Expert Systems with Applications 39 (2012) 6911–6920

Contents lists available at SciVerse ScienceDirect

Expert Systems with Applications

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

Intelligent decision support for effectively evaluating and selecting ships under uncertainty in marine transportation

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ARTICLE INFO

Keywords:
Uncertainty
Multicriteria analysis
Decision making
Task-oriented weighting
Intelligent decision support

ABSTRACT

This paper presents an intelligent decision support system for evaluating and selecting specific ships under uncertainty. A task-oriented procedure is developed for determining the relative importance of the evaluation and selection criteria with respect to a specific shipping task. A fuzzy multicriteria analysis algorithm is developed for determining the overall performance of each ship across all the selection criteria and their associated sub-criteria. An intelligent decision support system capable of integrating the developments above is proposed for facilitating the ship evaluation and selection process. An example is presented to demonstrate the effectiveness of the proposed intelligent decision support system.

1. Introduction

With the increasing globalization and the rapid growth in international trade exemplified by the growth of almost 70% from 1990 to 2004 (United Nations Conference on Trade, 2006), cargo shipping in marine transportation becomes increasingly important to all the stakeholders in international trade. This is especially the case in Australia due to its geographic location and its status as a major supplier of mineral materials in the world (Ang, Cao, & Ye, 2007). As a result, evaluating and selecting the most suitable ship from many available ships for a giving shipping task becomes a critical decision to be made in marine transportation.

Evaluating the suitability of individual ships for a specific task in marine transportation is complex and challenging. The complexity of the evaluation and selection process is due to: (a) the multidimensional nature of the problem (Deng & Wibowo, 2008), (b) the presence of multiple, often conflicting evaluation criteria and their associated sub-criteria (Balmat, Lafont, Maifret, & Pessel, 2009; Eleye-Datubo, Wall, & Wang, 2008), and (c) the existence of subjectiveness and uncertainty in the human decision making process (Wibowo & Deng, 2009; Zimmermann, 2000). The challenge of the evaluation and selection process comes from the need for making transparent and consistent decisions in a timely manner based on a comprehensive evaluation of the suitability of individual ships with respect to a specific shipping task (Ang et al., 2007; Meyrick and Associates, 2007).

Many approaches are developed for solving the ship evaluation and selection problem from different perspectives (Ang et al., 2007; Celik, Deha Er, & Fahri Ozok, 2009; Kandakoglu, Celik, & Akgun, 2009). Ang et al. (2007), for example, propose an integer programming approach for solving the ship evaluation and selection problem. Their approach focuses on maximizing the profit in evaluating and selecting individual ships while simultaneously considering the uncertainty on the shipping capacity in the decision making process. A weighting factor is introduced in assessing the overall suitability of individual ships for accommodating the fact that various objectives in a given situation are of different priorities. This approach is proved to be effective for addressing the ship evaluation and selection problem with limited resources (Gabriel, Kumara, Ordoneza, & Nasseriana, 2005). The approach, however, requires considerable computational effort due to the use of integer programming in the ship evaluation and selection process.

Celik et al. (2009) apply the analytical hierarchy process (AHP) (Saaty, 2007) for solving the ship evaluation and selection problem under uncertainty. With the use of this approach, multiple evaluation and selection criteria are simultaneously considered. To reduce the cognitive burden on the decision maker in the decision making process, pairwise comparison is used for assessing the performance of individual ships and the relative importance of the selection criteria. The approach is shown to be effective for solving the ship evaluation and selection problem. It, however, becomes cumbersome, and may lead to inconsistent decisions being made when the number of alternatives and criteria increases (Yeh, Deng, & Chang, 2000).

Kandakoglu et al. (2009) develop a hybrid approach by integrating business analysis, AHP (Saaty, 2007), and the technique on ordered preference by similarity to the ideal solution (TOPSIS) (Deng, Yeh, & Willis, 2000) for solving the ship evaluation and selection problem. Business analysis is used for adequately

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0957-4174/$ - see front matter
doi:10.1016/j.eswa.2012.01.003

determining the evaluation and selection criteria through a comprehensive consideration of the interest of various stakeholders in the decision making process. AHP is used for assessing the relative importance of these evaluation and selection criteria. TOPSIS is adopted for determining the overall performance of individual ships across all the evaluation and selection criteria. The approach is found to be intuitively easy to understand and implement. This approach, however, is questioned on its modeling of the uncertainty and subjectiveness of the human decision making process.

This paper presents an intelligent decision support system (DSS) for effectively evaluating and selecting ships under uncertainty in marine transportation. To effectively handle the multi-dimensional nature of the problem, the methodology of multi-criteria is used. To adequately determine the relative importance of the evaluation and selection criteria with respect to a specific shipping task in the weighting process, a task-oriented procedure is proposed. To determine the overall performance of each ship across all the selection criteria and their associated sub-criteria on which the selection decision is made, a fuzzy multicriteria analysis algorithm is developed based on the concept of ideal solution and the degree of dominance. To demonstrate the applicability of the proposed intelligent DSS for solving the ship evaluation and selection problem under uncertainty, an example is presented.

