Evaluating Ship Selection Criteria for Maritime Transportation

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***Abstract*—Nowadays, with the growth of international merchandise trade, the role of the maritime transportation becomes crucial. Selecting the most suitable ship, in order to transport the cargo from an origin port to a destination port, among multiples alternatives is a complex decision process due to the presence of multiple and conflicting criteria. This paper proposes a decision approach based on Decision Making Trial and Evaluation Laboratory (DEMATEL) methodology to determine influential ship selection criteria in maritime transportation industry. Real-world data will be used to illustrate the application of the proposed approach.**

***Index Terms*—maritime supply chain management, ship selection, DEMATEL, criteria weighting**

I. Introduction

In today's globalized world, maritime transportation becomes one of the most important industries with its immense share in the global trade. As the efficiency of the transportation influences directly the growth of the world economy [1], quantitative techniques to manage better maritime transport activities have received increasing attention. Selecting the most suitable sea carrier, in order to transfer a cargo between two seaports, among multiples alternatives is a complex decision process due to the presence of multiple and conflicting criteria.

This paper proposes a decision approach based on Decision Making Trial and Evaluation Laboratory (DEMATEL) methodology to determine influential ship selection criteria in maritime transportation industry. The rest of the paper is organized as follows. The following section outlines the DEMATEL method. Section III defines the criteria used for ship selection. In Section IV, the application of the proposed approach with real data is presented. Conclusion and directions for further research are provided in Section V.

II. DEMATEL Method

The decision making trial and evaluation laboratory (DEMATEL) method [2] is developed by the Science and Human Affairs Program of the Battelle Memorial Institute of Geneva between 1972 and 1976 [3]. The DEMATEL method enables the decision maker to visualize influences between criteria and it computes their importance weights. The steps of the method can be summarized as follows [3]-[5]:

Obtain the initial direct influence matrix *A*. The decision-maker is asked to indicate the direct influence that he believes each factor *i* exerts on each factor *j* of the others, as indicated by a_{ij}, using an integer scale [3].

The integer scale is generally going from "0" to "4" where "0" represents "no influence," and "4" represents "extreme strong influence".

In case of there are multiple respondents, the direct matrix *A* can be obtained by computing the average matrix.

Calculate the normalized initial direct influence matrix D. The normalized initial direct influence matrix can be obtained by normalizing the average matrix *A* which is also called the initial direct influence matrix in the following way [3]-[5]:

D=*s*. *A*, where

$$s = \min\left[\frac{1}{\max_{1\le i\le n}\sum_{j=1}^{n}|a_{ij}|}, \frac{1}{\max_{1\le i\le n}\sum_{i=1}^{n}|a_{ij}|}\right] \quad (1)$$

Calculate the total relation matrix. The total relation matrix T is defined as $T = D(I-D)^{-1}$, where I is the identity matrix.

Define *r* and *c* be *n* x 1 and 1 x *n* vectors representing the sum of rows and sum of columns of the total relation matrix *T*, respectively. Suppose r_i be the sum of *i*th row in matrix *T*, then r_i shows both direct and indirect effects given by factor *i* to the other factors. If c_j denotes the sum of *j*th column in matrix *T*, then c_j shows both direct and indirect effects by factor *j* from the other factors [5].

When $j = i$, the sum $(r_i + c_j)$ is regarded as the degree of importance for factor *i* in the entire system [5,6].

In addition, the difference $(r_i - c_j)$ represents the net effect that factor *i* contributes to the system. Specifically, if $(r_i - c_j)$is positive, factor *i* is a net causer, and when $(r_i - c_j)$ is negative, factor *i* is a net receiver [5].

Set up a threshold value, which is determined by the decision makers, to obtain the network relationship map which explains the structural relations among criteria [5].

III. Ship Selection Criteria

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Selecting the most suitable water carrier, in order to transfer a cargo between two seaports, is considered as one of the most important decisions for a successful supply chain management system. With its need to trade-off multiple criteria, ship selection is a complex multi-criteria decision making (MCDM) problem.

The complexity of the evaluation process is due to the presence of many conflicting criteria and the existence of subjectivity in the human decision making process [7]. In general, experienced decision makers subjectively prioritize selection criteria and make quick decisions. These ad hoc decisions are not always reliable and consistent [7]. Multi-criteria decision making approaches can be used in order to obtain an effective decision for a ship evaluation and selection problem which is characterized by the availability of various alternatives and the presence of multiple and conflicting decision criteria [7].

In this paper, in order to define ship selection criteria, a literature survey is conducted. The criteria used in previous research papers concerning operational reliability assessment of maritime transportation system [8], maritime risk assessment [9-10], and ship evaluation and selection [7, 11] are listed and reformulated by two ship broker experts. The ten ship selection criteria obtained as a result of this work are listed in Table I.

TABLE I. SHIP SELECTION CRITERIA

Criteria
Cost (C1)
Payment due date (C2)
Delivery time (C3)
Reputation of the shipping company (C4)
Flag (C5)
Year of construction (Age of the ship) (C6)
Duration of detentions (C7)
Class (C8)
Gross tonnage (Ship capacity) (C9)
Speed (C10)

The criteria selected are: the total cost of the shipping company to transport the cargo from an origin port to a destination port (C1), the due date of the payment (C2), delivery time (C3), the reputation of the shipping company (C4), the flag of the ship (C5), the age of the ship (C6), the number of days of detentions after the ship has been inspected [10] (C7), the classification organization (C8), the capacity of the ship (C9), the speed of the ship (C10).

IV. APPLICATION

This case study aims at determining and prioritizing criteria used in the selection process of an appropriate ship among candidate ships.

