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A multi-criteria intuitionistic fuzzy group decision making for supplier selection with TOPSIS method

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ABSTRACT

Supplier selection, the process of finding the right suppliers who are able to provide the buyer with the right quality products and/or services at the right price, at the right time and in the right quantities, is one of the most critical activities for establishing an effective supply chain. On the other hand, it is a hard problem since supplier selection is typically a multi criteria group decision-making problem involving several conflicting criteria on which decision maker's knowledge is usually vague and imprecise. In this study, TOPSIS method combined with intuitionistic fuzzy set is proposed to select appropriate supplier in group decision making environment. Intuitionistic fuzzy weighted averaging (IFWA) operator is utilized to aggregate individual opinions of decision makers for rating the importance of criteria and alternatives. Finally, a numerical example for supplier selection is given to illustrate application of intuitionistic fuzzy TOPSIS method.

1. Introduction

Supply Chain Management (SCM) has received recently considerable attention in both academia and industry. The major aims of SCM are to reduce supply chain (SC) risk, reduce production costs, maximize revenue, improve customer service, optimize inventory levels, business processes, and cycle times, and resulting in increased competitiveness, customer satisfaction and profitability (Chou & Chang, 2008; Ha & Krishnan, 2008; Heizer & Render, 2004; Monczka, Trent, & Handfield, 2001; Simchi-Levi, Kaminsky, & Simchi-Levi, 2003; Stevenson, 2005).

One of the important activities for SC success is an effective purchasing function (Cakravastia & Takahashi, 2004; Chou & Chang, 2008; Giunipero & Brand, 1996; Porter & Millar, 1985). The purchasing function has received a great deal of attention in the SCM due to factors such as globalization, increased value added in supply and accelerated technological change. The purchasing function involves buying the raw materials, supplies and components for the organization. The most important activity of the purchasing function is the selection of appropriate supplier, since it brings significant savings for the organization (Haq & Kannan, 2006).

One of the well known studies on supplier selection belongs to Dickson (1966) who identified 23 important evaluation criteria for supplier selection. Weber, Current, and Benton (1991) reviewed and classified 74 articles addressed the supplier selection problem. de Boer, Labro, and Morlacchi (2001) identified four stages for supplier selection including definition of the problem, formulation of criteria, qualification, and final selection, respectively. They reviewed and classified MCDM approaches for supplier selection.

Several methodologies have been proposed for the supplier selection problem. The systematic analysis for supplier selection includes categorical method, weighted point method (Timmerman, 1986; Zenz, 1981), matrix approach (Gregory, 1986), vendor performance matrix approach (Soukup, 1987) vendor profile analysis (VPA) (Thompson, 1990), analytic hierarchy process (AHP) (Barbarosoglu & Yazgac, 1997; Narasimhan, 1983; Nydick & Hill, 1992), analytic network process (ANP) (Sarkis & Talluri, 2000), mathematical programming (Chaudhry, Forst, & Zydiak, 1993; Pan, 1989; Rosenthal, Zydiak, & Chaudhry, 1995; Sadrian & Yoon, 1994; Weber & Current, 1993) and multiple objective programming (MOP) (Buffa & Jackson, 1983; Feng, Wang, & Wang, 2001; Ghoudsypour & O'Brien, 1998; Sharma, Benton, & Srivastava, 1989; Weber & Ellram, 1992).

Most of these methods do not seem to address the complex and unstructured nature and context of many present day purchasing decisions (de Boer, Van der Wegen, & Telgen, 1998). In many existing decision models in the literature, only quantitative criteria have been considered for supplier selection. Several influence factors are often not taken into account in the decision-making process, such as incomplete information, additional qualitative criteria and imprecision preferences (Chen, Lin, & Huang, 2006; Zhang, Zhang, Lai, & Lu, 2009). Therefore, fuzzy set theory (FST) has been applied to supplier selection recently. Li, Fun, and Hung (1997) and Holt (1998) discussed the application of FST in supplier

