Information Sciences 424 (2018) 301–316

Contents lists available at ScienceDirect

Information Sciences

journal homepage: www.elsevier.com/locate/ins

ELECTRE methods in prioritized MCDM environment

Xiaohan Yu*, Suojuan Zhang, Xianglin Liao, Xiuli Qi

College of Command Information Systems, PLA University of Science and Technology, Nanjing Jiangsu 210007, China

ARTICLE INFO

Article history:
Received 30 November 2016
Revised 18 September 2017
Accepted 20 September 2017
Available online 27 September 2017

Keywords:
ELECTRE
Multicriteria decision making
Prioritized MCDM
Prioritization

ABSTRACT

In most cases, ELECTRE methods just apply to traditional multicriteria decision making (MCDM) problems with independent criteria. However, there exist more or less interdependences among criteria in actual situations. A special case is MCDM with prioritizations among criteria, called prioritized MCDM. In recent years, how to deal with MCDM problems in the environment of prioritized criteria becomes hot topic increasingly. Lots of existing methods, including PROMETHEE, are modified for the prioritized MCDM, but the advantages of ELECTRE have not been exploited to the prioritized MCDM. In my opinion, design specific ELECTRE methods for prioritized MCDM problems will benefit the developments of both ELECTRE and prioritized MCDM. In this paper, we firstly reformulate the expressions of concordance and discordance indices for use in the MCDM problems with dependent criteria, especially prioritized criteria, based on the concepts of fuzzy measures and digraphs respectively. After replacing the fuzzy measure by a prioritized measure, we successfully validate the concordance of an assertion under prioritized criteria. Furthermore, we design an approach to validate the discordance of the assertion based on a digraph constructed by the criteria and their prioritizations. Finally, we design three procedures to construct outranking relations in the prioritized MCDM environment according to the ideas of ELECTRE-I, ELECTRE-Iv, and ELECTRE-IS respectively. It is meaningful of this paper to provide a new idea to solve the prioritized MCDM problems and widen the application scope of ELECTRE methods by means of the reformulations of concordance and discordance.

1. Introduction

Since it was introduced in mid-1960s, multicriteria decision making (MCDM) has been a hot topic in decision making and systems engineering [9,14,22], and been proven as a useful tool due to its broad applications in a number of practical problems, such as energy planning [8,21,34], supply-chain selection [11,32,33], risk management [17,23,31], water-resources management [4,15,35], and so on. The family of ELECTRE methods, proposed by B. Roy in 1965, is famous and efficient to solve MCDM problems. The original ideas of ELECTRE methods were first merely published as a research report in 1966 [1] (the notorious Note de Travail 49 de la SEMA). Shortly after its appearance, ELECTRE I was found to be successful when applied to a vast range of fields [3]. Two further versions known as ELECTRE-Iv [18] and ELECTRE-IS [28] appeared subsequently. ELECTRE-Iv took into account the notion of a veto threshold, and ELECTRE-IS was used to modeling situations in which the data was imperfect. These are the versions of ELECTRE methods for choice problematic. But how to establish an adequate system of ranking for several actions/alternatives? This led to the birth of ELECTRE-II: a method for dealing with

* Corresponding author.
E-mail address: yua2006@126.com (X. Yu).

https://doi.org/10.1016/j.ins.2017.09.061
0020-0255/

the problem of ranking actions from the best option to the worst [10]. Just a few years later a new method for ranking actions was devised: ELECTRE-III [27]. The main new ideas introduced by this method were the use of pseudo-criteria and fuzzy binary outranking relations. Another ELECTRE method, known as ELECTRE-IV [12], made it possible to rank actions without using the relative criteria importance coefficients. This method was equipped with an embedded outranking relations framework. However, in the late seventies a new technique of sorting actions into predefined and ordered categories was proposed. The first sorting method is ELECTRE-A. After being extended and improved, this method was developed into a simpler and more general method: ELECTRE-TRI [46].

