Computers & Industrial Engineering 66 (2013) 258–263

Contents lists available at SciVerse ScienceDirect

Computers & Industrial Engineering

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

Extension of Fuzzy ELECTRE based on VIKOR method ☆

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ARTICLE INFO

Article history:
Received 23 November 2010
Received in revised form 26 January 2012
Accepted 24 June 2013
Available online 2 July 2013

Keywords:
Fuzzy multiple criteria decision making
ELECTRE
VIKOR
Site selection

ABSTRACT

Many decision problems in real-world deal with conflicting criteria, uncertainty and imprecise information. Some also allow a group of decision makers (DMs) to make their opinions independently. Multi-criteria decision making (MCDM) is a well known decision method that can make the quality of group multiple criteria decisions better by creating a more explicit, rational and efficient process. A group of MCDM models known as "outranking methods" have been used to rank a set of alternatives. ELECTRE I is an outranking method which is simple, but provides partial ranking. So we consider VIKOR and try to mitigate this problem with regard to relations between VIKOR and ELECTRE. The objective of this paper is to extend ELECTRE I method based on VIKOR to rank a set of alternatives versus a set of criteria to show the decision maker's preferences.

1. Introduction

Multi criteria decision making methods (MCDM) are widely used in science, government management and engineering. MCDM methods help the decision maker consider all criteria of the problem using a more explicit, rational and efficient decision making process (Wang & Triantaphyllou, 2008). These methods can be broadly classified into two main categories (Hwang & Yoon, 1981):

I. MODM methods are generally considered as the continuous kind of the MCDM. MODM requires decision makers to reach multiple objectives while these multiple objectives are non-commensurable and do not agree with each other. An MODM model considers a vector of decision variables, objective functions, and constraints. Decision makers seeks to maximize (or minimize) the objective functions. In practice these methods including software and application, linear programming, mixed integer and data envelopment analysis, are quite complex to be used conveniently by operating managers. The other fallback of these methods is their inability to include qualitative factors (Sanayei, Mousavi, & Yazdankhah, 2010).
II. MCDM methods can provide the decision maker with a countable number of alternative decisions with several attributes attached to each decision. These attributes are also referred to as decision criteria that have to be taken into consideration simultaneously. These methods include multi attribute utility theory (MAUT), analytical hierarchy process (AHP), analytical network process (ANP), technique for order performance by similarity to ideal solution (TOPSIS) and outranking methods. Among these methods, it is difficult to obtain a mathematical representation of the decision maker's utility function for using MAUT (Opricovic & Tzeng, 2007). TOPSIS, another MCDM method is based on aggregating function representing "closeness to ideal". The TOPSIS method introduces two reference points, but it does not consider the relative importance of the distances from these points, on the other hand normalized values by vector normalization in the TOPSIS method may depend on the evaluation unit (Chu, Shyu, Tzeng, & Khosla, 2007). In these class AHP and its more sophisticated version ANP, have some problems: ranking reversal and difficulty in accommodating a large number of candidates (Holder, 1990).

Outranking methods apply the pair wise comparison of alternatives to build an outranking relation. This outranking relation is exploited in order to provide the decision makers with a recommendation. One advantage of using outranking methods is that there is no need for converting the original scales into abstract using an arbitrary dictated range, instead you can use purely ordinal scales in these methods (Martel & Roy, 2006), thus these methods are able to maintain the original concrete verbal meaning simultaneously for another methodology considering purely ordinal scales, see (Greco, Matarazzo, & Słowin, 2001). Similar arguments have been put forward for other multi criteria methods for instance, AHP (Saaty, 2005), MAUT (Keeney & Raiffa, 1976), TOPSIS (Hwang & Yoon, 1981) as well as methods based on fuzzy integrals (Grabisch, 1996; Grabisch & Labreuche, 2005).

☆ This manuscritp was processed by Area Editor Dr. Imed Kacem.

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http://dx.doi.org/10.1016/j.cie.2013.06.011

In contrast to the other methods, outranking methods allow incomparability between alternatives that can occur because of lack of information or inability of the decision maker to compare alternatives (Siskos, 1982). Indifference and preference thresholds can provide meaningful and useful information when modeling the imperfect data.

The first outranking method called ELECTRE I was developed by Roy (1968). After that, several other outranking methods were developed mainly during 1970s and 1980s, namely ELECTRE II (Roy & Bertier, 1973), ELECTRE III (Roy, 1978), ELECTREIV (Roy & Hugonnard, 1982), PROMETHEEI and II (Brans & Vincke, 1985), QUALIFLES (Paelinck, 1978), ORESTE (Roubens, 1982; Pastijn & Leysen, 1989), MELCHIOR (Leclercq, 1984), PRAGMA (Matarazzo, 1986), MAPPACC (Matarazzo, 1986), and TACTIC (Vansnick, 1986).

The most preferred method in this group is ELECTRE and its derivatives because they have been widely used for different real world applications such as energy planning (Beccali, Cellura, & Mistretta, 2003), vendor selection (Montazer, Qahri Saremi, & Ramezani, 2009), electric project selection (Buchanan & Vanderpooten, 2007), civil and environmental engineering (Hobbs & Meier, 2000).

