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FUZZY PROGRAMMING FOR MULTI-CHOICE BILEVEL TRANSPORTATION PROBLEM

RITU ARORA[1*], KAVITA GUPTA[2]

[1]Department of Mathematics, Keshav Mahavidyalaya, University of Delhi, H-4-5 Zone, Pitampura Near Sainik Vihar, Delhi 110034, India

[2]Department of Mathematics, Kirori Mal College, University of Delhi, Delhi 110007, India

Multi-choice programming problems arise due to the diverse needs of people. In this paper, multi-choice optimization has been applied to the bilevel transportation problem. This problem deals with transportation at both the levels, upper as well as lower. There are multiple choices for demand and supply parameters. The multi-choice parameters at the respective levels are converted into polynomials which transmute the defined problem into a mixed integer programming problem. The objective of the paper is to determine a solution methodology for the transformed problem. The significance of the formulated model is exhibited through an example by applying it to the hotel industry. The fuzzy programming approach is employed to obtain a satisfactory solution for the decision-makers at the two levels. A comparative analysis is presented in the paper by solving the bilevel multi-choice transportation problem with goal programming mode as well as by the linear transformation technique. The example is solved using computing software.

Keywords: *bilevel programming, transportation problem, fuzzy programming, goal programming, tolerance limits, satisfactory solution*

1. Introduction

An individual has several options to travel from one place (origin) to another (destination) through diverse routes, using alternate modes of transportation. Similarly, options also exist for the transportation of goods and materials. The advancement in transportation and logistics has evolved with technology. Different techniques and issues related to transportation problems have been taken up by various authors. Jacobs and Greaves [10] studied the transportation issues in developing and emerging nations. Ji and Chu [13] proposed the dual matrix approach to solve the transportation problem.

[*]Corresponding author, email address: ritu.arora@keshav.du.ac.in
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Scott et al. [27] discussed the requirement of public transport in metropolitan cities. Mardani et al. [22] reviewed multiple criteria decision-making techniques in transportation systems. Speranza [29] considered the history and future trends in the area of transportation. Transport is also a source of income as it is used to carry people and raw materials from one place to another. Bastiaanssen et al. [3] discussed the relationship between employment and transport.

The concept of fuzzy mathematical programming and multi-objective programming has been implemented by researchers to solve the transportation problem. Kaur and Kumar [14] represented transportation cost, availability and demand of the product as generalised trapezoidal fuzzy numbers and proposed a new method for solving it. Kaur et al. [15] solved multi-objective multi-index real-life transportation problem by an exponential membership function. Singh et al. [28] studied multi-objective transportation problems and applied a goal programming approach to obtain fuzzy efficient solutions for them. Goswami et al. [8] applied fuzzy programming to a multi-objective transportation problem with varied costs. Abounacer et al. [1] proposed an epsilon-constraint method to three objective programming problem which generates Pareto front. Liang [18] used interactive fuzzy linear programming to solve multi-objective transportation problems. Kumar et al. [17] solved the transportation problem using Pythagorean fuzzy numbers. Pratihar et al. [25] solved the fuzzy transportation problem by a modified Vogel's approximation method.

It is observed from the above that researchers used a multi-objective approach to formulate the transportation problem. However, bilevel programming is another tool to solve them. Bilevel programming problem (BLPP) plays an important role in the field of transportation. BLPP is a hierarchical programming problem that moves sequentially from the upper level to the lower level problem. The bilevel problem in which transportation is defined at both levels is called the bilevel transportation problem. Various researchers used bilevel programming to model transportation problems and proposed methodologies for solving them. Clegg et al. [6] applied the bilevel model to optimise urban transportation. Msigwa et al. [24] formulated a bilevel model for solving transportation problems concerning both road toll pricing and capacity expansions. Zhang and Gao [30] formulated the transportation network design problem as a mixed-integer non-linear bilevel programming problem and solved it. Liu and Zhang [19] solved the bilevel transportation problem by the exact penalty method. Du et al. [7] applied fuzzy bilevel programming to a multi-depot vehicle routing problem for solving the multi-objective multi-item solid transportation problem. Midya et al. [23] employed intuitionistic fuzzy programming to solve multi-stage multi-objective fixed charge solid transportation problems.

Multi-choice optimisation has been studied by various authors due to its relevance in day-to-day life. It can be seen in a wide range of problems like production planning, assignment problem, inventory transportation, knapsack problem, logistic distribution, etc. Researchers have considered multi-choice optimisation for modelling multi-objective programming problems in the transportation industry. Ho et al. [9] dealt with the problem