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A new LCM modification for finding an IBFS for fuzzy transportation problems

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***Abstract*---**In this research, we present a modified approach to "the least cost method" (LCM) of finding "the initial basic feasible solution" (IBFS) to the fuzzy transportation problem (FTP). The problem is in a foggy environment where the cost of transporting the product, the resources, and the demand in the destinations are fuzzy numbers. We solved the (FTP) by converting it to an equivalent crisp form using (a robust ranking technique). A numerical example is presented to demonstrate the suggested approach.

Keywords*---Trapezoidal fuzzy number, Triangular fuzzy number, Fuzzy transportation problems.*

Introduction

Classical transportation problems (TP) assume that the decision-maker is certain about the exact values of transportation cost, product availability, and demand. Inaccuracy and randomness are inevitable in real reality due to emergency and unforeseen circumstances. In the (FTP), the transport cost of units and the value of (supply) and (demand) are fuzzy numbers. The aim of the (FTP) is to find a transportation table that reduces total (FTP) costs while also meeting supply and requirement constraints. When solving (TP), problem data should be in crisp values. But in the labor market and modern life, the "supply and demand and unit transfer cost" may be unclear and accurate; the reason is due to many factors and problems, so the inaccuracy and uncertainty are represented by fuzzy numbers. In (Zadeh, 1965), proposed the fuzzy set concept. The notion of "the optimal solution (OS) for transportation with fuzzy coefficients" represented as fuzzy numbers was developed by Chanas D. (Chanas & Kuchta, 1996). Nagoor Gani and Edward Samuel (Gani, Samuel, & Anuradha, 2011) applied

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"Arshamkhan's Algorithm" to resolve the (FTP). The authors introduced many papers in several fields of sciences such as operation researchs (Hassan, 21-22 April 2021; Hassan & Muter, December 2017), and optimization (Dreeb, Hashim, Hashim, & Shiker, 5-6 December 2020; Dwail et al., 22-23 October 2020; K. H. Hashim, Hashim, k Dreeb, & Shiker, 5-6 December 2020;), but In this paper, we present a new approach (ST) to find the (IBFS) to the (FTP) by converting it to its equivalent crisp form using the (a robust ranking technique). We applied this technique to the triangular fuzzy number, Trapezoidal fuzzy number, hexagonal fuzzy number, octagonal fuzzy number, and nonagonal fuzzy numbers. With each new fuzzy number, we derive a new ordering function. Finally, the results of the proposed technique were compared with the (LCM) and (VAM), and the results were always less than the (LCM) and sometimes a few equal to (VAM) or the optimal solution (OS).

2 Preliminaries

Triangular fuzzy number

A fuzzy number $\check{A}(x) = (a, b, c)$ is said to be a triangular fuzzy number if its membership function $\mu_{\check{A}}(x)$ is

$$\mu_{\check{A}}(x) = \begin{cases} x - a/b - a & a \leq x \leq b \\ c - x/c - b & b \leq x \leq c \\ 0 & \text{otherwise} \end{cases}$$

Trapezoidal fuzzy number

A fuzzy number A ̌(x)=(a,b,c,d) is said to be a triangular fuzzy number if its membership function μ_A ̌ (x) is

$$\mu_{\check{A}}(x) = \begin{cases} x - a/b - a & a \leq x \leq b \\ One\ b \leq x \leq c & \\ d - x/d - c & c \leq x \leq d \\ 0 & \text{otherwise} \end{cases}$$

Robust's Ranking Techniques

Robust's ranking technique satisfies compensation, linearity, and additivity properties and provides results consisting of human intuition. If $\widetilde{a}$ is a fuzzy number, then the robust ranking is defined by:

$$R(\widetilde{a}) = \int_0^1 (0.5)(a_\alpha^L, a_\alpha^U) d\alpha,$$

where (a_α^L, a_α^U) is the α level cut of the fuzzy number $\widetilde{a}$. The Roubast ranking index $R(\widetilde{a})$ gives the representative value of the fuzzy number $\widetilde{a}$.

A NEW ALGORITHM TO FIND IBFS

Step1:

Build the transportation table depending on the given fuzzy transportation problem. Examination whether aggregate supply equals the aggregate demand; if not, the (FTP) must be balanced.

Step 2:

In the first row of the transportation table, choose the lowest cost cell minimum (c_{ij})

Step 3:

Allocate the uttermost possible units to this cell which is equivalent to the lower among ready offer and request requirements, i.e., for minimum (c_{ij}), $x_{ij} =$ minimum (S_i, D_j). At least one of these requirements will then be met.

