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A method of determining attribute weights in evidential reasoning approach based on incompatibility among attributes ☆

Kwai-Sang Chin [a,b,*], Chao Fu [c,d], Yingming Wang [b]

[a] Department of Systems Engineering and Engineering Management, City University of Hong Kong, 83 Tat Chee Avenu, Kowloon Tong, Hong Kong
[b] School of Management, Wuhan University of Technology, Wuhan, PR China
[c] School of Management, Hefei University of Technology, Hefei, Box 270, Hefei 230009, PR China
[d] Key Laboratory pf Process Optimization and Intelligent Decision-making, Ministry of Education, Hefei, Box 270, Hefei 230009, PR China

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ABSTRACT

Decisions on attribute weights are important problems in multiple attribute decision making. Many methods have been proposed to create attribute weights which are used to aggregate attributes in a simple additive weighting way. In this paper, a method of deriving attribute weights from incompatibility among attributes and possible constraints on the weights is developed based on the evidential reasoning approach in which attribute aggregation is nonlinear rather than linear. The incompatibility is a flexible combination of deviation incompatibility and decision incompatibility with a relaxation coefficient. The deviation incompatibility measures differences between assessments of alternatives on each attribute and the decision incompatibility quantifies differences between assessments of alternatives on one attribute and the aggregated assessments of the alternatives. For a specific alternative, two pairs of optimization problems with a constraint on the difference between potential weights and the combination of deviation incompatibility and decision incompatibility are designed to generate the favorable intervals of attribute weights and those of utilities of assessment grades. A problem of car performance assessment is investigated to demonstrate the applicability of the proposed method. The method is validated by comparison with other methods of producing attribute weights using the problem.

1. Introduction

Multiple attribute decision making (MADM) is usually used to analyze a set of alternatives and choose the best alternative from them depending on multiple attributes (also called criteria). In MADM, attribute weights significantly influence the process of decision making. Accordingly, the determination of attribute weights is a key step in MADM.

In literature, many approaches have been proposed to determine attribute weights. These approaches can be primarily divided into three categories, namely, subjective, objective, and hybrid methods (Wang & Luo, 2010). Subjective methods depend on the subjective preference of a decision maker to generate attribute weights. Representative elicitation methods include point allocation (Doyle, Green, & Bottomley, 1997; Roberts & Goodwin, 2002), direct rating (Bottomley & Doyle, 2001; Roberts & Goodwin, 2002), eigenvector method (Saaty, 1977; Takeda, Cogger, & Yu, 1987), Delphi method (Hwang & Lin, 1987; Hwang & Yoon, 1981), linear programming of preference comparisons (Horsky & Rao, 1984), linear programming model (Horowitz & Zappe, 1995), mathematical programming model based on pairwise comparisons of alternatives (Deng, Xu, & Yang, 2004), goal programming model based on pairwise comparison ratings (Shirland, Jesse, Thompson, & Iacovou, 2003), and others (Figueira & Roy, 2002; Pekelman & Sen, 1974; Wang, 2005; Zhang, Chen, & Chong, 2004). In objective methods, attribute weights are derived from an objective decision matrix. Typical methods include entropy method (Chen & Li, 2010,Chen & Li, 2011; Deng, Yeh, & Willis, 2000; Hwang & Yoon, 1981; Xu, 2004), multiple objective programming model (Choo & Wedley, 1985), standard deviation (SD) method (Deng et al., 2000), correlation coefficient and standard deviation integrated (CCSD) method (Wang & Luo, 2010), criteria importance through intercriteria correlation (CRITIC) method (Diakoulaki, Mavrotas, & Papayannakis, 1995), and deviation maximization method (Wang, 1998). Hybrid methods synthetically employ the subjective preference of a decision maker and an objective decision matrix to produce attribute weights. In this perspective, Ma, Fan, and Huang (1999) designed

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* Corresponding author at: Department of Systems Engineering and Engineering Management, City University of Hong Kong, 83 Tat Chee Avenu, Kowloon Tong, Hong Kong. Tel.: +852 34428306; fax: +852 34428306.

E-mail address: mekschin@cityu.edu.hk (K.-S. Chin).

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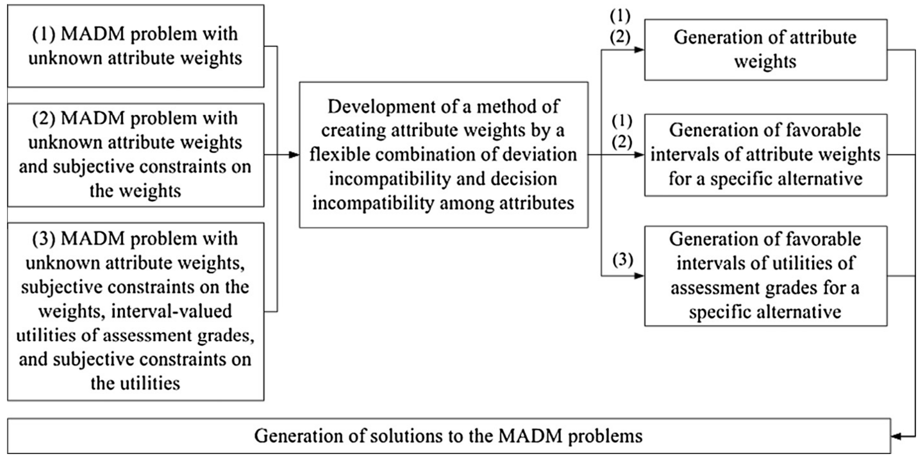

