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An integrated fuzzy approach for provider evaluation and selection in third-party logistics

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ABSTRACT

The demand of third-party logistics (3PL) provider becomes an increasingly important issue for corporations seeking improved customer service and cost reduction. The present paper presents an integrated fuzzy approach for the evaluation and selection of 3PL providers. This method consists of three different techniques: (1) use fuzzy Delphi method to identify important evaluation criteria; (2) apply fuzzy inference method to eliminate unsuitable 3PL providers; and, (3) develop a fuzzy linear assignment approach for the final selection. The proposed method enables decision analysts to better understand the complete evaluation process of 3PL selection. Furthermore, this approach provides a more accurate, effective, and systematic decision support tool for 3PL provider selection. Finally, an actual industrial application is presented to demonstrate the proposed method.

1. Introduction

Logistics plays a significant role in integrating the supply chain of industries. However, as the market becomes more global, logistics is now seen as an important area where industries can cut costs and improve their customer service quality (Yan, Chaudhry, & Chaudhry, 2003). Logistics outsourcing or third-party logistics (3PL) is an emerging trend in the global market. Basically, a 3PL provider (hereinafter referred to as provider) involves using external companies to perform logistics functions which have been conventionally operational within an organization (Işıklar, Alptekin, & Büyüközkan, 2006). Specifically, a provider can offer an enterprise with its needed services such as professional logistics transportation, warehousing, logistics information system, product returns service, inventory management, and product packaging (Rabinovich, Windle, Dresner, & Corsi, 1999; Sink & Langley, 1997). Hence, 3PL plays a key role in the logistic activities between the outsourcing company, the marketplace, and the customers.

The main benefits of logistics alliances are to allow the outsourcing company to concentrate on the core competence, increase the efficiency, improve the service, reduce the transportation cost, restructure the supply chains, and establish the marketplace legitimacy (Bhatnagar, Sohal, & Millen, 1999; Hertz & Alfredsson, 2003; Skjoett-Larsen, 2000). Hence, a proper 3PL provider which meets various demands is crucial for the growth and competence of an enterprise.

Recently, numerous researches have extensively discussed the relevant topics of 3PL in different perspectives (Andersson & Norrman, 2002; Bagchi & Virum, 1998; Boyson, Corsi, Dresner, & Rabinovich, 1999; Embleton & Wright, 1998; Hertz & Alfredsson, 2003; Jharkharia & Shankar, 2007; Lewis & Talalayevsky, 2000; Murphy & Poist, 2002; Razzaque & Sheng, 1998; Skjoett-Larsen, 2000; Sohail & Sohal, 2003; Van Laarhoven, Berglund, & Peters, 2000; Wilding & Juriado, 2004). Among those various topics, the present study focuses on the issue concerning evaluation and selection of providers. So far, different types of methods have already been designed and developed to address the supplier evaluation or provider selection problems. These methods include the discriminant analysis and data envelopment analysis (Liu, Ding, & Lall, 2000), rule-based and model-based expert system (Sarkis & Sundarraj, 2000), analytic hierarchy process (Barbarosoglu & Yazgac, 1997; Handfisld, Walton, Stroufe, & Melnyk, 2002), principal component analysis and factor analysis (Carr & Pearson, 2002), scoring method and fuzzy expert system (Kwong, Ip, & Chan, 2002), case-based reasoning (Yan et al., 2003), checklist and interview method Vaidyanathan (2005), fuzzy TOPSIS approach (Chen, Lin, & Huang, 2006), hybrid decision support system (Işıklar et al., 2006), analytic network process (Jharkharia & Shankar, 2007), etc.

In the present paper, we propose an integrated fuzzy decision analysis method for provider selection that suits the different logistic needs of the outsourcing company. The proposed method integrates fuzzy Delphi, fuzzy inference, and fuzzy linear assignment techniques to deal with uncertain and imprecise decision situations. In the following paragraphs, we will explain the idea of the proposed method.

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As we know, each outsourcing company has its unique needs for the logistic support of a provider. The evaluation criteria should not be the same and the weight of these criteria may vary dramatically from company to company. Delphi is a widely used and effective method that can integrate the opinions of the decision analysts (hereinafter referred to as analysts) from the outsourcing company by utilizing multiple questionnaires. By merging their opinions, Delphi assists the analysts to identify the important evaluation criteria and to obtain their weights for provider selection. In the present paper, we designed a fuzzy Delphi method to achieve this goal. Moreover, this method can effectively reduce the number of required questionnaires and expedite the convergence of opinions.

During the course of provider selection, the outsourcing company often faces the problem of dealing with a large number of logistics providers (Vaidyanathan, 2005). How to effectively and efficiently screen the unsuitable providers becomes a tough challenge for the analysts. To solve this problem, we employed a fuzzy inference approach that can assist the analysts in efficiently eliminating the unsuitable providers. Based on their subjective judgments, experiences and expertise, they can generate some preliminary screening heuristics for rejecting unsuitable providers. In the present study, these heuristics are represented as "IF–THEN" rules which are inferred by applying approximate reasoning principles. The results of the inference identify the potential providers for the final selection.

In the final selection stage, we developed a fuzzy linear assignment method for evaluating potential providers. This method is actually a type of multi-criteria decision-making (MCDM) approach. According to Chen et al. (2006), the supplier selection problem can be viewed as a group decision-making problem with multiple criteria. Furthermore, the weights of the evaluation criteria and the performance ratings of the providers are usually imprecise, uncertain or fuzzy in real-life problems. Hence, we intend to develop a fuzzy MCDM (fuzzy linear assignment) approach that can assist the analysts in selecting the best provider in the fuzzy environment.

