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A conflict-eliminating approach for emergency group decision of unconventional incidents

Yejun Xu, Wancheng Zhang, Huimin Wang *

State Key Laboratory of Hydrology-Water Resources and Hydraulic Engineering, Hohai University, Nanjing 210098, PR China
Business School, Hohai University, Jiangning, Nanjing, Jiangsu 211100, PR China

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ABSTRACT

In multiple attribute group decision making (MAGDM) problems, the conflict-elimination process is a vital procedure to get an agreement with low degree of conflict for emergency decision of unconventional incidents. In this paper, we put forward a discrete model to support the conflict-elimination process. Firstly, based on the contribution of each expert to the group opinion, a weight-updating model is constructed to adjust the experts' weights. In preference-modifying process, an iterative algorithm is proposed to adjust the individual preferences which have the maximum deviation from the corresponding group one to retain the original opinion of experts as much as possible. Then, the choice of the best alternative(s) from the group decision is obtained by the simple additive weighting (SAW) method. Finally, an illustrate example and comparative analysis with the existing methods are given to verify the effectiveness of the proposed model.

1. Introduction

Unconventional emergency incidents, such as earthquakes and hurricanes, often lead to unexpected catastrophic consequences [43]. Because of complexity, abruptness and high destructiveness of these kinds of incidents, the emergency management of unconventional incidents should be paid more attention. It has been demonstrated that when emergency operations are conducted in accordance with existing plans, reaction time is reduced and coordination is improved, with fewer casualties and reduced economic damage as results [28]. Whenever such disasters occur, emergency management plays an important role in reduction of their influences. Usually, an emergency decision has the following two features [55]. First, as information in emergencies is often limited in terms of quantity and quality [9], an emergency decision must be made in a short period of time under the situation in which the information is insufficient, uncertainty and inaccuracy. Second, these decisions may have potentially serious risks. In many situations, a wrong decision could result in deadly consequences [27]. In order to avoid this kind of risks, group decision making (GDM) [10,18,23] is introduced to handle emergency decision problems.

GMD is one of the main measures for modern decision science [52]. It will improve the effectiveness and transparency of emergency management through integrating multiple decision-makers' wisdom into group wisdom, it has been widely applied in the fields of management science, operational research, and industrial engineering [4,6,20]. Nevertheless, some unique elements also cause some disadvantages of emergency decisions which utilize the MAGDM compared to the normal ones, such as the diversity of the source of experts and the large differences between each expert's features like background of specialty, structure of knowledge. Because of the inherent complexity and uncertainty of multi-attributes emergency decision making, experts' opinions are diverse, and therefore, the conflict exists among different experts.

Fortunately, some methodologies have been developed to assist in understanding, modeling and analysis the conflict [15]. These methodologies, which include game theory [29], metagame analysis [22], conflict analysis [16], drama theory [21], and the graph model for conflict resolution [15,25], share many characteristics in which they provide a method to represent and analyze conflict situations with at least two decision makers (DMs), each of whom has multiple options and multiple objectives, which imply distinctive preferences over the outcomes [24]. Extent to the problem we are faced with today, some necessary improvements should be

* Corresponding author at: Business School, Hohai University, Jiangning, Nanjing, Jiangsu 211100, PR China. Tel.: +86 25 68514611.

E-mail addresses: xuyejohn@163.com (Y. Xu), 799474163@qq.com, hmwang@hhu.edu.cn (H. Wang).

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made to handle the conflict of group decision. Xu et al. [39] developed a matrix representation for conducting status quo analysis in the graph model for conflict resolution. Based on the traditional status quo analysis, they introduced a matrix representation because of its convenient computer implementation and easy expansion to new analysis techniques. As a result, these analysis methods will have the potential to deal with large and complicated conflict problem. Besides the methodologies, some new techniques have also been utilized to handle conflict problems in different fields. Zhang et al. [56] proposed a conflict resolution framework based on GIS system to solve the conflict of land use planning. Through the development of the methodologies and techniques of conflict analysis, we can realize its significance in decision making, especially in the emergency decision.

Nowadays, some consensus models have been developed to solving conflicts between experts in GDM. The well-known conflict-eliminating models are the ones using multiplicative preference relations [11,33], fuzzy preference relations [8,19,26], and linguistic preference relations [2]. Levy and Taji [27] utilized a group analytic network process (GANP) to construct a GDSS to support hazard planning and emergency management under incomplete information. Zografos et al. [57] presented a methodological framework for developing a hazardous material emergency response (HAMER) decision support system (DSS) to manage emergency response operations for large-scale industrial accidents. Ben-Arieh and Chen [2] presented a conflict-eliminating measure that uses a measure of the contribution of the group members. They also provided a method to modify the weight of the experts based on their support of the group opinion, which allows the experts to maintain their opinions and not to compromise in order to arrive at a desired consensus level. Yu and Lai [55] proposed a new distance-based multi-criteria GDM methodology which is proposed to support unconventional emergency decisions, by providing a rational solution to the two unresolved key issues. Fu and Yang [17] extended the traditional evidential reasoning (ER) approach to group consensus (GC) situations for multiple attribute group decision analysis problems. They proposed a group consensus based evidential reasoning approach for multiple attributive group decision analysis problems. Herrera-Viedma et al. [19] presented a conflict-eliminating model for incomplete fuzzy preference relations. They developed a feedback mechanism to generate advice on how experts should change or complete their preferences in order to reach a solution with high consensus and consistency degrees. Wu and Xu [38] developed a consistency and consensus based decision model for GDM based on reciprocal preference relations. Parreiras et al. [31] developed a flexible conflict-eliminating model for multi-criteria GDM under linguistic assessment. An optimization procedure that searches the weight of expert's opinion which can maximize the soft consensus index was utilized to obtain an optimal adjustment. Xu et al. [45] put forward a distance-based consensus model to deal with fuzzy preference relations and multiplicative preference relations.

