

Decision making for Shipping Network based on Adaptive Cumulative Prospect Theory

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Abstract : *This paper aims to propose optimal method to assess and cumulate the daily profit for liner shipping to support the shipping lines in making optimal decision with the highest average daily profit. This paper not only explains the actual calculated results align with decision-makers' behavior from concepts indicated in cumulative prospect theory but also contributes to an easy-to-apply method for liner shipping network predictability in and provides optimal decision-making is helpful for shipping managers for the best effective selection of the most appropriate alternative under uncertainties.*

Key words : *Decision-making; Shipping network, Cumulative prospect theory, Daily profit model, Expected utility theory*

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선사 네트워크 의사결정 방법

Contents

1. Introduction
2. Motivation and Objectives
3. Modelling and Methodology
4. Results and Conclusions

1 한국해양대학교

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Introduction

- Container carriers, faced with challenges of increased costs, to seek greater profitability, giving a strategic decision to reroute to alternative ports of call is regarded as one of the efficient treatments
- 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 the maritime industry
- Therefore, this paper focuses on suggesting an average daily profit model with uncertain combination factors influencing shipping route choice behaviour by applying cumulative prospect theory (CPT)
- There are a few methods that can be used to support decision-making, including cost-benefit analysis (CBA), SWOT analysis, multiple criteria decision-making (MCDM), Pareto analysis, Analytical Hierarchy Processes, TOPSIS, Game theory, etc
- Programs and algorithms are too complex and difficult for many decision-makers

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Motivation and Objectives

Motivation

- Shipping companies are willing to pay attention to optimizing container network operations to promote higher quality service, profit, and competitive advantage
- Several methods to support decision-making are often too advanced for most decision-makers

Objectives

- Suggest the optimal decisions regarding the following issues: transportation demand, voyage itinerary, and maximizing daily voyage profits in a round-trip operation
- Investigate and explain the decision-making behaviour of shipping lines
- Contribute to this by providing an analysis of route choice behaviour from the perspective of the shipping lines based on uncertainty criteria

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Modelling and Methodology

Notation	Description	Unit
c^l	Total cost of the round voyage	USD
r^l	Total revenue of the round voyage	USD
p^l	Daily profit of the round voyage	USD
J	Index of port: $J = \{1, \dots, n\}$	
G	Vessel gross tonnage	GT
c^{bn}	Total bunker expense for the round voyage	USD
c_z^t	The transshipment service cost on the leg z	USD
c^{rc}	Total running cost per round trip	USD
c_z^p	Port dues	USD
c_z^{cb}	Commission and brokerage on the leg z	USD
c_z^o	Other cost	USD
t^l	Total time spent for round voyage	Days
f_z^k	Freight rate of k -type container on the leg z	USD/TEU
q_z^k	Shipment demand of container type k on the leg z	TEU

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Modeling and Methodology

Notation	Description	Unit
c_i^{pc}	Port charges on the leg $x(x \in Z)$ of round route	USD
c_i^{inv}	Inventory cost on the leg $x(x \in Z)$ of round route	USD
c_i^{com}	Commission fees on the leg $x(x \in Z)$	USD
c_i^{br}	Broker fees on the leg $x(x \in Z)$	USD
c_i^{ot}	Other cost of round route	USD
c_i^{dv}	Daily running cost of a vessel	USD
c_j^{ad}	Anchorage dues in USD charged by port authorities for the use of anchorage facilities in port j	USD
c_j^{cl}	Custom declaration fees are charged by customs authorities for the use of the anchorage facilities in port j	USD
c_j^{cf}	Clearance fees in port j	USD
r_j^{tm}	Tonnage due rate in port j	USD
r_j^{nm}	Navigation rate is calculated based on gross tonnage for each nautical mile	USD
d_j^{nm}	The distance in nautical mile when the vessel travels through navigable port j	Days
r_j^{db}	Daily berth rate per day is charged per day for the use of berth	USD/TEU
d_j^{db}	Number of days in berth	Days

Modeling and Methodology

Notation	Description	Unit
	Number of tugboat use to support the ship in entering and leaving the port j safety	USD
	Tugboat measurement of power in horse power	USD
	Mooring / unmooring price in port j	USD
	Quarantine, disinfection fees in port j	USD

