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D-DEMATEL: A new method to identify critical success factors in emergency management

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ABSTRACT

Due to the variety and destructiveness of disasters, emergency management has emerged as a world theme and attracted more and more public attention. A large quantity of research on optimizing the emergency management has been done while still has improvement space. In this paper, a new method called D-DEMATEL which combines D number theory and decision-making trial and evaluation laboratory (DEMATEL) to identify the critical success factors (CSFs) in emergency management is proposed. Firstly, multiple experts evaluate the direct relations of influential factors in emergency management respectively from positive and negative side. The evaluation results are presented as intuitionistic fuzzy numbers (IFNs). Secondly, convert the IFNs into D numbers and use the combination rule of D numbers to fuse group opinions. Thirdly, based on DEMATEL, the cause-effect classification of factors can be obtained. Finally, the factors in cause category are identified as CSFs in emergency management. Based on the proposed method, the optimization of emergency management can be efficiently simplified into optimizing the identified CSFs. The proposed method is well addressed the fuzziness and subjectivity in linguistic assessment. Hence, the proposed method is well applicable to identify the CSFs in emergency management which inherently has a linguistic assessment process.

1. Introduction

Emergency management has emerged as a world theme and attracted more and more public attention for the variety and destructiveness of disasters, such as the earthquake and nuclear leak event of Fukushima, Japan in 2011, and the outbreak of Ebola virus in West Africa in 2014.

Emergency management is the discipline of applying science, technology, planning and management to deal with extreme events that can produce extensive damage (Drabek and Hoetmer, 1991). Hitherto, there is a wide-spread concern over the issue of the optimization of emergency management and a large quantity of research has been done. For example, Sheu (2007) pointed out the efficient logistics play a vital role in relieving the impact of disasters and designed a hybrid fuzzy clustering method to optimize the operation of emergency management. Huang et al. (2016) developed the Internet of intelligences to drive a risk radar monitoring dynamic risks for emergency management in community. Zappini et al. (2015) analyzed the use of evolutionary metaheuristic for the management of emergency rescue operations applied to real-word scenarios. Nevertheless, vast majority of the existing studies have the following limitations:

(1) The relations among influential factors in emergency management are without consideration.
(2) The concern is confined on a narrow set of fields or activities.

As for (1), discarding the relations among factors is unreasonable. One factor may be optimized with the optimization of the other factors. To enhance the efficiency of emergency management optimization, only factors with strong relationships need to be taken into consideration.

DEMATEL is an effective method which collects group knowledge, analyzes the inter-relationships among system factors, and visualizes this structure by cause-effect relationship diagram (Gabus and Fontela, 1972; Fontela and Gabus, 1976). DEMATEL has been widely applied in various areas (Baykasoğlu et al., 2013;

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Tsai and Chou, 2009; Shieh and Wu, 2016; Tzeng et al., 2007) and can be further extended by other theories and methods such as fuzzy numbers (Wu and Lee, 2007; Jassbi et al., 2011; Patil and Kant, 2014), grey theory (Bai and Sarkis, 2013; Xia et al., 2015; Su et al., 2015a) and AHP/ANP (Wu, 2008; Chou et al., 2012; Sara et al., 2015).

As for (2), emergency management refers to a series of necessarily coping mechanisms, including precautions, responses and rehabilitations, and covers many fields such as natural disasters (Yates and Paquette, 2011), medicine (Haghighi et al., 2013) and nuclear (Xie et al., 2016). To promote the welfare of the system as a whole, emergency management should be optimized from a higher viewpoint.

Furthermore, it is difficult to optimize the emergency management in all aspects. There is no need to analyze every single influential factor for the relationships among factors as well. A more efficient way is focusing on the most urgent and important factors. These factors that have the greatest influence on system are named critical success factors (CSFs). CSF has a wide application especially in commerce (Disterheft et al., 2015; Trkman, 2010), but it is rarely applied in emergency management. In this paper, CSF is introduced in the study which develops a more feasible and efficient approach to optimize the emergency management in a stepwise mode.

In the vast majority of prior studies, CSFs are identified by expert evaluation or linguistic assessment. However, two crucial problems have to be considered in this process.

(1) The subjectivity in expert evaluation.
(2) The fuzziness in linguistic assessment.

