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An evidential DEMATEL method to identify critical success factors in emergency management

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ABSTRACT

As the result of the warmer climate and the worse environment, human beings are facing with more serious natural disasters. It is urgent to improve emergency management. Due to the fact that performance of emergency management is affected by many factors, it is difficult to improve all of them in limited resources. Thus, a feasible way is to figure out some important and urgent ones to optimize. For this purpose, a new method identifying the critical success factors (CSF) is proposed in this paper. In this method, the evaluations of influencing factors in the form of intuitionistic fuzzy numbers (IFNs) are converted into basic probability assignments (BPAs). Then Dempster–Shafer theory is adopted to combine group decision. By doing so, there is no need for defuzzification of IFNs, and DEMATEL is applied on each fused BPA to seek for a final result from different aspects. Finally, five CSFs are found out. By optimizing the five CSFs, the effectiveness and efficiency of the whole emergency management could be greatly promoted.

1. Introduction

Due to the global climate warming, social wealth accumulating and population expanding, human beings are facing with increasingly serious issues of natural disasters. These natural disasters have been causing enormous losses. But the performance of emergency management needs great improvement due to its current level. Such as emergency information system for ensuring information transferring is not so effective. And lacking of modern logistics technology is also an issue. So a growing number of researchers focus on optimization of emergency management. Until now, most existing studies just focus on choosing one or two specific procedures of emergency management to optimize. But this kind of measures cannot systematically improve the overall emergency performance and management. Therefore, to enhance the efficiency of emergency management as a whole, it is useful to segment the emergency management into meaningful factors so as to find out the relationship among them and to promote the whole process stepwise.

Since many related works addressing the specific activity of emergency management have actually involved influencing factors, it is a feasible way to extract influencing factors from these literatures. Based on an intensive literature review, influencing factors have been managed to derive from the summary of factors in prior researches [1]. However, it is unrealistic to improve all influencing factors simultaneously due to limited resources of emergency management. A more feasible way is to clarify the relationship among factors and to find out the most urgent and important factors. These kinds of factors are named as critical success factors (CSF) and they have the greatest influence on the whole emergency management [1]. If these factors are improved, the efficiency of emergency management can be greatly facilitated. So decision makers can only focus on these CSFs.

In prior research, CSFs are identified by case study and interviewing with experts. Nevertheless, these methods are easily influenced by the subjectivity of humans. In order to address the issue, a better way is to utilize multiple criteria decision making methods [2,3] to identify CSFs. Some similar but technically different solutions were also proposed by Tseng et al. [4], Wu [5] and Zhou et al. [1]. In these literatures, before fuzzy DEMATEL is applied to identify the CSFs, triangular fuzzy numbers are converted into crisp values by a series of defuzzification steps. However, our method is not just to extend this issue to group decision making, but also to acquire the final results from two different aspects. For this purpose, instead of converting intuitionistic fuzzy numbers to crisp values before employing DEMATEL method, we transform them into a similar form, namely, basic probability assignments (BPAs) and fuse them by Dempster–Shafer theory. In addition,

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to find out the CSFs, we take both the degree of direct relation and the degree of indirect relation into consideration. Based on our knowledge, it is the first time that Dempster–Shafer theory and DEMATEL method have been combined together to deal with emergency management. And in the proposed method there is no need for defuzzification of fuzzy numbers before utilizing DEMATEL method. So, this method can faithfully reflect the uncertainty of evaluation. Finally, we apply DEMATEL twice on each fused BPA to seek for the final results from different aspects, which is another contribution of our study.

Former researchers focus on one or two specific activities, trying to optimize certain procedures of emergency management. For example, Rouvroye and Bliek [6] proposed an approach for comparing different safety analysis techniques in emergency management system and described the qualitative and quantitative results from the comparison. Park et al. [7] using a training simulator of the nuclear power plant to analyze operators' performance under emergencies. Cowing et al. [8] discussed tradeoffs between productivity and safety in critical engineering systems. Park and Jung [9] designed a human performance database under simulated emergencies of nuclear power plants to act as a serviceable data source for scrutinizing human performance.

