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A mathematical programming-based method for heterogeneous multicriteria group decision analysis with aspirations and incomplete preference information

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ABSTRACT

Aspirations, which serve as a performance target and simplify cognitive processes associated with decision making, are an important decision factor for individuals and organizations. However, this factor is usually ignored in traditional multicriteria decision making. This paper considers a multicriteria group decision making problem with aspirations and incomplete preference information, in which criteria values and aspirations accept multiple formats. To solve this problem, new consistency and inconsistency indices considering importance and interaction as well as aspirations of criteria are defined. Then, we propose a bi-objective intuitionistic fuzzy programming model to identify importance and interaction parameters, based on which, an individual ranking of alternatives can be elicited. Next, to elicit a group ranking of individuals, a flexible mix 0–1 nonlinear programming model of minimizing the inconsistencies between the group final ranking and the individual ranking is established by comprehensively considering both the majority and the minority principles. Finally, an example of selecting the best strategic freight forwarder is used to illustrate the feasibility of the proposed method, followed by a sensitivity analysis and a comparison analysis. The prominent advantages of the developed method are its ability to handle multiple preference information characterizing bounded rationality and nonadditive behaviors of decision makers as well as improve a cardinal inputs-based group decision making model.

1. Introduction

Multicriteria decision making is a normal human activity which helps in making decisions mainly in terms of choosing, ranking or sorting alternatives (Figueira, Greco, & Ehrgott, 2005). Recent years have witnessed the fast development in the field of multicriteria decision making (MCDM) (Büyüközkan & Göçer, 2016; Govindan, Kannan, & Shankar, 2015; Mulliner, Malys, & Maliene, 2016; Tsui, Tzeng, & Wen, 2015) or multicriteria group decision making (MCGDM) (Chen, 2015; Chiao, 2016; Joshi & Kumar, 2016; Zhang, Ju, & Liu, 2016). Especially, MCDM/MCGDM with multiple formats of criteria values, which is referred to as heterogeneous MCDM/MCGDM, has more and more gained the attention of researchers (Angilella, Corrente, & Greco, 2015; Fan, Zhang, Chen, & Liu, 2013; Feng & Lai, 2014; Lourenzutti & Krohling, 2016; Wan & Dong, 2015; Wan & Li, 2013; Wan, Xu, & Dong, 2016; Xu, Wan, & Dong, 2016; Zhang, Xu, & Wang, 2015; Zhang, Zhu, Liu, & Chen, 2016) due to the increasing complexity of real-world problems.

In the framework of MCDM/MCDGDM, how to elicit the weights of criteria is an important issue that every decision analyst has to face. Considering the criteria weights are imprecise or uncertain, Corrente, Greco, Kadziński, and Słowiński (2013) suggested to elicit such parameters in an indirect way, in that directly asking decision makers (DMs) to provide precise values for the considered parameters requires more cognitive effort. Moreover, with less cognitive effort, the DMs can easily distinguish the exact relations between the given preference information and the final results. With this consideration, the existing heterogeneous MCGDM methods can be roughly classified into three categories in terms of the preference information structure provided by the DMs.

The first category considers both the incomplete preference relations (IPRs) over alternatives and the incomplete preference information on criteria. For a state-of-the-art review on IPRs, one can refer to Ureña, Chiclana, Morente-Molinera, and Herrera-Viedma (2015) for more details. In the spirit of LINear programming technique for Multidimensional Analysis of Preference (LINMAP) (Srinivasan & Shocker,

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1973), Wan and Li (2013) constructed an intuitionistic fuzzy (IF) programming model for solving heterogeneous MCDM, in which the IPRs over alternatives are represented by intuitionistic fuzzy numbers (IFNs) and the incomplete preference information on criteria is characterized by five basic linear inequalities (Park & Kim, 1997). Later, Li and Wan (2013) and Wan and Li (2014) extended the work of Wan and Li (2013) from two different ways. Specifically, Li and Wan (2013) developed a new programming model in which IPRs over alternatives are with trapezoidal fuzzy numbers. On the other hand, Wan and Li (2014) extended the work of Wan and Li (2013) for solving heterogeneous MCGDM. For situations where IPRs over alternatives are represented by interval-valued intuitionistic fuzzy numbers (IVIFNs), Wan and Li (2015) proposed an IVIF programming model for solving heterogeneous MCDM with a consideration of incomplete preference information on criteria, which was then generalized for solving heterogeneous MCGDM by Wan and Dong (2015). Recently, Zhang, Ju et al. (2016) developed a mathematical programming-based method for MCGDM by considering interactions among criteria and those among their ordered positions, in which the IPRs over alternatives are with IVIFNs. Taking into account the psychological behavior of the DMs, Zhang, Zhu et al. (2016) integrated regret theory and LINMAP to develop a heterogeneous MCGDM method. Different from the idea of LINMAP, Angilella et al. (2015) combined the Choquet integral with stochastic multiobjective acceptability analysis to solve MCDM considering incomplete preference information on criteria and that on alternatives.

The second category considers the incomplete preference information on criteria but ignores the preference relations over alternatives. For example, Zhang et al. (2015) proposed a deviation modeling method to solve heterogeneous MCGDM with incomplete preference information on criteria. Recently, Xu et al. (2016) and Wan et al. (2016) developed new methods to solve heterogeneous MCGDM problems by considering incomplete preference information on criteria.

