Journal of Computer and Mathematical Sciences, *Vol.10(1),43-54 January 2019* *ISSN 0976-5727 (Print)*
(An International Research Journal), *www.compmath-journal.org* *ISSN 2319-8133 (Online)*

Feasibility of Fuzzy New Method in finding Initial Basic Feasible Solution for a Fuzzy Transportation Problem

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(Received on: December 22, 2018)

ABSTRACT

The fuzzy transportation problem can be transformed into crisp problem using Robust Ranking method. It is solved by using four methods; Fuzzy Vogel Approximation Method, Fuzzy New Method, Fuzzy Zero Suffix Method and Fuzzy Monalisha Approximation Method. The above methods are used to find the Initial Basic Feasible Solution in terms of fuzzy numbers. The solution procedure is illustrated with a numerical example.

Keywords: Trapezoidal fuzzy number; fuzzy transportation problem; Robust Ranking; Initial basic feasible solution.

1. INTRODUCTION

The transportation problem refers to a special case of linear programming problem. The basic transportation problem was developed by Hitchcock[6]. In Mathematics and Economics transportation theory is a name given to the study of optimal transportation and allocation of resources. Transportation problems deal with the distribution of single commodity from various sources of supply to various destinations of demand in such a manner that the total transportation cost is minimized. In order to solve a transportation problem the decision parameters such as availability, requirements and the unit cost of transportation the model must be fixed at crisp values. But in real life applications supply, demand and unit transportation cost may be uncertain due the several factors. These imprecise data may be represented by fuzzy numbers.

The idea of fuzzy set was introduced by Zadeh[9] in 1965. Bellman and Zadeh[1] proposed the concept of decision making in fuzzy environment. After this pioneering work many authors have studied fuzzy linear programming problem techniques such as Fang. S.C[5], H. Rommelfanger[7] and H. Tanaka[8] etc., Chanas et al developed a method for solving fuzzy transportation problems by applying the parametric programming technique using the Bellman – Zadeh criterion. Chanas and Kuchta[4,2] proposed a method for solving a fuzzy transportation problem with Crisp objective function which provides only crisp solution to the given problem. The fuzzy transportation problem can be solved by fuzzy linear programming techniques[3]. But most of the existing techniques provide the crisp solution of the fuzzy transportation problem. Ranking method is used to change fuzzy numbers into crisp form. In this paper, an algorithm is proposed from the Fuzzy Vogel Approximation Method, Fuzzy New Method, Fuzzy Monalisha Approximation Method & Fuzzy Zero Suffix Method and is compared with the other three methods using a numerical example.

2. PRELIMINARIES

In this section, some basic definitions, arithmetic operations and comparison of trapezoidal fuzzy number are presented.

2.1 Basic definitions

Definition 1. A Fuzzy set A is defined as the set of ordered pairs $(X,\mu_A(x))$, where x is an element of the universe of discourse U and $\mu_A(x)$ is the membership function that attributes to each X∈U a real number∈[0,1] describing the degree to which X belongs to the set.

Definition 2. A crisp set is a special case of Fuzzy set, in which the membership function takes only two values 0 and 1.

Definition 3. A fuzzy number $\bar{A}$ = (a,b,c,d) is said to be a trapezoidal fuzzy number if its membership function $\mu_{\bar{A}}(x)$ is given by,

$$\mu_{\bar{A}}(x) = \begin{cases} \frac{x-a}{b-a}, a \le x \le b \\ 1, \quad b \le x \le c \\ \frac{d-x}{d-c}, c \le x \le d \\ 0, \quad otherwise \end{cases}$$

Graphically, a trapezoidal fuzzy number can be represented as (figure1):

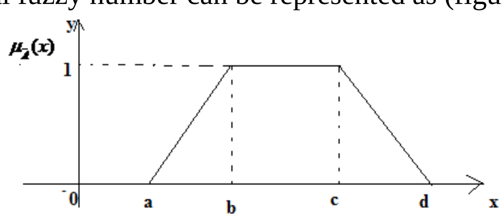

Figure 1. Trapezoidal fuzzy number.

