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Evaluating suppliers via a multiple levels multiple criteria decision making method under fuzzy environment ☆

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A R T I C L E   I N F O

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A B S T R A C T

Suppliers are an important component of the supply chain. Their ability and performance are what largely determine the success or failure of the supply chain. Thus the evaluation of suppliers has become a very important part of the supply chain management of a company. This paper suggests a multiple levels multiple criteria decision making (MCDM) model under fuzzy environment to evaluate and select suppliers, where a general hierarchical structure is developed to depict the relationship among parent criteria and their sub-criteria and sub-sub-criteria and so on. These criteria are classified into quantitative and qualitative ones. The ratings of alternatives versus qualitative criteria and the importance weights of all criteria in the hierarchical structure are assessed in linguistic values represented by triangular fuzzy numbers. The ranking approach of center of area is suggested to rank all the fuzzy numbers before their weighted ratings aggregation. The final evaluation values of alternatives can then be obtained through the additive weighted ratings from the last to the first level in the criteria structure. Finally a numerical example demonstrates the feasibility of the proposed model.

1. Background

Supply chain management is the strategic coordination of the supply chain for the purpose of integrating supply and demand management. Benefits of effective supply chain management include lower inventories, lower costs, higher productivity, greater agility, shorter lead time, higher profits, and greater customer loyalty (Stevenson, 2008). Suppliers are an important component of the supply chain. Their ability and performance are what largely determine the success or failure of the supply chain. According to DeGarmo, Black, and Kosher (1997), the cost of the raw materials and parts is about 20% from the cost of a product. In most industries, the cost of raw materials and component parts constitute the main cost of the product, such that in some cases it accounts for up to 70% (Ghodsypour & O'Brien, 1998). This shows how important it is to effectively manage the purchasing function in which supplier selection is a vital task to achieve cost reduction. Managing the purchasing task in the supply chain has been a challenge in the last decade for many corporations. The need to gain a global competitive edge on the supply side has increased substantially (Saen, 2007). If the relationship between a supplier and a manufacturing company is built on long-term basis, the company's supply chain creates one of the strongest barriers to entry for competitors (Briggs, 1994; Choi & Hartley, 1996). As purchasing activities within a supply chain play a more strategic role and trends including the movement from spot purchasing to long-term contractual relationships, sound supplier selection has become a strategic decision, meaning that it has become a vital source for adding strength to value proposition and for improving the competitiveness of manufacturers (Ha & Krishnan, 2008; Wise & Morrison, 2000).

Supplier (vendor) selection is a common problem for acquiring the necessary materials to support the output of organizations. The problem is to find and evaluate periodically the best or most suitable supplier (vendor) for the organization based on various suppliers' (vendors') capabilities. This usually happens when the purchase is complex, high-dollar-value and perhaps critical (Dobler & Burt, 1996; Shyur & Shih, 2006). Many supplier selection and evaluation works have been investigated. A review can be seen in (Chang, Wang, & Wang, 2006; Chen, Lin, & Huang, 2006; De Boer, Labro, & Morlacchi, 2001; Demirtas & Ustun, 2009; Huang & Keskar, 2007; Sarkar & Mohapatra, 2006; Sonmez, 2006; Sung & Krishnan, 2008). Due to the fact that the evaluation always involves conflicting performance criteria of suppliers/vendors, the techniques of MCDM (multiple criteria decision making) are coherently derived to manage the problem (Shyur & Shih, 2006). Evaluating suppliers, many criteria including quantitative, such as cost/price, as well as qualitative, such as relationship closeness, must be considered (Choi & Hartley, 1996; Chou & Chang, 2008; Dowlatshahi, 2000; Verma & Pullman, 1998; Weber, Current, & Desai, 1998). In addition, criteria

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may have different importance. Referring specifically to a multi-criterion analysis, the value of a certain alternative concerning a given attribute often can not be precisely defined, the decision maker is unable (or unwilling) to express his preferences precisely, the evaluations or opinions are expressed in linguistic terms (Bevilacqua, Ciarapica, & Giacchetta, 2006). Besides, the relative importance of criteria is usually expressed by means of linguistics judgments (Bottani & Rizzi, 2008). Therefore, a MCDM approach for the selection and evaluation of suppliers under fuzzy environment is necessary. A review of fuzzy MCDM methods can be seen in (Carlsson & Fuller, 1996; Chu & Lin, 2009; Ribeiro, 1996) and some recent applications can be seen in (Al-Najjar & Alsyouf, 2003; Chou, Chou, & Tzeng, 2006; Chou, 2007; Önüt, Kara, & Işik, 2009).

Moreover, many of the criteria used in the supplier's evaluation process may have sub-criteria and these sub-criteria may in turn have sub-sub-criteria, etc. For example, in the case in Tahriri, Osman, Ali, Yusuff, and Esfandiary (2008), Supplier decision criteria are classified into six categories such as trust, quality, cost, delivery, management and organization, and financial, which forms the second level. These six parent criteria have a total of 16 sub-criteria and each of the six criteria has 2 sub-criteria with the exception of management and organization having six sub-criteria. And these 16 sub-criteria have a total of 35 sub-sub-criteria, which forms the fourth and final level. Thus a multiple levels structure for depicting the relationship among the criteria is needed.

