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Rotational priority investigation in fuzzy analytic hierarchy process design: An empirical study on the marine engine selection problem

Emrah Bulut [a,*], Okan Duru [b], Gazi Koçak [c]

[a] Department of Business Administration, Yıldız Technical University, Istanbul, Turkey
[b] Department of Ship and Marine Technology Engineering, Izmir Katip Celebi University, Izmir, Turkey
[c] Department of Marine Engineering, Istanbul Technical University, Tuzla 34940, Istanbul, Turkey

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ABSTRACT

The aim of this paper is to improve the applicability of the fuzzy-AHP method by using the rotational priority investigation (RPI) method. Despite its popularity and convenience, the AHP and fuzzy-AHP method is criticized by many scholars because of intransitivity and the rank reversal phenomenon. Experts may question the rational choice theory and cross priorities may indicate conflicting interactions. Also, the extraction of a number of alternatives may cause a different order of priorities. The rotational priority investigation method is proposed to investigate sub-group priorities and their corresponding rankings. Every rotation refers to the investigation of sub-group priorities after extraction of an alternative. The final result is based on the normalized average priority among the several rotations. An empirical study is presented by using the RPI method in the fuzzy AHP for the marine engine selection problem in the shipping industry.

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1. Introduction

The purpose of expert decision-making methods is to simplify and classify a decision- making problem and to make the best selection based on the interpretations of priorities and cost-benefit particulars. In the existing literature, there are several methods suited for decision-making problems and these methods improve the decision-making process by ensuring simplicity and functionality. In some cases, very complicated algorithms are proposed for complex decision-making problems. Often decision-making methods based on many assumptions and imperfections which may invalidate the process to some degree.

Among the variety of decision-making models, the Analytic Hierarchy Process (AHP) is the most cited and applied method in the literature. It has several benefits such as segmentation of the decision task, classification of the criteria and capability of using both linguistic and numerical information. Conversely, many scholars criticize such things as the setback of the rational choice theory, rank reversal and intransitivity.

The rational choice theory is an approach used in social sciences to understand human behavior and the particulars of their decisions. In the economics literature, Becker [1] is the first researcher to point out its importance and the theory is used in many scientific fields to explain decision characteristics. One of the basic principles of the theory is the transitivity

* Corresponding author. Tel.: +90 212 383 2582.
E-mail address: bltemrah@gmail.com (E. Bulut).

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of cross decisions. For example, if criteria A is 5 times more important than criteria B and criteria B is 4 times more important than criteria C, criteria A should be $5 \times 4 = 20$ times more important than C (also $A > B > C$). However, the Saaty's [2] scale limits priorities to a total of nine. Therefore, AHP does not ensure proof of the theory in some cases. The results may have different particulars under different sub-groups of alternatives.

Since scale inconsistency exists, the rank reversal phenomenon is expected in the case of addition and extraction of an alternative. The rotational priority investigation (RPI) is proposed to eliminate inconsistent results by calculating priorities of downsized elements of a decision matrix. In the RPI method, one alternative is extracted from a group of alternatives in every rotation and the final priority matrix is calculated for every combination of downsized groups. If the number of alternatives is n, then n number of combinations will be generated. The mean of the n priority matrices is considered the final priority matrix and the superior alternative is selected. The same procedure is proposed to be useful for the criteria matrix and the priorities of the criteria set may have critical changes which directly affect the final result of the analysis.

The remainder of this paper is organized as follows. Section 2 overviews the FAHP method, consistency control and describes the proposed method RPI. Section 3 presents an empirical work for the selection of a marine engine in a ship building project. Section 4 concludes the paper.

2. Criticism for AHP and FAHP method

2.1. Fuzzy sets and triangular numbers

Fuzzy set theory was first introduced by Zadeh [3] and it was developed based on the premise that the key elements in human thinking are not numbers, but linguistic terms of fuzzy sets. Fuzzy set theory has been widely applied to represent uncertain or flexible information in many different applications, such as selection problems, engineering design, and production management.

For numerical efficiency, trapezoidal or triangular fuzzy numbers are used to represent uncertain parameters. In this paper, a triangular fuzzy number is applied and defined as follows:

$\tilde{A}$ is a triangular fuzzy number which has three dimensions $\tilde{A} = (a, b, c)$, lower boundary, midpoint and upper boundary respectively (Fig. 1).

Center of gravity method, which is calculated by averaging a, b and c, is the most used method for defining the crisp result of a fuzzy set.

Definition 1. A fuzzy set $\tilde{A}$ in a universe of discourse X is characterized by a membership function $\mu_{\tilde{A}}(x)$ which associates with each element x in X is a real number in the interval $[0, 1]$. The function value $\mu_{\tilde{A}}(x)$ is termed the grade of membership of x in $\tilde{A}$.

Definition 2. A fuzzy number is a fuzzy subset in the universe of discourse X that is both convex and normal.

Definition 3. A triangular fuzzy number denotes as $\tilde{A} = (a, b, c)$, where $a \leqslant b \leqslant c$ has the following triangular type membership function;

$$\mu_{\tilde{A}}(x) = \begin{cases} 0, & x < a, \\ (x-a)/(m-a), & a \leqslant x < b, \\ 1, & x = b, \\ (c-x)/(c-b), & b < x \leqslant c, \\ 0, & c < x. \end{cases} \tag{1}$$

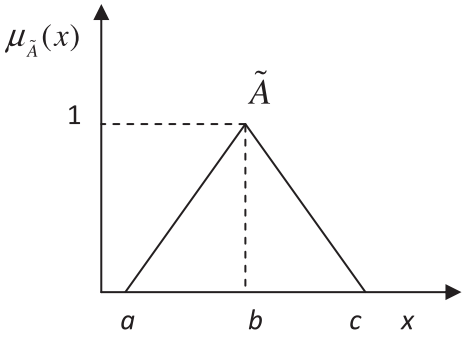

Fig. 1. A triangular fuzzy number $\tilde{A}$.

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