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Distribution planning decisions using interactive fuzzy multi-objective linear programming

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Abstract

This work develops an interactive fuzzy multi-objective linear programming (i-FMOLP) method for solving the fuzzy multi-objective transportation problems with piecewise linear membership function. The proposed i-FMOLP method aims to simultaneously minimize the total distribution costs and the total delivery time with reference to fuzzy available supply and total budget at each source, and fuzzy forecast demand and maximum warehouse space at each destination. Additionally, the proposed method provides a systematic framework that facilitates the fuzzy decision-making process, enabling a decision maker (DM) to interactively modify the fuzzy data and related parameters until a set of satisfactory solutions is obtained. An industrial case is presented to demonstrate the feasibility of applying the proposed method to real transportation problems. Consequently, the proposed method yields an efficient solution and overall degree of DM satisfaction with the determined objective values. Especially, several significant management implications regarding the practical application of the proposed i-FMOLP method are presented.

Keywords: Transportation; Distribution planning decisions; Interactive fuzzy multi-objective linear programming; Fuzzy numbers; Supply chains

1. Introduction

The distribution planning decision (DPD) involves optimizing the transportation plan for allocating goods and/or services from a set of sources to various destinations in a supply chain. Essentially, the DPD problem is a special type of the ordinary linear programming (LP) problem that can be solved using the simplex method. Additionally, some special solution algorithms such as the stepping stone method and the modified distribution (MODI) method, allow DPD problems to be solved much more easily than the LP method [24,31]. However, when any of the ordinary LP or the existing solution algorithms is used to solve DPD problems, the objective function and model inputs are generally assumed to be deterministic/crisp. In most real-world DPD problems, environment coefficients and model parameters, such as available supply, forecast demand and related cost/time coefficients, are frequently imprecise/fuzzy because some information is incomplete and/or unavailable over the planning horizon. Obviously, conventional deterministic LP and special solution algorithms cannot solve all imprecise/fuzzy DPD programming problems.

Fuzzy set theory presented by Zadeh [35] has been found extensive applications in various fields. In 1976, Zimmermann [36] first introduced fuzzy sets into an ordinary LP problem with fuzzy objective and constraints. Following the

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fuzzy decision-making concept proposed by Bellman and Zadeh [2], that study confirmed the existence of an equivalent ordinary LP form. Subsequently, Zimmermann's fuzzy linear programming (FLP) has developed into several fuzzy optimization methods for solving DPD problems in fuzzy environments. Chanas et al. [6] presented an FLP model for solving transportation problems with crisp cost coefficients and fuzzy supply and demand values. Moreover, Chanas and Kuchta [7] proposed the concept of the optimal solution of the transportation problem with fuzzy coefficients expressed as L–R fuzzy numbers, and developed an algorithm for obtaining the optimal solution. Additionally, Chanas and Kuchta [8] designed an algorithm for solving the integer fuzzy transportation problem with fuzzy supply and demand volumes in the sense of maximizing the joint satisfaction of the fuzzy goal and constraints. Jimenez and Verdegay [20] developed a parametric approach for obtaining an auxiliary parametric solid transportation problem (PSTP) related to the original problem. An evolutionary algorithm was applied to find a good fuzzy solution to the PSTP. Related studies on the use of fuzzy programming method to solve fuzzy DPD problems included Bit et al. [3], Chanas et al. [5], Jimenez and Verdegay [18,19], and Tzeng et al. [32].

In practical TPD problems, however, the decision maker (DM) frequently handles conflicting objectives that govern the use of the constrained resources within organizations. Particularly, the DM must simultaneously optimize these conflicting objectives in a framework of fuzzy aspiration levels. For instance, these objectives are minimizing total distribution/transportation costs, number of rejected items and delivery time/distance, and/or maximizing total profits, relative safety and customer service level [1,10,17,24,26]. In 1978, Zimmermann [37] first extended his FLP method [36] to a multi-objective linear programming (MOLP) problem with linear membership functions to represent fuzzy objectives. For each of the objective functions in this MOLP problem, the DM was assumed to have fuzzy objective, such as "the objective function should be substantially less than and/or equal to some values''. Related studies on fuzzy goals programming (FGP) included Chen and Tsai [9], Dubois et al. [13], Hannan [15], Kuwano [21], Leberling [23], Luhandjula [25] and Sakawa [27].

Additionally, researchers have developed several FGP methods to solve multi-objective DPD problems. Bit et al. [4] proposed an additive fuzzy programming model that considered weights and priorities for all non- equivalent objectives for the transportation planning problem. Li and Lai [24] presented a fuzzy compromise programming method to obtain a non-dominated compromise solution for multi-objective transportation decision problems in which various objectives were synthetically considered with the marginal evaluation for individual objectives and the global evaluation for all objectives functions. Moreover, Abd El-Washed [1] designed a fuzzy programming approach to determine the optimal compromise solution of a multi-objective DPD problem by measuring the degree of closeness of the compromise solution to the ideal solution using a family of distance functions. Related studies on solving DPD problems with fuzzy multiple objectives included Das et al. [11] Hussein [16], and Verma et al. [33].

This work develops an interactive fuzzy multi-objective linear programming (i-FMOLP) method for solving the fuzzy multi-objective transportation problems with piecewise linear membership function. The proposed i-FMOLP method aims to simultaneously minimize the total distribution costs and the total delivery time with reference to fuzzy available supply and total budget at each source, and fuzzy forecast demand and maximum warehouse space at each destination. The remainder of this work is organized as follows. Section 2 describes the problem, details the assumptions and formulates the original fuzzy multi-objective DPD problem. Section 3 then develops the interactive i-FMOLP method for solving the fuzzy multi-objective DPD problem. Subsequently, Section 4 presents an industrial case for implementing the feasibility of applying the proposed model to real DPD problems. Next, Section 5 discusses the significant findings for the practical application of the proposed model. Finally, conclusions are drawn in Section 6.

2. Problem formulation

2.1. Problem description, assumptions and notation

The fuzzy multi-objective DPD problem examined here can be described as follows. Assume that the logistics center in a company seeks to determine the right transportation plan for allocating a homogeneous commodity from m sources (factories) to n destinations (distribution centers). Each source has a total available supply of the commodity to distribute to various destinations, and each destination has a forecast demand of the commodity to be received from various sources. The total available supply for each source and the forecast demand for each destination are often fuzzy due to incomplete and/or unavailable information over the planning horizon. This work focuses on developing