Expert Systems with Applications 38 (2011) 7208–7221

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Optimal location selection for an international distribution center by using a new hybrid method

Ming-Shin Kuo *

Department of Transportation Technology and Management, Kainan University, No. 1, Kainan Rd., Luchu, Taoyuan 338, Taiwan
Department of Industrial Engineering and Management, National Formosa University, 64 Wun Hwa Road, Hu Wei, Yunlin 632, Taiwan

ARTICLE INFO

Keywords:
Fuzzy MCDM
TOPSIS
ANP
Fuzzy DEMATEL
Fuzzy environment

ABSTRACT

The selection of a location for an international distribution center (IDC) is a most important decision for international logistics managers owing to the need to consider various criteria that involve a complex decision process in which multiple requirements and uncertain conditions have to be taken into consideration simultaneously. Moreover, the criteria often exist simultaneously as independent and dependent characteristics when the problems of location selection have become very complex. A new hybrid method combining the concepts of fuzzy DEMATEL and a new method of fuzzy multiple criteria decision-making (MCDM) in a fuzzy environment is proposed to solve the problems of IDC location selection. In this paper, the fuzzy DEMATEL is proposed to arrange a suitable structure between criteria, and the analytic hierarchy/network process (AHP/ANP) is used to construct weights of all criteria. The linguistic terms characterized by triangular fuzzy numbers are used to denote the evaluation values of all alternatives versus various criteria. Finally, the aggregation fuzzy assessments of different alternatives are ranked to determine the best selection. Furthermore, this paper uses an empirical case for optimal location selection for an IDC in Pacific Asia to illustrate the proposed method, and the results show that the method is an effective means for tackling fuzzy MCDM problems.

1. Introduction

In recent years, international logistics businesses have been active in searching for suitable locations for international distribution centers (IDC) in order to increase economy of scale and reduce transportation costs. As all the activities in an international logistics system often take place between international customers and suppliers, the evaluation and selection of a suitable IDC location has become one of the most important decision issues for international logistics firms. In general, selection and evaluation of locations considering various criteria is a MCDM process. In the past, many precision-based methods of MCDM for evaluating/selecting alternatives have been developed. These methods have been widely used in various fields such as information project selection, material selection, management decisions, strategy selection, and problems relating to decision-making. Besides, the characteristics of criteria are often simultaneously independent and dependent when the selection of locations has become very complex or difficult. Therefore, many studies have tended to reduce a complex MCDM process to a simple one by assuming the criteria are either independent or dependent (e.g. Baucells & Sarin, 2003; Tzeng, Ou Yang, Lin, & Chen, 2006). When considering independent criteria, the studies concern uncertain or imprecise data and the subjectiveness and imprecision of human behavior. Chen (2000) used MCDM to solve decision problems in uncertain conditions, for which the method used was based on TOPSIS. Chen and Tzeng (2004) presented another new fuzzy MCDM method based on TOPSIS and grey relations to select the expatriate host countries. Ding and Liang (2005) applied fuzzy MCDM to select partners of strategic alliances using a method based on TOPSIS and entropy weighting. Deng (1999) incorporated the fuzzy pairwise comparison and the basic concepts of positive and negative ideals to expand MCDM in a fuzzy environment. Liang (1999) incorporated the fuzzy set theory based on concepts of positive and negative ideals to expand MCDM in a fuzzy environment. Yeh, Deng, and Chang (2000) proposed a new fuzzy MCDM method based on the concepts of positive and negative ideal points to evaluate the performance of bus companies. Yeh, Deng, and Pan (1999) proposed a new fuzzy MCDM method to evaluate a dredger dispatching problem. These studies, under the condition of assuming all criteria as independent, all proposed methods of fuzzy MCDM based on the concepts of positive and negative ideal solutions.