Step 4:

Repeat steps 2,3 for all rows.

Step 5:

Calculate the total cost by using the following equation:

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

3 Numerical Examples

Example 1. Consider the following (FTP) with triangular fuzzy numbers (Christi, 2017):

Table 1
Schedule of (FTP)

Sources	D_1	D_2	D_3	D_4	Supply
S_1	(71,75,78)	(66,70,74)	(80,85,88)	(78,80,85)	(70,80,90)
S_2	(82,86,90)	(76,82,86)	(92,96,100)	(84,90,92)	(130,150,170)
S_3	(98,102,106)	(86,90,94)	(132,136,140)	(114,120,126)	(210,230,250)
S_4	(96,100,102)	(92,98,100)	(110,115,120)	(100,112,118)	(140,170,200)
Demand	(90,100,110)	(180,200,220)	(160,180,200)	(120,150,180)	

$$Min\ Z = R(71,75,78)x_{11} + R(66,70,74)x_{12} + R(80,85,88)x_{13} + R(78,80,85)x_{14}$$
$$+R(\ 82,86,90)x_{21} + R(76,82,86)x_{22} + R(92,96,100)x_{23} + R(84,90,92)x_{24}$$
$$+ R(\ 98,102,106)x_{31}$$

$+R(86,90,94)x_{32} + R(132,136,140)x_{33} + R(114,120,126)x_{34} + R(96,100,102)x_{41}$
$+R(92,98,100)x_{42} + R(110,115,120)\,x_{43} + R(100,112,118)x_{44}$

Using the robust ranking methodology

$R(\tilde{a}) = \int_0^1 (0.5)(a_\alpha^L, a_\alpha^U)d\alpha$, where $(a_\alpha^L, a_\alpha^U) = \{a + (b-a)\alpha, c + (b-c)\alpha\}$
$R(71,75,78) = 74.5, R(66,70,74) = 70, R\,(80,85,88) = 84.5, R\,(78,80,85) = 81.5$
$R(82,86,90) = 86, R\,(76,82,86) = 81, R\,(92,96,100) = 96, R\,(84,90,92) = 88$
$R(98,102,106) = 102, R\,(86,90,94) = 90, R(132,136,140) = 136, R(114,120,126) = 120$
$R(96,100,102) = 99, R\,(92,98,100) = 96, R(110,115,120) = 115, R(100,112,118) = 111.5$
Rank of all supply
$R(70,80,90) = 80, R(130,150,170) = 150, R(210,230,250) = 230, R\,(140,170,200) = 170$

Rank of all Demands

$R(90,100,110) = 100, R(180,200,220) = 200, R(160,180,200) = 180, R(120,150,180) = 150$

Table 2
Crisp form of the (FTP)

Sources	D_1	D_2	D_3	D_4	Supply
S_1	74.5	70	84.5	81.5	80
S_2	89	81	96	88	150
S_3	102	90	136	120	230
S_4	99	96	115	111.5	170
Demand	100	200	180	150	630

The above (TP) is balanced.

Using (ST) technique to obtain the (IBFS)

Table 3
Transportation cost using (ST)

Sources	D_1	D_2	D_3	D_4	Supply
S_1	74.5 ×	70 80	84.5 ×	81.5 ×	80
S_2	89 30	81 120	96 ×	88 ×	150
S_3	102 70	90 ×	136 10	120 150	230
S_4	99 ×	96 ×	115 170	111.5 ×	170
Demand	100	200	180	150	630

The minimum cost of the (IBFS) is:

$$Z = (80 \times 70) + (30 \times 86) + (120 \times 81) + (70 \times 102) + (10 \times 136) + (150 \times 120) + (170 \times 115)$$
$$= 63950\ units$$

Example 2. Consider the following (FTP) with trapezoidal fuzzy numbers (Bisht & Srivastava, 2020):

Table 4
Schedule of (FTP)

Sources	D_1	D_2	D_3	D_4	Supply
S_1	(1,2,3,4)	(1,2.67,4.33,6)	(4,6.67,9.33,12)	(5,7,9,11)	(1,4.67,8.33,12)
S_2	(0,1.33,2.64,4)	(1,2,3,4)	(5,6,7,8)	(0,1,2,3)	(0,1,2,3)
S_3	(3,4.67,6.33,8)	(5,7.33,9.67,12)	(12,14.33,16.67,19)	(7,8.67,10.33,12)	(5,8.53,12.07,15.6)
Demand	(5,6.67,8.33,10)	(1,4,7,10)	(1,2.67,4.33,6)	(1,2,3,4)	(1,4.67,8.33,12)