Fig. 1. Contributions of this paper.

a two-objective mathematical programming model to integrate the subjective consideration of the decision maker and objective information. Fan, Ma, and Zhang (2002) integrated the fuzzy preference of the decision maker on alternatives and an objective matrix into one model. Wang and Parkan (2006) integrated fuzzy preference relations of the decision maker on alternatives, multiplicative preference relations of the decision maker on attribute weights, and an objective matrix into a general framework.

Most studies focus on subjective methods. However, these methods are not always available because a decision maker may find it difficult or even impossible to give preference about attribute weights due to lack of information, knowledge, and data. For example, a decision maker from the development and reform commission of local government in a city of China intends to select five industries from twelve candidates as leading industries to preferentially develop. The twelve industries are evaluated using seven attributes, comprising expandability, pioneer, adaptability, competitiveness, environmental protection, difficulty, and risk. The choice of leading industries has an important effect on local economic structure and development. As such, judgments of the decision maker on attribute weights are very important for local development. However, the decision maker lacks sufficient knowledge to decide which attribute is more crucial than others in selecting leading industries and there is no information available for assigning attribute weights using subjective methods. Thus, the decision maker thinks it difficult or even impossible to elicit attribute weights by some subjective methods. More critically, even the judgments on attribute weights can be provided by the decision maker, different attribute weights may be generated when different subjective methods are employed. There is no single method that can guarantee a more accurate set of attribute weights than others (Deng et al., 2000; Diakoulaki et al., 1995). Meanwhile, the decision maker is also unsure about which principle is the best to create the most appropriate attribute weights.

Under the above conditions, objective methods are particularly useful. When partial or incomplete constraints on attribute weights are available, hybrid methods are also helpful. Existing objective and hybrid methods usually aggregate assessments on each attribute in a simple additive weighting (SAW) way (e.g., Fan et al., 2002; Ma et al., 1999; Wang & Luo, 2010; Wang & Parkan, 2006). The SAW way is easy to be applied, but it is not feasible in some contexts, for example, in evidential reasoning (ER) context. Furthermore, many objective methods depend only on the differences between assessments of alternatives on any attribute to determine attribute weights, such as the SD (Deng et al., 2000), deviation maximization (Wang, 1998), entropy (Deng et al., 2000), and CRITIC (Diakoulaki et al., 1995) methods. Differently, the CCSD method (Wang & Luo, 2010) employs a combination of the above differences and the differences between the assessments of alternatives on any attribute and the aggregated assessments of the alternatives to create attribute weights. The method seems more flexible and applicable than the former four methods. However, it still lacks flexibility in a balance between the two types of differences, which are called deviation incompatibility and decision incompatibility in this paper for simplicity.

To handle the situation where subjective methods of producing attribute weights are unavailable and overcome the deficiencies of existing objective methods presented above, this paper proposes a method of determining attribute weights based on the ER approach (Chin, Wang, Poon, & Yang, 2009; Fu, Huhns, & Yang, 2014; Fu & Yang, 2010; Fu & Yang, 2011; Fu & Yang, 2012; Guo, Yang, Chin, & Wang, 2007; Wang, Yang, & Xu, 2006; Yang, 2001; Yang, Wang, Xu, & Chin, 2006). The approach was intended for modeling and analyzing uncertain MADM problems. A nonlinear analytical algorithm (Wang, Yang, & Xu, 2006) was applied in the approach to combine assessments of alternatives on each attribute, different from the existing objective and hybrid methods. A mixture of deviation incompatibility and decision incompatibility is employed in the proposed method to generate attribute weights. Unlike the CCSD method, a relaxation coefficient (see Section 3.1) is used to balance deviation incompatibility and decision incompatibility, by which their combination becomes more flexible and applicable. An attribute with a larger mixture of the two types of incompatibility should be assigned a larger weight. Following this idea, an optimization model is constructed to create attribute weights. Subjective constraints on attribute weights derived from a decision maker can be incorporated into the model to affect the resulting attribute weights.

Given a specific alternative, a pair of nonlinear optimization problems with a constraint on the difference between attribute weights and the mixture of deviation incompatibility and decision incompatibility is designed to determine the favorable intervals of attribute weights. In a similar way, another pair of nonlinear optimization problems is constructed to generate the favorable intervals of utilities of assessment grades (the concept of the utilities can be seen in Section 2). Subjective constraints on utilities of assessment grades can also be handled by the developed pairs of optimization problems.

The main contributions of this paper include the following: (1) the development of a method of deriving attribute weights from an elastic combination of deviation incompatibility and decision incompatibility, possible constraints on attribute weights,