To resolve the above problems, this paper suggests evaluating suppliers using a multiple levels multiple criteria decision making method under fuzzy environment, where criteria are classified to qualitative (QL) and quantitative (QT) ones. A hierarchical structure is mathematically developed to depict the multiple levels multiple criteria and formulas are clearly displayed. Quantitative criteria are further classified to benefit (B) and cost (C) ones. Benefit criterion has the characteristics: the larger the better, and cost criterion has the characteristics: the smaller the better. Ratings of suppliers versus qualitative criteria and the importance weights of all the criteria are assessed in linguistic values represented by fuzzy numbers. However, when there is more than one level in the criteria hierarchy, the multiplication of more than three fuzzy numbers will be encountered. Currently there is no solution to produce the membership function for the multiplication of more than three fuzzy numbers. The best way to resolve the above limitations may be to defuzzify all the fuzzy numbers before applying them to the suggested model. Thus, a proper defuzzification method is needed. Many approaches for ranking/defuzzifying fuzzy numbers have been studied. A review and comparison of many of these approaches can be found in Bortolan and Degani (1985) and Wang and Kerre (2001). Some recent methods can be seen in (Abbasbandy & Asady, 2006; Asady, 2010; Liu & Han, 2005; Nehi, 2010; Wang & Lee, 2008; Yong, Zhu, & Liu, 2006). However, in spite of the merits, some of these methods are computational complex and difficult to implement and none of them can satisfactorily rank fuzzy numbers in all situations and cases. In this work, the method of center of area (COA) is suggested to rank fuzzy numbers due to its simplicity of implementation. The concept of COA defuzzification can be found in Tong (1978) as early as 1978. The COA method chooses the output value of a fuzzy controller, which divides the area under the membership function in half. Moreover, the COA method has become one of the commonly employed defuzzification methods that are applicable primarily for fuzzy controllers (Halgamuge, 1998; Leekwijck & Kerre, 1999; Mizumoto, 1989; Runkler & Glesner, 1993). Herein, formulae for COA in defuzzifying triangular fuzzy numbers are developed to complete the suggested model. A numerical example is used to demonstrate the computational process of the proposed model. Finally, two more tests are conducted for the suggested model. In the first test, one set of fuzzy numbers is used for evaluating both weights and ratings. In the second test, two sets of fuzzy numbers are used for evaluating weights and ratings, respectively. Ranking results from these two tests are the same as the one from the numerical example, which roughly shows robustness of the suggested model.

The rest of this work is organized as follows. Section 2 briefly introduces fuzzy set theory. Section 3 introduces the suggested model. Meanwhile, an example is presented in Section 4 to demonstrate the feasibility of the proposed model and conclusions are made in Section 5.

2. Fuzzy set theory

2.1. Fuzzy sets

A fuzzy set A can denoted by $A = \{(x, f_A(x))|x \in U\}$, where U is the universe of discourse, x is an element in U, A is a fuzzy set in U, $f_A(x)$ is the membership function of A at x (Kaufmann & Gupta, 1991). The larger $f_A(x)$, the stronger the grade of membership for x in A.

2.2. Fuzzy numbers

A real fuzzy number A is described as any fuzzy subset of the real line R with membership function f_A which possesses the following properties (Dubois & Prade, 1978):

(a) f_A is a continuous mapping from R to $[0,1]$;
(b) $f_A(x) = 0, \forall x \in (-\infty, a]$;
(c) f_A is strictly increasing on $[a, b]$;
(d) $f_A(x) = 1, x \in [b, c]$;
(e) f_A is strictly decreasing on $[c, d]$; (f) $f_A(x) = 0, \forall x \in [d, \infty)$;

where a, b, c and d are real numbers. We may let $a = -\infty$, or $a = b$, or $b = c$, or $c = d$, or $d = +\infty$.

Unless elsewhere specified, it is assumed that A is convex, normal and bounded, i.e. $-\infty < a, d < \infty$. For convenience, fuzzy number A can be denoted by $A = [a, b, c, d]$. The opposite of A can be given by $-A = [-d, -c, -b, -a; 1]$ (Kaufmann & Gupta, 1991). Fuzzy number A is a triangular fuzzy number, denoted by (a, b, c), if its membership function f_A is given by (van van Laarhoven & Pedrycz, 1983):

$$f_A(x) = \begin{cases} (x-a)/(b-a), & a \leqslant x \leqslant b, \\ (x-c)/(b-c), & b \leqslant x \leqslant c, \\ 0, & \text{otherwise}. \end{cases} \tag{1}$$

2.3. Linguistic values

A linguistic variable is a variable whose values are expressed in linguistic terms. Linguistic variable is a very helpful concept for dealing with situations which are too complex or not well-defined to be reasonably described by traditional quantitative expressions (Zadeh, 1975). For example, "importance" is a linguistic variable whose values include UI (Unimportant), SI (Slightly Important), FI (Fairly Important), I (Important) and VI (Very Important). These linguistic values can be further represented by triangular fuzzy numbers such as UI = (0.0, 0.1, 0.3), SI = (0.0, 0.2, 0.5), FI = (0.3, 0.45, 0.7), I = (0.5, 0.7, 0.8) and VI = (0.7, 0.9, 1.0). We assume that decision makers have fully understood the meanings of these linguistic values and their corresponding fuzzy numbers before they assign these values to criteria.

3. Defuzzifying triangular fuzzy numbers with COA

The following formulas are developed to defuzzify triangular fuzzy numbers based on dividing the area under the membership