$Min\, Z = R(1,2,3,4)x_{11} + R(1,2.67,4.33,6)x_{12} + R(4,6.67,9.33,12)x_{13} + R(5,7,9,11)x_{14}$
$+R(0,1.33,2.64,4)x_{21} + R(1,2,3,4)x_{22} + R(5,6,7,8)x_{23} + R(0,1,2,3)x_{24} + R(3,4.67,6.33,8)x_{31}$
$+R(5,7.33,9.67,12)\, x_{32} + R(12,14.33,16.67,19)x_{33} + R(7,8.67,10.33,12)x_{34}$

Using the robust ranking methodology

$R(\tilde{a}) = \int_0^1 (0.5)(a_\alpha^L, a_\alpha^U)d\alpha,$ where $(a_\alpha^L, a_\alpha^U) = \{a + (b-a)\alpha, d + (c-d)\alpha\}$
$R(1,2,3,4) = 2.38, R\ (1,2.67,4.33,6) = 3.30, R(4,6.67,9.33,12) = 7.19, R(5,7,9,11) = 7.78$
$R(0,1.33,2.64,4) = 2.00, R(1,2,3,4)2.38, R(5,6,7,8) = 6.78, R(0,1,2,3) = 1.50$
$R(3,4.67,6.33,8) = 5.15, R(5,7.33,9.67,12) = 8.4, R(12,14.33,16.67,19) = 16.37$
$R(7,8.67,10.33,12) = 9.86$

Rank of all supply

$R(1,4.67,8.33,12) = 6.25, R(0,1,2,3) = 1.50, R(5,8.53,12.07,15.6) = 9.10$

Rank of all Demands

$R(5,6.67,8.33,10) = 7.50, R(1,4,7,10) = 5.26, R(1,2.67,4.33,6) = 3.30, R(1,2,3,4) = 2.38$

Table 5
Crisp form of the (FTP)

Sources	D_1	D_2	D_3	D_4	Supply
S_1	2.38	3.30	7.19	7.78	6.25
S_2	2.00	2.38	6.78	1.50	1.50
S_3	5.15	8.04	16.37	9.86	9.10
Demand	7.50	5.26	3.30	2.38	

The given (TP) is unbalanced. Now we convert it into balanced (TP)

Table 6
Balanced (TP)

Sources	D_1	D_2	D_3	D_4	Supply
S_1	2.38	3.30	7.19	7.78	6.25
S_2	2.00	2.38	6.78	1.50	1.50
S_3	5.15	8.04	16.37	9.86	9.10

S_4	0	0	0	0	1.59
Demand	7.50	5.26	3.30	2.38	

Table 7
Transportation cost using (ST)

Sources	D_1	D_2	D_3	D_4	Supply
S_1	2.38 6.25	3.30 ×	7.19 ×	7.78 ×	6.25
S_2	2.00 ×	2.38 ×	6.78 ×	1.50 1.50	1.50
S_3	5.15 1.25	8.04 5.26	16.37 2.59	9.86 ×	9.10
S_4	0 ×	0 ×	0 0.71	0 0.88	1.59
Demand	7.50	5.26	3.30	2.38	

The minimum cost of the (IBFS) is:

$$Z = (6.25 \times 2.38) + (1.50 \times 1.50) + (1.25 \times 5.15) + (5.26 \times 8.04) + (2.59 \times 16.37) = 108.2512\ units$$

4 Result Analysis

Table 8
Comparison of Methods

Name	LCM	ST
Ex 1.	66.460	63.950
Ex 2.	116.5724	108.2512

As shown in Table 8, the suggested approach (ST) produces better results than the classical algorithm (LCM), which in other situations is either optimal or near to optimal.

Conclusion

Various firms aspire to provide items to clients cost-effectively in today's increasingly competitive industry. The transportation model offers a powerful framework for determining the most efficient means of delivering items to customers. A novel ranking function is provided in this paper, which provides the best (IBFS) while assuring the lowest transit cost. This will assist individuals who desire to optimize their profit by reducing transportation costs in achieving their aim.

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