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Evaluating emergency response capacity by fuzzy AHP and 2-tuple fuzzy linguistic approach

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ABSTRACT

Emergency management (EM) is a very important issue with various kinds of emergency events frequently taking place. One of the most important components of EM is to evaluate the emergency response capacity (ERC) of emergency department or emergency alternative. Because of time pressure, lack of experience and data, experts often evaluate the importance and the ratings of qualitative criteria in the form of linguistic variable. This paper presents a hybrid fuzzy method consisting fuzzy AHP and 2-tuple fuzzy linguistic approach to evaluate emergency response capacity. This study has been done in three stages. In the first stage we present a hierarchy of the evaluation index system for emergency response capacity. In the second stage we use fuzzy AHP to analyze the structure of the emergency response capacity evaluation problem. Using linguistic variables, pairwise comparisons for the evaluation criteria and sub-criteria are made to determine the weights of the criteria and sub-criteria. In the third stage, the ratings of sub-criteria are assessed in linguistic values represented by triangular fuzzy numbers to express the qualitative evaluation of experts' subjective opinions, and the linguistic values are transformed into 2-tuples. Use the 2-tuple linguistic weighted average operator (LWAO) to compute the aggregated ratings of criteria and the overall emergency response capacity (OERC) of the emergency alternative. Finally, we demonstrate the validity and feasibility of the proposed hybrid fuzzy approach by means of comparing the emergency response capacity of three emergency alternatives.

1. Introduction

In recent years, various kinds of emergency events frequently take place, such as disastrous events and calamities, including earthquakes, volcanoes, floods, hurricanes, chemical spills, nuclear radiation escapes, epidemics, crashes, explosions, urban fires, etc. These disasters have not only caused tremendous suffering to people's lives and property, but also affected the stability of society, and such disasters may occur around the world at any time (Oloruntoba, 2010). Consequently, modern societies have established public emergency services such as ambulances, fire brigades, police forces, civil defense and other organizations to attempt to manage various disasters and their impacts on life and property (Liu, 2004). According to Drahek and Hoetmer (1991), emergency management is the discipline and profession of applying science, technology, planning and management to deal with extreme events that can produce extensive damage. Emergency management is often conceptualized as a complex multi-objective optimization problem concerning how to solve the emergency situation with limited resources (Zhou, Huang, & Zhang, 2011). Many efforts have been made to reinforce emergency management in academia recently. Dave and Scott (2011) presented a case study based on the action research of how social media technologies were used, what influences they made on knowledge sharing, reuse, and decision-making, and how knowledge was effectively maintained in knowledge management systems (KMS). Yuan and Wang (2009) presented two mathematical models for path selection in emergency logistics management by considering more actual factors in time of disaster. The objective of the model is to minimize total travel time along a path. A modified Dijkstra algorithm and an ant colony optimization algorithm are proposed to solve the models. Sheu (2007) pointed out efficient logistics play an important role in relieving the impact of disasters, and he designed a hybrid fuzzy clustering method to optimize the operation of emergency management. Josefa and Juan (2001) proposed the use of advanced knowledge models to support environmental emergency management as an adequate response to the current needs and technology. Manali, Ajay, Salil, and Cory (2005) proposed multiple average-multiple threshold (MAMT) active queue management (AQM) as a solution for providing available and dependable service to traffic from emergency users after disasters. Zhou et al. (2011) used a fuzzy decision-making trial and evaluation laboratory (DEMATEL) method to identify critical success factors in emergency

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management. Sheu (2010) presented a dynamic relief-demand management model for emergency logistics operations under imperfect information conditions in large-scale natural disasters.

Emergency response capability evaluation (ERCE) is one of the major activities in emergency management. Emergency response capability (ERC) is a comprehensive capability to deal with disasters such as natural disasters, sudden public health incidents, sudden public safety incidents, military conflicts and so on. There are two main modes of the evaluation of ERC: the first one is to deal with the emergency incidents timely; and the second one is to reduce the total costs of emergency rescue and restoration. The problem of ERCE is essentially multi-criteria decision making (MCDM) problem in the presence of many criteria and sub-criteria. A decision maker needs to make use one of the MCDM methods. Some of the widely used MCDM methods include analytic hierarchy process (AHP), analytic network process (ANP), simple multi-attribute rating technique (SMART) (Chou & Chang, 2008), and grey relational analysis (GRA). There have been many literatures about ERC, most of which focus on the analysis of affect factors and the selection of assessment methods. Zeng, Wu, Wei, and Gao (2009) established the emergency management model of chemical industry park and putted forward the countermeasures of emergency management for chemical industry park. Zhang (2010) established the evaluation index system of emergency capability on the basis of different emergency management phase. He and Cui (2010) established assessment system about subway disaster emergency response capacity on the basis of characteristics of subway disaster emergency. Tian and Yang (2008) used expert estimation to select the main indicators with the objective reality as the target set and then constructed emergency response capacity evaluation model by AHP. Chen, Tong, and Sun (2010) established a network hierarchy model for the evaluation of community emergency capability and calculated the weights of indexes by ANP. Liu and Xie (2008) used the fragmentary AHP and indeterminate AHP to assess the cities' ability of reducing earthquake disaster.

