A QFD-Based Decision Model for Ship Selection in Maritime Transportation

Zeynep Sener and Ece Ozturk

***Abstract*—Maritime transportation is a cost-effective method which enables companies to transfer an international cargo between two seaports. With its need to trade-off multiple criteria, selecting the most suitable ship among multiple alternatives is a complex multiple criteria decision making (MCDM) problem. This paper presents a decision approach based on quality function deployment (QFD) methodology for ship selection in maritime transportation industry. The proposed decision model takes into account company needs and ship attributes and also the relations between them. The simple additive weighting (SAW) method is used to obtain a final score for each ship alternative.**

***Index Terms*—Quality function deployment, ship selection, multiple criteria decision making, supplier selection.**

I. Introduction

Due to the expanding competition in today's business world, transportation activities become crucial for globalized companies. As the efficiency of these activities enhance the competitive advantage of organizations, firms must select the right way to transport their merchandises with the right supply chain partners.

Nowadays, maritime transportation is one of the most important industries with its immense share in the global trade. Maritime transportation is a cost-effective method which enables companies to transfer an international cargo between two seaports. Hence, selecting the most suitable sea carrier to transport the cargo from an origin port to a destination port, which can be viewed as a supplier selection problem, is a strategic decision of the supply chain management system. Selecting the right suppliers improves the company's competitiveness.

With its need to trade-off multiple criteria, ship selection or maritime logistic partner selection is an important multiple criteria decision making (MCDM) problem. Selecting the most suitable ship, in order to transfer a cargo between two seaports, among multiples alternatives is a very complex decision process.

In order to transport merchandise in a reliable and low-cost way, it is necessary to select a ship from a shipping agency which can be aligned with the needs of the company. Thus, a decision making approach for ship selection requires both company demands and ship characteristics and their interactions to be considered.

This paper presents a decision approach based on quality function deployment (QFD) methodology for ship selection. The proposed decision model takes into account user needs and ship attributes and also the relations between them.

The rest of the paper is organized as follows. The following section outlines the QFD methodology. A QFD-based decision approach for ship selection is introduced in Section III. Section IV presents the application of the proposed approach. Finally, concluding remarks and directions for further research are provided in Section V.

II. Quality Function Deployment

QFD is a strategic tool which is used to develop improved products and services responsive to customer needs. It is a systematic process for translating customer needs into engineering characteristics of a product or a service to ensure a quality level that meets the desires of customer throughout each stage of production.

The basis of QFD is to obtain and translate customer needs into engineering characteristics, and subsequently into part characteristics, process plans and production requirements. In order to establish these relationships, QFD usually requires four matrices: product planning, part deployment, process planning, and production/operation planning matrices, respectively [1].

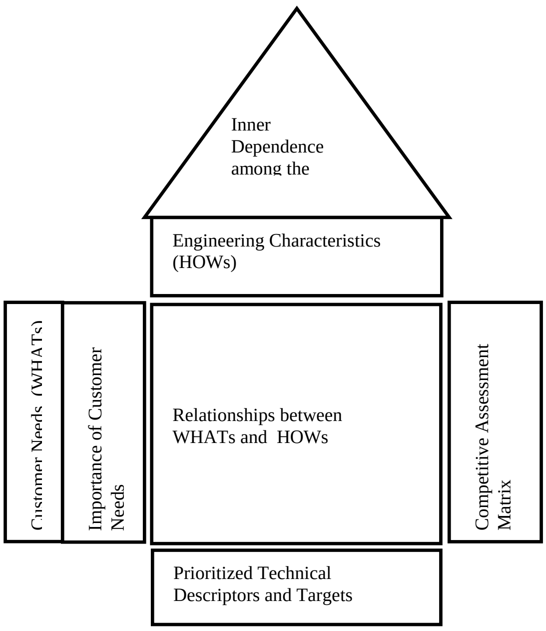

Fig. 1. The house of quality.

The product planning matrix, also called the house of quality, translates customer needs which are subjective and qualitative, into technical engineering characteristics. The relationships between customer needs and engineering

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The authors are with Galatasaray University, Turkey (e-mail: zsener@gsu.edu.tr, eceoztrk8@gmail.com).

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characteristics are shown in each cell in the body of the house of quality which contains seven elements as shown in Fig. 1.

The house of quality is the most frequently used matrix in QFD process. Han *et al.* [2] state that many companies, such as Volvo, have found a great deal of benefit can be achieved from just completing this first matrix.

