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Decision Support

A new method for elicitation of criteria weights in additive models: Flexible and interactive tradeoff

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A B S T R A C T

This paper proposes the Flexible and Interactive Tradeoff (FITradeoff) method, for eliciting scaling constants or weights of criteria. The FITradeoff uses partial information about decision maker (DM) preferences to determine the most preferred in a specified set of alternatives, according to an additive model in MAVT (Multi-Attribute Value Theory) scope. This method uses the concept of flexible elicitation for improving the applicability of the traditional tradeoff elicitation procedure. FITradeoff offers two main benefits: the information required from the DM is reduced and the DM does not have to make adjustments for the indifference between two consequences (trade-off), which is a critical issue on the traditional tradeoff procedure. It is easier for the DM to make comparisons of consequences (or outcomes) based on strict preference rather than on indifference. The method is built into a decision support system and applied to two cases on supplier selection, already published in the literature.

1. Introduction

One of the most relevant issues in using a multicriteria decision model is probably that of evaluating the weights of criteria (or attributes) in the aggregation procedure. This is particularly relevant for aggregation using an additive model. In practice, this aggregation procedure is the most commonly found in a multicriteria decision model (Spliet & Tervonen, 2014), for instance when selecting suppliers (Xia & Wu, 2007), or planning of metro extension lines (Hurson & Siskos, 2014). The additive model can be applied under some basic assumptions covered by many earlier studies (Fishburn, 1967; Keeney, 1972; Keeney, 1992; Keeney & Raiffa, 1976). Stewart´s survey on multicriteria methods shows some useful characteristics for an additive model (Stewart, 1992). A more recent survey considers eliciting the weights of criteria as a central issue (Riabacke, Danielson, & Ekenberg, 2012). Eisenführ, Weber, and Langer (2010) give a broad overview on weights elicitation procedures for additive models.

Previous studies on experimental analysis (Borcherding, Eppel, & von Winterfeldt, 1991; Weber & Borcherding, 1993) on the main elicitation procedures for additive models have identified some major difficulties and challenges. The results of these studies prompted our research and led to the original achievement proposals to overcome those issues that this article sets out. First of all, it has long been held that the tradeoff elicitation procedure (Keeney, 1992; Keeney & Raiffa, 1976) has a strong axiomatic foundation (Weber & Borcherding, 1993). Nevertheless, experimental studies have shown that inconsistencies have been found when applying this procedure (Weber & Borcherding, 1993).

The method proposed in this paper contributes to overcoming some of these inconsistencies. This paper proposes a flexible elicitation procedure, which collects information from the DM, and evaluates this information. The main difference from previous studies is related to the elicitation process. In flexible elicitation, incomplete or imprecise information, a priori, is not assumed. Whether the DM is or is not able to give complete information, this is evaluated in the elicitation process itself, in a flexible way. For this reason, right from the start, the flexible process seeks complete information, based on the tradeoff elicitation procedure. However, at any point further on, it may consider incomplete information in either of the following two situations: when a unique solution is found or when the DM is not able to give additional information.

The method is built into a DSS (decision support system), which uses a flexible elicitation concept that requires less effort from the DM (Decision Maker). Before presenting the method proposed and its DSS, a brief review of the related literature is presented. In order to illustrate how the method named FITradeoff (Flexible and Interactive Tradeoff) works, the DSS is used on two applications

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dealing with supplier selection problems (Barla, 2003; Xia & Wu, 2007).

2. Literature related to the additive model and the elicitation of weights

As previously stated, eliciting a criterion weight (k_i) is probably the main concern of an additive model with regard to aggregating the value functions $v_i(x_i)$ over the consequences x_i for all criteria i $(i = 1,\ldots, n)$, which is represented (Fishburn, 1967; Keeney, 1972; Keeney, 1992; Keeney & Raiffa, 1976) in (1), usually assuming the normalization in (2).

$$v(x) = \sum_{i=1}^{n} k_i v_i(x_i). \tag{1}$$

$$\sum_{i=1}^{n} k_i = 1 \quad \text{and} \quad k_i \geq 0. \tag{2}$$

In many studies the use of the term scaling constant for k_i is preferred to weight, considering that these parameters are not related only to the meaning of the importance of criteria, but include other issues (Edwards & Barron, 1994; Keeney, 1992; Keeney & Raiffa, 1976; Kirkwood & Corner, 1993). In this paper, these issues are also considered, although the term weight is used for the sake of simplification. Similarly, the term criteria is applied in the same sense as attributes.

With regard to the evaluation of criteria weights, many studies are found in the literature on eliciting scaling constants or weights of criteria in an additive model obtained from a DM's preferences (Eisenführ et al., 2010; Keeney, 1972; Keeney, 1992; Keeney & Raiffa, 1976; Kirkwood, 1997). Several procedures in additive models are discussed in a recent survey on the procedures for eliciting weights, which considers both value and utility functions (Riabacke et al., 2012).