In what follows, we first present the ship evaluation and selection problem in the context of multicriteria analysis, followed by a task-oriented procedure for determining the weightings of the selection criteria. We then develop a fuzzy multicriteria analysis algorithm for solving the ship evaluation and selection problem on which an intelligent DSS is proposed. Finally we present an example for demonstrating the applicability of the proposed intelligent DSS for solving the ship evaluation and selection problem under uncertainty.

2. Formulating the ship evaluation and selection problem

RightShip is formed as a joint venture company by two biggest producers of mineral resources in Australia including BHP Billiton and Rio Tinto. The objective of the company is to improve the decision making process of evaluating and selecting available ships with respect to a specific shipping task in the two companies respectively, and at the same time to offer its ship evaluation and selection services to their global customers involved in marine transportation. Since being formed in 2001, RightShip has grown substantially to serve a global client base far beyond its parent companies.

The challenge that RightShip faces in evaluating and selecting ships is to make timely and consistent recommendations to its customers on the selection of specific ships by adequately considering the interest of various stakeholders in the ship evaluation and selection process (Guneri, Cengiz, & Seker, 2009; Kandakoglu et al., 2009). To assign the most suitable ship to a specific task, the decision maker needs to evaluate the overall performance of each available ship with respect to the specific conditions of individual ships and the requirements of a given task (Deng & Wibowo, 2008; Vis, 2006). With the multi-dimensional nature of the ship evaluation and selection problem, multicriteria analysis provides a systematic framework for effectively solving the ship evaluation and selection problem (Yeh, Deng, Wibowo, & Xu, 2010).

A typical ship evaluation and selection problem is usually characterized by the availability of various ships and the presence of multiple, usually conflicting evaluation and selection criteria and their associated sub-criteria if existent. The ship evaluation and selection process consists of: (a) identification of the requirements for a specific shipping task, (b) assessment of the task requirements, (c) evaluation of the overall performance of all the available ships, and (d) selection of the most suitable ship.

Identifying the requirements of a shipping task for solving the ship evaluation and selection problem involves in determining the interest of various stakeholders in a given situation. These stakeholders may include the ship owner, the ship manager, the financial institution, and the insurance company (Barnhart & Laporte, 2007; Guneri et al., 2009). They often have different interests on the selection of a specific ship for a given task, reflected by the specific requirements on the selection of individual ships. For example, ship owners concern more about the overall efficiency of the ship (Balmat et al., 2009). Ship managers care more about the shipping cost and compliance with international regulations (Ang et al., 2007). Financial institutions are more interested in the return on their investment (Barnhart & Laporte, 2007). Insurance companies are concerned with the safety of each ship.

Task requirements as a reflection of the expectations of the stakeholders on a given task are usually assessed subjectively by the decision maker. This often leads to different weightings being given to various evaluation and selection criteria in the multicriteria decision making process. For example, a ship manager who concerns about the cost of the ship will give a higher weighting on the operating efficiency criterion. On the other hand, the insurance company who is more concerned about the safety of each ship will allocate a higher weighting to the ship risk potential criterion (Balmat et al., 2009; Kandakoglu et al., 2009).

The performance rating of individual ships with respect to each criterion or its associated sub-criterion is usually determined by the decision maker subjectively. With the determination of the performance of individual ships and the weightings of the evaluation and selection criteria, the overall performance of each ship across all the criteria and their associated sub-criteria can then be calculated on which the most suitable ship can then be selected.

A typical ship evaluation and selection problem usually involves in the evaluation and selection of one or more ships (alternatives) from a set of n available ships (alternatives) A_i ($i = 1,2,\ldots,n$). These alternatives are to be assessed based on m evaluation and selection criteria C_j ($j = 1,2,\ldots,m$). Each criterion C_j may be broken down into p_j sub-criteria C_{jk} ($k = 1,2,\ldots,p_j$). Fig. 1 shows the hierarchical formulation of the ship evaluation and selection problem in the context of multicriteria analysis, in which the evaluation and selection criteria and their associated sub-criteria are discussed in the following.

The operating efficiency (C_1) is used for reflecting the subjective assessment of the decision maker on the financial feasibility of the ship with respect to the budget situation of an organization (Xie et al., 2008). It is measured by the fuel efficiency (C_{11}), the maintenance efficiency (C_{12}), the insurance cost (C_{13}), and the ship crew cost (C_{14}).

The ship capacity (C_2) reflects on the subjective perception of the decision maker on the features and specifications of each available ship (Xie et al., 2008). It is assessed by the size of the ship (C_{21}), the gross tonnage of the ship (C_{22}), the net tonnage of the ship (C_{23}), and the speed of the ship (C_{24}) (Balmat et al., 2009).

The level of risk (C_3) that each ship has reflects the decision maker's subjective assessment on the potential of failure of the ship during its journey (Barnhart & Laporte, 2007; Sambracos, Paravantis, Tarantilis, & Kiranoudis, 2004). This is measured by the weather condition and traffic density (C_{31}), the route near shallow waters (C_{32}), navigator failure (C_{33}), and machinery failure (C_{34}).

There are a large variety of cargoes including manufactured consumer goods, unprocessed fruits and vegetables, processed food, livestock, industrial equipments, processed materials, and raw materials in marine transportation (Barnhart & Laporte, 2007). The nature of the cargo therefore has a direct impact on the selection of a specific ship. As a result, the characteristics (C_4)