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An integrated FANP–MOLP for supplier evaluation and order allocation

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ABSTRACT

In the face of acute global competition, supplier management is rapidly emerging as a crucial issue to any companies striving for business success and sustainable development. To optimize competitive advantages, a company should incorporate "suppliers" as an essential part of its core competencies. Supplier evaluation, the first step in supplier management, is a complex multi-criteria decision-making (MCDM) problem, and its complexity is further aggravated if the highly important interdependence among the selection criteria is taken into consideration. The objective of this paper is to suggest a comprehensive decision method for identifying top suppliers by considering the effects of interdependence among the selection criteria, as well as to achieve optimal allocation of orders among the selected suppliers.

1. Introduction

Due to the ever-mounting global competition, supplier management has come to play an increasingly crucial role as a key to business success. To secure competitive advantages, organizations have to integrate their internal core competencies and capabilities with those of their suppliers. How to choose capable suppliers is thus an imperative issue in the management of modern business organizations. Existing researches in the field of supplier selection can be divided into two major categories: those focusing on isolating different supply source selection criteria and assessing the degree of their importance from the purchasing firm's point of view [1]; and those aiming to identify different alternative suppliers by developing and applying specific methods, such as cluster analysis [2], case based reasoning systems [3], statistical models [2], decision support systems [2,3], data envelopment analysis [2,4,5], analytic hierarchy process [2,6], total cost of ownership models [2,7], activity based costing [8], artificial intelligence [2,3], and mathematical programming [9,5,10].

Some of the above methods tend to treat each of the selection criteria and alternative suppliers as an independent entity. Price and quality, for example, are treated as two separate criteria without affecting each other. This is, however, seldom the case in the real world business context in which selection criteria and alternative suppliers are in fact characterized by interdependence. Analytic network process (ANP) can therefore be adopted to accommodate the concern of interdependence among selection criteria or alternatives.

The ANP method recognizes only crisp comparison ratios. Yet human judgments are usually uncertain of its preferences. Mikhailov and Singh [11] utilizes the interval values to express the comparisons and develops the fuzzy preference programming (FPP) method to calculate the weight of every level for coping with inconsistent and uncertain judgments.

The objective of this paper is to suggest a comprehensive decision method for identifying top suppliers by considering the effects of interdependence among the selection criteria, as well as to achieve optimal allocation of orders among the selected

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suppliers. The proposed method accordingly incorporates two stages: (i) Combine ANP with FPP into a more powerful FANP for selection of top suppliers, and (ii) Apply multi-objective linear programming (MOLP) to facilitate optimal allocation of orders.

2. Analytic network process

Analytic network process (ANP) introduced by Saaty is a comprehensive decision-making technique appropriate for both quantitative and qualitative data types and capable of overcoming the problem of interdependence and feedback among alternatives or criteria so as to facilitate a more systematic analysis. ANP uses a network without the need to specify levels as in a hierarchy. ANP has been broadly used in decision-making and various other applications, such as equipment replacement [12], project selection [13], financial-crisis forecasting [14], machine selection [15] and supplier selection [16]. In order to facilitate more effective solutions, ANP in numerous studies is integrated with various mathematical programming models. For instance, Wey and Wu [17] use ANP priorities with goal programming in resource allocation. Ustun and Demirtas [18] integrate ANP and multi-period, multi-objective mixed integer linear programming (MOMILP) for choosing the best suppliers and define the optimum quantities among the selected suppliers.

The method of the ANP unfolds in the following steps. The first step compares the criteria in an entire system to form a supermatrix [19] adopted to measure the relative importance of each criterion. The relative importance value can be determined using a scale of 1–9 to represent equal importance to extreme importance [20]. The next step is to calculate the influence (i.e. the principal eigenvector) of the elements (criteria) in each component (matrix) using the eigenvalue approach. The unweighted supermatrix is then multiplied by the priority weights from the clusters to yield the weighted supermatrix. Finally the supermatrix reaches a steady state by multiplying the weighted supermatrix by itself until the supermatrix's row values converge to the same value for each column of the matrix.

3. Fuzzy preference programming

Fuzzy preference programming (FPP) method proposed by Mikhailov and Singh [11] is mainly used to derive priority vectors from a set of comparison judgments or interval comparisons. The FPP method can be described as follows:

Let $A = \{l_{ij}, u_{ij}\}$ represents an interval comparison matrix with n components where l_{ij} and u_{ij} are the lower and the upper bounds of the corresponding uncertain judgments. When the interval judgments are consistent, the priority vectors satisfy the following inequalities (1)

$$l_{ij} \leqslant \frac{w_i}{w_j} \leqslant u_{ij}, \quad i = 1,2,\ldots,n-1; \quad j = 2,3,\ldots,n; \quad j > i. \tag{1}$$

Inconsistency in the judgments indicates that no priority vector satisfies all the interval judgments simultaneously. Thus, a good enough solution vector has to satisfy all the interval judgments as much as possible.

$$l_{ij} \tilde{\leqslant} \frac{w_i}{w_j} \tilde{\leqslant} u_{ij}, \quad i = 1,2,\ldots,n-1; \quad j = 2,3,\ldots,n; \quad j > i, \tag{2}$$

where the symbol $\tilde{\leqslant}$ denotes the statement "fuzzy less or equal to."

The above set of m fuzzy constraints can be presented in the following matrix form:

$$Rw \tilde{\leqslant} 0, \tag{3}$$

where the matrix $R \in \Re^{m \times n}$; $m = n(n-1)$.

The kth row of Rw, a fuzzy linear constraint, can be defined as a linear membership function of the type

$$u_k(R_k w) = \begin{cases} 1 - \frac{R_k w}{d_k} & R_k w \leqslant d_k, \\ 0 & R_k w \geqslant d_k, \end{cases} \tag{4}$$

where d_k is a tolerance parameter for the kth row of Rw, representing the admissible interval of approximate satisfaction of all judgments. The value of the membership function $u_k(R_k w)$ is equal to zero when the corresponding crisp constraint $Rw \leqslant 0$ is strongly violated; $u_k(R_k w)$ is between zero and one when the crisp constraint is approximately satisfied; and it is greater than one when the constraint is fully satisfied.

In order to solve the prioritization problem, FPP method has two additional assumptions. The first lets $u_k(R_k w)$, $k = 1, 2, \ldots, m$ be membership functions of the fuzzy constraints $Rw \tilde{\leqslant} 0$ on the $n-1$ dimensional simplex

$$Q^{n-1} = \left\{(w_1, w_2, \ldots, w_n) | w_i > 0, \sum_{i=1}^{n} w_i = 1\right\}. \tag{5}$$