Expert Systems with Applications 36 (2009) 6227–6235

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

An integrated fuzzy QFD model proposal on routing of shipping investment decisions in crude oil tanker market

Metin Celik [a,*], Selcuk Cebi [b], Cengiz Kahraman [b], I. Deha Er [c]

[a] Department of Maritime Transportation & Management Engineering, Istanbul Technical University, Tuzla 34940, Istanbul, Turkey
[b] Department of Industrial Engineering, Istanbul Technical University, Macka 34367, Istanbul, Turkey
[c] Department of Marine Engineering, Istanbul Technical University, Tuzla 34940, Istanbul, Turkey

ARTICLE INFO

Keywords:
Fuzzy QFD
FAHP
FAD
SoQ
Shipping investments
Tanker markets
.

ABSTRACT

Monitoring the market has crucial roles for executing the shipping investment decisions in maritime transportation industry. The high level of managerial effort requires bringing market tendencies with the up-to-date data over dynamic parameters. This paper extends the Quality Function Deployment (QFD) principles towards shipping investment process via the originally proposed Ship of Quality (SoQ) framework. Furthermore, the Fuzzy Analytic Hierarchy Process (FAHP) and Fuzzy Axiomatic Design (FAD) algorithms are integrated into the SoQ frame in order to involve quantitative outcomes into the shipping investment decisions. The SoQ is performed over a set of periodical data and recent trends of the principal crude oil tanker markets such as Very Large Crude Oil Carriers (VLCCs), Suezmaxes, and Aframaxes in order to ensure the illustrative results. As an effective investment tool, the proposed SoQ model is expected to provide invaluable decision aid for the relevant shipping executives.

1. Brief introduction on shipping investment

Monitoring and predicting dynamic parameters of the maritime transportation industry such as freight rates, ship sale and purchase prices, new building trends, bunker prices, and scrapping rates (Tsolakis, Cridland, & Haralambides, 2003) have enforced the executives in shipping business. Integration of innovative technologies (Lee et al., 2006), effective communication (Jenssen & Randoy, 2006), and improving managerial skills (Celik & Er, 2006a; Hork, 2004; Panayides, 2006) are the key aspects to ensure customer satisfaction in the market. Especially, the investment decision and timing (Alizadeh & Nomikos, 2007) are the potential issues to manage the market competitiveness in maritime transportation industry. The investment decisions in shipping require assessing the high level of up-to-date information towards the technical and commercial variables of maritime transportation market. At this point, diversity of the different market options (*i.e. bulk carrier market, crude oil market, container market, gas & chemical markets*) increases the complexity of the shipping investment problem. Moreover, additional assessments need to be performed over critical issues such as return on investment (Cullinane, 1995), catastrophic risks (Celik & Er, 2006b), and oil crises (Bergin & Glick, 2007) to ensure the feasibility of the shipping enterprises. However, the customer satisfaction levels in the market can systematically be linked to the route of new investment decisions. This idea reduces the additional efforts in shipping investment decisions and it provides the reflection of the overall market trends for the relevant decision-makers. In maritime transportation industry, the charterers are recognized as the potential customers of the ship management companies who operate the merchant fleets on behalf of the ship owners. In this way, the ship owners and the relevant managers as potential decision-makers can shift the route of shipping investments with respect to the recent tendencies of charterers and daily statistics over the market indicators.

This paper focuses on structuring a decision aid mechanism on the basis of Quality Function Deployment (QFD) model under fuzzy environment in order to route investment decisions with respect to the customer satisfaction level of shipping charterers in crude oil tanker markets. It aims at measuring charterers' tendencies to route the investment decisions of global ship owners. The research methodology ensures embedding the recent statistical data of different markets (*i.e. Very Large Crude Oil Carriers (VLCCs), Suezmaxes, and Aframaxes*) into the QFD-based decision-aid mechanism. On the other hand, the Fuzzy Analytic Hierarchy Process (FAHP) algorithm derives the relative importance of performance characteristics of each market while the Fuzzy Axiomatic Design (FAD) ensures the selection of the suitable market alternative.

The remaining parts of this paper are organized as follows: in Section 2, the theoretical background of the research methodology

* Corresponding author. Tel.: +90 216 395 1064;fax: +90 216 395 4500.
E-mail address: celikmet@itu.edu.tr (M. Celik).

0957-4174/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.eswa.2008.07.031

which also includes a literature review on the QFD applications through measuring customer satisfaction is described . In Section 3, the extension of the Fuzzy QFD model to shipping investment decisions is illustrated towards crude oil tanker markets via using the recent statistical data. Concluding remarks and proposals for further research are expressed within the last section of this paper.

2. Research methodology

The research methodology of this paper is established on the basis of OFD principle. The house of quality (HoQ) is modified to ensure the compliance of the proposed mechanism with the shipping investment decisions. Furthermore, the solution is performed based on decision-making algorithms under fuzzy environment. This section enables the required information through the methodological concept of this research.

2.1. Background of QFD

Historically, the concept of QFD was initiated by *Akao* in 1966, expanded in 1969, and published as a system prototype in 1972. Then, the application of idea was widespread towards the individual organizations (*i.e. Mitsubishi Heavy Industry, Toyota Auto Body, Sawada Auto Body etc.*) in different industrial branches (Velle, Cox, & Moran, 1997). In the last decade, there have been several modifications performed over the initial structure and principles of QFD.

