SOLUTION OF FULLY Z-TRANSPORTATION PROBLEMS

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Abstract

In this paper, we present an innovative approach to solving the transportation problem with fully Z-number parameters (FZTP). First, we convert the FZTP to an FFTP with a certain reliability. Then the FFTP problem can be tackled by using additive inverse methods. This approach ensures that information regarding reliability is not lost.

Keywords: Z-number, triangular Z-number, trapezoidal Z-number, fuzzy transportation problem, Z- transportations problem.

1. Introduction

The concept of fuzzy sets was introduced by Zadeh [20] in 1965, and it dealt with imprecision and vagueness in real-world situations. A lot of fuzzy transportation problems were investigated by Chiang Kao [5], Chanas et al. [3], Chanas and Kutcha [4], Kaur and Kumar [6,7], Lin [9], Chandran and Kandaswamy [2], Liu and Kao [10], and Li et al. [8]. The Fully Fuzzy Transportation Problem have been investigated by Uma Maheshwari and Ganesan [19], Ambadas Deshmukh et al. [1], Pandian and Natarajan [14], Shanmugasundari & Ganesan [17], Muruganandam and Srinivasan [12], Mohanaselvi and Ganesan [11], Nagoor Gani and others [13].
In our previous paper, we proposed a new approach to solving ZTP [15] and a new approach for solving transportation problem with Z-number parameters [16]. In this paper, we give an innovative approach to solving the TP with fully Z-number parameters (FZTP). FZTP can be considered as a generalisation of fully fuzzy transportation problem. We convert the fully Z-transportation problem (FZTP) to a fully fuzzy transportation problem (FFTP) with a certain reliability. Then by solving the FFTP problem the solution to FZTP is obtained.. The proposed method utilizes R-type operations introduced by Stephen [18].

2. Preliminaries

Definition 2.1 Fuzzy set

A fuzzy set in X is defined as a set of ordered pairs A=$\{(x, \mu_A(x)) | x \in X\}$, where $\mu_A(x)$ is referred to as the membership function for the fuzzy set. If X is a group of objects represented by the generic symbol X, then X is the definition of a fuzzy set A in X. Each element of X is assigned a membership value between 0 and 1 using the membership function.

Definition 2.2 Triangular fuzzy number

A fuzzy number A= (a_1, a_2, a_3) is defined as a triangular fuzzy number only if the membership function of this is represented as:

$$\mu_A(\text{x})=\begin{cases} \frac{x-a_1}{a_2-a_1} & a_1 \leq x \leq a_2 \\ \frac{a_3-x}{a_3-a_2} & a_2 \leq x \leq a_3 \\ 0 & x \geq a_3 \end{cases}$$

Definition 2.3 Arithmetic operations on triangular fuzzy number

Let A= (a_1, a_2, a_3) and $B = (b_1, b_2, b_3)$ be any two triangular fuzzy numbers. Then

(i) $(a_1, a_2, a_3) + (b_1, b_2, b_3) = (a_1 + b_1, a_2 + b_2, a_3 + b_3)$

(ii) $(a_1, a_2, a_3) - (b_1, b_2, b_3) = (a_1 - b_3, a_2 - b_2, a_3 - b_1)$

(iii) $(a_1, a_2, a_3) \cdot (b_1, b_2, b_3) = (a_1 \cdot b_1, a_2 \cdot b_2, a_3 \cdot b_3)$

Definition 2.4 Additive inverse operation on triangular fuzzy numbers
Let A= (a_1, a_2, a_3) and $B = (b_1, b_2, b_3)$ be any two triangular fuzzy numbers. We denote this operation by I_+.

$$(a_1, a_2, a_3)\ \mathrm{I}_+\ (b_1, b_2, b_3) = (a_1 - b_1, a_2 - b_2, a_3 - b_3)$$

Definition 2.5 Trapezoidal fuzzy number
A fuzzy number A= (a_1, a_2, a_3, a_4) is a trapezoidal fuzzy number if its membership function is given by

$$\mu_A(\mathrm{x}) = \begin{cases} \frac{x-a_1}{a_2-a_1} & a_1 \le x \le a_2 \\ 1 & a_2 \le x \le a_3 \\ \frac{x-a_4}{a_3-a_4} & a_3 \le x \le a_4 \\ 0 & x \ge a_4 \end{cases}$$

