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Screening in multiple criteria decision analysis

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Abstract

Screening is a process for multiple criteria decision analysis (MCDA) that reduces a large set of alternatives to a smaller set that most likely contains the best choice. To study screening in detail, MCDA is first interpreted as consequence-based preference aggregation. Consequence data and preference expressions (values and weights) are defined and the aggregation steps are elaborated. Based on these concepts, screening and sequential screening are defined and their properties are discussed. Then, it is shown how several popular MCDA methods can be integrated into a decision support system for sequential screening based upon available decision information. Finally, an illustrative application to water supply planning is presented.

Keywords: Multiple criteria decision analysis; Preference information; Screening; Sequential screening; Water supply planning

1. Introduction

The task of multiple criteria decision analysis (MCDA) is to help a decision maker (DM) *choose*, *rank* or *sort* alternatives within a finite set according to two or more criteria [23]. During the past few decades, various MCDA methods have been proposed based upon different philosophies such as multi-attribute utility theory [14], outranking methods [26] and the analytic hierarchy process (AHP) [24]. Meanwhile, many decision support systems (DSSs) have been designed in MCDA to assist DMs in analyzing problems and making decisions more easily. For example, within the journal *Decision Support Systems*, a multiple criteria decision analysis software tool, the Intelligent Decision System, was suggested to help business self-assessment [27], a multicriteria DSS for housing evaluation was proposed [17], and a DSS combining techniques from MCDA and soft systems thinking to tackle complex decision problems was presented in Ref. [19].

For the basic MCDA problem of choosing a best alternative, it is useful for a DM to *begin by eliminating those alternatives that do not appear to warrant further attention* [12]. This procedure is often called *screening*. Screening helps by allowing the DM to concentrate on a smaller set that (very likely) contains the best alternative. Many approaches have been adapted for screening alternatives. For example, a case-based distance model for screening is proposed in which criterion weights and a screening threshold are obtained by assessment of a representative case set [6]. However, there has been no comprehensive examination and comparison of these screening techniques in the literature.

A systematic procedure for executing screening is developed in this paper and its usefulness is demonstrated by employing a realworld case study. This approach provides a theoretical framework upon which decision

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support systems for screening can be constructed. Section 2 interprets MCDA as a consequence-based preferences aggregation procedure, and definitions of consequence data, preference expressions and aggregation are given. Section 3 provides detailed descriptions of screening, sequential screening, and screening properties, and introduces several screening methods in sequence. A sequential screening procedure in water resources planning is demonstrated in Section 4, while Section 5 provides a summary and conclusions as well as suggests future research topics.

2. Multiple criteria decision analysis

2.1. Basic structure

The analysis procedure of an MCDA problem begins with problem construction which is a serial process of defining objectives, arranging them into criteria, identifying all possible alternatives, and then measuring consequences. A consequence is a direct physical measurement of the success of an alternative according to a criterion such as cost in dollars. Note that in this paper, it is assumed that consequences can be measured without uncertainty.

The basic structure of an MCDA problem established by the above processes is shown in Fig. 1. In this figure, $\mathbf{A}=\{A^1, A^2,\ldots, A^i,\ldots, A^n\}$ is the set of alternatives, and $\mathbf{Q}=\{1, 2,\ldots, j,\ldots, q\}$ is the set of criteria. The consequence on criterion j of alternative A^i is expressed as $c_j(A^i)$, which can be shortened to c_j^i when there is no possibility of confusion. Note that there are n alternatives and q criteria altogether.

2.2. Problématiques

Based upon this basic structure, the DM may conceive the decision problem in several ways. Different MCDA *problématiques* (basic tasks) is suggested in Ref. [23] for a decision problem with alternative set **A**:

- *Choice problématique*. Choose the best alternative from **A**.

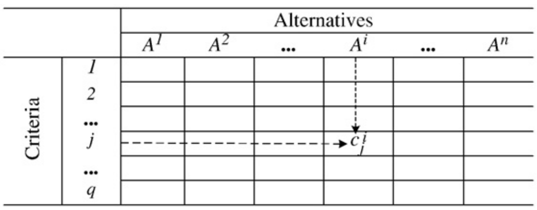

Fig. 1. The structure of MCDA.

- *Sorting problématique*. Sort all alternatives in **A** into different groups which are arranged in a preference order.
- *Ranking problématique*. Rank the alternatives of **A** from best to worst.

2.3. Preference expressions

The DM's preferences are crucial to the solution of any MCDA problem. Different methods have been designed to assist DMs to acquire and aggregate preferences. Here, two kinds of preference expressions are summarized: *values* (preferences on consequences) and *weights* (preferences on criteria).

2.3.1. Preferences on consequences

There are several ways for a DM to express preferences based directly on consequence data. Among them, the best known are utility theory-based methods [14] and outranking-based approaches [26]. Here, preferences on consequences are captured as values, which are refined data obtained by processing consequence data according to the needs and objectives of the DM. The relation between consequence data and preference data can be expressed as

$$v_j\left(A^i\right) = f_j\left(c_j^i\right) \tag{1}$$

where $v_j(A^i)$ (or v_j^i when no confusion can result) and c_j^i are a value datum and a consequence datum, respectively; $f_j(\cdot)$ is a mapping from consequence data to the relevant values. The value vector for A^i is $\mathbf{v}(A^i)=(v_1(A^i),v_2(A^i),\ldots,v_q(A^i))$.

The following basic properties of values are assumed.

Definition 1.

- Preference availability: The DM can express which of two different consequence data on a criterion is preferred.
- Preference monotonicity: All criteria are either positive or negative, where criterion $j\in\mathbf{Q}$ is positive iff $c_j(A^l)>c_j(A^m)$ implies $v_j(A^l)\geq v_j(A^m)$ for all $A^l, A^m\in\mathbf{A}$, and negative iff $c_j(A^l)<c_j(A^m)$ implies $v_j(A^l)\geq v_j(A^m)$ for all $A^l, A^m\in\mathbf{A}$.

2.3.2. Preferences on criteria

Preferences on criteria refer to expressions of the relative importance of criteria. Here we assume that these preferences are expressed using *weights*; the weight for criterion $j\in\mathbf{Q}$ is $w_j\in\mathbb{R}$. Usually $w_j>0$ for all criteria, j, and $\sum_{j\in\mathbf{Q}} w_j = 1$. A weight vector is denoted as $\mathbf{w}=(w_1, w_2,\ldots, w_j,\ldots, w_q)$. Two kinds of weights, tradeoff-based weights and non-tradeoff-based weights, are summarized in Ref. [2]. Tradeoff-based