Some models are also designed for decision making with incomplete weight information. Xu and Zhang [51] proposed an optimal method for hesitant fuzzy preference relation with incomplete weight information. They have first utilized the maximizing deviation method to determine the optimal relative weights of attributes under hesitant fuzzy environment. Then they proposed a novel approach on the basis of TOPSIS to solve the multi-attribute decision making problem which can avoid the loss of too much information in the process of information aggregation. Wei [36] proposed a maximizing deviation model for the situations that the weight vector of attributes is partly unknown and completely unknown. Based on the maximizing deviation theory that if one attribute has similar attribute values across alternatives, it should be assigned a small weight; On the contrary, the attribute which makes larger deviations should be assigned a bigger weight. Then, he constructed a linear programming model to determine the weight vector which meets the above requirement. Chen and Yang [7] proposed a method for determining the DMs' weights with respect to each evaluation value under intuitionistic fuzzy environment. In that method, the weights of the DMs are derived from decision matrices, and the DM whose evaluation value is close to the average evaluation value has a big weight, while the DM whose evaluation value is far from the average evaluation value would have a small weight.

However, for existing conflict-eliminating models for decreasing conflict indices, it is often the case that the final improved preference relations significantly differ from the DMs' original judgment information, which is only from the mathematical convergence point of view. If DMs' opinions are significantly distorted, the final solution may be questionable. In order to obtain a reliable solution, in this paper, we propose a model to retain the DMs' opinions as much as possible. Furthermore, a weight-updating model is also proposed to adjust the weights of experts. The weight reflects the expert's contribution to the group opinion. By changing the weights of the experts based on their contributions, we decrease the conflict degree of experts and reinforce the group decision.

To overcome the drawbacks of the existing models, in this paper, we propose a conflict-eliminating model for unconventional incidents. The model has two basic features: (1) The model retains the original preference values of experts as much as possible. (2) Considering the time shortage and the serious consequences the unconventional incidents could cause, the model is designed to be simple under the condition of realizing its function. In this case, the conflict eliminating process of the model will be time-saving and easy to be realized.

The remainder of this paper is organized as follow. Section 2 presents some basic concepts and definitions of MAGDM problems. In Section 3, we introduce the basic theory of weight-updating model based on individual contribution. Section 4 shows the conflict-eliminating model for MAGDM problem. In Section 5, an example is given to examine how the model works in practice. Finally, some conclusions are drawn in Section 6.

2. Basic concepts and definitions

In this section, some basic concepts and definitions of multi-criteria GDM problem are presented.

For simplicity, let $M = \{1, 2, \ldots, m\}$, $N = \{1, 2, \ldots, n\}$ and $T = \{1, 2, \ldots, t\}$. Let $X = \{x_1, x_2, \ldots, x_n\}\,(n \geqslant 2)$ be a finite set of n potential alternatives, $F = \{f_1, f_2, \ldots, f_m\}\,(m \geqslant 2)$ be a finite set of m attributes, and $w = (w_1, w_2, \ldots, w_m)^T$ is the weight vector of attributes, where $\sum_{j=1}^{m} w_j = 1$, $w_j \in [0, 1]$, $j \in M$ and w_j denotes the weight of attribute f_j. Let $E = \{e_1, e_2, \ldots, e_t\}$ $(t \geqslant 2)$ be a set of experts and $\lambda = (\lambda_1, \lambda_2, \ldots, \lambda_t)^T$ be the weight vector of experts, where $\sum_{k=1}^{t} \lambda_k = 1$, $\lambda_k \in [0, 1]$, $k \in T$. Suppose $A_k = (a_{ij,k})_{n\times m}$ is the numeric decision matrix given by the expert $e_k \in E$, where $a_{ij,k}$ represents the preference of the alternative x_i with respect to the attribute f_j.

In multiple attribute decision making problems, as different attributes are often incommensurable, the attribute values must be normalized. Generally, there are benefit attributes and cost attributes. Suppose $R_k = (r_{ij,k})_{n\times m}$ is the corresponding normalized decision matrix, where

$$r_{ij,k} = \frac{\max_i(a_{ij,k}) - a_{ij,k}}{\max_i(a_{ij,k}) - \min_i(a_{ij,k})}, \quad i \in N, \quad j \in M, \quad k \in T \qquad (1)$$