3. MATHEMATICAL FORMULATION OF FUZZY TRANSPORTATION PROBLEM

A fuzzy Transportation Problem can be stated as Min z = $\sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}x_{ij}$ Subject to $\sum_{j=1}^{n} x_{ij} = a_i, i = 0,1,2,...m$, $\sum_{i=1}^{m} x_{ij} = b_j, j = 0,1,2,...n$, where $x_{ij} \geq 0, i = 1,2,3...m, \ j = 1,2,3...n$ where i = 0,1,2,…,m in which the transportation cost c_{ij}, supply a_i, and b_j quantities are fuzzy quantities. The necessary and sufficient condition for the fuzzy linear programming is given as $\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j$ (RIM conditions)

4. COMPUTATIONAL PROCEDURE

4.1 Robust Ranking Technique

Robust Ranking technique which satisfies compensation, linearity, and additive properties and provides results which are consist human intuition. If ã is a fuzzy number then the Robust Ranking is defined by R(ã) = $\int_{0}^{1} 0.5(a_{\alpha}^{L}, a_{\alpha}^{U})d\alpha$ where $(a_{\alpha}^{L}, a_{\alpha}^{U})$ is the α level cut of the fuzzy number ã and $(a_{\alpha}^{L}, a_{\alpha}^{U}) = \{((\alpha(b-a)+a)+(d-(d-c)\alpha)\}$ In this paper it is attempted to use this method for ranking the objective values. The Robust ranking index R(ã) gives the representative value of fuzzy number ã

4.2 The Computation procedure for **Fuzzy Vogel's Approximation Method (FVAM)**

The steps for finding FIBFS using FVAM are as follow:

Step 1: Take the first row and choose its smallest entry and subtract this from next smallest entry, and write in front of the row on the right. This is the fuzzy penalty for first row. Similarly compute fuzzy penalties for all the columns and write them in the bottom of the FTT below corresponding columns.

Step 2:Select the highest fuzzy penalty and observe the row or column for which this corresponds. Determine the smallest fuzzy cost in the selected row or column. Let it be c_{ij}.

Find x_{ij} = minimum (a_i , b_j)

There may arise the following three cases:

Case(i) If minimum (a_i , b_j) = a_i then allocate $x_{ij} = a_i$ in the (i , j)th cell of mxn FTT. Ignore the i^{th} row to obtain a new FTT of order (m-1)xn. Replace b_j by $b_j - a_i$ in obtained FTT. Go to Step 3.

Case(ii) If minimum (a_i , b_j) = b_j then allocate $x_{ij} = b_j$ in the (i , j)th cell of mxn FTT. Ignore the j^{th} column to obtain a new FTT of order mx(n-1). Replace a_i by $a_i - b_j$ in obtained FTT. Go to Step 3

Case(iii) If minimum $a_i = b_j$ then either follow Case (i) or Case (ii) but not both, simultaneously. Go to step2

Step 3: Calculate fresh penalties for the obtained FTT as in Step 1. Repeat Step 2, until the FTT is reduced into FTT of order 1x1.

Step 4:Allocate all x_{ij} in the (i,j)th cell of the given FTT.

Step 5:The IFBFS solution and initial fuzzy transportation cost are x_{ij} and $\sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}.x_{ij}$, respectively

This process gives the initial basic feasible solution and we can optimize using FMODI method if it is non-degenerate.

4.3 The Computation procedure of **Fuzzy New Method(FNM):**

To find the fuzzy initial basic feasible solution (FIBFS) of a fuzzy transportation problem the algorithm is proposed:

Step 1 : Find the Fuzzy penalty cost ie. fuzzy difference between the maximum fuzzy cost and minimum fuzzy cost in each row and column.

Step 2 : Choose a row or column with maximum penalty by ranking method. If maximum penalty is more than one choose any one arbitrarily.

Step 3 : From the selected row or column choose a fuzzy minimum cost and allocate as much as possible in that cell depending on supply and demand.

Step 4 : Delete the row or column which is fully exhausted. Repeat the process till all the rim R are satisfied.

4.4 The Computation procedure for **Fuzzy Zero Suffix Method (FZSM)**

We, now introduce a new method called the zero suffix method for finding fuzzy initial basic feasible solution(FIBFS) to the transportation problem.

Step 1: Construct the transportation table.

Step 2: Subtract each row entries of the transportation table from the corresponding row minimum after that subtract each column entries of the transportation table from the corresponding column minimum.

