Computers & Industrial Engineering 72 (2014) 160–168

Contents lists available at ScienceDirect

Computers & Industrial Engineering

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

Fuzzy stochastic solid transportation problem using fuzzy goal programming approach ☆

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ARTICLE INFO

Article history:
Received 11 June 2012
Received in revised form 31 December 2013
Accepted 3 March 2014
Available online 15 March 2014

Keywords:
FCFSSTP
FGP
Additive FGP
Fuzzy weighted additive FGP

ABSTRACT

A fixed charge fuzzy stochastic solid transportation problem (FCFSSTP) is formulated with random budget and time constraints, random sources, demands and capacities of conveyances. Fuzzy stochastic constraints involving the symbols '$\tilde{\geqslant}$' (approximately or fuzzily greater than or equal to) and '$\tilde{\leqslant}$' (approximately or fuzzily less than or equal to) are used and appropriately transformed to deterministic ones. Fuzzy goal programming (FGP) approach is applied to solve the said FCFSSTP under several constraints. This paper also presents additive FGP models for the FCFSSTP. This method aggregates the membership functions of the stochastic constraints with the help of crisp and fuzzy weights based on importance of the objectives to construct the relevant decision function. From this general formulation, different particular models can be derived. As an example, one particular model with two fuzzy-stochastic constraints has been formulated. Moreover, as a particular case, three dimensional representation of an existing model is also presented. Transformed deterministic models are derived and solved by a gradient based non-linear optimization method-Generalized Reduced Gradient (GRG) technique. Two dimensional (with single conveyance) representation of a proposed FCFSSTP is derived and solved numerically. The optimum results of this model are compared with the solid transportation model. The suggested models and approaches are illustrated by a real-life practical problem.

1. Introduction

There are many production systems with transportation operations where raw materials of the company are transported from origins (source) to destinations (demand) by different types of conveyances like trucks, cargo flights, goods trains etc. This type of transportation problem known as STP is the generalization of traditional transportation problem (TP). Though most of the real life TP belongs to STP, initial impetus in this direction was made by Haley (1962). After that extensive research works have been made on STP incorporating different real life phenomena.

Uncertainty in TPs is a well established phenomena. In fact uncertainty exists everywhere in practical problems. It can be mainly classified in two senses-stochastic and fuzzy. Several researchers considered TP in stochastic (Chalam, 1994; Cooper, 1978) and fuzzy (Kaur and Kumar, 2012; Keshavarz and Khorram, 2011; Liu and Kao, 2004; Saad and Abbas, 2003) environments. Study on STP in uncertain environment started during last two decades. A STP with one or more random or fuzzy parameters is defined as a stochastic or fuzzy solid transportation problem (SSTP) or FSTP respectively. Yang and Feng (2007) solved a bicriteria STP in stochastic environment. Ojha et al. (2010a) considered a stochastic discounted multi-objective STP for breakable items using analytic hierarchy process. Bit et al. (1993) presented a fuzzy programming model for a multi-objective STP. Jimenez and Verdegay (1996) developed an evolutionary algorithm based on parametric approach to solve fuzzy STP. Jimenez and Verdegay (1998) studied two kinds of demands and conveyance capacities, which were interval numbers and fuzzy numbers respectively. Gen et al. (1995) presented a genetic algorithm for solving bi-criteria FSTP. Li et al. (1997a) presented an improved genetic algorithm to solve multi-objective STP with fuzzy numbers. Kundu et al. (2013)solved multi-objective multi-item solid transportation problem in fuzzy environment.

Liu (2006) developed a STP in fuzzy environment where total fuzzy transportation cost is optimized. Ojha et al. (2010b) developed a STP for an item with fixed charge, vehicle cost and price discounted varying charge using genetic algorithm. Tao et al. (2012)

☆ This manuscript was processed by Area Editor Iris F.A. Vis.

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http://dx.doi.org/10.1016/j.cie.2014.03.001
0360-8352/

used rough multiple objective programming for solving a STP, where total transportation cost and time are minimized. Kundu et al. (2014) presented type-2 fuzzy variables for solving fixed charge transportation problem where total transportation cost is minimized. Ojha et al. (2014) used fuzzy-stochastic cost for solving a transportation problem.

On the other hand fixed charge TP was initiated by Hirsch and Dantzig (1968). Up to now, it has been widely applied in many decision-making and optimization problems (Gottlieb and Paulmann, 1998; Kennington and Unger, 1976; Robers et al., 1976, Sun et al., 1998; Yang and Liu, 2007) developed fuzzy fixed charge STP and developed algorithms to solve the problem using possibility and credibility measure on fuzzy sets.

