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Fuzzy decision support system for spread mooring system selection

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ABSTRACT

Spread mooring systems are associated with high level uncertainties and risks during tanker loading/unloading operations. In addition, the design of such complex systems consists of many subjective and imprecise parameters. Therefore, in the present study, a fuzzy based decision support methodology is designed to overcome aforementioned characteristics. The fuzzy methodology incorporates qualitative and partially known information into the decision support model and provides a robust mathematical framework for modeling of the spread mooring systems. Proposed model is based on the analytic hierarchy method (AHP) and the technique for order performance by similarity to ideal solution (TOPSIS) methods in a fuzzy environment where the vagueness and subjectivity are handled with linguistic and fuzzy values. The fuzzy AHP method is used to analyze the structure of the mooring system selection problem and determine the weights of the attributes while fuzzy TOPSIS method is employed for ranking the spread mooring systems. The case study demonstrates the effectiveness and feasibility of the proposed methodology.

1. Introduction

The spread mooring system is a multiple point mooring technique that allows a tanker to moor at a fixed geographic location with a stationary heading angle at all weather conditions during the loading/unloading operations. Spread moorings can be utilized for the operations that require long service life for various sizes of vessels and deployed at various water depths. Several LPG distribution companies in the Gulf of Izmit on Sea of Marmara in Turkey utilized different spread mooring configurations. They usually prefer the cheapest solution in terms of the initial investment cost. However, due to several small-scale accidents and increasing loading/unloading capacity they keep changing the configuration over the years (Odabasi et al., 2006). The companies spend a lot of money and time to repair or rebuild the facilities. Therefore, there is a need for an effective decision making technique at the initial design stage of the spread mooring system.

Decision making may be defined as a procedure to choose the best among a set of feasible alternatives. Decision maker (DM) uses an improved decision making algorithm or develops new algorithms in order to effectively make a decision among existing alternatives for precise choices at each stage of production. Many decision making problems involve uncertainty. Therefore, one of the most important aspects of a useful decision support is to provide the ability to handle imprecise and vague information, such as ‘large’ profit, ‘fast’ speed and ‘cheap’ price (Riberio, 1996).

Multi-criteria decision making (MCDM) is one of the most well known branches of decision making and generally involves decision-maker’s subjective judgments and preferences in the presence of multiple, usually conflicting criteria. MCDM is divided into two categories depending on whether the problem is a selection problem or a design problem, namely, the multiple attribute decision making (MADM) and the multiple objective decision making (MODM) (Lai & Hwang, 1994). MADM methods evaluate and select the desired one from a finite number of alternatives, which are characterized by multiple attributes. MODM consists of a set of conflicting goals that cannot be achieved simultaneously. Usually, MODM concentrates on continuous decision spaces, has several objective functions and can be solved with mathematical programming techniques.

The present MADM methods become defective if rates of a decision matrix used for solution of a problem are foggy and deficient. Many real world problems have inexact information about the alternatives with respect to an attribute. To handle the decision making problems which have unquantifiable, incomplete, non-obtainable and partial ignorance information, fuzzy multiple attribute decision making (FMADM) techniques and methods have to be used. FMADM presents its most powerful aspect by actualizing the complex systems which have uncertainty in their definitions. FMADM has an advantage compared to the other techniques, in solving systems, which are most complex, ambiguous and uncured with traditional MCDM methods. FMADM problems among which the ratings and the weights of attributes are evaluated on imprecision, uncertainty

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and vagueness are usually expressed by linguistic terms and then set into fuzzy numbers (Zimmermann, 1996).

There are several external factors affecting the design of the spread mooring systems such as motion response, operational requirements, reliability, selection of installation methods, as well as the external forces on the system in the presence of wave, wind and current, etc. Some of these factors depend on deterministic factors while the others have fuzzy non-deterministic parameters. Therefore, there is a need for a fuzzy decision support algorithm that guides effective decisions to the most proper type of mooring system for different operation regions. The selection algorithm should use the design criteria and attributes such as characteristics of goals of utilization like oil/gas storage and offloading. The approach of using fuzzy multi attribute decision making will become the most proper method for the selection of a tanker-buoy mooring system.

The objective of this paper is to improve a decision support model based on fuzzy AHP and fuzzy TOPSIS methods in selecting the mooring alternative for the gas companies situated near Yarimca on the Eastern Marmara Sea Region in Turkey. The paper incorporates the FST and the nature of subjectivity due to the ambiguity to achieve a flexible fuzzy decision support system approach suitable for uncertain environment. The rest of this paper is organized as follows: Section 2 briefly reviews the current literature on FST, fuzzy AHP and fuzzy TOPSIS methods. Section 3 defines the fuzzy set, fuzzy numbers and basic operations used in this study. Section 4 provides details of the proposed FMADM methodology. In Section 5, the proposed methodology is applied to the best spread mooring system selection problem. Lastly, concluding remarks and future research opportunities are addressed in the final section.