Step 3: In the reduced cost matrix there will be the atleast one zero in each row and column, then find the suffix value of all the zeros in the reduced cost matrix by following simplification, the suffix value is denoted by S, Therefore

$$\text{Cost } S = \frac{\text{Add the cost of nearest adjacent sides of zero which are greater than zero}}{\text{No of costs added}}$$

Step 4: Choose the maximum of S, if it has one maximum value then first supply to that demand corresponding to the cell. If it has more equal values then select $\{a_i, b_j\}$ and supply to that demand maximum possible.

Step 5: After the above step, the exhausted demands (column) or supplies (row) to be trimmed. The resultant matrix must possess at least one zero is each row and column, else repeat Step 2.

Step 6: Repeat Step 3 to Step 5 until the optimal solution is obtained.

4.5 The Computation procedure for **Fuzzy Monalisha`s Approximation Method (FMAM)**

Step 1. Determine the cost table from the given problem.
(i) Examine whether total demand equals total demand/supply. If yes, go to step 2.
(ii) If not , introduce dummy row/column having all its cost elements as zero and supply/ demand as the (+ve) difference of supply and demand.
Step 2. Locate the smallest element in each row of the given cost matrix and then subtract the same from each element of that row.
Step 3. In the reduced matrix obtained in step 2, locate the smallest element of each column and then subtract the same from each element of that column.
Step 4. For each row of the transportation table identify the smallest and the next - to - smallest costs. Determine the difference between them for each row. Display them alongside the transportation table by enclosing them in parenthesis against the respective rows. Similarly compute the differences for each column.
Step 5. Identify the row or column with the largest difference among all the rows and columns. If a tie occurs, use any arbitrary tie breaking choice. Let the greatest difference correspond to ith row and let 0 be in the i^{th} row. Allocate the maximum feasible amount $x_{ij}=\min(a_i ,b_j)$ in the (i, j)th cell and cross off either the i^{th} row or the j^{th} column in the usual manner.
Step 6. Re-compute the column and row differences for the reduced transportation table and go to step 5.

Repeat the procedure until all the rim R (the various origin capacities and destination R are listed in the right most outer column and the bottom outer row respectively) are satisfied.

5. NUMERICAL EXAMPLE

Problem: To **illustrate the new method let us consider a fuzzy transportation**

Table 5.1

	D1	D2	D3	D4	Availability
O1	(1,2,3,4)	(1,3,4,6)	(9,11,12,14)	(5,7,8,11)	(4,6,7,9)
O2	(0,1,2,4)	(-1,0,1,2)	(5,6,7,8)	(0,1,2,3)	(0,1,2,3)
O3	(3,5,6,8)	(5,8,9,12)	(12,15,16,19)	(7,9,10,12)	(5,10,12,15)
R	(5,7,8,10)	(-1,5,6,7)	(1,3,4,6)	(1,2,3,4)	(9,17,21,27)

Solution: Let us find the ranks of each cell using Robust ranking technique:

R(ã) = $\int_0^1 0.5(a_\alpha^L, a_\alpha^U)d\alpha$ where (a_α^L, a_α^U) is the α level cut of the fuzzy number ã and $(a_\alpha^L, a_\alpha^U) = \{((\alpha(b-a)+a)+(d-(d-c)\alpha)\}$

So rank of a_{11} = $\bar{a}(1,2,3,4) = \int(0.5)((2-1)\alpha+1+4-(4-3)\alpha)d\alpha = 2.5$

Table 5.2

Element	Rank	Element	Rank	Element	Rank	Element	Rank	Availability	Rank
a_{11}	2.5	a_{12}	3.5	a_{13}	11.5	a_{14}	7.5	A_1	6.5
a_{21}	1.5	a_{22}	0.5	a_{23}	6.5	a_{24}	1.5	A_2	1.5
a_{13}	5.5	a_{32}	8.5	a_{33}	15.5	a_{34}	9.5	A_3	11
R_1	7.5	R_2	5.5	R_3	3.5	R_4	2.5	T	19

Note: R: requirement, A: Availability
So the crisp problem be based on ranking shown below

Table 5.3

Element	Rank	Element	Rank	Element	Rank	Element	Rank	A	Rank
a_{11}	2.5	a_{12}	3.5	a_{13}	11.5	a_{14}	7.5	A_1	6.5
a_{21}	1.5	a_{22}	0.5	a_{23}	6.5	a_{24}	1.5	A_2	1.5
a_{13}	5.5	a_{32}	8.5	a_{33}	15.5	a_{34}	9.5	A_3	11
R_1	7.5	R_2	5.5	R_3	3.5	R_4	2.5	T	19