Goal programming (GP) is one of the most powerful, multi-objective decision making approaches in practical decision making problems. Aenaida and Kwak (1994) have applied goal programming to find a satisfactory solution for a multi-objective transportation problem (MOTP). Fuzzy goal programming (FGP) problem has also been addressed using various methods such as probability distribution, penalty function, fuzzy numbers, preemptive FGP, interpolated membership function and the weighted additive programming. Narasimhan (1980) presented the initial FGP model and solution procedure. Hannan (1982) introduced interpolated membership functions (i.e. piecewise linear membership functions) into the FGP model and then the FGP model was solved using linear programming method. GP in fuzzy environment was further developed by Ignizio (1982), Tiwari et al. (1987), Mohamed (1992) and other researchers. Weighted and fuzzy weighted additive FGP were developed by Lin (2004) and Iskander (2004).

In spite of the above investigations, there are some gaps in the formulation and analysis of FCFSSTP, which are summarized below.

- Though there are some articles on fuzzy-random TPs, till now, none has formulated and solved FCFSSTP with random objective goal expressed as fuzzy constraints.
- FGP technique with its different approaches is one of the powerful methods to solve the decision making problems with fuzzy goal. Till now, no FCFSSTP has been solved by the different approaches of FGP.
- The fuzzy stochastic constraint involving '$\tilde{\geqslant}$' or '$\tilde{\leqslant}$' is not used in FCFSSTP and appropriately is not defuzzified and derandomized.
- None has formulated a real-life practical problem as a FCFSSTP model and the solved by FGP.

In this paper, considering all these lacunas, FCFSSTPs are formulated and discussed in fuzzy random environment. Here transportation costs are two types, one is direct cost and another fixed charge. Total transported cost goal, total time goal, sources, demands and capacities of conveyances are taken as random parameters and expressed as fuzzy constraints. Here, in the constraints, the symbols '$\tilde{\geqslant}$' (approximately or fuzzily greater than or equal to) and '$\tilde{\leqslant}$' (approximately or fuzzily less than or equal to) are introduced. To transform the FCFSSTP into the corresponding deterministic one, this paper presents a derandomization method following Chalam (1994) along with four defuzzification methods such as FGP, additive FGP, crisp and fuzzy weighted FGP. From this general formulation, different particular models can be derived. As an example, one particular model with random total time and demands has been formulated. Moreover, as a particular case three dimensional representation of an existing model (cf. Chalam, 1994) is also presented. Transformed deterministic models are derived and solved using a gradient based non-linear optimization method-Generalised Reduced Gardient (GRG) technique. The suggested models and approaches are illustrated by a real-life practical problem. Two dimensional (with single conveyance) representation of a proposed FCFSSTP is also derived and solved.

Rest of the paper is organized as follows. Section 1 gives the literature survey and gist of the proposed models. In Section 2, assumptions and notations of the proposed FCFSSTP models are listed. In Section 3, mathematical formulation of FCFSSTP models are presented. Multi-objective problems are transformed to single-objective problems in Section 4. Particular models are derived and discussed in Section 5. Numerical illustration and a real life practical problem are provided in Section 6. Section 7 gives a brief discussion and practical uses of the models. Finally a conclusion is drawn in Section 8.

2. Assumptions and notations

A FCFSSTP is considered with two types of costs; the direct costs and fixed charges. The direct cost is the cost with respect to transportation of per unit amount. The fixed charge arises for the transportation activity between a source and a destination by a conveyance. In order to construct the mathematical model for the unbalanced FCFSSTPs, the following notations are introduced:

M	Number of origins/sources of the transportation problem.
N	Number of destinations/demands of the transportation problem.
K	Number of conveyances i.e. different modes of transporting units from sources to destinations.
A_i	Amount of homogeneous product available at the i-th origin.
B_j	Demand at the j-th destination.
E_k	Amount of the product which is carried by k-th conveyance.
C_{ijk}	per unit transportation cost for transporting one unit from i-th origin to j-th destination by k-th conveyance.
t_{ijk}	Transportation time for transporting one unit from i-th origin to j-th destination by k-th conveyance.
f_{ijk}	Fixed transportation charge for selecting the path from i-th origin to j-th destination by k-th conveyance.
x_{ijk}	The amount transported from i-th origin to j-th destination by k-th conveyance.
T	Total transported time goal.
R	Total transported cost goal.

m_x, σ_x^2 represents mean and variance of a random variable $\hat{x}$.
Symbols$\hat{}$ are used with the above notations to represent corresponding random parameters.

The fixed charge will be paid if the transportation activity is assigned from source i to destination j by conveyance k. In view of this fact, we should add the fixed charge to the total transportation cost if $x_{ijk} > 0$. Thus for the convenience of constructing mathematical model, we introduce the variable.

$$y(x_{ijk}) = \begin{cases} 1 & \text{for } x_{ijk} > 0 \\ 0 & \text{otherwise} \end{cases}$$

3. Formulation of FCFSSTP with total cost and total time constraint

As goals for total transportation cost and time are given by R and T respectively, So the crisp fixed charge STP is to find the optimum values of x_{ijk} such that