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Fuzzy goal programming for health-care organization

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ABSTRACT

This paper presents fuzzy goal programming using with exponential membership function, which uses the modeling, and solving of health care system for optimal efficient management. The limited human resources and budget in a health-care organization are described with fuzzy conditions for determine the future strategies for unknown situations. In this study, the exponential membership function is preferred dynamic situation in next period. The study aims to assign the resources for optimization with enable management to meet the fuzzy objective of minimizing the system costs while patients are satisfied. The fuzzy goals are identified and prioritized for the strategic planning and resource allocation. A fuzzy goal-programming model is illustrated using the data provided by a health-care organization in Turkey-Sakarya private hospital.

1. Introduction

The fuzzy goal-programming model is developed and used the health-care organization for strategic planning and allocation in limited human resources. Turkey's health care system consists of the public and private sector, which are facing to very competitive conditions reason of the patients' selection independence in these days. It is facing extreme pressures to do extremely well in an environment of rapidly changing expectations, exploding global resource needs, and increased financial demands, and patients' pressure that forces to managers to give to right decisions. Furthermore, today's health-care systems are complicated by multiple objectives, multiple evaluation criteria, and evaluated by multiple decision-makers within the system, while resources and budget are extremely limited (see Tables 1 and 2).

As the health-care systems react to severe financial pressures, too much emphasis will be often placed on balancing the budget at the expense of the goals of the systems. The critical issue in the management of a health-care system is not just financial efficiency. The operational policy must be based on the compromised agreements of the diverse groups within the health-care system. Therefore, a systematic analysis and evaluation for effective resource allocation in a system are essential to provide competitive advantages for future survival and actions for the goal achievement. In this paper, a fuzzy goal-programming model is developed based on the data obtained from a private health-care organization in the Sakarya region of the Turkey. The model is analyzed and interpreted. This fuzzy goal-programming model can facilitate planning, decision-making, and managerial control by providing health-care management information. Fuzzy goal programming with exponential membership formulation for optimal resource allocation of private healthcare organization is presented.

The paper organized as follows. Section 2 presents a description of the fuzzy goal programming with exponential membership function. The main features of the proposed model construction are explained in Section 3. In next section represents the real life application and Section 5 covers the conclusion.

2. Fuzzy goal programming

Goal programming is important method for multi-objective decision making approaches in practical decision making in real life. In a standard GP formulation, goals and constraints are defined precisely but sometimes the system aim and conditions include some vague and undetermined situations. In particular, expressing the decision maker's unclear target levels for the goals mathematically and the need to optimize all goals at the same needs to complicated calculations. The fuzzy approach for goal programming tries to solve this kind of unclear difficulties.

This study includes one than more goals to optimize the resource allocation. Goal programming preferred due to realize two or more aim in the system. It is a kind of the multi criteria decision making problem which includes the crisp and vague values.

First time fuzzy set defined mathematically by Zadeh (1965) with the assigning to each possible element in the universe of

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0360-8352/

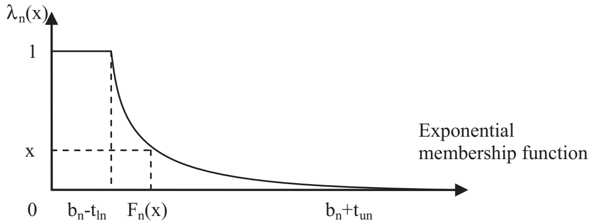

Fig. 1. Exponential membership function type for the minimization objectives.

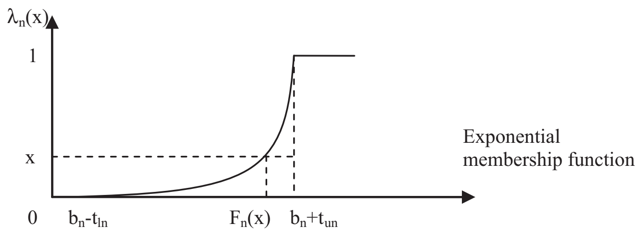

Fig. 2. Exponential membership function type for the maximization objectives.

discourse a value representing its grade of membership in the fuzzy set. This grade corresponds to the degree to which that element is similar to the concept represented by the fuzzy set. So elements may belong in the fuzzy set to a greater or lesser degree, which indicated by a larger or smaller membership grade. These membership grades are very often represented by real number values ranging in the closed interval between 0 and 1. Bellman and Zadeh (1970) mentioned the decision making in fuzzy environment. Zimmermann (1978) reviewed the fuzzy programming and linear programming with several objective functions and introduced the field of multi-objective optimization problems. Ahn (2015) presented the simple method for finding the extreme points of various types of incomplete attribute weights. Also Slowinski (1986) applied fuzzy linear programming method to water supply system development planning.

A goal that is not completely achieved has an under-achievement (negative deviation) or overachievement (positive deviation) of the goal. If the objective is to exceed stated goals, the objective function will only contain a negative deviational variable, *d*−. If the objective is to be under the stated goal, the objective function will contain a positive deviational variable, *d*+.

