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A Fuzzy Goal Programming Approach for Solid Waste Management under Multiple Uncertainties

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Abstract

In this study a fuzzy chance constrained programming approach is developed for municipal solid waste management to minimize the net system cost and maximize the revenue generated from different treatment facilities. Most of the parameters involved with this model are imprecisely defined and probabilistically uncertain. A fuzzy chance programming model is developed to minimize the net system cost of sorting and transporting the wastes and to maximize the revenue generated from different treatment facilities. To resolve the cases arising due to the multiple occurrences of fuzzy goals, a fuzzy goal programming has been adopted. To expound the potential use of the approach, modified version of a case example, studied previously, has been considered and solved. The achieved model solution is compared with the existing technique for waste management, studied earlier.

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Keywords: Chance constrained programming, fuzzy number, fuzzy goal programming, solid waste, system costs, treatment facilities;

1. Introduction

Ever since the ancient times, human and animals are using the resources of the earth to support life and disposing the wastes that are discarded as useless or unwanted. In those days, the disposal of wastes did not pose significant problems as the population was small and a vast expanse of land was available for the assimilation of such wastes.

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However, in recent years due to accelerated urbanization and growing population, waste management has become challenging to urban communities (Cheng et al., 2009). Also environmental protection has challenged many regional planners and decision makers. Such challenges are complicated by the rapid socioeconomic development associated with increasing contaminant emissions and decreasing resources availabilities (Maqsood and Huang, 2003). As the capacity of the landfill areas gradually decreases, there is arising an increasing demand of other waste treatment facilities such as incinerator, composting facility and recycling facility. Thus those facilities are becoming an integrated part of waste management systems (Tang et al., 2008; Guo et al., 2008; Guo et al., 2009). Also, balancing the conflicts among various system components and considering limitations of the constraints of resources, it is necessary to develop acceptable planning techniques to effectively allocate the available resources (Maqsood et al., 2004).

In the context of modeling municipal solid waste (MSW) management problems, probabilistic or possibilistic uncertainties are frequently involved with the amount of disposal of wastes and the costs related to collections, transportations, treatment of wastes, etc. Moreover, these uncertainties may further affect not only interactions among these complex, dynamic and uncertain parameters, but also Consequently, various methods dealing with uncertainties have been developed for planning MSW management systems. Most of them can be dealt with fuzzy, stochastic and interval mathematical programming approaches (Kirca and Erkip, 1988; Zhu and Revelle, 1993; Leimbach, 1996; Chang and Wang, 1994).

Charnes and Cooper (1962, 1963) first introduced chance constrained programming (CCP) for dealing with probabilistic uncertainties. A bibliography has been presented by Infanger (1993) on stochastic programming. The researchers (Kataoka, 1963; Geoffrion, 1967) further extended the concept of CCP technique for solving different real life problems. With this advancement in computational resources and scientific computing techniques, many complicated optimization models can now be solved efficiently. Guo*et al.*(2008) presented an interval stochastic quadratic programming approach to municipal solid waste management.

Another type of uncertainty that the researchers often face is fuzzy (Bellman and Zadeh, 1970) or possibilistic uncertainty. It is worthy to mention here that the possibilistic uncertainties arise if the parameters of the model are not properly defined. Bellman and Zadeh(1970) first introduced the concept of decision making in fuzzy environment. Tanaka *et al.* (1973) extended this concept for solving mathematical programming problems. Afterwards, Delgado *et al.*(1989) presented a general model for solving fuzzy linear programming (FLP) problems in which constraints are involved with fuzzy inequality and the parameters of the constraints are fuzzy numbers. In order to solve those types of FLP problems, different approaches have been presented by several researchers.

In recent years the decision makers feel the presence of probabilistic and possibilistic uncertainty simultaneously. In fuzzy CCP, probabilistic and fuzzy aspects are combined together to derive an efficient model to describe real-life planning problems where uncertainty and imprecision of information co-occur. However, this kind of combination creates a great challenge for the researcher (Iskander, 2006; Liu, 2001) to find an efficient solution method for solving decision making models involving both fuzzy and stochastic terms.

For dealing with the models consisting of an imprecisely defined multiple numbers of objectives, fuzzy goal programming (FGP) technique (Hannan, 1980; Narasimhan, 1980) is appeared as an efficient tool for making proper decisions. FGP technique for solving CCP problems involving fuzzy random variables (FRVs) have been recently studied by Biswas and Modak(2011, 2012).

Li *et al.* (2008) developed an inexact stochastic quadratic programming method for municipal solid waste management in which the uncertainties relating to operational and transportation costs are expressed in terms of probability distributions and discrete intervals. Afterwards, Guo and Huang (2011)proposed an inexact fuzzy-stochastic quadratic programming approach for waste management under multiple uncertainties. However, the Interval parameter quadratic programming (IQP) encountered difficulties when the model's right-hand-side coefficients in theconstraints are highly uncertain.