In this paper, the process of figuring out CSFs is considered as a multiple criteria decision making problems [10]. Thus, Decision Making Trial and Evaluation Laboratory (DEMATEL) method can be adopted to find out the total relation of the factors in emergency management and to figure out CSFs [11]. Evaluation given by experts is always linguistic assessment. For the convenience of express uncertainty, linguistic values can be represented by intuitionistic fuzzy numbers (IFNs) [12–15]. In prior research, DEMATEL is extended to fuzzy DEMATEL method to deal with fuzzy numbers [16]. In this paper, IFNs are not converted into crisp values directly, but transformed into BPAs. By doing so, the uncertainty of evaluation is still kept. And then, Dempster–Shafer theory which has been applied in many fields [17–22] is adopted to aggregate the group assessment BPA matrix. Under this circumstance, DEMATEL method can be applied directly on each BPA. As mentioned above, based on two different aspects, CSFs can be identified.

The rest of this paper is organized as follows. Section 2 introduces the basic theories applied in this paper. The proposed method is described in Section 3. Effectiveness of the method is analyzed in Section 4. Section 5 concludes the paper.

2. Basic theories

2.1. Dempster–Shafer theory

Dempster–Shafer theory, was first proposed by Dempster [23] and then developed by Shafer [24]. It has the ability of combining pairs of bodies of evidence to derive a new evidence. With the ability of dealing with the uncertainty, Dempster–Shafer theory has been widely applied to many fields, such as identifying influential nodes [19], decision making [17] and so on [18].

In Dempster–Shafer theory, a problem domain, which may be the set of states in an event or the set of targets to be identified, is denoted by a finite nonempty set U of mutually exclusive and exhaustive hypotheses, called frame of discernment. Let 2^U denote the power set of U, which means for any element of 2^U, such as A, A is a subset of U, and A is called a proposition.

Definition 1 *(Mass function).* For a frame of discernment U, a mass function is a mapping m from 2^U to [0, 1], formally defined by:

$$m: \quad 2^U \to [0,1] \tag{1}$$

which satisfies the following conditions:

$$m(\emptyset)=0 \quad and \quad \sum_{A\in 2^U} m(A)=1 \tag{2}$$

A mass function is also called a basic probability assignment (BPA) of the frame of discernment U. Consider two pieces of evidence indicated by two BPAs m_1 and m_2 on the frame of discernment U. Dempster's rule of combination described as follows is used to generate a new BPA from two or more BPAs.

Definition 2 *(Dempster's rule of combination).* Dempster's rule of combination, also called orthogonal sum, denoted by $m = m_1 \oplus m_2$, is defined as follows

$$m(A)=\frac{1}{1-K}\sum_{B\cap C=A} m_1(B)m_2(C) \tag{3}$$

with

$$K=\sum_{B\cap C=\emptyset} m_1(B)m_2(C) \tag{4}$$

where K is a normalization constant, called conflict coefficient of two BPAs. Note that the Dempster's rule of combination is only applicable to such two BPAs which satisfy the condition $K < 1$.

2.2. Intuitionistic fuzzy sets

Definition 3. Let $X = \{x_1, x_2, \cdots, x_n\}$ be a finite universal set. An intuitionistic fuzzy set A in X is an object having the following form [25]:

$$A=\{< x_j, \mu_A(x_j), \nu_A(x_j) > \big| x_j \in X\}$$

where the functions

$$\mu_A : X \mapsto [0,1]$$

$$x_j \in X \to \mu_A(x_j) \in [0,1]$$

and

$$\nu_A : X \mapsto [0,1]$$

$$x_j \in X \to \nu_A(x_j) \in [0,1]$$

define the degree of membership and degree of non-membership of the element $x_j \in X$ to the set $A \subseteq X$, respectively, and for every $x_j \in X$, $0 \le \mu_A(x_j)+\nu_A(x_j) \le 1$. We call

$$\pi_A(x_j)=1-\mu_A(x_j)-\nu_A(x_j).$$

the intuitionistic index of the element x_j in the set A. It is the degree of indeterminacy membership of the element $x_j \in X$ to the set A.

It is obvious that for every $x_j \in X$, $0 \le \pi_A(x_j) \le 1$.

Following the conceptions of IFS, [26] introduced the concepts and arithmetic operations of intuitionistic fuzzy numbers, shortly, IFNs. An IFN a is defined as an ordered pair (μ_a, ν_a) satisfying the following conditions:

$$\mu_a \in [0,1], \qquad \nu_a \in [0,1], \qquad \mu_a+\nu_a \le 1$$

IFNs have been widely applied in MADM problems, and the final ranking of the alternatives is determined by the ranking of corresponding IFNs [26].