Definition 2.6 Arithmetic operations on trapezoidal fuzzy number
Let A= (a_1, a_2, a_3, a_4) and $B = (b_1, b_2, b_3, b_4)$ be any two triangular fuzzy numbers. Then

(i) $(a_1, a_2, a_3, a_4) + (b_1, b_2, b_3, b_4) = (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4)$

(ii) $(a_1, a_2, a_3, a_4) - (b_1, b_2, b_3, b_4) = (a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1)$

(iii) $(a_1, a_2, a_3, a_4) \cdot (b_1, b_2, b_3, b_4) = (a_1 \cdot b_1, a_2 \cdot b_2, a_3 \cdot b_3, a_4 \cdot b_4)$

Definition 2.7 Additive inverse operation on trapezoidal fuzzy numbers
Let A= (a_1, a_2, a_3, a_4) and $B = (b_1, b_2, b_3, b_4)$ be any two trapezoidal fuzzy numbers. We denote this operation by I_+.

$$(a_1, a_2, a_3, a_4)\ \mathrm{I}_+\ (b_1, b_2, b_3, b_4) = (a_1 - b_1, a_2 - b_2, a_3 - b_3, a_4 - b_4)$$

Definition 2.8 Zadeh's definition of z-number
A Z-number is an ordered pair of fuzzy numbers Z=(A,B), associated with the uncertain real-valued variable X, with the first component A, a restriction on the possible values for X, as well as the second component B, a measure of the first component's reliability.

Definition 2.9 Triangular Z-number
In the Z-number Z= (A, B), if both components A and B are triangular fuzzy numbers, then the corresponding Z-number is called a Triangular Z-number.

Definition 2.10 Trapezoidal Z-number
In the Z-number Z= (A, B), if the two component A and B are trapezoidal fuzzy numbers, then the corresponding Z-number is called a Trapezoidal Z-number.

Definition 2.11 MIN R Type operation
Let $* \epsilon \{+, -, \times, /\}$, the MIN R operation on the set of all continuous Z-number is defined to be

(A, B)($*$, MIN)(C, D)= (A$*$C, MIN (B, D)), where the extension principle is used to calculate A$*$C and MIN (B, D) = B if $R_k(B) < R_k(D)$ and D if $R_k(D) < R_k(B)$

Definition 2.12 Sum of two Triangular Z-numbers by MIN R
Let Z_1= (A_1, B_1) & Z_2= (A_2, B_2) be any two Triangular Z-numbers, then $Z_1(+, MIN)Z_2 = (\mathrm{A}_1, \mathrm{B}_1)(+, \mathrm{MIN})(\mathrm{A}_2, \mathrm{B}_2) = (A_1 + A_2, MIN(B_1, B_2))$

Definition 2.13 Product R Type operation
Let $* \epsilon \{+, -, \times, /\}$, the Product R operation on the set of all continuous Z-number is defined to be (A, B) ($*, \cdot$) (C, D)= (A$*$C, B $\cdot$ D), where A$*$C and B $\cdot$ D are calculated using extension principle

Definition 2.14 Sum of two Triangular Z-numbers by Product R
Let Z_1= (A_1, B_1) & Z_2= (A_2, B_2) be any two Triangular Z-numbers, then $Z_1(+,\cdot)Z_2 = (A_1,B_1)(+,\cdot)(A_2,B_2) = (A_1 + A_2, B_1 \cdot B_2)$

3. Fully Z-Transportation Problem (FZTP):

Here we will consider Fully Z-Transportation Problem (FZTP)- a transportation problem where the costs, supply, and demand are Z-numbers.

The FZTP can be mathematically formulated as follows

Minimize $Y=\sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}x_{ij}$, i=1,2,...,m j=1,2,...,n

Subject to

$\sum_{j=1}^{n} x_{ij} = a_i$, i=1,2,...,m

$\sum_{i=1}^{m} x_{ij} = b_j$, j=1, 2, ...,n

and x_{ij} are fuzzy numbers with support in $[0,\infty]$

where $c_{ij} = (c_{ij1}, c_{ij2})$, $a_i = (a_{i1}, a_{i2})$ and $b_j = (b_{j1}, b_{j2})$ are all Z-numbers.

The given Z-Transportation Problem is said to be balanced if

$$\sum_{i=1}^{m} a_{i1} = \sum_{j=1}^{n} b_{j1}$$

i.e., if the total supply equal to the total demand.

3.1 Converting FZTP to FFTP

In this section, a novel approach to solving the Fully Z-Transportation problem is suggested.