Other studies concern decision problems with interactions between criteria. Chiou and Tzeng (2002) presented a non-additive

* Address: Department of Transportation Technology and Management, Kainan University, No. 1, Kainan Rd., Luchu, Taoyuan 338, Taiwan. Fax: +886 3 2705695.
E-mail addresses: mingshin@mail.knu.edu.tw, mingshin.kuo@gmail.com

0957-4174/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.eswa.2010.12.002

technique to evaluate a green engineering industry case in a fuzzy MCDM problem. They demonstrated that the non-additive fuzzy integral was an effective evaluation, and the results appeared to be appropriate. Tzeng et al. (2006) presented a new hierarchical MCDM method based on fuzzy integrals to evaluate enterprise intranet web sites in a fuzzy environment, and the results showed that the fuzzy integral was more suitable than other traditional multiple criteria evaluation methods for human subjective evaluation. Chiou, Tzeng, and Cheng (2005) used a non-additive fuzzy integral to evaluate sustainable fishing development strategies. This study demonstrated that the non-additive fuzzy integral technique can overcome the case where criteria are not independent. They showed that if an additive aggregating method is employed to derive the synthetic utility, which is the same as the traditional assumption for independent relationships among criteria, it will overestimate when the criteria have substitutive properties, or underestimate when the criteria have multiplicative properties. Chen and Tzeng (2001) used fuzzy integrals to evaluate subjectively perceived travel costs, and they also demonstrated this method with non-independent criteria. Chen and Weng (2002) presented fuzzy integrals to evaluate quality improvement alternatives, where the fuzzy integral technique was employed for performing information fusions of objective evidence from various input information sources with the associated degree of importance of subsets of these sources. The results showed that this technique can effectively deal with non-independent criteria. Zhang, Ma, and Xu (2005) presented a new fuzzy MCDM method based on a trapezoidal fuzzy AHP and hierarchical fuzzy integral. In addition, Tzeng, Chiang, and Li (2007) presented a novel hybrid MCDM to evaluate intertwined effects in e-learning programs, where this technique included both DEMATEL and fuzzy integrals. They used DEMATEL to arrange a suitable structure between criteria, and employed fuzzy integrals to evaluate effects according to a suitable structure. These studies assumed all criteria are dependent.

Based on the above concepts from the mentioned studies, we know that using the "technique for order performance by similarity to ideal solution" (TOPSIS), it is easy to find the positive ideal point, which is composed of all best criteria values attainable, and the negative ideal point, composed of all worst criteria values attainable, using the Euclidean distance or Hamming distance. However, the TOPSIS method does not consider dependent criteria, and there is only one preference order (Chen, 2000; Chen & Tzeng, 2004). Besides, the above method only considers the characteristics of either independent criteria or dependent criteria in structures. In these studies, that the independent and dependent criteria exist simultaneously is not considered. Although these methods can be applied to any decision-making problem, typical fuzzy multiple criteria analysis requires the comparison of fuzzy numbers. This comparison process can be quite complex and produce unreliable and/or reliable results, as it may: (1) involve considerable computations, (2) produce inconsistency by respective fuzzy ranking methods, and (3) generate counter-intuitive ranking outcomes for similar fuzzy utilities (see Bortolan & Degani, 1985; Yeh et al., 1999; Yeh et al., 2000).

In this paper, based on the above concepts from the literature, fuzzy MCDM problems are discussed under uncertainty, and a new hybrid method, which may reflect subjective judgment, objective information and handle the independent and dependent criteria that exist simultaneously in real-life situations, is proposed. This hybrid method is based on two concepts of the fuzzy DEMATEL and a new fuzzy MCDM to deal with IDC location selection and MCDM problems in a fuzzy environment. The fuzzy DEMATEL is used to depict the hierarchical/network structure in order to construct a suitable hierarchical/network framework of evaluation/selection IDC location. This technique can be used to obtain relational degree between criteria and a suitable hierarchical/network framework. Through this technique, the proposed evaluation method of fuzzy MCDM is easy to use in real-life evaluation problems. The proposed evaluation method is based on combining the concepts of additive/non-additive measurements and a concept of TOPSIS, and the resulted ranking of the alternatives is obtained from the comparison of their corresponding closeness coefficient values. Finally, this paper uses an example for a location selection problem of IDC in Pacific Asia to illustrate the new hybrid method. Through this case, this paper can demonstrate a new hybrid method of combining fuzzy DEMATEL and a new fuzzy MCDM method for selecting location of IDC, which is a good means of evaluation, and it appears to be more appropriate than other methods.

