Expert Systems with Applications 39 (2012) 1315–1323

Contents lists available at SciVerse ScienceDirect

Expert Systems with Applications

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

Emergency alternative evaluation under group decision makers: A method of incorporating DS/AHP with extended TOPSIS

Yanbing Ju [a,*], Aihua Wang [b]

[a] School of Management and Economics, Beijing Institute of Technology, Beijing 100081, PR China
[b] Graduate School of Education, Peking University, Beijing 100871, PR China

ARTICLE INFO

Keywords:
Group multi-criteria decision making
TOPSIS
Dempster–Shafer theory
Analytic hierarchy process
Decision matrix
Belief interval

ABSTRACT

How to select suitable emergency alternative is critical to emergency management and has attracted much attention for both researchers and practitioners. In the process of evaluating emergency alternative problems, there usually exists incomplete and uncertain information, and the decision makers can not easily express their judgments on the candiates with exact and crisp values. The Dempster–Shafer theory (DST) is well suited for dealing with such problems and can generate comprehensive assessments for different alternatives. In this paper, the DS/AHP method and extended TOPSIS method are incorporated to solve group multi-criteria decision making (GMCDM) problems with incomplete information. The proposed method involves three steps: (1) Identify the focal elements of each decision maker according to the group decision matrix. (2) Construct the group weighted normalized belief interval decision matrix using Dempster's rule of combination. (3) Propose the Extended TOPSIS approach for group interval data to rank the emergency alternatives. In this method, the positive ideal solution vector is defined as the maximum plausibility of all emergency alternatives with respect to each criterion, and the negative ideal solution vector is defined as the minimum belief of all emergency alternatives with respect to each criterion. An emergency alternative evaluation selection problem is taken as an illustrative example to demonstrate the feasibility and practicability of the proposed methods for group decision making in emergency management.

1. Introduction

In the process of emergency management, a major issue is to evaluate the emergency alternative, and it has attracted much research attention recently (Georgiadoua, Papazogloub, Kiranoudisc, & Markatos, 2007). Emergency alternative evaluation (EAE) in a fuzzy group setting is a very important strategic decision involving decisions balancing within a number of criteria and opinions from different decision maker. Moreover, these criteria usually conflict with each other and there may be no solution satisfying all criteria simultaneously. Different decision makers have different knowledge about emergency alternatives, and they may make different contributions to different emergency alternatives. Therefore, emergency alternative evaluation select problem (EAESP) belongs to a multi-criteria decision making (MCDM) problem which involve both quantitative and qualitative criteria with various kinds of uncertainties such as ignorance, fuzziness, interval data, and interval belief degrees.

Many MCDM approaches have been proposed to help decision makers to solve problems in uncertain environment. Amongst these methods, TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) method, presented in Chen and Hwang (1992) and with reference to Hwang and Yoon (1981) has been widely used in many areas. Recently, Abo-Sinna and Amer (2005) extended TOPSIS approach to solve multi-objective nonlinear programming problems. Chen (2000) extended the concept of TOPSIS to develop a methodology for solving multi-person multi-criteria decision making problems in fuzzy environment. Ye (2010) extended the TOPSIS method with interval-valued intuitionistic fuzzy numbers to solve virtual enterprise partner selection. Jahanshahloo, Lotfi, and Izadikhah (2006) proposes an algorithmic method to extend TOPSIS for decision making problems with interval data. Saremi, Mousavi, and Sanayei (2009) used TOPSIS to select total quality management consultant in small- and medium-sized enterprises under fuzzy environment.

The analytic hierarchy process (AHP) is another important MCDM approach, which was originally proposed by Saaty (1977, 1980). The AHP has been widely used by both researchers and practitioners. Amiri (2010) used the AHP and fuzzy TOPSIS methods to select project for oil-fields development. Sloane, Liberatore, Nydick, Luo, and Chung (2003) used the AHP as a clinical engineering tool to facilitate an iterative and microeconomic health technology assessment. Liu and Shih (2005) integrated AHP and data mining for

---

* Corresponding author. Tel.: +86 1068912453; fax: +86 1068912483.
E-mail address: juyb@bit.edu.cn (Y. Ju).

0957-4174/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.eswa.2011.08.012

product recommendation based on customer lifetime value. Ngai (2003) used the AHP to select the web sites for online advertising. Yang and Kuo (2003) proposed a hierarchical AHP/DEA methodology for the facilities layout design problem. Theoretically, the methodology is valuable when the decision making framework has a unidirectional hierarchical relationship among decision levels.

Another favorable technique for solving MCDM problems is the Dempster–Shafer theory of evidence (DST) (Dempster, 1968; Shafer, 1976). Yang, Wang, Xu, and Chin (2006) proposed the evidential reasoning approach for MCDM under both probabilistic and fuzzy uncertainties. Yang and Xu (2002) presented the evidential reasoning algorithm for MCDM under uncertainty. Guo, Yang, Chin, and Wang (2007) introduced evidential reasoning based preference programming for MCDM under uncertainty. Chin, Wang, Poon, and Yang (2009) proposed failure mode and effects analysis using a group-based evidential reasoning approach. Wang, Yang, and Xu (2006) used the evidential reasoning approach to assess the environmental impact. The merit of ER approach is to handle MCDM problems having both quantitative and qualitative information with uncertainties and subjectivity.