Let us discuss two distinct cases related to the FZTP.

Case (i):

Here the summation is interpreted as a $(i_+, \min)$ operation.

Consider the FZTP

	D_1	D_2	⋯	D_n	Supply
S_1	(c_{11}, c'_{11})	(c_{12}, c'_{12})	⋯	(c_{1n}, c'_{1n})	(a_1, a'_1)
S_2	(c_{21}, c'_{21})	(c_{22}, c'_{22})	⋯	(c_{2n}, c'_{2n})	(a_2, a'_2)
⋮	⋮	⋮	⋮	⋮	⋮
S_m	(c_{m1}, c'_{m1})	(c_{m2}, c'_{m2})	⋯	(c_{mn}, c'_{mn})	(a_m, a'_m)
Demand	(b_1, b'_1)	(b_2, b'_2)	⋯	(b_n, b'_n)	

The above FZTP is converted into the following FFTP

	D_1	D_2	⋯	D_n	Supply
S_1	c_{11}	c_{12}	⋯	c_{1n}	a_1
S_2	c_{21}	c_{22}	⋯	c_{2n}	a_2
⋮	⋮	⋮	⋮	⋮	⋮
S_m	c_{m1}	c_{m2}	⋯	c_{mn}	a_m
Demand	b_1	b_2	⋯	b_n	

The reliability of this system is

Min $(c'_{11}, c'_{12}, \dots, c'_{1n}, c'_{21}, c'_{22}, \dots, c'_{2n}, \dots, c'_{m1}, c'_{m2}, \dots, c'_{mn}, a'_1, a'_2, \dots, a'_m, b'_1, b'_2, \dots, b'_n)$

Solving the FFTP:

Consider the case where $c_{11}, c_{12}, \dots, c_{1n}, c_{21}, c_{22}, \dots, c_{2n}, \dots, c_{m1}, c_{m2}, \dots, c_{mn}, a_1, a_2, \dots, a_m, b_1, b_2, \dots, b_n$ are all triangular fuzzy numbers.

Then the FFTP can be solved by the additive inverse operation.

Example 3.1:

Consider the fully ZTP, in which the cost matrix, supply, and demand are all triangular Z- numbers in the following table.

	D_1	D_2	D_3	Supply
A	(approx.16, sure)	(approx.20, Very sure)	(approx.12, sure)	(approx.200, completely sure)
B	(approx.14, very sure)	(approx.8, sure)	(approx.18, sure)	(approx.160, very sure)
C	(approx.26, completely sure)	(approx.24, very sure)	(approx.16, very sure)	(approx.90, sure)
Demand	(approx.180, very sure)	(approx.120 , sure)	(approx.150 , very sure)	

The linguistic terms can be converted to fuzzy terms in the following table:

	D_1	D_2	D_3	Supply
A	((15,16,17), (.75,.8,.85))	((19,20,21), (.85,.9,.95))	((11,12,13), (.75,.8,.85))	((190,200,210), (1,1,1))
B	((12,14,16), (.85,.9,.95))	((7,8,9), (.75,.8,.85))	((17,18,19), (.75,.8,.85))	((150,160,170), (.85,.9,.95))
C	((24,26,28), (1,1,1))	((23,24,25), (.85,.9,.95))	((15,16,17), (.85,.9,.95))	((85,90,95), (.75,.8,.85))
Demand	((175,180,185), (.75,.8,.85))	((110,120,130), (.75,.8,.85))	((140,150,160), (.85,.9,.95))	

Solution:

First, we convert the given FZTP into FFTP

	D_1	D_2	D_3	Supply
A	(15,16,17)	(19,20,21)	(11,12,13)	(190,200,210)
B	(12,14,16)	(7,8,9)	(17,18,19)	(150,160,170)
C	(24,26,28)	(23,24,25)	(15,16,17)	(85,90,95)
Demand	(175,180,185)	(110,120,130)	(140,150,160)	(425,450,475)

The reliability of this FFTP system is Min (very sure, sure, completely sure)

$$= \text{Min}((.85,.9,.95),(.75,.8,.85),(1,1,1))$$

$$= (.75,.8,.85) = \text{sure}$$

Since $\sum a_{i1} = \sum b_{j1} = (425,450,475)$, the problem is balanced FFTP. Hence, there exists a feasible solution.

The supply at A is (190,200,210) and the demand at D_1 is (175,180,185).

