Computers and Electrical Engineering 000 (2018) 1–15

Contents lists available at ScienceDirect

Computers and Electrical Engineering

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

A multi-objective transportation model under neutrosophic environment☆

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ARTICLE INFO

Article history:
Received 23 November 2017
Revised 15 February 2018
Accepted 16 February 2018
Available online xxx

Keywords:
Neutrosophic set
TOPSIS
Transportation problem
Multi-objective
Compromise solution
Zimmermann's fuzzy programming

ABSTRACT

In this paper, a new compromise algorithm for multi-objective transportation problem (MO-TP) is developed, which is inspired by Zimmermann's fuzzy programming and the neutrosophic set terminology. The proposed NCPA is characterized by assigning three membership functions for each objective namely, truth membership, indeterminacy membership and falsity membership. With the membership functions for all objectives, a neutrosophic compromise programming model is constructed with the aim to find best compromise solution (BCS). This model can cover a wide spectrum of BCSs by controlling the membership functions interactively. The performance of the NCPA is validated by measuring the ranking degree using TOPSIS approach. Illustrative examples are reported and compared with exists models in the literature. Based on the provided comparisons, NCPA is superior to fuzzy and different approaches.

1. Introduction

Despite the enormous efforts to build an intelligent transportation model, the complex working environment of the recent real-life applications, i.e., Smart Cities applications [1] makes building such systems a big challenge. Thus, a Transportation Model is an urgent need to solve the Transportation Problem (TP) that aims to transport the goods from several supply points to different demand points through considering the minimization of the total transportation costs. TP model has a wide range of practical applications includes logistic systems, the supply chain management, manpower planning, inventory control, the production planning, etc. However, in reality, TP is characterized by multiple, incommensurable, and conflicting objective functions, being called the multi-objective transportation problem (MO-TP). Thus, in multi-objective transportation problem (MO-TP), the concept of optimal solution gives place to the concept of best compromise solution or the non-dominated solutions. Many studies have been investigated on MO-TPs. Aneja and Nair [2] developed a new approach to solve bi-criteria TP. Isermann [3] proposed a method to identify the set of non-dominated solutions for a MO-TP. In [4], Ringuest and Rinks were presented two interactive approaches to find the solution of the MO-TP.

In general, multi-objective transportation problems (MO-TPs) are solved with the assumptions that the cost parameters, sources, and destinations are specified in a precise way, i.e., in a crisp environment. Nevertheless, when handling real-life

☆ Reviews processed and recommended for publication to the Editor-in-Chief by Guest Editor Dr. S. H. Ahmed.

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https://doi.org/10.1016/j.compeleceng.2018.02.024

Nomenclature

m	number of sources
n	number of destinations
K	number of objective functions
s_i	label of the ith source
d_j	label of the ith decision variable destinations
c_{ij}^k	the penalty of transportation from s_i to d_j on the kth objective
Z^k	kth element of objective function vector
$\mathbf{Z}$	objective function vector
x_{ij}	denotes the quantity transported from s_i to d_j
Ω	the feasible set of solutions
E	the efficient set of solutions
$\mathbf{Z}_0^+$	ideal objective function vector
$\mathbf{Z}_*^-$	anti-ideal objective function vector
Y	space of points (objects)
S	neutrosophic set
T_S	truth membership
I_S	indeterminacy membership
F_S	falsity membership
t_k,s_k	predetermined real numbers in (0,1)
L_k	lower bound of the kth objective
U_k	upper bound of the kth objective
C	fuzzy constraints
G	fuzzy goal
D	fuzzy decision
α, β, γ	auxiliary parameters
FST	fuzzy set theory
FA	fuzzy approach
TP	transportation problem
BCS	best compromise solution
NCPA	neutrosophic compromise programming approach
MO-TP	multi-objective transportation problem

transportation models, the circumstances of imprecision in the description of the problem's parameters may appeared. Thus the conflict and imprecise parameters nature of the MO-TP make the mathematical formulation of the problem difficult to solve by conventional methods. To overcome this difficulty, fuzzy set theory (FST) was developed by Zadeh [5] to deal with impreciseness and uncertainties in the candidate data. A fuzzy set was defined as a set of elements where each element has some degree or grade of belongingness between 0 and 1 and such degrees determine the membership value of an element in that set. Since the new concepts by Bellman and Zadeh have been introduced [6], several inventions have been developed based on FST to solve different types of transportation problems under imprecise aspects [7–14]. In some large-scale applications, stochastic algorithms [15,16] are employed to find a near-optimal solution. In this context, some approaches based on genetic algorithm are employed to solve MO-TP [17,18].

Although FST is very useful when dealing with uncertainties, it cannot handle certain cases of uncertainties where it is hard to depict the membership degree using one specific value. To overcome the lack of knowledge of non-membership degrees, intuitionistic fuzzy set (IFS) was proposed in 1986 by Atanassov [19] as an extension of FST. In IFS, each element in a set is attached with two grades, membership grade and non-membership grade, where the sum of these two grades is restricted to less or equal to one. Thus, the grade of non-belongingness for a certain element is equal to 1 minus the grade of belongingness. The IFS has been flourished in applications of decision making [20]. Additionally, many authors have been employed IFS for solving different types of transportation problems [21,22]. Although the development of FST and IFS, dealing with all sorts of uncertainty in different areas still lack for a general framework, where the indeterminate knowledge cannot be managed. For example, let we ask the opinion of an expert regarding a particular statement, one may say that the possibility in which the statement is true is 0.6, the statement is false is 0.5 and the statement is not sure is 0.2. This issue is beyond the scope of FST and IFS and therefore dealing with a type of indeterminate situations of uncertain data undoubtedly becomes a true challenge.

Recently, a generalized form of FST and IFS is the neutrosophic set that was studied by Smarandache [23]. It provides a more general structure and very suitable form to overcome the mentioned issues. The term neutrosophy means the knowledge of neutral thought and this neutral represents the primary distinction between fuzzy and intuitionistic fuzzy logic. The neutrosophic set is established based on logic in which elements of the universe is presented by three degrees. Namely,