In real life applications are used to somewhere by researchers, such as Chen and Tsai (2001) used to capacity allocation and choice problem, Jamalnia and Soukhakian (2009) developed aggregate production planning for a medium range capacity planning, Biswas and Pal (2005) presented low fuzzy goal programming can be effectively used for modeling and solving land use planning problems in agricultural systems for optimal production of several seasonal crops in a planning year. Tsai, You, Lin, and Tsai (2008) presented to address a steel supplier's channel allocation problem that includes decisions of channel mix and capacity allocation for each distribution channel with fuzzy goal programming approach. Also Kumar, Vrat, and Shankar (2004) used the fuzzy goal programming to vendor selection problem in supply chain. Zeng, Kang, Li, Zhang, and Guo (2010) applied to fuzzy multi objective linear programming to crop and planning in a fuzzy environment. Kwak and Lee (1997) suggested the linear goal programming for human resource allocation in a health care organization. Also Romero (1986) generalized the goal programming approach. Khalili-Damghani, Sadi-Nezhad, and Tavana (2013) applied to fuzzy goal programming to the project selection problems with TOPSIS and a fuzzy preference relation. In our study we preferred to the Pareto analysis.

Li and Hu (2009) proposed satisfying optimization method based on goal programming for fuzzy multiple objective optimization problem. Chen and Tsai (2001) suggested the fuzzy goal programming with different importance and priorities to capacity allocation and choice problem. Also Liang proposed the fuzzy multi-objective Project management decisions using two-phase fuzzy goal programming approach. Also, Baky developed a new algorithm for solving decentralized bi-level multi-objective programming (DBL-MOP) problems with a single decision maker at the upper level and multiple decision makers at the lower level. Wang and Li derived interval weights on fuzzy preference relations to goal programming. Jimenez and Bilbao represented the pareto-optimal solutions in fuzzy multi-objective linear programming. Mehrjerdi (2011) suggested to solving fractional programming through fuzzy goal setting and approximation. Sakawa and Matsui (2012) used random variables in two-level linear programming with Stackelberg solutions. Gong, Li, Zhou, and Yao (2009) suggested the priority vectors from the intuitionistic fuzzy preference relations in goal programming approach. Silva and Marins (2014) suggested for solving aggregate production-planning problems under uncertainty.

However in contrast to LP and GP approaches, fuzzy programming (FP) approach to resource allocation and efficiency usage in health care organization problems has not been appeared extensively in the literature. In this paper, fuzzy goal programming formulation for optimal resource allocation and usage is presented for health care organization.

$$\left.\begin{array}{ll} \text{Find } x_i, & i = 1,\ldots,n \\ Z_m(x_i) \prec \bar{Z}_m & m = 1,\ldots,M \\ Z_k(x_i) \prec \bar{Z}_k & k = M+1,\ldots,K \\ g_j(x_i) \leqslant b_j & j = 1,\ldots,J \\ x_i \geqslant 0 & i = 1,\ldots,n \end{array}\right\} \tag{1}$$

where $Z_m(x_i)$ is the mth goal constraint, $Z_k(x_i)$ is the kth goal constraint, $\bar{Z}_m(x_i)$ is the target value of mth goal, $\bar{Z}_k(x_i)$ is the target value of the kth goal, $g_j(x_i)$ is the jth inequality constraint and b_j is the available resource of inequality constraint j (Zimmermann, 1978).

In formulation (1) the symbols "$\prec$ and $\succ$ " denote the fuzzified versions of "$\leqslant$ and $\geqslant$ and can be read as "approximately less/greater than or equal to". These two types of linguistic terms have different meanings. Under "approximately less than or equal to" situation, the goal m is allowed to be spread to the right-hand side of $\bar{Z}_m(\bar{Z}_m = l_m$ where l_m denote the lower bound for the mth objective) with a certain range of $r_m(\bar{Z}_m + r_m = u_m$, where l_m denote the upper bound for the mth objective). Similarly, with "approximately greater than or equal to", p_k is the allowed left side of $\bar{Z}_k(\bar{Z}_k + r_m = l_k$ and $\bar{Z}_k = u_k)$.

In this paper, an exponential, instead of linear membership function is proposed. The fuzzy goals are characterized by exponential membership function with defining the lower or upper tolerance limit (see Figs. 1 and 2). The advantages of using exponential membership are twofold. First, the resulting problems can be transformed to linear ones when the "product" and several other nonlinear aggregate operators are used. Secondly, exponential representation is more realistic than the linear ones usually used for some practical applications. It depends on the fuzzy restriction given to a fuzzy goal of the problem in a fuzzy decision-making situation. Let t_{ln} and t_{un} be the lower- and upper-tolerance ranges considered respectively, for achievement of the aspired level b_n of the nth fuzzy goal. Then, the exponential membership function $\mu_n(X)$, for the fuzzy goal $F_n(X)$ can be characterized the lower tolerance limit $(b_n - t_{ln})$ and upper tolerance limit $(b_n + t_{un})$ are presented as follows (Pal, Moitra, & Maulik, 2003):