Taking into account above issues, Zhou et al. used fuzzy DEMATEL which has ability to address the fuzziness in linguistic assessment to optimize the emergency management (Zhou et al., 2011). Based on evidence theory and DEMATEL, Li et al. proposed evidential DEMATEL which reduces the subjectivity of expert evaluations through fusing multiple expert opinions (Li et al., 2014). Both of fuzzy DEMATEL and evidential DEMATEL are effective to optimize emergency management. Nevertheless, fuzzy DEMATEL considers the fuzziness in linguistic assessment while it cannot combine the judgments of multiple experts to raise the objectivity of evaluation results. Evidential DEMATEL reduces the subjectivity of expert evaluations through fusing expert judgments without considering the fuzziness in linguistic assessment. In other words, evidence theory has the hypothesis that each element in frame of discernment must be mutually exclusive. In linguistic assessment, the linguistic scale such as "Bad", "Fair" and "Good" cannot totally satisfy this requirement.

In order to unite the advantages of fuzzy DEMATEL and evidential DEMATEL, D number theory is introduced in this paper (Deng, 2012). As an extension of evidence theory, D number theory which gives the framework with nonexclusive hypotheses is more applicable in linguistic assessment than evidence theory (Deng et al., 2014a; Fan et al., 2016; Liu et al., 2014; Deng et al., 2015a, 2014b). Combining D number theory with DEMATEL, both issues will be well addressed.

In this paper, a new method called D-DEMATEL which combines D number theory and DEMATEL to identify the CSFs in emergency management is proposed. The procedure can be divided into three steps.

Firstly, multiple experts evaluate the direct relations of influential factors in emergency management respectively from positive and negative side. The evaluation results are presented as IFNs. Secondly, convert the IFNs into D numbers and use the combination rule of D numbers to fuse group opinions. Thirdly, based on DEMATEL, the cause-effect classification of factors can be obtained. Finally, the factors in cause category are identified as CSFs in emergency management.

Based on the proposed method, the optimization of emergency management can be efficiently simplified into optimizing the identified CSFs. The proposed method is well addressed the fuzziness and subjectivity in linguistic assessment. Hence, the proposed method is well applicable to identify the CSFs in emergency management which inherently has a linguistic assessment process. Besides, since the emergency management covers many fields and refers to a series of necessarily coping mechanisms, including precautions, responses and rehabilitations, the proposed method has ability to promote the overall welfare of the system from a higher viewpoint.

The rest of paper is organized as follows. Section 2 introduces the preliminaries of this work. Section 3 presents the procedure of CSFs identification in emergency management based on D-DEMATEL, and an illustration is given in Section 4. Section 5 discusses the rationality and superiority of the proposed method. Section 6 ends the paper with the conclusion.

2. Preliminaries

2.1. Dempster-Shafer evidence theory

Dempster-Shafer evidence theory (Dempster, 1967; Shafer et al., 1976) which is also known as evidence theory, is used to handle uncertain information. It has the advantage of directly expressing the "uncertainty" by assigning the probability to the subsets of the set composed of multiple objects, rather than to each of the individual objects. Besides, it has the ability to combine pairs of bodies of evidence or belief functions to derive a new piece of evidence or belief function. It should be pointed out that evidence theory has some open issues, such as conflicting management (Deng, 2015a; Yu et al., 2015; Jiang et al., in press; Deng et al., 2015b; Yang and Han, 2016), generating basic probability assignment (Jiang et al., 2016c; Xu et al., 2014; Jiang et al., 2015a) and dependence evidence combination (Yager, 2009; Su et al., 2016). However, with the superiority in uncertain environment and the practicability in engineering (Zavadskas et al., 2016, 2015), evidence theory has been widely applied in various fields such as fault diagnosis (Jiang et al., 2016a), risk assessment (Deng et al., 2015c,b), failure mode and effects analysis (Jiang et al., 2016b; Liu et al., 2015), pattern recognition (Liu et al., 2016), gender profiling (Ma et al., 2016) and human reliability analysis (Su et al., 2015b). For completeness of the explanation, some basic concepts are introduced as below.

Let U denote the frame of discernment, a set of collectively exhaustive and mutually exclusive events. Then suppose 2^U is the power set of a frame of discernment U, each element of 2^U is a proposition. Based on the two conceptions, basic probability assignment (BPA) and the combination rule of BPAs are defined as follows.

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

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

satisfying

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

where $\varnothing$ is an empty set. If $m(A) > 0$, A is called a focal element.

Definition 2 (*Dempster's rule of combination*). Suppose two BPAs m_1 and m_2 are two pieces of evidence from different and independent sources. Dempster's rule of combination, denoted by $m = m_1 \oplus m_2$, is defined as follows.