The third category considers the aspirations of criteria. Aspirations serve as a key decision factor for individuals and organizations. Substantial research reveals that aspirations help to simplify the cognitive processes associated with managerial decision making (Mezias, Chen, & Murphy, 2002). In many situations, a DM's utility may not depend on the absolute level of a rating on each criterion, but rather on whether that level of a rating meets an aspiration (Tsetlin & Winkler, 2007). With this spirit, Fan et al. (2013) proposed a prospect theory-based method to solve heterogeneous MCDM considering aspirations of criteria. Feng and Lai (2014) developed an integrated MCGDM method with a consideration of DMs' aspirations, in which the criteria values and the aspirations are with heterogeneous formats.

To get a better view of the aforementioned methods, Table 1 shows the main characteristics of them.

The forgoing methods made great contributions to the development of MCDM/MCGDM, however, the methods mentioned in Table 1 have some limitations:

(1) Most of the existing MCDM/MCGDM methods (Angilella et al., 2015; Li & Wan, 2013; Wan & Dong, 2015; Wan & Li, 2013, 2014, 2015; Wan et al., 2016; Xu et al., 2016; Zhang, Ju et al., 2016; Zhang et al., 2015) are based on the assumption that the DMs are of perfect rationality, neglecting the influence of psychological (or bounded rationality) behavior of DMs in decision making.
(2) Most of the existing heterogeneous MCDM/MCGDM methods (Fan et al., 2013; Feng & Lai, 2014; Li & Wan, 2013; Wan & Dong, 2015; Wan & Li, 2013, 2014, 2015; Wan et al., 2016; Xu et al., 2016; Zhang, Zhu et al., 2016; Zhang et al., 2015) are based on the hypothesis of independent criteria, neglecting the interaction phenomena of criteria, thus the nonadditive behavior of DMs cannot be captured.
(3) Most of the existing decision making methods (Fan et al., 2013; Feng & Lai, 2014; Li & Wan, 2013; Wan & Dong, 2015; Wan & Li, 2013, 2014, 2015; Wan et al., 2016; Xu et al., 2016; Zhang, Zhu et al., 2016; Zhang et al., 2015) can only deal with one kind or two kinds of preference information, neglecting the facts that DMs may have additional preference information and different preference information structures provided by DMs may produce different results, which is illustrated in Section 7.4. Additionally, the existing cardinal inputs-based group decision making (GDM) method (Zhang et al., 2015) can sometimes produce indifferent solutions, which is demonstrated in Section 7.5.

The aim of this study is to develop a novel decision analysis method to address the stated limitations. Our contributions in this study can be summarized into the following three aspects:

(1) In order to elicit the individual ranking orders in the framework of heterogeneous MCGDM, we propose a bi-objective intuitionistic fuzzy programming model, based on which, the preference information provided by DMs, including the incomplete preference information on the importance of criteria and interaction between couples of criteria, the incomplete preference information (or IPRs) over alternatives as well as the aspirations with respect to (w.r.t.) criteria, is efficiently aggregated. In addition, some special cases of the proposed model are investigated.
(2) In order to elicit the opinion of the group, we design an ordinal inputs-based GDM model to aggregate the individual opinions derived from the preferences of DMs. It is worthy to mention that the proposed GDM method improves the existing one (Zhang et al., 2015), which is based on cardinal inputs.
(3) An example of selecting the best strategic freight forwarder is

Table 1
Some characteristics of the existing MCDM/MCGDM methods.

Methods proposed by	Type of criteria values	Preference information structures*	Relationship between criteria	Number of DMs (N)	Considering different weights of DMs
Zhang, Ju et al. (2016)	Homogeneous	Both $S1$ and $S2$	Correlative	$N > 1$	No
Wan and Li (2013)	Heterogeneous	Both $S1$ and $S2$	Independent	$N = 1$	No
Li and Wan (2013)	Heterogeneous	Both $S1$ and $S2$	Independent	$N = 1$	No
Wan and Li (2014)	Heterogeneous	Both $S1$ and $S2$	Independent	$N > 1$	Yes
Wan and Li (2015)	Heterogeneous	Both $S1$ and $S2$	Independent	$N = 1$	No
Wan and Dong (2015)	Heterogeneous	Both $S1$ and $S2$	Independent	$N > 1$	No
Zhang, Zhu et al. (2016)	Heterogeneous	Both $S1$ and $S2$	Independent	$N > 1$	No
Angilella et al. (2015)	Heterogeneous	Both $S1$ and $S2$	Correlative	$N = 1$	No
Zhang et al. (2015)	Heterogeneous	$S1$	Independent	$N > 1$	Yes
Xu et al. (2016)	Heterogeneous	$S1$	Independent	$N > 1$	No
Wan et al. (2016)	Heterogeneous	$S1$	Independent	$N > 1$	No
Fan et al. (2013)	Heterogeneous	$S3$	Independent	$N = 1$	No
Feng and Lai (2014)	Heterogeneous	$S3$	Independent	$N > 1$	Yes

* $S1$: Incomplete preference information on criteria; $S2$: Incomplete preference relations over alternatives; $S3$: Aspirations on criteria.

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