It is clear that the existing literatures mostly deal with a specific activity in the emergency response process. Researchers care more about evaluation index, and used crisp numbers to evaluate the emergency response capacity. However, in many practical cases, especially evaluating emergency response capacity, it is difficult for experts to express their preferences by using crisp values. The experts might be unable to assign crisp values to the comparison judgments. A more feasible method is to adopt fuzzy method to represent experts' subjective judgments. This paper presents a hybrid fuzzy method consisting of fuzzy AHP and 2-tuple fuzzy linguistic approach to evaluate emergency response capacity. The proposed approach can deal with decision makers' ambiguities, uncertainties and vagueness in the course of evaluating emergency response capacity, and it allows the experts to incorporate unquantifiable information, incomplete information, unobtainable information and partially ignorant facts into decision alternatives. The research methodology applied in this study is shown in Fig. 1. As shown, this study begins with the literature review on emergency response capacity evaluation and applications of fuzzy AHP and 2-tuple fuzzy linguistic approach. Evaluation index system for emergency response capacity evaluation has been designed. After designing the evaluation index system, a suitable expert team for conducting case study has been selected, and then, the necessary data have been gathered for conducting the case study. Then, Apply fuzzy AHP to determine the weights of criteria and the global weights of sub-criteria respectively and use 2-tuple fuzzy linguistic computing approach to assess the ratings of sub-criteria. What it follows, compute the overall emergency response capacity based on the global weights and the ratings of sub-criteria, and compare the overall emergency response capacities and select the best emergency alternative. Finally, the results have been practically validated in the emergency department to explore its feasibility.

The remainder of the paper is organized as follows. In Section 2, we present an evaluation index system for ERC. In Section 3, we introduce the procedures of Chang's extent analysis method, 2-Tuple linguistic representation model, transformation between crisp value and 2-tuple linguistic variables, and operation laws of 2-tuple linguistic variables. In Section 4, we present the procedures of the proposed hybrid fuzzy method based on fuzzy AHP and

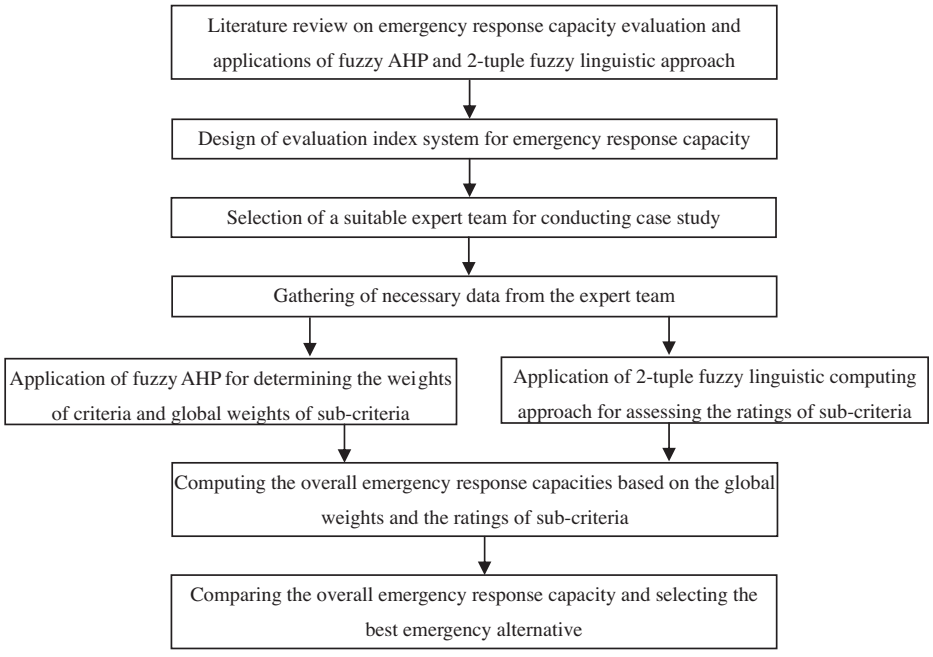

Fig. 1. Research methodology.