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A fuzzy linear programming method for group decision making with additive reciprocal fuzzy preference relations

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Abstract

The existing methods for solving the group decision making (GDM) problems with preference relations generally include four steps: (1) estimation of missing preferences, (2) consistency and consensus reaching, (3) aggregation and (4) exploitation, which make the GDM process complicated. Relatively, very few research results focus on exploring the methods which can simplify this process to improve the efficiency. In this paper, we develop a new fuzzy linear programming method (FLPM) to deal with the GDM problems with additive reciprocal fuzzy preference relations (FPRs). The FLPM can directly produce meaningful results without the four steps. An effect index is developed to measure the decision makers (DMs)' effects in the GDM problems. Based on the FLPM and the effect index, we propose a new method to determine the DMs' weights. A step by step procedure is further proposed to deal with the GDM problems with all the developed methods, and its performance is illustrated by examples.
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Keywords: Group decision making (GDM); Fuzzy preference relations (FPRs); Fuzzy linear programming method (FLPM); Effect index

1. Introduction

In recent decades, decision making theories, methods, and applications have received great attention in the fields of management science, operational research, and industrial engineering. In the real world, the high complexity of socioeconomic environments often makes it difficult for a single decision maker (DM) to consider all the important aspects of a decision making problem. Therefore, the problems often take place in group settings [1–3] as group decision making problems which aim to find the best objective from a set of feasible ones.

Based on a common interest in reaching eventual agreement on selecting the best objective, the DMs provide their preferences over paired comparisons of the objectives to construct preference relations [4,5]. The commonly used valued preference relations are multiplicative preference relations [6] and fuzzy preference relations (FPRs) [7,8]. Taking the DMs' characteristics with regard to knowledge, skills, experience and personality into account, they can choose their favorable preference relations to represent preferences. Particularly, FPRs can be considered as a basic

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format to integrate multiplicative preference relations (see [9,10]). Therefore, we explore the GDM problems with FPRs in this paper.

In practice, due to some influences in the problem domain, such as time pressure, lack of knowledge and limited expertise, some preference(s) may be lost or unknown. In such a case, we can only get the incomplete FPRs rather than the complete FPRs. For the most existing GDM methods with the incomplete FPRs, it is necessary to estimate the missing preference(s). For example, to get the complete FPRs, Alonso, Chiclana, Herrera, Herrera-Viedma, Alcalá-Fdez and Porcel [11] put forward a learning procedure; Fedrizzi and Giove [12] developed a consistency optimization method; Lee, Chou, Fang, Tseng and Yeh [13] proposed an iterative procedure; Liu, Pan, Xu and Yu [14] developed a least square completion method.

Continued with the complete FPRs, there require two steps to obtain the best objective [15,16]: (1) consistency and consensus reaching, and (2) selection. Consistency is associated with the transitivity property. Consistency reaching is to ensure that one DM is being neither random nor illogical in his/her preferences [17,18]. Consensus is meant as a full and unanimous agreement between the DMs. Consensus reaching refers to how to obtain the maximum degree of consensus, or how to control the consensus degree within a reasonable range [19–22]. For the GDM problems with FPRs, both consistency reaching and consensus reaching should be pursued to guarantee meaningful and reliable solutions.

The selection step also includes two steps: (1) aggregation, and (2) exploitation. The aggregation step is to aggregate the individual preferences into group ones by some aggregation techniques, such as the weighted arithmetic mean and the geometric mean. The exploitation step aims to rank the objectives by some prioritization methods which can derive priorities from FPRs. For example, Fan, Ma, Jiang, Sun and Ma [23] developed a goal programming approach; Gong [24] developed a least-square method; Xu and Da [25] developed a least deviation method; Xu [26] developed a new goal programming method.

From the discussion above, we conclude four basic steps of the GDM problems with FPRs: (1) estimation of missing preferences, (2) consistency and consensus reaching, (3) aggregation and (4) exploitation, which appear to be complicated and time consuming. Is it possible to integrate these steps to make the GDM process more simple and efficient? We do not know of any previous work that focuses on this topic. In this paper, we develop a new fuzzy linear programming method (FLPM) that aims to directly solve the GDM problems without the four steps. To better understand the FLPM, we give visual and numerical interpretations of the FLPM with illustrative examples.

On the other hand, it is important to determine the DMs' weights in the GDM problems, because the DMs commonly have different interests, abilities and hierarchical ranks, etc. From different points of view, the weights can be obtained based on some related researches, such as the game theory [27], the influence relations [28], the relative importance coefficients [29], the eigenvectors [30], the distance measure [31], the deviation measure [32] and the TOPSIS method [33].

In this paper, we define an effect index to measure the DM's effects in the GDM problems on the basis of the FLPM, then propose a new method to determine the DMs' weights from the decision-making effect point of view. With all the developed methods, we further give a step by step procedure to deal with the GDM problems with FPRs, where the DMs' weights are unknown.

The rest of this paper is organized as follows. Section 2 gives some preliminaries related to FPRs. Sections 3 and 4 develop the FLPM and the method that determines the DMs' weights, respectively. The step by step procedure for the GDM problems is proposed in Section 5. In Section 6, we give visual and numerical interpretations of the FLPM to better understand it. Section 7 gives illustrative examples for the GDM problems following the step by step procedure. Section 8 draws conclusions based on these results.

2. Preliminaries

For a set of objectives, $X = \{x_1, x_2 \dots, x_n\}$, a fuzzy preference relation (FPR) is defined as follows.

Definition 1. (See [34].) An FPR R on X is represented by a fuzzy set on the product set $X \times X$, which is characterized by a membership function, $\mu_R : X \times X \to [0, 1]$.

When the cardinality of X is small, the FPR can be represented by an $n \times n$ matrix $R = (r_{ij})_{n \times n}$ where $r_{ij} = \mu_R(x_i, x_j)$ $(i, j = 1, 2, \dots, n)$ is interpreted as the preference degree of x_i over x_j. If $r_{ij} = 0.5$, then it indicates

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