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selection. Chen et al. (2006) extended the concept of TOPSIS method to develop a methodology for solving supplier selection problems in fuzzy environment. Haq and Kannan (2006) presented a structured model for evaluating the supplier selection for the rubber industry using AHP and the model is verified with the fuzzy AHP. Bayrak, Çelebi, and Taşkin (2007) presented a fuzzy multi-criteria group decision-making approach to supplier selection based on fuzzy arithmetic operation. Chou and Chang (2008) presented strategy-aligned fuzzy simple multi-attribute rating technique (SMART) approach for solving the supplier selection problem from the perspective of strategic management of the SC. Chan, Kumar, Tiwari, Lau, and Choy (2008) presented fuzzy AHP to efficiently tackle both quantitative and qualitative decision factors involved in the selection of global supplier. Önüt, Kara, and Işık (2009) developed a supplier evaluation approach based on ANP and TOPSIS methods for the supplier selection.

This paper proposes an intuitionistic fuzzy multi-criteria group decision making with TOPSIS method for supplier selection problem. The importance of the criteria and the impact of alternatives on criteria provided by decision makers are difficult to precisely express by crisp data in the selection of supplier problem. Intuitionistic fuzzy sets introduced by Atanassov (1986) are suitable way to deal with this challenge and applied many decision-making problem under uncertain environment. In group decision-making problems, aggregation of expert opinions is very important to appropriately perform evaluation process. Therefore, IFWA operator is utilized to aggregate all individual decision makers' opinions for rating the importance of criteria and the alternatives. The TOPSIS method considering both positive-ideal and negative-ideal solution is one of the popular methods in multi-attribute decision-making problem. Therefore, TOPSIS method combined with intuitionistic fuzzy set has enormous chance of success for supplier selection process.

Rest of this paper is organized as follows. In Section 2, brief description of intuitionistic fuzzy sets is given. Section 3 presents detailed description of intuitionsitic fuzzy TOPSIS method. In Section 4, a numerical example is demonstrated. Finally conclusion of this paper is presented in Section 5.

2. Intuitionistic fuzzy sets

Intuitionistic fuzzy set introduced by Atanassov (1986) is an extension of the classical FST, which is a suitable way to deal with vagueness. Intuitionistic fuzzy sets have been applied many areas such as; medical diagnosis (De, Biswas, & Roy, 2001; Szmidt & Kacprzyk, 2001, 2004), decision-making problems (Atanassov, Pasi, & Yager, 2005; Chen & Tan, 1994; Hong & Choi, 2000; Liu & Wang, 2007; Szmidt & Kacprzyk, 2002, 2003; Wang, 2009; Xu, 2007a, 2007b, 2007c; Xu & Yager, 2006, 2008) and pattern recognition (Hung & Yang, 2004; Li & Cheng, 2002; Liang & Shi, 2003; Vlachos & Sergiadis, 2007; Wang & Xin, 2005; Zhang & Fu, 2006).

Intuitionistic fuzzy set A in a finite set X can be written as:

$$A = \{\langle x, \mu_A(x), v_A(x)\rangle | x \in X\}$$

where $\mu_A(x)$, $v_A(x)$: $X \to [0,1]$ are membership function and non-membership function, respectively, such that

$$0 \leqslant \mu_A(x) + v_A(x) \leqslant 1 \tag{1}$$

A third parameter of IFS is $\pi_A(x)$, known as the intuitionistic fuzzy index or hesitation degree of whether x belongs to A or not

$$\pi_A = 1 - \mu_A(x) - v_A(x) \tag{2}$$

It is obviously seen that for every $x \in X$:

$$0 \leqslant \pi_A(x) \leqslant 1 \tag{3}$$

If the $\pi_A(x)$ is small, knowledge about x is more certain. If $\pi_A(x)$ is great, knowledge about x is more uncertain. Obviously, when $\mu_A(x) = 1 - v_A(x)$ for all elements of the universe, the ordinary fuzzy set concept is recovered (Shu, Cheng, & Chang, 2006).

Let A and B are IFSs of the set X, then multiplication operator is defined as follows (Atanassov, 1986):

$$A \otimes B = \{\mu_A(x) \cdot \mu_B(x), v_A(x) + v_B(x) - v_A(x) \cdot v_B(x) | x \in X\} \tag{4}$$

3. Intuitionistic fuzzy TOPSIS

Let $A = \{A_1, A_2, \ldots, A_m\}$ be a set of alternatives and $X = \{X_1, X_2, \ldots, X_n\}$ be a set of criteria, the procedure for Intuitionistic Fuzzy TOPSIS method has been given as follows:

Step 1. Determine the weights of decision makers.

