Pairwise Comparison for Weight Restriction in DEA/ARI

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2016年2月
The study’s objective is to develop a framework, based on the utilization of multi-criteria decision analysis tools, to support strategic decision making and resolve a problem with many alternatives and criteria, with an overall goal to improve the quality of decision making. The thesis is eclectic in nature, as it aims to contribute not only to a more broad area of decision-making solutions, but also to the more technical research area of the Data Envelopment Analysis (DEA) methodology, which incorporates weight restrictions in detail. The concept involves introducing an effective method to support the decision maker in choosing or evaluating alternatives. Therefore, both technical and broad aspects are included in strategic decision making. The study, and its technical aspect, is concerned with establishing a theoretical method, based on the development of the DEA model with an Assurance Region of type I (ARI) weight-restriction technique. A more broad aspect suggests a proposed method for DEA with ARI, in addition to an Analytic Hierarchy Process (AHP), to solve decision-making problems and obtain one ideal solution.

The thesis consists of six chapters. Chapter 1 is an overview of the decision-making problem and its importance. Chapter 2 outlines the decision-making techniques used in this thesis. The DEA model is a powerful tool for management analysis, and is capable of evaluating performance or efficiency of a large number of alternatives which refers as decision making units or DMUs, based on a mathematical programming approach. However, the method has poor discrimination in an assessment of the different alternatives; thus, it could not provide an optimum solution for selection or ranking purposes. The DEA, due to complete weight flexibility, might also assign unrealistic or unreasonable weight variables to input and output criteria, and these weights might be inconsistent with the decision maker’s accepted views. The ARI technique is applied by adding additional constraints to the original DEA model. The technique involves restricting regions of weights, by imposing constraints on the weights’ relative magnitude to a specific area. This also allows the decision maker to incorporate perspectives and value judgments into an analysis, so that the decision process includes a combination of both tacit and explicit knowledge. The efficiency score in the corresponding DEA model is degraded by additional ARI constraints, and a DMU previously evaluated as efficient by the original DEA may subsequently be assessed as inefficient. Therefore, the solution’s discrimination is improved. Imposing these limits on weights, however, may cause issues with infeasibility conditions for the DEA linear programs, since the feasible region for the weights is limited by ARI constraints. Therefore, the primary difficulty with the ARI approach is determining values of bounds represented in ratios between each pair of input weights and ratios between each pair of output weights that could
circumvent the infeasibility problems for linear programming models. Moreover, the bound values must legitimately reflect the decision maker's judgment or opinion expressed during assessment processes. This chapter also reveals the AHP method, which can integrate different measures into one overall score for ranking decision alternatives, to handle a multi-criteria problem with few alternatives.

The ARI technique can be found in performance measurement and decision-making applications, which could influence the reader and decision maker in determining appropriate bound values. Nevertheless, a majority of the literature are presented as illustrative manner in the applied studies with little attention to illustrate the process in which the values of the weight bounds could be derived or analyze the weights used in evaluating the efficiency of DMUs. The issue related to the possibility of infeasibility is scarcely mentioned in ARI literature. No studies have focused on developing a strategy or method for obtaining a feasible solution directly by setting possible bounds in the ARI, to the best of this author's knowledge. Thus, it is necessary to develop a practical method to set bounds that can hold transitivity in ARI constraints. Chapter 3 presents a methodology to simplify and set ARI weight restriction constraints that could avoid the infeasibility problem. The proposed method introduces two main techniques that involve the decision maker to provide judgment during the decision process, that is, a grading system and pairwise comparison. Grades are used to specify the degree of importance of each single criterion with respect to the objective of the analysis. The decision maker can then more easily evaluate the importance of each criterion instead of comparing each pair of criteria. Moreover, each criterion is directly considered relative to the problem or objective of the decision. A pairwise comparison is applied to compare the level of importance between each pair of grades. The number of comparisons is then reduced, which again makes it simple for a decision maker to arrive at a judgment. The primary advantages of the proposed method are that it provides conditions for developing the transitivity property, which is an operational constraint preserving internal consistency and is a critical property to be satisfied when the data is computed for pairs in ARI inequality equations. Therefore, this can guarantee the existence of feasibility for the resulting linear programming model. Moreover, the proposed method is ease for employment. Since imposition of weight restrictions by incorporating value judgments can be a problem during analysis when dealing with a manager who does not necessarily comprehend the DEA, the proposed procedure only requires management or the decision maker to express their opinions regarding the degree of importance of each criterion with respect to the objective of an evaluation, and the relative importance between each pair of criteria. The mathematical model does not require the decision maker's
involvement, and the proposed method also allows easy conversion of the decision maker’s opinion into the values of weight bounds in practice. This method is developed to support general decision-making or efficiency measurements and hence the method can be applied to any problem. This also allows decision makers to adjust parameters until they obtain a satisfactory solution. The values of the weight bounds also correspond to the decision maker’s perspective, and are consistent with objective; thus, a suitable solution is likely to be obtained.

Chapter 4 offers two numerical applications to explain the utilization of decision-making tools in solving real-world decision-making problems. The first example demonstrates the use of the proposed method for setting bounds on ARI constraints to handle facility location selection, a large-scale problem. The second example illustrates an AHP application, to select one ideal alternative from a route selection problem. Chapter 5 provides a discussion on the development of the proposed technique and relevant issues. The key contributions of the proposed method are then highlighted. This chapter also presents an analysis of solutions from numerical application, using DEA with ARI and the proposed method. Finally, Chapter 6 concludes the research with a general summary of the thesis, and recommends supporting tools for strategic decision making.

This thesis provides contributions to both academics and practitioners. For academics, it introduces an improvement of methodology to handle multi-criteria decision-making problems by using the DEA with ARI. For practitioners, the technique proposed in this thesis serves as a useful tool that helps the decision maker achieve improved results from an application, which could contribute to a successful final decision. Therefore, the referees recognize that this submitted thesis meets their requirements and the author should be granted a doctoral degree of Management Engineering.

February 2016

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