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A fuzzy multi-criteria decision making model for supplier selection

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ABSTRACT

This paper presents a hybrid fuzzy model for group Multi Criteria Decision Making (MCDM). A modified fuzzy DEMATEL model is presented to deal with the influential relationship between the evaluation criteria. The modified DEMATEL captures such relationship and divides the criteria into two groups, particularly, the cause group and the effect group. The cause group has an influence on the effect group where such influence is used to estimate the criteria weights. In addition, a modified TOPSIS model is proposed to evaluate the criteria against each alternative. Here, a fuzzy distance measure is used in which the distance from the Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FNIS) are calculated. The resulted distances were used to calculate the similarity to Ideal and Anti-ideal points. Later, an optimal membership degree (closeness coefficient) of each alternative is computed to estimate to which extent an alternative belongs to both FPIS and FNIS. The closer the degree of membership to FPIS and the farther from FNIS the more preferred the alternative. The membership degree is obtained by the optimization of a defined objective function that measures the degree to which an alternative is similar/dissimilar to the Ideal/Anti-Ideal solutions. The closeness coefficient is used to rank the alternatives. To better have a high contrast between the ranks of alternatives an optimization problem was introduced and solved to maximize the contrast.

The presented hybrid model was applied on an industrial case study for the selection of cans supplier/suppliers at Nutridar Factory in Amman-Jordan to demonstrate the proposed model. Finally a sensitivity analysis is introduced to verify the resulting ranks of the available suppliers via testing different values of the used parameters. The sensitivity analysis has shown robust and valid results that are close to real preferences of the consulted experts.

1. Introduction

MCDM is the process of finding the best option among a set of feasible alternatives. In most of MCDM problems the multiplicity of criteria used to judge the alternatives is pervasive. That is, in many cases, in industry for instance, the decision maker needs to take a decision based on multiple criteria to select an alternative from those feasible ones. Multi-criteria evaluation often requires the decision makers to provide qualitative/quantitative assessments to identify the value of each alternative with respect to each criterion, as well as the relative importance of the criteria with respect to the overall objective of the problem. Such aspects will usually result in uncertain, imprecise, indefinite and subjective data, which makes the decision-making process complex and challenging. In other words, decision-making often occurs in a fuzzy environment where the available information is imprecise/uncertain which may confuse the decision makers in the decision-making process.

The weights and ratings are usually difficult to be precisely judged because of the existence of uncertainty, which may be handled by linguistic terms such as “Good”, “Poor”, or “Important”, “Very Important”, and so on. Such evaluations are fuzzy measures in nature. Real-life applications of multi criteria decision-making require the processing of imprecise, uncertain, qualitative or vague data. One efficient way to model uncertainty and imprecision is the use of fuzzy sets theory. Fuzzy sets provide the flexibility required to represent and handle the uncertainty and imprecision resulting from the lack of knowledge or ill-defined information.

Fuzzy Logic was initiated in 1965 by, Zadeh (1965). Basically, Fuzzy Logic is a multi-valued logic that allows intermediate values to be defined between conventional evaluations like True/False, High/Low, Yes/No, etc. Notions like “Rather Tall” or “Very Fast” can now be formulated mathematically and processed by computers in order to apply more human-like way of thinking in programming, (Dalalah & Magableh, 2008; Zadeh, 1984). Fuzzy sets are widely used in describing linguistic information because they can effectively represent the gradual changes of people’s recognition to a concept in a certain context, (Dalalah & Bataineh, 2008; Zadeh, 1975).

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The study in Lin and Wu (2008) develops a fuzzy DEMATEL method (The Decision-Making Trial and Evaluation Laboratory), a very popular method in Japan, which applies matrices and digraphs for visualizing the structure of complicated causal relationships. DEMATEL involves group decision-making which consists of gathering ideas and then analyzing the cause–effect relationship of complex problems. The DEMATEL, originated from the Geneva Research Centre of the Battelle Memorial Institute (Fontela & Gabus, 1976; Gabus & Fontela, 1973), aimed at the fragmented and antagonistic phenomena of world societies and search for integrated solutions. It is useful for visualizing the structure of complicated causal relationships with matrices or digraphs. Hence, the DEMATEL model can convert the relationship between the causes and effects of criteria into an intelligible structural model of the system. In our study, we will modify the DEMATEL model to handle fuzzy rating and evaluations as will be illustrated shortly.

A survey of the MCDM methods has been presented by, Hwang and Yoon (1981). The Technique for Order Performance by Similarity to Ideal Solution (TOPSIS), one of the known classical MCDM methods, was first developed in this survey. It is based on the concept that the chosen alternative should have the shortest distance from the Positive Ideal Solution (PIS), i.e., the solution that maximizes the benefit criteria; and the farthest from the Negative Ideal Solution (NIS), i.e., the solution that minimizes the benefit criteria (Benitez, Martin, & Roman, 2007; Wang & Elhag, 2006). In short, the positive ideal solution is composed of all best values attainable of criteria, whereas the negative ideal solution consists of all worst values, (Saghafian & Reza Hejazi, 2005; Wang, 2008). In our study, we will modify the TOPSIS model to handle fuzzy rating, weights and evaluations as will be illustrated shortly.