2. Literature review

2.1. Fuzzy set theory

Fuzzy set theory (FST) first pioneered by Zadeh (1965) dealing with uncertainty due to imprecision and vagueness has been extensively used over the past 40 years. FST is a valuable tool to strengthen the comprehensiveness and reasonableness of the decision making process. The theory is an important method to provide measuring the ambiguity of concepts that are associated with human beings' subjective judgments including linguistic terms, satisfaction degree and importance degree that are often vague (Zimmermann, 1996). FST has been applied to many problems in engineering, business, medical and natural sciences. Some of the application areas of the FST are network, linear and non-linear programming, dynamic programming, reliability, quality control, multiple criteria decision making, group decision making, decision support systems, expert systems and so on. FST helps to improve oversimplified models and provides more robust and flexible models for real world complex systems, especially those involving human aspects. The role of FST is significant when applied to complex phenomena that cannot be easily described by traditional mathematical methods, especially when the goal is to find a good appropriate solution.

Bellman and Zadeh (1970) were the first to relate FST to decision making problems using vague, imprecise and uncertain data to generate decision. Yager and Basson (1975) proposed FST to decision making problems. Bass and Kwakernaak (1977) and Yager (1978) established some FMADM methods that are widely regarded as the classical work of fuzzy MADM methods. An increasing number of FMADM studies have overcome the uncertain fuzzy problems by applying the FST. The theory has been applied in a great variety of applications reviewed by several authors (Kahraman, Gulbay, & Kabak, 2006; Klir & Yuan, 1995; Lootsma, 1997; Zimmermann, 1996).

FMADM methods are proposed to solve the problems that involve vague and imprecise data. During the last four decades, several FMADM methods have been proposed and reviewed (see, for example, Bass & Kwakernaak, 1977; Chen & Hwang, 1992; Figueira, Greco, & Ehrgott, 2004; Triantaphyllou, 2000; Triantaphyllou & Lin, 1996; Yager & Basson, 1975).

2.2. Fuzzy AHP

Since the conventional analytic hierarchy process (AHP) was introduced by Saaty (1980) it has been widely used as a practical solution method for multiple criteria decision making tool or a weight estimating technique in different areas such as engineering, manufacturing, industry, management decision making, economics, and so on.

The conventional AHP uses an exact value to identify the decision maker's opinion although it becomes subjective and imprecise. This method creates and deals with a very unbalanced scale of judgment. Also, the conventional AHP cannot handle the inherent uncertainty and imprecision in the pair-wise comparison process. To overcome these shortcomings, a number of fuzzy AHP methods have been developed to deal with fuzzy comparison matrices. Fuzzy AHP is basically the combination of the two concepts: fuzzy set theory and AHP. Van Laarhoven and Pedrycz (1983) extended the AHP to fuzzy hierarchical analysis and applied fuzzy logic principle to AHP. Buckley (1985) initiated trapezoidal fuzzy numbers to express the DM's evaluation on alternatives and employed the geometric mean method to calculate fuzzy weights for each fuzzy matrix to determine final fuzzy weights for the alternatives. Chang (1996) introduced a new extend analysis method for the synthetic extend values of the pair-wise comparisons. Deng (1999) presented a fuzzy approach for tackling qualitative multi-criteria analysis problems. Kwiesielewich (1998) presented a pseudo-inverse generalization approach to solve the fuzzy least squares problem. Xu (2000) developed a fuzzy least-square priority method based on the distance metric defined as the integral of Euclidean distance between the α-level sets of two fuzzy numbers with respect to α-level.

Many researchers have attempted to use and develop fuzzy AHP for selecting and solving problems. One of the significant literature surveys is presented by Vaidya and Kumar (2006). They have reviewed and analyzed the applications of the AHP methods.

2.3. Fuzzy TOPSIS

The TOPSIS (technique for order preference by similarity to an ideal solution), first proposed and developed by Hwang and Yoon (1981), is one of the widely used techniques in multi-attribute decision making (MADM) problems. TOPSIS can rank finite number of feasible alternatives according to the features of each attribute for every alternative and to the decision maker's choice.

In classical TOPSIS method, the weights of the criteria and the ratings of alternatives are known as crisp values. However, solving real life problems, crisp data are inadequate under many conditions, so the fuzzy TOPSIS method is proposed to remove the deficiency of the traditional TOPSIS with using linguistic variables represented by fuzzy numbers.

The fuzzy TOPSIS method has been widely used and successfully adopted in various fields by various authors (e.g. Byun & Lee, 2006; Chen, 2000; Chen & Hwang, 1992; Chen, Lin, & Huang, 2006; Chu & Lin, 2003; Dagdeviren, Yavuz, & Kilinc, 2009; Deng & Yeh, 2006; Deng, Yeh, & Willis, 2000; Ertuğrul & Karakaşoğlu, 2009; Hwang & Yoon, 1981; Kahraman, Büyüközkan, & Ateş, 2007; Kuo, Tzeng, & Huang, 2007; Liang, 1999; Mentes, 2010; Mentes & Helvacioglu, 2009; Olcer & Odabasi, 2005; Wang & Elhag, 2006; Wang, Fan, & Wang, 2010; Wang & Lee, 2009; Yeh & Chang, 2009).