The ELECTREI method is used to construct an incomplete prioritization and choose a set of promising alternatives. The ELECTREII is used for ranking the alternatives. ELECTRE III was developed to improve ELECTRE II and consider inaccurate, imprecise or uncertainty of data. Other versions are known as ELECTRE IV, ELECTRE IS and ELECTRE TRI (Figueira, Mousseau, & Roy, 2005).

To rank alternatives in problems we have considered ranking a given set of alternatives from the best to the worst. It is important to keep in mind that ELECTREI is the solution aim which is oriented towards the selection of a small set of "good" alternatives in such a way that a single alternative may finally be chosen (Roy, 2005). In this study, we extend ELECTRE I method under fuzzy environment to rank alternatives. Although ELECTRE II and III methods can be also applied to this matter but they have their own problems. For example, in ELECTRE III an outranking degree is constituted between two alternative decisions that represent an outranking credibility. This makes the method sophisticated and at the same time difficult to interpret.

In order to overcome the shortcoming of ELECTRE I in ranking, a combination of ELECTREI and VIKOR method is proposed based on the principles that have been discussed in Section 3.The solution aim for ELECTRE I is choice problematic and for VIKOR is ranking problematic. In this paper, we took advantage of characteristics of both methods and introduced a new method which is simple and easy to use in real world problems. The proposed method considers the fuzziness in the decision data and group decision making process. Linguistic variables are used to be applied to represent the intensity of preferences of one criterion over another. It allows a group of DMs to make their opinion independently with linguistic terms and use the fuzzy decision matrix and criteria weights to aggregate their opinions.

The paper is organized as follows: In Section 2 an overview of the concepts of the fuzzy approach is given. Section 3 describes developed ELECTRE_VIKOR method to solve MCDM problems. In Section 4 a numerical example is illustrated. And at the end conclusions are given in Section 5.

2. Fuzzy numbers and linguistic variables

Zadeh (1965) has introduced the fuzzy set theory to deal with the uncertainty caused by imprecision and vagueness of data. Fuzzy set theory unlike other theories is capable of representing vague data. The theory also allows mathematical operators and programming be applied to the fuzzy domain. A fuzzy set is a class of objects with a continuum of grades of membership. Such a set is characterized by a membership (characteristic) function, which assigns to each object a grade of membership ranging between zero and one (Kahraman, 2003).

In this section, some basic definitions of fuzzy sets, fuzzy numbers and linguistic variables which are used throughout this paper are reviewed.

Definition 1. A positive triangular fuzzy number $\tilde{n}$ can be defined as (n_1, n_2, n_3) and membership function $\mu_{\tilde{n}}(x)$ is defined as (Kaufmann & Gupta, 1991):

$$\mu_{\tilde{n}}(x) = \begin{cases} 0 & x < n_1 \\ \frac{x-n_1}{n_1-n_2} & n_1 < x < n_2 \\ \frac{n_3-x}{n_3-n_2} & n_2 < x < n_3 \\ 0 & x > n_3 \end{cases}$$

Definition 2. A non-fuzzy number r can be expressed as (r, r, r). By the extension principle, the fuzzy sum $\oplus$ and fuzzy subtraction of any two triangular fuzzy numbers are also triangular fuzzy numbers; but the multiplication $\otimes$ of any two triangular fuzzy numbers is only an approximate triangular fuzzy number. Given any two positive triangular fuzzy numbers $\tilde{a} = (a_1, a_2, a_3)$, $\tilde{b} = (b_1, b_2, b_3)$ and a positive real number r, some main operations of fuzzy numbers $\tilde{a}$ and $\tilde{b}$ are as follows:

$$\tilde{a} \oplus \tilde{b} = (a_1 + b_1, a_2 + b_2, a_3 + b_3)$$
$$\tilde{a} \ominus \tilde{b} = (a_1 - b_3, a_2 - b_2, a_3 - b_1)$$
$$\tilde{a} \otimes \tilde{b} \approx (a_1 b_1, a_2 b_2, a_3 b_3)$$
$$\tilde{a} \otimes r = (a_1 r, a_2 r, a_3 r)$$

Definition 3. The matrix $\widetilde{D}$ is called a fuzzy decision matrix if at least one element is a fuzzy number.

Definition 4. A linguistic variable is a variable whose values are expressed in linguistic terms.

The concept of linguistic variables is very useful in dealing with situations, which are too complex or not well defined to be reasonably described in conventional quantitative expressions (Zimmermann, 1991). In this research linguistic variables are expressed in positive triangular fuzzy numbers as shown in Figs. 1 and 2.

3. The proposed method

In this section a systematic approach is given for ranking a set of alternatives under fuzzy environment.

Step (1) Determine the decision matrix

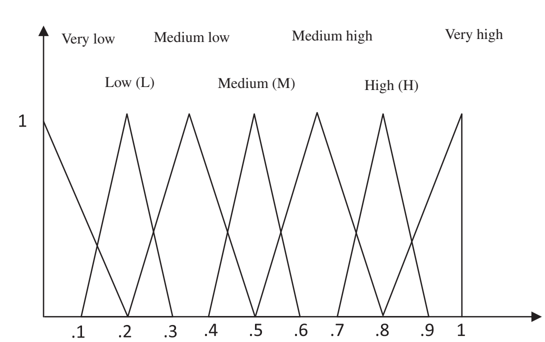

Fig. 1. Alternative linguistic variables for importance weight of each criterion.