option 1 or option 2.

After assessing the impact of adaptation parameters on the model, alternative 1 emerged as the safest with the least effect and the lowest variation in CPV. Alternative 2 is suggested as the most effective option for managers seeking the highest potential CPV and opportunities to achieve greater CPV on daily profit. Alternative 3, on the other hand, offers the lowest profitability and is heavily influenced by uncertainty. As a result, it is recommended to eliminate Alternative 3 as a feasible choice. In fact, the Hai

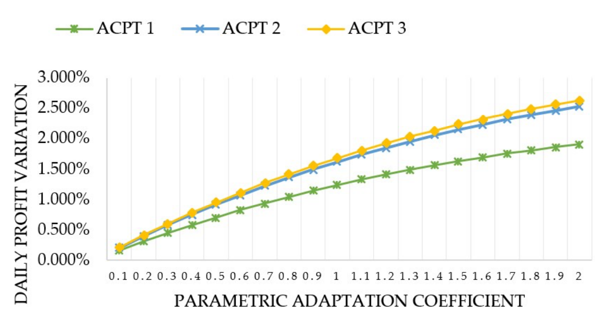


Figure 8. *Effect of adaptive parameter on average daily profit*

Table 9. *Relative comparison between alternatives from the CPV and EUV approaches*

Alternative/Comparison	CPV	EUV
Alternative 1	44,371,043	493,002,474
Alternative 2	44,470,292	500,414,678
Alternative 3	42,694,100	478,634,306
RC23 (Relative comparison between alternative 2 and alternative 3)	4.16%	4.55%
RC13 (Relative comparison between alternative 1 and alternative 3)	3.93%	3.0%
RC21 (Relative comparison between alternative 2 and alternative 1)	0.22%	1.5%

Table 10. *Relationship between the parametric adaptation coefficient and the variation in CPV and EV*

μ_1	Variation in CPV (%)			Variation in EUV (%)		
	Alternative 1	**Alternative 2**	**Alternative 3**	**Alternative 1**	**Alternative 2**	**Alternative 3**
0.1	0.156	0.202	0.209	0	0	0
0.2	0.305	0.393	0.409	0	0	0
0.3	0.449	0.576	0.599	0	0	0
0.4	0.578	0.750	0.779	0	0	0
0.5	0.705	0.915	0.951	0	0	0
0.6	0.824	1.071	1.113	0	0	0
0.7	0.937	1.219	1.267	0	0	0
0.8	1.044	1.360	1.414	0	0	0
0.9	1.144	1.493	1.552	0	0	0
1.0	1.239	1.619	1.682	0	0	0
1.1	1.328	1.738	1.806	0	0	0
1.2	1.411	1.849	1.922	0	0	0
1.3	1.489	1.954	2.032	0	0	0
1.4	1.562	2.054	2.135	0	0	0
1.5	1.631	2.147	2.231	0	0	0
1.6	1.694	2.234	2.322	0	0	0
1.7	1.753	2.315	2.407	0	0	0
1.8	1.808	2.392	2.490	0	0	0
1.9	1.858	2.463	2.560	0	0	0
2.0	1.905	2.529	2.629	0	0	0

An shipping line has also mainly operated with a frequency of three voyages per week on the Hai Phong to Ho Chi Minh round voyage, while the number of voyages to TICT is only one voyage per week. Furthermore, in Vietnam's domestic shipping market, routing as alternative 1 is not only the most popular route because the demand for shipment is stable and regular but also has the longest history route and is deployed by many liner shipping companies with the same operating routes and ship size, including Vosco, Vinafco, Vietsun, Tan Cang shipping, Vsico, and GLS shipping companies. This fact with the above proof and argument can be explained by the fact that decision makers who prefer certainty tend to be averse to risks in gains and are willing to sacrifice potentially high profit for a greater level of assurance. This paper presents a case study that explains why alternative 1 is preferred over alternative 2, despite not having the highest daily profitability. The findings indicate that decision makers in the Vietnam domestic container shipping market value stability and predictability over potential revenue, which is consistent with the principles of CPT.

Notwithstanding efforts to perform a comprehensive analysis with real data, several assumptions were made because of missing data and accompanying uncertainty. One shipping line contributed the data for this study, which is considered a major drawback and resulted in a limited amount of data. Another limitation of this study is its exclusive focus on economic aspects, neglecting technical considerations. Future research could broaden the scope of research by incorporating diverse criteria beyond quantitative measures like voyage time. Qualitative factors, such as reliability of transportation modes, route characteristics (such as navigational safety and security), weather conditions, and the influence of government policies, could be explored using linguistic variables in fuzzy and uncertain environments and should be investigated through expert surveys. Moreover, future studies could enhance the algorithm by using random forest instead of decision tree to deal with larger, more intricate datasets, thereby enhancing accuracy.

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Authorship Contributions

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

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