Since the demand is less than the supply. So we allot (175,180,185) to (A, D_1) cell.

Now after this allotment what is remaining origin at A?

Remaining supply at A= (190,200,210) I_+ (175,180,185)

$$= (190 - 175, 200 - 180, 210 - 185)$$

$$= (15,20,25)$$

Since this is less than the demand (110,120,130) at the destination D_2. This amount is allotted to (A, D_2) cell.

Now the total allotment from A=(175,180,185) + (15,20,25) = (190,200,210) = total supply at A

Proceeding like this, we get the following initial table by using the north-west corner method.

	D_1	D_2	D_3	Supply
A	(15,16,17) (175,180,185)	(19,20,21) (15,20,25)	(11,12,13)	~~(190,200,210)~~ ~~(15,20,25)~~
B	(12,14,16)	(7,8,9) (95,100,105)	(17,18,19) (55,60,65)	~~(150,160,170)~~ ~~(55,60,65)~~
C	(24,26,28)	(23,24,25)	(15,16,17) (85,90,95)	~~(85,90,95)~~
Demand	~~(175,180,185)~~	~~(110,120,130)~~ ~~(95,100,105)~~	~~(140,150,160)~~ ~~(85,90,95)~~	

Solving the FFTP, we get the following fuzzy optimal solution is

$x_{11} = (135,140,145)$; $x_{13} = (55,60,65)$; $x_{21} = (40,40,40)$; $x_{22} = (110,120,130)$;

$x_{33} = (85,90,95)$

The fully fuzzy transportation cost

$$= [(15,16,17) \times (135,140,145)] + [(11,12,13) \times (55,60,65)] + [(12,14,16) \times (40,40,40)]$$
$$+[(7,8,9) \times (110,120,130)] + [(15,16,17) \times (85,90,95)]$$
$$= [(2625,2880,3145) + (605,720,845) + (480,560,640) + (770,960,1170) +$$
$$(1275,1440,1615)]$$
$$= (5755,6560,7415)$$

The solution for the FZTP is $x_{11} = (135,140,145)$; $x_{13} = (55,60,65)$; $x_{21} = (40,40,40)$;

$x_{22} = (110,120,130)$; $x_{33} = (85,90,95)$

The Z-transportation cost $= ((5755, 6560, 7415), (.75, .8, .85))$

Case (ii)

Here the summation is interpreted as a $(+, \cdot)$ operation.

The reliability of this system is

Product $(c'_{11}, c'_{12}, \ldots, c'_{1n}, c'_{21}, c'_{22}, \ldots, c'_{2n}, \ldots, c'_{m1}, c'_{m2}, \ldots, c'_{mn}, a'_1, a'_2, \ldots, a'_m, b'_1, b'_2, \ldots, b'_n)$

Solving the FFTP:

FFTP can be solved as in Case (i).

Example 3.2:

Consider the ZTP in which the cost matrix, supply and demand are all trapezoidal fuzzy numbers in the following table.

	D_1	D_2	D_3	D_4	Supply
A	(approx.19, sure)	(approx.30, sure)	(approx.50, very sure)	(approx.. 10, almost sure)	(approx.7, sure)
B	(approx.70, sure)	(approx.30, very sure)	(approx.40, sure)	(approx.. 60, completely sure)	(approx.9, very sure)
C	(approx.40, very sure)	(approx.8, completely sure)	(approx.70, sure)	(approx.20, sure)	(approx.18, sure)
Demand	(approx.5, very sure)	(approx.8, sure)	(approx.7 , very sure)	(approx. 14, almost sure)	

The linguistic terms can be converted to fuzzy terms in the following table:

	D_1	D_2	D_3	D_4	Supply
A	((17,18,20,21), (.75,.8,.85,.9))	((28,29,31,32), (.75,.8,.85,.9))	((48,49,51,52), (.85,.9,.95,1))	((7,9,11,13), (.65,.7,.75,.8))	((1,4,10,13), (.75,.8,.85,.9))
B	((68,69,71,72), (.75,.8,.85,.9))	((26,29,31,34), (.85,.9,.95,1))	((38,39,41,42), (.75,.8,.85,.9))	((56,59,61,64), (1,1,1,1))	((2,6,12,16), (.85,.9,.95))
C	((36,39,41,44), (.85,.9,.95,1))	((5,7,9,11), (1,1,1,1))	((66,69,71,74), (.75,.8,.85,.9))	((17,19,21,23), (.75,.8,.85,.9))	((13,16,20,23), (.75,.8,.85,.9))
Demand	((1,3,7,9), (.85,.9,.95,1))	((2,5,11,14), (.75,.8,.85,.9))	((1,5,9,13), (.85,.9,.95,1))	((12,13,15,16), (.75,.8,.85,.9))	