QFD was originally proposed to develop products and services with higher quality to satisfy customer expectations. Hence, at first, QFD was employed for product development and quality management. Later, this method's functions have been expanded to wider fields (design, engineering, decision-making, etc...). Essentially there is no definite boundary for QFD's potential fields of applications [3].

III. QFD-Based Decision Model for Ship Selection

In this section, a decision making approach based on QFD method is presented to solve the ship selection problem. 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 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 [4]. 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 [4].

In a ship selection problem, the objective of the companies is to find a ship to transport their merchandise safely [5], within a predetermined time limit [5], at a lower cost via a reputable shipping company. Thus, user needs which can be used in the QFD process are delivery of cargo in undamaged condition (CN1), timely delivery of cargo (CN2), total cost (CN3), reputation of the shipping company (CN4). The company needs are listed in Table I.

TABLE I: Company Needs

Delivery of cargo in undamaged condition (CN1)
Timely delivery of cargo (CN2)
Total cost (CN3)
Reputation of the shipping company (CN4)

In this paper, in order to define ship characteristics, a literature survey is conducted. The criteria used in previous research papers concerning operational reliability assessment of maritime transportation system [5], maritime risk assessment [6], [7], and ship evaluation and selection [4], [8] are listed and reformulated by the QFD team which includes two ship broker experts and the supply chain manager of the company. The five ship characteristics obtained as a result of this work benefiting from expert opinions and earlier studies are listed in Table II.

The ship characteristics selected are: the flag of the ship (SC1), the age of the ship (SC2), the number of days of detentions after the ship has been inspected [7] (SC3), the experience of the shipping company in the maritime transportation sector (in years) (SC4), and the general condition of the ship (SC5).

TABLE II: Ship Characteristics

Flag (SC1)
Year of construction (Age of the ship) (SC2)
Duration of detentions (SC3)
Experience in the sector (Years) (SC4)
General condition of the ship (SC5)

The company needs are need to be prioritized by the QFD team considering the priority level of the strategic objectives of the company. Then, the relationships between company needs and ship characteristics must be identified in order to calculate the weights of the ship characteristics which are one of the main outputs of the house of quality [9]. The importance weight of each ship characteristic is determined as the weighted sum of the relationship scores with the prioritized company needs.

When the weighting of each ship characteristic is completed, the QFD team has to do assess each ship vis-à-vis the attribute in question and combine these assessments with ship characteristics' weights to establish a final ranking of ship alternatives [9].

The paper proposes to use the simple additive weight (SAW) method, which is the most widely used multiple attributes decision making method [10] to obtain a final score for each ship alternative. The SAW method consists of two steps: first, scaling the values of all attributes to make them comparable; and then, calculating the sum of the values of the all attributes for each alternative [10].

IV. Illustrative Ship Selection Problem

In this section, the application of the proposed QFD-based decision making approach is illustrated through a ship selection problem. The ship selection problem considered in here uses hypothetical data for 6 ship alternatives. The case examined is to select an appropriate bulk carrier with a capability of delivering 3000 tons of cargo between two European ports among candidate ships.

In order to construct the house of quality, company needs and ship characteristics determined in the previous section are employed.

The QFD team prioritized the company needs using an integer scale ranging from 1 to 5 where 1 represents very low importance and 5 represents very high importance. Weightings are based on team members' direct experience with the transport process [11]. The relative importance weights of company needs are shown in Table III.

TABLE III: Importance Weights of Company Needs

Company Needs	**Importance Degree**
CN1	5
CN2	5
CN3	4
CN4	3

The relationships between company needs and ship characteristics are determined by the QFD team indicating how much each ship characteristic affects each company need. The team seeks consensus on these evaluations and uses numbers or symbols to establish the strength of these relationships [11]. In this case study, a 1-3-9 numerical scale is employed to denote weak, medium and strong relationships between company needs and ship characteristics. The house of quality is shown in Fig. 2.

		Ship Characteristics				
Company Needs	**Importance**	**SC1**	**SC2**	**SC3**	**SC4**	**SC5**
CN1	5	**1**			**9**	**9**
CN2	5	**1**	**3**	**9**	**9**	
CN3	4	**1**	**9**	**3**	**9**	**9**
CN4	3	**3**	**3**	**9**	**9**	**3**

Fig. 2. The house of quality for ship selection.

The weights of the ship characteristics, which are one of the main outputs of the house of quality [9], can be calculated as the weighted sum of the relationship scores with the prioritized company needs. The importance weights of each ship characteristic are given in Fig. 3.