Assume that decision group contains l decision makers. The importance of the decision makers are considered as linguistic terms expressed in intuitionistic fuzzy numbers.

Let $D_k = [\mu_k, v_k, \pi_k]$ be an intuitionistic fuzzy number for rating of kth decision maker. Then the weight of kth decision maker can be obtained as:

$$\lambda_k = \frac{\left(\mu_k + \pi_k\left(\frac{\mu_k}{\mu_k + v_k}\right)\right)}{\sum_{k=1}^{l}\left(\mu_k + \pi_k\left(\frac{\mu_k}{\mu_k + v_k}\right)\right)} \tag{5}$$

and $\sum_{k=1}^{l} \lambda_k = 1$.

Step 2. Construct aggregated intuitionistic fuzzy decision matrix based on the opinions of decision makers.

Let $R^{(k)} = (r_{ij}^{(k)})_{mxn}$ is an intuitionistic fuzzy decision matrix of each decision maker. $\lambda = \{\lambda_1, \lambda_2, \lambda_3, \ldots, \lambda_l\}$ is the weight of each decision maker and $\sum_{k=1}^{l} \lambda_k = 1, \lambda_k \in [0, 1]$. In group decision-making process, all the individual decision opinions need to be fused into a group opinion to construct aggregated intuitionistic fuzzy decision matrix. In order to do that, IFWA operator proposed by Xu (2007d) is used. $R = (r_{ij})_{mxn}$, where

$$\begin{aligned} r_{ij} &= IFWA_\lambda(r_{ij}^{(1)}, r_{ij}^{(2)}, \ldots, r_{ij}^{(l)}) \\ &= \lambda_1 r_{ij}^{(1)} \oplus \lambda_2 r_{ij}^{(2)} \oplus \lambda_3 r_{ij}^{(3)} \oplus \cdots \oplus \lambda_l r_{ij}^{(l)} \\ &= \left[1 - \prod_{k=1}^{l}\left(1 - \mu_{ij}^{(k)}\right)^{\lambda_k}, \prod_{k=1}^{l}\left(v_{ij}^{(k)}\right)^{\lambda_k}, \prod_{k=1}^{l}\left(1 - \mu_{ij}^{(k)}\right)^{\lambda_k} - \prod_{k=1}^{l}\left(v_{ij}^{(k)}\right)^{\lambda_k}\right] \end{aligned} \tag{6}$$

Here $r_{ij} = (\mu_{A_i}(x_j), v_{A_i}(x_j), \pi_{A_i}(x_j))(i = 1, 2 \ldots, m; j = 1, 2, \ldots, n)$.

The aggregated intuitionistic fuzzy decision matrix can be defined as follows:

$$R = \begin{bmatrix} \left(\mu_{A_1}(x_1), v_{A_1}(x_1), \pi_{A_1}(x_1)\right) & \left(\mu_{A_1}(x_2), v_{A_1}(x_2), \pi_{A_1}(x_2)\right) & \cdots & \left(\mu_{A_1}(x_n), v_{A_1}(x_n), \pi_{A_1}(x_n)\right) \\ \left(\mu_{A_2}(x_1), v_{A_2}(x_1), \pi_{A_2}(x_1)\right) & \left(\mu_{A_2}(x_2), v_{A_2}(x_2), \pi_{A_2}(x_2)\right) & \cdots & \left(\mu_{A_2}(x_n), v_{A_2}(x_n), \pi_{A_2}(x_n)\right) \\ \vdots & \vdots & \ddots & \vdots \\ (\mu_{A_m}(x_1), v_{A_m}(x_1), \pi_{A_m}(x_1)) & (\mu_{A_m}(x_2), v_{A_m}(x_2), \pi_{A_m}(x_2)) & \cdots & (\mu_{A_m}(x_n), v_{A_m}(x_n), \pi_{A_m}(x_n)) \end{bmatrix}$$