In order to determine critical criteria in selecting a sea carrier, DEMATEL method described in previous section in employed. Two experienced ship brokers are asked separately to indicate the influence that they believes each criterion *i* exerts on each criterion *j* of the others, using an integer scale ranging from 0 to 4 represented in Table II.

TABLE II. PAIRWISE COMPARISON SCALE

Influence Level	Score
No influence	0
Very low influence	1
Low influence	2
High influence	3
Very high influence	4

The initial direct influence matrix, represented in Table III and Table IV, is obtained by computing the average of the influence matrices which are deducted from pairwise comparisons made by two experts.

TABLE III. INITIAL DIRECT INFLUENCE MATRIX (I)

	C1	C2	C3	C4	C5
C1	0	3	0	1.5	0
C2	1	0	0	0.5	0
C3	2	3	0	2	0
C4	1.5	3	1.5	0	0
C5	1.5	0	1.5	3	0
C6	3.5	0	2	3.5	3
C7	3.5	0	1.5	4	3.5
C8	2.5	0	1	4	0
C9	4	1.5	3	3.5	0
C10	3	0	3.5	1	0

The initial direct matrix is normalized and the total relation matrix is calculated.

TABLE IV. INITIAL DIRECT INFLUENCE MATRIX (II)

	C6	C7	C8	C9	C10
C1	0	0	0	0	0
C2	0	0	0	0	0
C3	0	0	0	0	1
C4	0	3	3	0	0
C5	0	3	2.5	0	0
C6	0	3	3.5	1.5	3
C7	0	0	3.5	0	0
C8	0	4	0	0	0
C9	0	1.5	1	0	4
C10	0	0	0	0	0

The sum of rows and sum of columns of the total relation matrix are shown in Table V.

TABLE V. SUM OF THE ROWS AND COLUMNS

	r	*c*
C1	0.263928	1.579915
C2	0.095307	1.004477
C3	0.478123	0.930581
C4	0.856305	1.657932
C5	0.914134	0.447985
C6	1.767477	0
C7	1.192866	1.086777
C8	0.905848	1.020111
C9	1.248134	0.065217
C10	0.470498	0.399626

When $j = i$, the sum $(r_i + c_j)$, is regarded as the degree of importance for criterion i in the entire system [5,6]. In addition, the difference $(r_i - c_j)$ represents the net effect that factor i contributes to the system. Specifically, if $(r_i - c_j)$ is positive, factor i is a net causer, and when $(r_i - c_j)$ is negative, factor i is a net receiver [5]. The sum of influences given and received [5] on each ship selection criterion are shown in Table VI and Table VII.

TABLE VI. TOTAL SUM OF THE ROWS AND COLUMNS OF EACH CRITERION

	$(r_i + c_i)$
C1	1.843843
C2	1.099784
C3	1.408704
C4	2.514237
C5	1.362119
C6	1.767477
C7	2.279643
C8	1.925959
C9	1.313351
C10	0.870124

TABLE VII. DIFFERENCE BETWEEN ROW AND COLUMN SUMS

	$(r_i - c_i)$
C1	-1.315987
C2	-0.909170
C3	-0.452458
C4	-0.801627
C5	0.466149
C6	1.767477
C7	0.106089
C8	-0.114263
C9	1.182917
C10	0.070872

As seen in Table VIII, the net causer criteria are flag (C5), year of construction (C6), duration of detentions (C7), gross tonnage (C9), and speed of the ship (C10).

The net receiver criteria are cost (C1), the due date of the payment (C2), delivery time (C3), the reputation of the shipping company (C4), and class (C8).

TABLE VIII. TYPE OF EACH SHIP SELECTION CRITERION

C1	Net receiver
C2	Net receiver
C3	Net receiver
C4	Net receiver
C5	Net causer
C6	Net causer
C7	Net causer
C8	Net receiver
C9	Net causer
C10	Net causer

As mentioned earlier, when $j = i$, the sum $(r_i + c_j)$ is regarded as the degree of importance for factor i in the entire system [5], [6]. Table IX shows the normalized importance degrees of criteria obtained by the sums given in Table VI.

TABLE IX. IMPORTANCE DEGREES OF CRITERIA

	Importance Degree
C1	0.112531
C2	0.067120
C3	0.085974
C4	0.153445
C5	0.083131
C6	0.107870
C7	0.139128
C8	0.117542
C9	0.080154
C10	0.053104

Reducing the number of criteria taken into account in the decision process enables the ship brokers to focus more on the key criteria. Based on a threshold value of 0.08, eight criteria (cost (C1), delivery time (C3), reputation of the company (C4), flag (C5), year of construction (C6), duration of detentions (C7), class (C8), gross tonnage (C9)) are determined. The importance weights for eight criteria are renormalized as shown in Table X.

TABLE X. IMPORTANCE WEIGHTS OF CRITERIA

	Importance Weights
C1	0.127908
C3	0.097723
C4	0.174414
C5	0.094491
C6	0.122611
C7	0.158140
C8	0.133605
C9	0.091108

According to the Table X, the most important criterion is the reputation of the company (C4). The duration of detentions (C7), the classification organization (C8), the cost (C1), and the age of the ship (C6) are the other critical factors.

V. CONCLUSION

Selecting the most suitable sea carrier, in order to transfer a cargo between two seaports, among multiples alternatives, is considered as one of the most important decisions for a successful supply chain management system. The selection of an appropriate ship is a complex decision process due to the presence of multiple and conflicting criteria.

In this paper, a decision approach based DEMATEL methodology to determine influential ship selection criteria in maritime transportation industry, is presented. The DEMATEL method enables the decision maker to visualize influences between criteria and it computes their importance weights. Future research will focus on developing MCDM approaches to ship selection problem, using the criteria obtained in this study.

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