Applied Mathematics and Computation 245 (2014) 416–426

Contents lists available at ScienceDirect

Applied Mathematics and Computation

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

An integrated approach for resource allocation in manufacturing plants

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ARTICLE INFO

Keywords:
Resource allocation
DEA
MOP
Voting method
LGP

ABSTRACT

Resource allocation in manufacturing plants can be characterized as an attempt to optimize a number of potentially conflicting objectives involving related activities, which often compete for the same limited resources. This paper proposes an integrated approach for resource allocation problem. The proposed approach combines the voting method and the Lexicographic Goal Programming (LGP) model and takes into account both qualitative and quantitative factors involved in the resource allocation decision process. The voting method is used to determine ratings of the evaluating goals. LGP models are then applied to determine the optimal allocation based on the ratings. The proposed approach is applied to a real-world resource allocation problem. The case company is the world's largest manufacturer of switch power supplies. Results of the case study indicate that the proposed approach is a practical and useful tool for solving the resource allocation problem.

1. Introduction

Resource allocation can be characterized as an attempt to optimize a number of potentially conflicting objectives involving related activities, which often compete for the same limited resources. Manufacturing plants require careful planning on how the resources available to each plant may be best used. The inadequacy of the resources available as well as presence of multiple objectives that planner seeks to optimize make multiple objective programming (MOP) model an appropriate and efficient tool to guide a decision maker in such a situation. This approach optimizes several objective functions rather than tries to force the model to derive a single objective optimization solution. The multiple objective programming presents a form of problem-solving, where the optimum solution to the problem of linear programming is substituted by a set of solutions which are efficient but not necessarily the optimum ones in the sense of the linear programming. This paper proposes an integrated approach for resource allocation problem. The proposed approach combines the voting method and the lexicographic goal programming (LGP) model and takes into account both qualitative and quantitative factors involved in the resource allocation decision process.

The voting method modified from data envelopment analysis (DEA) is used to determine ratings of the evaluating goals in the first stage of solving goal priorities problem. DEA is able to measure multiple inputs and outputs. This means that it can operate as a multi-criteria decision-making tool. But DEA does not require assigned numeric weights or modeling preferences for analysis. Up until now, DEA has been widely studied and applied in various areas for 30 years since Charnes et al. [1] first proposed DEA method with the CCR model. Among them, main forms of DEA models and their extensions

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http://dx.doi.org/10.1016/j.amc.2014.07.112
0096-3003/

include those of BCC model [2], the additive model [3] and the imprecise DEA models [4,5]. The CCR model assumes constant returns to scale, while the BCC model allows variable returns to scale.

An important issue in the decision-making framework is how to obtain a social ranking or a winning candidate from individuals' preferences on a set of candidates. In some voting systems, each voter selects n candidates and ranks them from the most to the least preferred. Among these systems, a well-known procedure to obtain a social ranking or a winning candidate is the scoring rules, where fixed scores are assigned to the different ranks. Cook and Kress [6] proposed DEA/AR model to evaluate each candidate with the most favorable scoring vector for him/ her. Green et al. [7] proposed benevolent cross-evaluation and aggressive cross-evaluation to select this vector. Hashimoto [8] proposed to apply DEA exclusion method which enables an efficient candidate to achieve a score greater than one by removing the constraint relative to the candidate in the formulation of Cook and Kress's model. Noguchi et al. [9] criticized the choice of discrimination intensity functions in Green et al.'s model. In this model, the weight assigned to a certain rank may be zero and, consequently, the votes granted to that rank are not considered. Furthermore, the weights corresponding to two different ranks may be equal and, therefore, the rank votes lose their meaning. They proposed changes in Green et al.'s model to avoid these drawbacks. In addition, Obata and Ishii [10] considered that, in order to compare the maximum score obtained by each candidate, it is fair to use scoring vectors of the same size. So, they suggested normalizing the most favorable scoring vectors for each candidate.

The goal programming model is generally considered to be MOP methods with no articulation or a priority articulation of decision maker's preferences. The most common paradigms of goal programming used in such applied studies are weighted GP (WGP) and lexicographic GP (LGP), Minmax GP (MGP), stochastic GP (SGP), fuzzy GP (FGP), interactive GP (IVGP).

According to Kettani et al. [11], for weighted GP, the weights associated with the objectives have two different roles. The first role is the normalization of the different units of measurement of the objectives based on the degree of proximity to goal, and the second role is the valorization of each objective which reflects decision maker's preferences. The determination and interpretation of weights remain a challenging task for decision maker (DM). In fact, it can be difficult, and hence a challenge, for DM to specify the weights of different objectives to obtain usable or valid information about DM's preferences [12,13].

The LGP, originally introduced by Charnes and Cooper [14], is an extension of linear programming (LP). This technique was developed to handle multi-criteria situations within the general framework of LP. The essence of this technique is the achievement of a satisfactory solution, which comes closest to meeting the stated goals according to the given constraints of the problem. Romero [15] interpreted their solutions from the point of view of the utility theory. Romero [16] provided a more generalized form of the achievement function. The LGP framework has been recently applied by De Andrés et al. [17] to a performance appraisal model.

MGP is one of the oldest GP variants. WGP and MGP variants are very similar except that the objective function of MGP is to minimize the maximum deviations [18]. Romero et al. [19] and Tamiz et al. [20] employed utility functions to connect with GP and other distance function methods. The solution generated by this type of GP formulation represents a balanced allocation among the achievements of the different goals.

SGP model was developed to deal with the uncertainty as defined by Zimmerman [21]. Aouni et al. [22] proposed the first formulation of the SGP model which explicitly integrates DM's preferences through satisfaction functions concept where the aspiration levels are stochastic. Liu [23] presented a method for solving stochastic GP based on genetic algorithms. The area of stochastic GP is closely related to fuzzy set theory and that is why the term fuzzy GP is used.

The FGP technique introduced by Mohamed [24] on proper distribution of decision powers for DMs to arrive at a satisfying decision for the overall benefit of an organization was developed to overcome the above undesirable situation. The FGP of Mohamed [24] was extended to solve multi-objective linear fractional programming (MOLFP) problems [25].

The interactive GP corresponds to the use of GP model in an interactive mode where the DM is playing a more significant role than other GP variants. Decision-making process here can be conceived as a continuous process in which the DM's preferences are integrated in a progressive and iterative manner. Bai and Kwong [26] presented an interactive approach based on inexact genetic algorithm. Their approach could generate a set of inexact optimal target values with an acceptable satisfaction degree. Popular interactive GP algorithms include methods of Nakayama [27], Hwang and Masud [28]. In addition, Gardiner and Steuer [29] incorporated GP interactive algorithms into their unified MOP interactive algorithm.

A major objective of this research is to find a method of providing acceptable decision support to top management in making decisions regarding resource allocation. More specifically, objectives of this study are as follows:

(1) Provide a pragmatic and flexible methodology capable of addressing complex decision variable problems where several objectives as well as many variables and constraints are involved;
(2) Develop an integrated multi-criteria model that incorporates voting approach with LGP to solve optimization problems;
(3) Unlike the ones from paired comparison, it provides an efficient method to rank goal priorities.

The remainder of this paper is organized as follows. Section 2 describes voting method. Section 3 introduces GP techniques. A LGP model application is presented in Section 4, in which the proposed approach is applied to the world's largest manufacturer of switch power supplies in Taiwan. Finally, conclusions are drawn in Section 5.