Assumptions

- Vessel is assumed to be parallel, to follow the same route, and to have a capacity that is adapted to transport demand
- Vessel is assumed to be parallel, to follow the same route, and to have a capacity that is adapted to transport demand
- Assume that the freight rate is adjusted to increase or decrease together for all
- Fuel consumption during operation is assumed to be stabilized

Modeling and Methodology

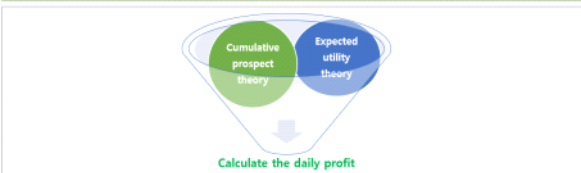
The average daily profit function

$$J^d = \frac{(\sum_{z \in Z} c_z^i + \sum_{z \in Z} c_z^{pc} + c^{inv} + \sum_{z \in Z} c_z^{com} + \sum_{z \in Z} c_z^{br} + c^{ot}) - \sum_{k \in K} \sum_{z \in Z} (f_z^k \circ q_z^k)}{p^d}$$

Voyage total cost function

$$c^i = \sum_{z \in Z} c_z^i + c^{inv} + \sum_{z \in Z} c_z^{pc} + \sum_{z \in Z} c_z^{com} + \sum_{z \in Z} c_z^{br} + c^{ot}$$

Methodology



Modeling and Methodology

Total time spent for round voyage

$$t^{cv} = \frac{\sum_{z \in Z} d_z}{24 * v^{alt}} + 2 * \sum_{j=1}^n m_j^i + \sum_{j=1}^n (\frac{q_j^i}{r_j^i} + \frac{q_j^d}{r_j^d}) \quad (3)$$

Port dues

$$c_j^{pc} = c_j^{ad} + c_j^{cl} + c_j^{cf} + c_j^{br} + c_j^{tm} + c_j^{nm} + c_j^{db} + c_j^{dq} + c_j^{dm} + c_j^{dv} + c_j^i + c_j^d \quad (4)$$

Total running cost for a round voyage

$$c^{trc} = c^{dv} * t^{cv}$$

Total bunker cost for a round voyage

$$c^{bim} = s^{icv} * f^b * c^{fb} + t^{cv} * f^o * c^{do} \quad (5)$$

The total transshipment cost

$$\sum_{z \in Z} c_z^o = \sum_{z \in Z} (q_z^o * u_z^o) \quad (6)$$

Modeling and Methodology

Concepts of Prospect Theory

1) Losses loom large than gains

- People are loss-averse
- Individuals dislike losses more than equivalent gains they are more willing to take risks to avoid a loss
- People need help making optimal choices

2) Diminishing sensitivity

- People focus on ratios rather than absolute values

3) Evaluation is relative to a neutral reference point

- For financial outcomes, the usual reference point is the your current status (Status Quo)

▷ Outcomes better than the reference point are gains

▷ Outcomes below the reference point are losses



Modeling and Methodology

The prospect of an alternative

$$v(a, p) = \sum_{i=1}^n w(p_i) * v(a_i)$$

$v(a, p)$: Prospect of an alternative
 $w(p_i)$: The weighting of the alternative of the probability.

Value function of an outcome

$$v(a_i) = \begin{cases} a_i^{0.88} & a_i \geq 0 \\ -2.25(-a_i)^{0.88} & a_i < 0 \end{cases}$$

The weighting of the probability function"

$$w^+(p) = p^\alpha / [p^\alpha + (1-p)^\alpha]^\beta + \hat{\alpha}$$

$$w^-(p) = p^\beta / [p^\beta + (1-p)^\beta]^\alpha + \hat{\beta}$$

$\alpha=0.61$ (for gains);
 $\hat{\alpha}=0.69$ (for losses)

The cumulative prospect of outcome

$$CPV(a) = \sum_{i=1}^m v(a_i) * w^-(p_i) + \sum_{i=m+1}^n v(a_i) * w^+(p_i)$$

Losses are ranked from $i=1$ to $i=m$

Gains are ranked from $i=m+1$ to $i=n$

$v(a_i)$: The value of outcome
 a_i : An alternative
 a_i : An outcome

The expected utility value of each alternative

$$EV(x) = \sum_{i=1}^n p_i * x_i$$

Where: $\sum_{i=1}^n p_i = 1$

i : Alternative
 n : Number of alternative payoffs
 p_i : Probability of alternative
 x_i : Payoff of an alternative