The remainder of this paper is organized as follows. The basic definitions and notations of the fuzzy numbers and linguistic variables are introduced in Section 2. Based on the above concepts from Section 2, a new hybrid method is proposed in Section 3. In Section 4, an empirical case applies a hybrid method to select locations of IDC. The hybrid method is ample discussed from comparative study in Section 5, after which we discuss and show how the hybrid method in this paper appears to be effective. Finally, conclusions are presented in Section 6.

2. Definitions and concepts of the fuzzy number

In this section, the basic definitions of fuzzy numbers are briefly introduced (see, e.g., Chen & Hwang, 1992; Kaufmann & Gupta, 1991; Yao & Wu, 2000; Zimmermann, 1996). Based on these basic concepts, a new hybrid method will be proposed.

Definition 1. A fuzzy set a_α of $\Re$, $\alpha \in [0,1]$, is called a level α fuzzy point if

$$\mu_{a_\alpha}(x) = \begin{cases} \alpha, & x = a, \\ 0, & x \neq a. \end{cases}$$

Let $F_M(\alpha)$ be the family of all level α fuzzy point.

Definition 2

(1) A fuzzy subset $\widetilde{A}$ of $\mathbf{R}$ is convex iff every ordinary subset $A(\alpha) = \left\{x | \mu_{\widetilde{A}}(x) \geqslant \alpha\right\}$, $\alpha \in [0,1]$ is convex, it is a closed interval of $\mathbf{R}$.
(2) A fuzzy subset $\widetilde{A}$ of $\mathbf{R}$ is normal iff $\sup_{x \in R} \mu_{\widetilde{A}}(x) = 1$.
(3) A fuzzy number in $\mathbf{R}$ is a fuzzy subset of $\mathbf{R}$ which is convex and normal.

Let F_N be the family of fuzzy numbers of $\mathbf{R}$ satisfying Definition 2(1). Let $F = F_N \cup F_M(1)$, $\widetilde{D} (\in F_N)$, $D(\alpha)$ is a non-empty bounded closed interval and it can be denoted by $D(\alpha) = [D_L(\alpha), D_R(\alpha)]$, $D_L(x)$ and $D_R(x)$ are lower and upper bounds of the closed interval, respectively (Kaufmann & Gupta, 1991; Yao & Wu, 2000).

Definition 3. The two fuzzy numbers are $\widetilde{D} \in F$ and $\widetilde{E} \in F$, define the signed distance of $\widetilde{D}$, $\widetilde{E}$ as follows (see Yao & Wu, 2000):

$$d\left(\widetilde{D}, \widetilde{E}\right) = \frac{1}{2} \int_0^1 [D_L(\alpha) + D_R(\alpha) - E_L(\alpha) - E_R(\alpha)] d\alpha,$$

where $d\left(\widetilde{D}, \widetilde{E}\right)$ is the distance of $\widetilde{E}$ to $\widetilde{D}$.

If $O \in F_M(1)$, then its lower and upper points of α-cut ($\alpha \in [0,1]$) are 0, for each $\widetilde{D} \in F$, $d\left(\widetilde{D}, O\right) = \frac{1}{2} \int_0^1 [D_L(\alpha) + D_R(\alpha)] d\alpha$.

Thus we can define $d\left(\widetilde{D}, \widetilde{E}\right) = d\left(\widetilde{D}, O\right) - d\left(\widetilde{E}, O\right)$.

Definition 4. Let $\widetilde{A} = (l_1, m_1, r_1)$ and $\widetilde{B} = (l_2, m_2, r_2)$ be two fuzzy numbers, then the signed distance is defined as (see Yao & Wu, 2000)