However, up to now most of the ELECTRE methods have just focused on the MCDM problems with independent criteria. Actually, there widely exist interdependences among criteria, due to the complexity of MCDM problems in our daily lives. A possible kind of interdependences among criteria can be prioritizations [5,6,40–42,47–50]. As stated by Yager [40,41], a typical example can be the relationship between the criteria of *safety* and *cost* in the case of selecting a bicycle for child. We usually do not allow a loss in *safety* to be compensated by a benefit in *cost*, i.e., any tradeoff between *safety* and *cost* is unacceptable in this case. Simply speaking, there is prioritization between the criteria of *safety* and *cost*, and *safety* has a higher priority than *cost*. Such a kind of MCDM problems with prioritizations among criteria are called prioritized MCDM ones. Recently, the research about the prioritized MCDM problems has focused on generating or devising weights associated with criteria for common aggregation operators (such as ordered weighted averaging (OWA) operator [20,39], triangular norms and conorms [16], Choquet integral [30], etc.) according to the prioritizations on the basis of consensus, in which the importance weights associated with the criteria with lower priorities are related to the satisfactions of those with higher priorities. For example, Yager [40] introduced an OWA prioritized criteria aggregation, in which the weight of a criterion is determined by the original OWA weighting vector together with the satisfactions of the criteria with higher priorities. Yager [41] designed several approaches to derive the overall satisfactions associated with the higher prioritized hierarchies (by means of the min operator, the OWA operator, etc.), based on which the weight of each hierarchy can be calculated and then a prioritized “anding” operator and a prioritized “oring” operator were introduced based on triangular norms and conorms respectively. The prioritized multicriteria aggregation problems were solved with strictly ordered prioritizations on the basis of the OWA operator by Yager [42]. A monotonic set measure [19] was used to describe the prioritizations by Yager et al. [43], and then an integral type aggregation (Choquet integral) was used to aggregate the evaluation values of criteria. Then, Yan et al. [44] proposed a prioritized weighted aggregation operator based on the OWA operator along with triangular norms, and furthermore, considering the decision maker’s requirements toward the higher priority hierarchy, a benchmark based approach was designed to induce the priority weight for each priority hierarchy. On the basis of existing work, Yu and Xu [47] introduced prioritized aggregation operators into intuitionistic fuzzy environment.

Yu et al. [48,50] have discovered an imperfectness of the prioritized aggregation operators based methods: such methods are inapplicable in a special situation that the evaluation values of all alternatives with respect to the criterion with the highest priority are close and do not satisfy the requirement of the decision maker. For example, suppose the *safeties* of two bicycles are identical and cannot reach the requirement of the consumer, then the overall evaluations of the two bicycles (the results of prioritized aggregations) are the same, and we cannot give out an effective advice which bicycle shall be chosen, even though the cheaper one shall be selected intuitively. In order to overcome such a drawback, Yu et al. [50] introduced one outranking method, PROMETHEE, into the prioritized MCDM problems. In such a case, we can select the best action/alternative by comparing the actions in pairs. Subsequently, Chen and Xu [5] proposed a PROMETHEE method for prioritized MCDM problems with weakly ordered prioritizations among criteria. Up to now, the existing work has introduced outranking methods into prioritized MCDM problems, but just PROMETHEE methods. How to use ELECTRE, the most famous outranking methods, to deal with prioritized MCDM problems, has not been developed. It is valuable to introduce ELECTRE into prioritized MCDM problems. On one hand, we can enrich the solutions of the prioritized MCDM problems. On the other hand, we extended the application domains of ELECTRE methods through generalizing the construction of outranking relations. Therefore, we try to develop some ELECTRE methods for prioritized MCDM problems in this paper.

The rest of the paper is organized as follows. We firstly introduce basic concepts of ELECTRE and prioritized MCDM in Sections 2 and 3, respectively. Then we design approaches to validate the concordance and discordance in the environment of prioritized MCDM based on the ideas of ELECTRE-I, ELECTRE-Iv and ELECTRE-IS in Sections 4 and 5, respectively. In Section 6, we describe how to construct outranking relations for prioritized criteria based on ELECTRE-I, ELECTRE-Iv and ELECTRE-IS, respectively. At length, the conclusions are given in Section 8.

2. ELECTRE

2.1. Outranking relation

In a multicriteria decision making (MCDM) problem with a set of m actions, $X = \{x_1, x_2, ..., x_m\}$, and a set of n criteria, $C = \{c_1, c_2, ..., c_n\}$, we always want to select the best action from X through evaluating or ranking all actions under the n criteria. Kaliszewski et al. [13] formulated the underlying model for MCDM as a vector optimization problem:

$$\begin{array}{ll} \max & \boldsymbol{c}(x) \\ s.t. & x \in X \end{array} \tag{1}$$