		Ship Characteristics				
Company Needs	**Importance**	**SC1**	**SC2**	**SC3**	**SC4**	**SC5**
CN1	5	**1**			**9**	**9**
CN2	5	**1**	**3**	**9**	**9**	
CN3	4	**1**	**9**	**3**	**9**	**9**
CN4	3	**3**	**3**	**9**	**9**	**3**
weights of ship characteristics		**23**	**60**	**84**	**153**	**90**
relative weights		**0.056**	**0.146**	**0.205**	**0.373**	**0.220**

Fig. 3. Relative weights of the ship characteristics.

The QFD team needs to assess the ratings of each ship alternative with respect to each ship characteristic as shown in Table IV. The ship selection problem considered in here uses hypothetical data for 6 ship alternatives.

TABLE IV: ASSESSMENT MATRIX

Ship Alternatives	**SC1**	**SC2**	**SC3**	**SC4**	**SC5**
SA1	Portugal	1985	3	5	4
SA2	Bulgaria	1996	1	10	7
SA3	Portugal	2004	2	3	10
SA4	Ukraine	1989	2	12	5
SA5	Bulgaria	1979	40	30	5
SA6	Cook Islands	1998	5	22	6

In this work, as in [7], for the first ship characteristic (*flag*), the excess factor of the Memorandum of Understanding of Paris (Paris MOU) report is used.

In order to make the data related to ship characteristics unit-free and comparable, a linear normalization scheme is employed. Ship characteristics such as the experience of the shipping company in the maritime transportation sector (in years) (SC4) and the general condition of the ship (SC5), for which the greater the performance value the more its preference are considered as benefit attributes. On the other hand, ship characteristics such as the flag of the ship (the excess factor of the flag) (SC1), the age of the ship (SC2), the number of days of detentions after the ship has been inspected [7] (SC3), whose lower values are desirable, are considered as cost attributes.

TABLE V: VALUES FOR FLAG CHARACTERISTIC

Ship Alternatives	**Flag Values**
SA1	0.17
SA2	0.22
SA3	0.17
SA4	0.53
SA5	0.22
SA6	1.62

The simple additive weight (SAW) method is employed to obtain a final score for each ship alternative using the relative weights of ship characteristics and the assessment matrix. The final scores obtained for 6 ship alternatives are given in Table VI.

TABLE VI: FINAL SCORES OF SHIP ALTERNATIVES

Ship Alternatives	**Final Scores**
SA1	0.328
SA2	0.611
SA3	0.562
SA4	0.441
SA5	0.576
SA6	0.547

According to the results, ship alternative 2 (SA2) is determined as the most suitable ship, which is followed by the ship alternative 5, and then by ship alternative 3.

V. CONCLUSION

In today's competitive business world, selecting the most suitable ship to transport the cargo from an origin port to a destination port, which can be viewed as a supplier selection problem, is a strategic decision of the supply chain management system. With its need to trade-off multiple criteria, ship selection or maritime logistic partner selection is an important MCDM problem.

In order to transport merchandise in a reliable and low-cost way, it is necessary to select a ship from a shipping agency which can be aligned with the needs of the company. Thus, a decision making approach for ship selection requires both company demands and ship characteristics and their interactions to be considered.

This paper presents a decision approach based on QFD methodology for ship selection. The proposed decision model takes into account user needs and ship attributes and also the relations between them. The simple additive weight (SAW) method is used to obtain a final score for each ship alternative.

Due to the fact that the relationships between company needs and ship characteristics are vague and imprecise, and ship selection criteria may have quantitative or qualitative dimensions, fuzzy sets theory can be used in ship selection problem. Future research will focus on developing MCDM approaches based on fuzzy-QFD to ship selection problem, using real-world data.

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Zeynep Sener is an assistant professor of industrial engineering at Galatasaray University, Turkey. She holds her BS, MS, and PhD degrees in industrial engineering from Galatasaray University. Her areas of interest include multiple criteria decision making, quality function deployment, and applications of fuzzy mathematical programming. She has coauthored articles that appeared in *International Journal of Production Research*, *Expert Systems with Applications*, *International Journal of Advanced Manufacturing Technology*, *Software Quality Journal*, and *Concurrent Engineering-Research and Applications.*

Ece Ozturk is a master's degree candidate in industrial engineering at Galatasaray University, Turkey. Her areas of interest include multiple criteria decision making and applications of quality function deployment.