The QFD is a technique for product or service development, brand marketing, and product management. The primary purpose of the QFD approach is to help planners in order to focus on the characteristics of the products or services from the viewpoints of market segments. Furthermore, it is a concept and mechanism for translating the voice of the customers through the various stages of product planning, engineering, manufacturing into product. Systematically, each translation uses a chart on the basis of HoQ frame. The HoQ typically contains information on "what to do" (performance characteristic), "how to do it" (engineering characteristics), and the integration of this information and the relevant benchmarking data (Kim, Jang, Lee, & Cho, 2000). The traditional QFD model is based on the paradigm of designing and manufacturing physical objects related to the system hardware. However, QFD has been extended beyond its initial concept.

2.2. A brief review on QFD applications

The QFD model has several applications in various eras. A wide range of literature review over QFD applications was already represented by Chan and Wu (2002) and Xie et al. (2003). The practical applications of the QFD approach have been forwarded to the key topics and fields as follows: automotive (De Vera, Glenon, Kenny, Khan, & Mayer, 1988; Tsuda, 1997), construction (Abdul-Rahman, Kwan, & Woods, 1999; Armacost, Componation, Mullunes, & Swart, 1994; Dikmen, Birgonul, & Kiziltas, 2005; Mallon & Mulligan, 1993), education (Bier & Cornesky, 2001; Chen & Bullington, 1993; Ermer, 1995; Franceschini & Terzago, 1998; Hwarn & Teo, 2001; Lam & Zhao, 1998; Pitman, Motwani, Kumar, & Cheng, 1995; Shieu-ming, 2004), electronics (Burrows, 1991; Herzwurm & Schockert, 2003; Kwong, Chen, Bai, & Chan, 2007; Liner, Loredo, Gitlow, & Einspruch, 1997; Tan & Neo, 2002), food industry (Bech, Hansen, & Wienberg, 1997; Benner, Linnemann, Jongen, & Folstar, 2003; Charteris, 1993; Costa, Dekker, & Jongen, 2000; Viaene & Januszewska, 1999), healthcare (Foester, 2001; Hauser, 1993; Jeong & Oh, 1998; Moores, 2006; Radharamanan & Godoy, 1996), marketing (Aungst, Barton, & Wilson, 2003; Lu & Kuei, 1995; Lu, Madu, Kuei, & Wikonur, 1994; Mohr-Hackson, 1996; Vairaktarakis, 1999), service (Arai & Shimomura, 2005; Denton, 1990; Dube, Johnson, & Renaghan, 1999; Ermer & Kniper, 1998; Ghobadian & Terry, 1965; Graessel & Zeidler, 1993; Pun, Chin, & Lau, 2000; Selen & Schepers, 2001), and software (Barnett & Raja, 1995; Chakraborty & Dey, 2007; Erikkson & McFadden, 1993; Elboushi & Sherif, 1997; Haag, Raja, & Schkade, 1996; Karlsson, 1997; Pai, 2002; Trappey, Trappey, & Hwang, 1996; Yoshizawa, Akao, Ono, & Shingo, 1993). The outcomes of the QFD-based models have ensured the required feedbacks to the relevant organizations in different industries. Besides the well-structured implementations, the QFD methodology has been integrated with other traditional methods in order to design hybrid assessment system. This paper has attempted to establish a decision-aid mechanism towards the execution of shipping investment decisions based on customer satisfaction levels in different markets.

2.3. Establishing of links to customer satisfaction & investment planning

In a broad sense, the QFD method consists of three main steps: (1) identifying the customer needs as voice of the customer (VoC), (2) determining the engineering characteristics of products or services that meet VoC, (3) setting development targets and test methods for the products or services. However, this paper eagerly motivates to establish a systematic decision mechanism over shipping investment by measuring the customer tendencies in the maritime market. Hence, the literature review for this study has shifted towards the QFD applications in measuring of the customer satisfaction. As an illustrative case from the literature, Kim et al. (2000) proposed a methodology based on HoQ to construct a decision path for Information Technology (IT) investments. Partovi (2007) proposed a QFD model with AHP integration that deals with the selection of adequate manufacturing system by concerning the needs the of customers in the target market on the basis of integrated QFD model. However, the outcomes of our paper act as a decision aid for new investments in market level instead of redesigning the existing organizational process. It is another phenomenon to assess a shareholder value as a guiding principle in customer relationships of firms (Stahl, Matzler, & Hinterhuber, 2003). Hence, this study settled the market indicators in the proposed QFD framework to analytically measure the charterers' perceptions as one of the potential shareholders of ship owners in maritime transportation industry.

In spite of the limited extensions of QFD to investment planning in the literature, many of the previous studies also directly focused on exploring customer satisfaction in order to manage the effectiveness in product development (Kumar & Midha, 2001; Pullman, Moore, & Wardell, 2002), environmental protection (Halog, Schultmann, & Rentz, 2001; Thurston, Lloyd, & Wallace, 1994), training curriculum redesign (Chou, 2004; Lee & Lo, 2003; Motwani, Kumar, & Mohamed, 1996), system integration (Shamsuddin, 2004), and so on. The remaining parts of this study eagerly focus on combining the investment decisions with the market-based data related to the customer satisfaction levels based on QFD model that is also supported with the integrated solution algorithms.

2.4. Integrated design & solution algorithms for QFD

2.4.1. Review on current approaches

Although QFD has been proposed and put in use for several decades, it is still in its developmental stage (Xie, Tan, & Goh, 2003). The structure of the QFD models was strengthen by integrated different traditional techniques and approaches such as Total Quality Management (TQM), Theory of solving inventive problems (TRIZ), Failure Mode and Effects Analysis (FMEA), Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Technique for Order