The main goal of the present study is to develop a systematic and integrated fuzzy decision analysis approach for provider selection which the analysts can apply to their organization. By integrating the three different techniques (fuzzy Delphi, fuzzy inference, and fuzzy linear assignment), the proposed research takes advantage of their strengths. Furthermore, this approach provides a precise and effective way for the analysts to identify important evaluation criteria, eliminate unsuitable providers, and select the best provider. Finally, the application of this method is demonstrated with a case company.

The rest of the present paper is organized as follows. Section 2 briefly introduces the definitions and operations of the fuzzy numbers utilized in the study. Section 3 describes the concepts and the research steps of the proposed fuzzy decision analysis approach for the provider selection problem. Section 4 uses a real industrial case to illustrate the research steps of the proposed method. The final section concludes the research paper.

2. Fuzzy numbers

We briefly review below some of the basic definitions and the relevant operations of fuzzy numbers (Dubois & Prade, 1980; Kaufmann & Gupta, 1991; Klir & Yuan, 1995).

Definition 1. Fuzzy sets A fuzzy set $\widetilde{A}$ in the universe of discourse X is characterized by a membership function $\mu_{\widetilde{A}}(x)$ which associates with each element x in X a real number in the interval $[0,1]$.

Definition 2. Convex and normal A fuzzy set $\widetilde{A}$ is convex if for all x_1 and x_2 in the universe of discourse X, such that

$$\mu_{\widetilde{A}}(\lambda x_1 + (1-\lambda)x_2) \geqslant \text{Min}(\mu_{\widetilde{A}}(x_1), \mu_{\widetilde{A}}(x_2)), \quad \lambda \in [0,1]. \tag{1}$$

Furthermore, a fuzzy set $\widetilde{A}$ is called a normal fuzzy set which implies that $\exists x_i \in X, \mu_{\widetilde{A}}(x_i) = 1$.

Definition 3. Trapezoidal fuzzy number A fuzzy number is a fuzzy set in X that is both convex and normal. Moreover, a trapezoidal fuzzy number $\widetilde{A}$ can be defined by (a_1,a_2,a_3,a_4) as shown in Fig. 1. The membership function $\mu_{\widetilde{A}}(x)$ is defined by

$$\mu_{\widetilde{A}}(x) = \begin{cases} 0, & x < a_1, \\ \frac{x-a_1}{a_2-a_1}, & a_1 \leqslant x \leqslant a_2, \\ 1, & a_2 \leqslant x \leqslant a_3, \\ \frac{a_4-x}{a_4-a_3}, & a_3 \leqslant x \leqslant a_4, \\ 0, & x > a_4. \end{cases} \tag{2}$$

Definition 4. α-cut of a trapezoidal fuzzy numberThe α-cut (A_α) of a trapezoidal fuzzy number $\widetilde{A}$ is defined as

$$A_\alpha = \{x | \mu_{\widetilde{A}}(x) \geqslant \alpha, x \in X\}, \quad \alpha \in [0,1], \tag{3}$$

where A_α is located in the interval $[A_\alpha^L, A_\alpha^R]$, while A_α^L and A_α^R are the lower and upper bounds of the closed interval.

Given any two positive trapezoidal fuzzy numbers, $\widetilde{A} = (a_1, a_2, a_3, a_4)$, $\widetilde{B} = (b_1, b_2, b_3, b_4)$, and a real number k, some arithmetic operations of $\widetilde{A}$ and $\widetilde{B}$ can be expressed as follows:

$$\begin{aligned} &\widetilde{A} \oplus \widetilde{B} = (a_1+b_1, a_2+b_2, a_3+b_3, a_4+b_4), \\ &\widetilde{A} \ominus \widetilde{B} = (a_1-b_4, a_2-b_3, a_3-b_2, a_4-b_1), \\ &\widetilde{A} \otimes \widetilde{B} = (a_1 \times b_1, a_2 \times b_2, a_3 \times b_3, a_4 \times b_4), \\ &k > 0, \quad k \cdot \widetilde{A} = (ka_1, ka_2, ka_3, ka_4). \end{aligned} \tag{4}$$

3. Proposed fuzzy approach

The proposed fuzzy approach is aimed at constructing a systematic provider evaluation process which consists of three main phases: preliminary screening of the evaluation criteria, elimination of unsuitable providers, and final selection. At first, we design a fuzzy Delphi method that can effectively identify important evaluation criterion and determine their weights from the results of multiple questionnaires. Next, we assist the analysts in the establishment of screening heuristics rules for the early rejection of unfavorable providers based on their knowledge or expertise. These rules were derived using fuzzy inference principles. The results of the inference provide an efficient way to eliminate unsuitable providers in the early stage. Finally, we developed a fuzzy MCDM method based on the concept of linear assignment and which can accurately determine the ranking order of the remaining providers. The detailed steps of each phase are discussed in the following section.

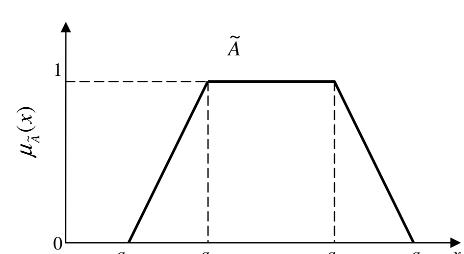

Fig. 1. A trapezoidal fuzzy number $\widetilde{A}$.