Note: R: requirement, A: Availability
So the crisp problem be based on ranking shown below

Table 5.4

	D1	D2	D3	D4	Availability
O1	2.5	3.5	11.5	7.5	6.5
O2	1.5	0.5	6.5	1.5	1.5
O3	5.5	8.5	15.5	9.5	11
R	7.5	5.5	3.5	2.5	19

Method i: Let us find IBPS using method-I by Fuzzy Vogel approximation method

Table 5.5

	D1	D2	D3	D4	A	Row Penality
O1	2.5	3.5	11.5	7.5	6.5	1
O2	1.5	0.5	6.5	1.5(1.5)	~~1.5~~	1
O3	5.5	8.5	15.5	9.5	11	3
R	7.5	5.5	3.5	~~2.5~~ 1		
Column Penality	1	3	5	6 **		
Note: ** Maximum penality						

Table 5.6 So eliminate second row

	D1	D2	D3	D4	A	Row Penality
O1	2.5	3.5	11.5	7.5	6.5	1
O3	5.5	8.5(5.5)	15.5	9.5	~~11~~ 5.5	3
R	7.5	5.5	3.5	1	19	
Column Penality	3	5**	4	2		

Table 5.7 So eliminate second column

	D1	D3	D4	A	Row Penality
O1	2.5(6.5)	11.5	7.5	~~6.5~~	5**
O3	5.5	15.5	9.5	5.5	4
R	~~7.5~~ 1	3.5	1	19	
ColumnPenality	3	4	2		

Table 5.8 So eliminate first row & continue the Process

	D1	D3	D4	A	Row Penality
O3	5.5 (1)	15.5(3.5)	9.5(1)	~~5.5~~	4
R	1	3.5	1		
Column Penality	~~5.5~~	~~15.5~~	~~9.5~~		

Table 5.9 Final table for FIBPS

	D1	D2	D3	D4	A
O1	2.5(6.5)	3.5	11.5	7.5	6.5
O2	1.5	0.5	6.5	1.5(1.5)	1.5
O3	5.5(1)	8.5(5.5)	15.5(3.5)	9.5(1)	11
R	7.5	5.5	3.5	2.5	

The FIBFS be Min Z = (2.5*6.5) + (1.5*1.5) + (5.5*1) + (8.5*5.5) + (15.5*3.5) + (9.5*1) = 134.5

Method ii: <u>Fuzzy New Method (FNM):</u>

Table 5.10

	D1	D2	D3	D4	A	Row Penalty
O1	2.5	3.5	11.5	7.5	6.5	9
O2	1.5	0.5	6.5	1.5	1.5	6
O3	5.5(7.5)	8.5	15.5	9.5	~~11~~ 3.5	10**
R	~~7.5~~	5.5	3.5	2.5		
Column Penalty	4	8	9	8		
Note: ** Maximum penalty						

Table 5.11

	D2	D3	D4	A	Row Penalty
O1	3.5	11.5	7.5	6.5	8
O2	0.5	6.5(1.5)	1.5	~~1.5~~	6
O3	8.5	15.5	9.5	~~11~~ 3.5	7
R	5.5	~~3.5~~ 2	2.5		
Column Penalty	8	9**	8		
Note: ** Maximum penality					

Table 5.12

	D2	D3	D4	A	Row Penality
O1	3.5(5.5)	11.5	7.5	~~6.5~~ 1	8
O3	8.5	15.5	9.5	3.5	7
R	~~5.5~~	2	2.5		
Column Penalty	5	4	2		
Note: ** Maximum penality					

Table 5.13

	D3	D4	A	Row Penality
O1	11.5	7.5	1	4
O3	15.5	9.5(2.5)	~~3.5~~ 1	6
R	2	~~2.5~~		
Column Penalty	4	2		
Note: ** Maximum penality				

Table 5.14

	D1	D2	D3	D4	Availability
O1	2.5	3.5(5.5)	11.5(1)	7.5	6.5
O2	1.5	0.5	6.5(1.5)	1.5	1.5
O3	5.5(7.5)	8.5	15.5(1)	9.5(2.5)	11
Requirement	7.5	5.5	3.5	2.5	

Table 5.15

	D3	A	Row Penality
O1	11.5(1)	1	11.5
O3	15.5(1)	1	15.5
R	2		
Column Penalty	4		

Soln be z = (3.5*5.5) + (11.5*1) +(6.5*1.5) + (5.5*7.5)+ (15.5*1) + (9.5*2.5)=121