The DS/AHP method was proposed by Beynon, Curry, and Morgan (2000), which incorporates Dempster–Shafer theory with AHP, shows potential on dealing with MCDM problems with incomplete information. The DS/AHP method is useful in that it could be an initial study of all the alternatives available, the results of which could lower the number of alternatives that fit the limited number of opinions given so far, with only a few opinions stated (Hua, Gong, & Xu, 2008). Hinted by the DS/AHP method, Hua et al. (2007) introduced the DS–AHP method for the MCDM problem with incomplete decision matrix. The DS–AHP method is useful in that it could identify all possible focal elements from the incomplete decision matrix. The framework of DS–AHP makes it possible to deal with various decision matrixes, either complete or incomplete, crisp or fuzzy, certain or uncertain, using the belief structure, which allows decision makers to describe their evaluations on decision alternatives (DAs) in a flexible, natural and reliable manner. In addition, the DS–AHP method has advantages over AHP on the number of comparisons and consistency checks.

In this paper, a method of incorporating DS/AHP with extended TOPSIS is proposed, and it has been applied to evaluate emergency alternative selection problem (EASP). The rest of the paper is organized as follows. The Dempster–Shafer theory and TOPSIS method are briefly introduced in Section 2. The method of incorporating DS/AHP with extended TOPSIS is described in Section 3. An emergency alternative evaluation selection problem is used as an example to illustrate the method of aggregating DS/AHP with extended TOPSIS in Section 4. A conclusion remark is presented in Section 5.

2. Dempster–Shafer theory and TOPSIS method

2.1. Dempster–Shafer theory

Dempster–Shafer theory is a generalization of the Bayesian approach. The Dempster–Shafer theory was first developed by Dempster in the 1960s. His work was later extended and refined by Shafer in the 1970s. This theory can deal with incomplete data by managing ignorance (Shafer, 1976). It is based on Dempster's works on the lower and upper limits of probabilities. Let $\theta = \{\theta_1, \theta_2, \ldots, \theta_N\}$ be a finite nonempty set of mutually exclusive hypothesis, and be called the frame of discernment (Shafer, 1976). This frame of discernment contains every possible hypothesis. The elements in θ could be enumerated by 2^θ, which is the power set of θ, consisting of all the subsets of θ.

Let $m(A)$ denote the basic probability assignment (BPA) to the subset A, which measures the extent to which the evidence supports A. The BPA is a function: m: $2^\theta \to [0,1]$, which is called a mass function and satisfies:

$$m(\phi) = 0 \quad \text{and} \quad \sum_{A \in \theta} m(A) = 1 \tag{1}$$

where ϕ is the null set, A is any subset of θ, and 2^θ is the power set of θ.Given a piece evidence, a belief level between [0,1], denoted by $m(\cdot)$, is assigned to each subset of θ. Each subset contains one or more hypothesis. No belief ought to be committed to an empty set. All the BPAs add up to unity.

Belief function is an important concept associated with the Dempster–Shafer theory, which is defined as follows:

$$Bel(A) = \sum_{B \subseteq A} m(B), \quad \text{for any } A \subseteq \theta \tag{2}$$

It reflects the exact support to the hypothesis A and is a function Bel: $2^\theta \to [0,1]$. $Bel(A)$ is the probability assigned to A considering all the premises of A. The difference of $m(A)$ and $Bel(A)$ is that $m(A)$ measures the assignment of belief only to A, not the total assignment of belief to A and all its subsets.

Plausibility function is another important concept associated with the Dempster–Shafer theory, which is defined as

$$Pl(A) = \sum_{A \cap B \neq \phi} m(B), \quad \text{for any } A \subseteq \theta \tag{3}$$

$Pl(A)$ represents the possible support to A, i.e. the total amount of belief that could be potentially placed in A. $[Bel(A), Pl(A)]$ constitutes the interval of support to A and can be seen as the lower and upper bounds of the probability to which A is supported. The information from independent sources is aggregated by Dempster's rule of combining as in Eq. (4). The Dempster's rule of combination is the core of the Dempster–Shafer theory.

$$m(A) = \frac{\sum_{B \cap C = A} m_1(B) m_2(C)}{1 - \sum_{B \cap C = \phi} m_1(B) m_2(C)} \quad A \neq \phi \tag{4}$$

2.2. The TOPSIS method

The TOPSIS is a multi-criteria decision making (MCDM) method to identify solutions from a finite set of alternatives. The basic principle is that the chosen alternative should have the shortest distance from the positive ideal solution (PIS) and the farthest distance from the negative ideal solution (NIS). Suppose that a MCDM problem has m alternatives A_i ($i = 1,2,\ldots,m$), and n criteria C_j ($j = 1,2,\ldots,n$). Each alternative is evaluated with respect to all n criteria. All the values assigned to the alternatives with respect to criteria may be expressed in a decision matrix format, denoted by $F = (f_{ij})_{m \times n}$. Let $\lambda = (\lambda_1, \lambda_2, \ldots, \lambda_n)$ be the relative weight vector of the criteria, satisfying the normalization conditions: $0 \leqslant \lambda_j \leqslant 1$ and $\sum_{j=1}^{n} \lambda_j = 1$. Then the main procedure of the TOPSIS can be summarized as follows:

Step 1: Normalize the decision matrix $F = (f_{ij})_{m \times n}$ using the following formula:

$$r_{ij} = \frac{f_{ij}}{\sqrt{\sum_{i=1}^{m} (f_{ij})^2}} \quad i = 1,2,\ldots,m;\ j = 1,2,\ldots,n \tag{5}$$

where r_{ij} is called the normalized criteria value.

Step 2: Calculate the weighted normalized decision matrix $Y = (y_{ij})_{m \times n}$ using the following formula:

$$y_{ij} = \lambda_j r_{ij} \quad i = 1,2,\ldots,\ m; j = 1,2,\ldots,n \tag{6}$$

where λ_j ($j = 1,2,\ldots,n$) is the relative weight of criteria C_j, satisfying $\lambda_j \in [0,1]$ and $\sum_{j=1}^{n} \lambda_j = 1$.