2. The hybrid model

In our hybrid model we use linguistic evaluations to rate both the criteria against each other as well as the alternatives against each criterion. To handle the vagueness in such evaluation we use fuzzy logic and the triangular fuzzy sets, (Dalalah, 2009). In a universe of discourse X, a fuzzy subset A of X is defined by a membership function $\mu_A(x)$, which maps each element x in X to a real number in the interval $[0,1]$. A fuzzy number A is a triangular fuzzy number if its membership function has $0 < l \leqslant m \leqslant u \leqslant \infty$, (Ding & Liang, 2005).

$$\mu_A(x) = \begin{cases} (x-l)/(m-l), & l \leqslant x \leqslant m, \\ (u-x)/(u-m), & m \leqslant x \leqslant u, \\ 0, & \text{otherwise}. \end{cases} \tag{1}$$

where l, m, and u are crisp values. A triangular fuzzy number can be denoted by (l,m,u). The parameter m gives the maximum grade of $\mu_A(x)$, i.e., $\mu_A(m) = 1$; it is the most probable value of the evaluation data, while l and u are the lower and upper bounds. They are used to reflect the fuzziness of the evaluation data. The narrower the interval $[l,u]$, the lower the fuzziness of the evaluation data.

2.1. Distance based similarity measure

There is a wide variety of approaches used to measure the distance between fuzzy numbers, (Fu, 2008; Heilpern, 1997; Hsieh & Chen, 1999). In this study, for a pair of triangular fuzzy numbers $\tilde{a} = (a_1, a_2, a_3)$ and $\tilde{b} = (b_1, b_2, b_3)$ the distance is calculated by:

$$d(\tilde{a},\tilde{b}) = \left|\tilde{a}^{def} - \tilde{b}^{def}\right|, \tag{2}$$

where $\tilde{a}_{def}$ and $\tilde{b}^{def}$ are the defuzzification points of $\tilde{a}$ and $\tilde{b}$. Defuzzification of any fuzzy number is obtained by calculating the point that divides the area of the fuzzy set into two equal parts. Based on the definition of the fuzzy sets in Eq. (1), the defuzzification point will be given by:

$$\text{Deffuzzification point} = \begin{cases} u - \sqrt{(u-l)(u-m)/2}, & u-m > m-l, \\ \sqrt{(u-l)(u-m)/2} - l, & u-m < m-l, \\ m, & \text{otherwise}. \end{cases} \tag{3}$$

It should be simple to show that this distance measure satisfies the properties: *first*, $d(\tilde{a},\tilde{a}) = 0$*second*, $d(\tilde{a},\tilde{b}) = d(\tilde{b},\tilde{a})$ and *third* the triangular fuzzy number $\tilde{b}$ is closer to $\tilde{a}$ than to $\tilde{c}$ if and only if $d(\tilde{a},\tilde{b}) < d(\tilde{a},\tilde{c})$. In this study we use the distance to measure the similarity of fuzzy sets. One way of distance based similarity assessment is proposed by Williams and Steele in Williams and Steele (2002). Their suggested formula contains an exponential expression as follows:

$$SM(\tilde{a},\tilde{b}) = e^{-\alpha.d(\tilde{a},\tilde{b})}, \tag{4}$$

where SM is the similarity measure and α is the steepness measure. Notice that when the distance between the two fuzzy sets is zero, a similarity measure of 1 will result. However, the farther the distance the lower similarity obtained.

2.2. The modified DEMATEL model

A typical decision making system contains a set of criteria $C = \{C_1, C_2, \ldots, C_n\}$. The criteria are to be rated for influence against each other using pair-wise comparison. In this study the pair-wise rating scale is divided into five levels as shown in Fig. 1. Table 1 presents the related fuzzy numbers of Fig. 1.

Our modified DEMATEL model starts with the direct-relation fuzzy matrices $\widetilde{Z}^{(k)}\ \forall k = 1, \ldots, p$, where $\widetilde{Z}^{(k)}$ is $(n \times n)$ matrix, n represents the number of criteria and p is the number of surveyed experts in the group. The direct relation matrices are all obtained by holding a pair-wise comparison among the criteria themselves in which $\tilde{z}_{ij}$ indicates the degree to which the criterion C_i affects criterion C_j. Accordingly, all the principal diagonal elements z_{ii} of matrix $\widetilde{Z}^{(k)}$ are set to zero.

$$\widetilde{Z}^{(k)} = \begin{matrix} & \begin{matrix} C_1 & C_2 & \cdots & C_n \end{matrix} \\ \begin{matrix} C_1 \\ C_2 \\ \vdots \\ C_n \end{matrix} & \begin{bmatrix} 0 & \tilde{z}_{12}^{(k)} & \cdots & \tilde{z}_{1n}^{(k)} \\ \tilde{z}_{21}^{(k)} & 0 & \cdots & \tilde{z}_{2n}^{(k)} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{z}_{n1}^{(k)} & \tilde{z}_{n2}^{(k)} & \cdots & 0 \end{bmatrix} \end{matrix}, \quad k = 1, 2, \ldots, p, \tag{5}$$

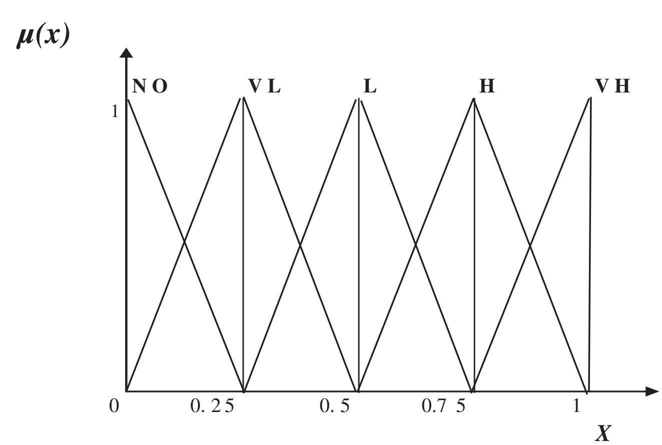

Fig. 1. Triangular fuzzy numbers for influence evaluations.