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A method using weight restrictions in data envelopment analysis for ranking and validity issues in decision making

Edward Bernroider*, Volker Stix

Vienna University of Economics and Business Administration, Department of Information Business, Augasse 2-6, A 1090 Vienna, Austria

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Abstract

In this article we introduce a comprehensive yet efficient approach based on data envelopment analysis (DEA) with restricted multipliers for accountable and understandable multiple attribute decision making (MADM). Information system (IS) appraisals are motivated and used for illustrating the proposed methodology. Results show that the given DEA based approach can easily and significantly increase the information frame of the decision maker by identifying disparate rankings and by affirming the stability and validity of ranking outcomes. The given validity concept is contrary to the directions given in the main body of research and can also be used to question ranking outcomes of classic MADM methods.

Keywords: Decision support; Decision analysis; Multi-attribute decision making; Validity; Ranking; Data envelopment analysis

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1. Introduction

Decision analysis has been recognized as an important tool for the evaluation of major decisions among the scientific community and also in the public sector. The use of decision analysis methodologies is not widespread in corporations and only a minor number of consulting firms are capable of demonstrating the value of methodologies based on decision analysis to their corporate customers [1]. Especially if the nature of the decision problem is characterized by complexity, regularity or significance, the application of a decision making methodology, apart from standard financial investment techniques, can effectively support the decision process in a number of ways, in particular by increasing the information frame.

In order to have a greater impact on corporate decision making, decision making methodologies need to be further exploited which can accomplish both, the acceptance by business management for complex corporate decisions and a sufficient coverage of the problem's facets. For the development of such a methodology, we seek to contribute to literature by adapting data envelope analysis (DEA) as a multi-attribute decision making (MADM) approach in a way that incorporates a weighting of attributes used in most popular classic MADM techniques. Traditionally, DEA is applied to assess the relative efficiency among different organizational decision making units (DMUs), e.g., [2,3]. Due to its simple structure and intuitive basic idea, it has spread through the last decades in different domains and a large amount of variations and adaptations to the model have been introduced. Early proposals and elaborations connecting

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* Corresponding author. Fax: +43 1 31336 739.
E-mail address: Bernroider@wu-wien.ac.at (E. Bernroider).

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DEA with MADM have been provided in the DEA literature [4,5], and the creation of new aggregated methods was anticipated [6]. Recent work introduced an interactive, hybrid methodology with distance concepts incorporated in the DEA immanent LP objective function [7]. In contrast to the latter approach, this work focuses on the constraint functions to incorporate preference information compatible to popular MADM approaches into the DEA model. The resulting MADM approach provides ranking of alternatives and validation of ranking outcomes, which will be explicitly discussed in the last part of this article.

The application area of this article refers to information system (IS) decisions which provide good examples for the mentioned problem characterization: in general, these decisions are highly complex and afford considerable risks due to their scope and the impact of the decision. The concept of value and its multi-dimensional facets as well as the nature of IS benefits and costs need to be considered. There are a number of human, organizational and political issues involved. Structural comparative analysis is needed, especially to answer the challenge of organizational fit. Literature reports extensively about the problems associated with IS evaluation [8].

The remainder of the paper is organized into four sections. The next section describes the conceptual background and the application domain comprising the concept of MADM, classic MADM methods, basic DEA, and the IS application domain. The third section imposes restrictions to DEA multipliers through which two similar DEA-based models are developed. Furthermore, this section gives insights to their application with real and experimental data. Thereafter, the validation issues and possible contributions of the DEA approach are given. The last section concludes the article.

2. Conceptual background and application domain

2.1. Multiple criteria/attribute decision making

Multiple criteria decision making (MCDM) has been one of the fastest growing areas of operational research, as it is often realized that many concrete problems can be represented by several (conflicting) criteria. It was described as the most well known branch of decision making [9] and can be broadly divided into two categories: MADM, and multiple objective decision making (MODM). Criteria can be used to denote both objectives and attributes [10]. Often the terms MADM, MCDM, and MODM are confused or used with the same meaning.

MADM studies problems where the decision space is discrete, i.e. these problems have a limited number of alternatives. The typical problem is associated with assessment and selection. The MODM method concentrates on problems where the alternatives are not pre-determined, i.e., MODM assumes continuous solution spaces or large number of points, e.g., as in multiple objective programming [11]. In a general way, it can be said that MADM selects the best alternative among a finite number of choices, unlike MODM where the best alternative is designed with multiple objectives based on continuous decision variables subject to constraints. Table 1 denotes the differences in classifying both approaches based on [12].

The MADM decision problem can be expressed by an $(n \times s)$ decision matrix D, in which the element d_{ij} represents the performance ratings or utilities of alternative i, A_i (for $i = 1, \ldots, n$), with respect to a set of attributes (or criteria) j, C_j (for $j = 1, \ldots, s$). Hence A_i is denoted by $A_i = (d_{i1}, \ldots, d_{is})$ and the vector $(d_{1j}, \ldots, d_{nj})^{\mathrm{T}}$ shows the contrast of each alternative with respect to attribute j.

To represent the importance of the attributes, a weight w_j for each criterion can be given resulting in a vector $w = (w_1, \ldots, w_s)$. The performance ratings and the attribute weights are cardinal values that represent the decision maker's absolute preferences [13]. In many cases the weights sum up to one, i.e., $\sum_{i=1}^{s} w_i = 1$, so that each weight can be interpreted as the percentage of importance of the corresponding attribute.

2.2. MADM methods

The MADM problem needs to be solved by one of the many methods available. Solving can imply the aggregation of utilities into an overall evaluation for each alternative leading to a final ranking. As each method has its own characteristics, there are many ways to classify them [1,12,14]. One classification method based on the type of data considers either deterministic, stochastic [15,16] or fuzzy methods [17,18]. An alternative way to classify methods pertains to the number of decision makers involved in the decision making process, i.e. focusing on supporting group