Many of these elicitation procedures are concerned with obtaining complete information, in order to assess the weights. For instance, the swing procedure is one of the procedures applied (Barron & Barrett, 1996a; Barron & Barrett, 1996b; Edwards & Barron, 1994). Macbeth (Measuring Attractiveness by a Categorical Based Evaluation Technique) is a method based on a qualitative evaluation of the difference of attractiveness (Bana e Costa, De Corte, & Vansnick, 2005), in which the weights for the additive model are evaluated, thereby avoiding that the DM has to produce a direct numerical representation of preferences. Another procedure based on complete information is the tradeoff procedure, which considers tradeoffs on criteria (Keeney, 1992; Keeney & Raiffa, 1976). The next section gives more details about the tradeoff procedure, on which this paper is based, and introduces flexible and interactive approaches for using partial information.

Some elicitation procedures use a complete evaluation (Edwards & Barron, 1994; Keeney & Raiffa, 1976) and others use partial information (Barron, 1992; Barron & Barrett, 1996a; Barron & Barrett, 1996b) in order to evaluate alternatives. The SMARTER method (Edwards & Barron, 1994) is one of the propositions based on partial information.

Studies making use of information of ranked weights indicate that there are two conceptual approaches to selecting the best alternative (Edwards & Barron, 1994). The first analyzes inequalities for weights, as shown in (3), in order to eliminate inferior alternatives. The second uses surrogate weights, which should be consistent with the ranked weights. Barron and Barrett (Barron & Barrett, 1996a; Barron & Barrett, 1996b) present rank-order centroid weights (ROC), on using the second approach.

For many partial information procedures, such as for the ROC, the conditions given in (2) and the information on the ranking of the weights ($k_1 > k_2 > \cdots k_i \cdots > k_{n-1} > k_n$), lead to the n-dimension weight space (φ_n) given by in (3):

$$\varphi_n = \left\{ (k_1, k_2, k_3, \ldots, k_n) | k_1 > k_2 > k_3 > \cdots > k_n; \; \sum_{i=1}^{n} k_i = 1); k_i > 0 \right\}. \tag{3}$$

The centroid consists of calculating the average of the extreme points of the weight space given by (3). Thus, the ROC weights are the coordinates of the centroid (Barron & Barrett, 1996a; Barron & Barrett, 1996b). The problem with such a procedure is that it may not reflect the DM´s preferences, although previous studies have shown there are many advantages to using this procedure (Barron & Barrett, 1996a; Barron & Barrett, 1996b).

With regard to the first mentioned approach for selecting the best alternative (Barron & Barrett, 1996a), which uses inequalities, it is observed that in many situations several alternatives remain which are not seen as evident choices for the best alternative (Barron & Barrett, 1996a; Kirkwood & Corner, 1993). Other approaches use partial ranking by clusters, but many alternatives remain in the best cluster (Kirkwood & Sarin, 1985). The PAIRS method (Salo & Hämäläinen, 1992) applies interval judgments, indicating a range for the weights. These are different approaches, which are unrelated to the context of the tradeoff elicitation procedure.

Regarding the use of imprecise or partial information, the literature presents quite a few of these approaches (Barron, 1992; Hazen, 1986; Li et al., 2012; Lofti, Stewart, & Zionts, 1992; Mármol, Puerto, & Fernández, 2002; Mustajoki, 2012; Park, 2004; Salo & Hämäläinen, 2001; Salo & Punkka, 2005; Steuer, 1976). Jiménez, Ríos-Insua, and Mateos (2003) presented a DSS to enable decisions with imprecise parameters for additive and multiplicative multi attribute utility functions, admitting imprecision for weights and utilities in terms of ranges.

Thus, eliciting single values may not be an easy task, which has inspired several approaches such as that presented by Danielson, Ekenberg, Idefeldt, and Larsson (2007) to deal with decision analysis problems that require a tool for enabling interval probabilities and interval weights for additive aggregation processes. The Cardinal Rank Ordering Step (CROC) used by Danielson et al. (2007) is detailed in Danielson, Ekenberg, Larsson, and Riabacke (2014).

Another kind of procedure is based on the DM making a holistic evaluation of a few alternatives, which are used to infer the parameters related to the additive model. The UTA (Utilité Additive) method (Jacquet-Lagréze & Siskos, 1982) is one of these procedures.

Although this section is not intended as an exhaustive literature review on partial information for building additive models, a framework is presented in Fig. 1 that summarizes different types of approaches introduced for partial information in the elicitation procedure. This framework considers three main steps, preference statements by the DM, forms of partial information and a final synthesis step for generating the output by dealing with partial information for screening alternatives. The second step represents an interface between the two other steps, and the structure of information applied. Although it is not explicit in Fig. 1, regression analysis may be applied in the synthesis step, which may be needed for holistic judgments, which may also apply LPP models.

The procedures mentioned above may be classified based on this framework. For instance, using the framework of Fig. 1, one can see that in the SMARTER procedure, the preference statements by the DM are given based on a structured elicitation process, all of this information is given at once, and a fixed process is applied. The form of partial information used is the ranking of weights. The final step of synthesis which generates the output by dealing with partial information is based on surrogate weights.

The concept of a dominance relation should be considered at this point. Let us first consider the concept as given by