Solution:

First, we convert the given FZTP into FFTP

	D_1	D_2	D_3	D_4	Supply
A	(17,18,20,21)	(28,29,31,32)	(48,49,51,52)	(7,9,11,13)	(1,4,10,13)
B	(68,69,71,72)	(26,29,31,34)	(38,39,41,42)	(56,59,61,64)	(2,6,12,16)
C	(36,39,41,44)	(5,7,9,11)	(66,69,71,74)	(17,19,21,23)	(13,16,20,23)
Demand	(1,3,7,9)	(2,5,11,14)	(1,5,9,13)	(12,13,15,16)	(16,26,42,52)

The reliability of this FTP system is Product (very sure, sure, completely sure, almost sure)

$$= ((.85,.9,.95,1) \cdot (.75,.8,.85,.9) \cdot (1,1,1,1), (.65,.7,.75,.8))$$

$$= (0.414375, 0.504, 0.605625, 0.72)$$

Since $\sum a_{i1} = \sum b_{j1} = (16,26,42,52)$, the problem is balanced FFTP. Hence, there exists a feasible solution.

The supply at A is (1,4,10,13) and the demand at D_1 is (1,3,7,9).

Since the demand is less than the supply. So we allot (1,3,7,9) to (A, D_1) cell.

Now after this allotment what is remaining origin at A?

Remaining supply at A= (1,4,10,13) I_+ (1,3,7,9)

$$= (1-1, 4-3, 10-7, 13-9)$$

$$= (0,1,3,4)$$

Since this is less than the demand (2,5,11,14) at the destination D_2. This amount is allotted to (A, D_2) cell.

Now the total allotment from A=(1,3,7,9) + (0,1,3,4) = (1,4,10,13) = total supply at A

Proceeding like this, we get the following initial table by using the north-west corner method.

	D_1	D_2	D_3	D_4	**Supply**
A	(17,18,20,21) **(1,3,7,9)**	(28,29,31,32) **(0,1,3,4)**	(48,49,51,52)	(7,9,11,13)	~~(1,4,10,13)~~ ~~(0,1,3,4)~~
B	(68,69,71,72)	(26,29,31,34) **(2,4,8,10)**	(38,39,41,42) **(0,2,4,6)**	(56,59,61,64)	~~(2,6,12,16)~~ ~~(0,2,4,6)~~
C	(36,39,41,44)	(5,7,9,11)	(66,69,71,74) **(1,3,5,7)**	(17,19,21,23) **(12,13,15,16)**	~~(13,16,20,23)~~ ~~(12,13,15,16)~~
Demand	~~(1,3,7,9)~~	(2,5,11,14)	(1,5,9,13)	(12,13,15,16)	

Solving the FFTP, we get the following fuzzy optimal solution is

$x_{11} = (1,3,7,9); x_{14} = (0,1,3,4); x_{22} = (1,1,3,3); x_{23} = (1,5,9,13); x_{32} = (1,4,8,11);$

$x_{34} = (12,12,12,12)$

The fuzzy transportation cost

$= (17,18,20,21) \times (1,3,7,9) + (7,9,11,13) \times (0,1,3,4) + (26,29,31,34) \times (1,1,3,3) + (38,39,41,42) \times (1,5,9,13) + (5,7,9,11) \times (1,4,8,11) + (17,19,21,23) \times (12,12,12,12)$

$= (17,54,140,189) + (0,9,33,52) + (26,29,93,102) + (38,195,369,546) + (5,28,72,121) + (204,228,252,276)$

$= (290,543,959,1286)$

The solution for the FZTP is $x_{11} = (1,3,7,9); x_{14} = (0,1,3,4); x_{22} = (1,1,3,3); x_{23} = (1,5,9,13);$

$x_{32} = (1,4,8,11); x_{34} = (12,12,12,12)$

The Z-transportation cost $= ((290, 543, 959, 1286),(0.414375, 0.504, 0.605625, 0.72))$

4. Conclusion

An innovative approach to solving FZTP by using additive inverse methods has been provided in this paper. Here we demonstrate approach using the numerical examples.

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