Method:3: <u>Fuzzy Zero Suffix Method (FZSM)</u>:

Table 5.16

	D1	D2	D3	D4	A
O1	2.5	3.5	11.5	7.5	6.5
O2	1.5	0.5	6.5	1.5	1.5
O3	5.5	8.5	15.5	9.5	11
R	7.5	5.5	3.5	2.5	

<u>Table 5.17 Determine row minima</u>

	D1	D2	D3	D4	Availability	Row min
O1	2.5	3.5	11.5	7.5	6.5	2.5
O2	1.5	0.5	6.5	1.5	1.5	0.5
O3	5.5	8.5	15.5	9.5	11	5.5
R	7.5	5.5	3.5	2.5		

Table 5.18 Subtract the values with particular rows and also determine column minima

	D1	D2	D3	D4	Availability
O1	0	1	9	5	6.5
O2	1	0	6	1	1.5
O3	0	3	10	4	11
R	7.5	5.5	3.5	2.5	
col.min	0	0	6	1	

Table 5.19 Above Process continue

	D1	D2	D3	D4	Availability
O1	$0^{(1)}$	1	3	4	6.5
O2	1	$0^{(2.4)}$	$0^{(3)}$	$0^{(3.5)}$**1.5**	~~1.5~~
O3	0	3	4	3	11
R	7.5	5.5	3.5	~~2.5~~ 1	

Table 5.20 Eliminate row 2

	D1	D2	D3	D4	Availability
O1	$0^{(1)}$	1	3	4	6.5
O3	0	3	4	3	11
R	7.5	5.5	3.5	1	
Col. minima	0	1	3	3	

Table 5.21

	D1	D2	D3	D4	Availability
O1	$0^{(2)}$**6.5**	$0^{(1.5)}$	$0^{(1.33)}$	1	~~6.5~~
O3	$0^{(2)}$	2	1	$0^{(1)}$	11
R	~~7.5~~ 1	5.5	3.5	1	

Table 5.22

	D1	D2	D3	D4	Availability
O3	$0^{(2)}{}_{1}$	2 $_{5.5}$	1 $_{3.5}$	$0^{(1)}{}_{1}$	~~11~~ ~~10~~ 9
R	~~7.5~~ 1	5.5	3.5	1	

Table 5.23

	D1	D2	D3	D4	A
O1	2.5 $_{6.5}$	3.5	11.5	7.5	6.5
O2	1.5	0.5	6.5	1.5 $_{1.5}$	1.5
O3	5.5 $_{1}$	8.5 $_{5.5}$	15.5 $_{3.5}$	9.5 $_{1}$	11
R	7.5	5.5	3.5	2.5	

Solution be z = (2.5*6.5) + (1.5*1.5) +(5.5*1) + (8.5*5.5)+ (15.5*3.5) + (9.5*1)=**134.5**

Method:4: Fuzzy Manolisha Approximation Method (FMAM):

Table 5.24

	D1	D2	D3	D4	A
O1	2.5	3.5	11.5	7.5	6.5
O2	1.5	0.5	6.5	1.5	1.5
O3	5.5	8.5	15.5	9.5	11
R	7.5	5.5	3.5	2.5	

Table 5.25 Determine row minima

	D1	D2	D3	D4	A	Row min
O1	2.5	3.5	11.5	7.5	6.5	2.5
O2	1.5	0.5	6.5	1.5	1.5	0.5
O3	5.5	8.5	15.5	9.5	11	5.5
R	7.5	5.5	3.5	2.5		

Table 5.26 Subtract the values with particular rows & Determine column minima

	D1	D2	D3	D4	A
O1	0	1	9	5	6.5
O2	1	0	6	1	1.5
O3	0	3	10	4	11
R	7.5	5.5	3.5	2.5	
Column minima	0	0	6	1	

Table 5.27 Above Process continue

	D1	D2	D3	D4	A	Penality
O1	0	1	3	4	6.5	1
O2	1	0	0	0	1.5	0
O3	0 (7.5)	3	4	3	~~11~~ 3.5	3(Max)
R	~~7.5~~	5.5	3.5	2.5		
Penality	0	1	3	3		

Table 5.28 Eliminate D1

	D2	D3	D4	A	Penality
O1	1	3	4	6.5	1
O2	0	0(1.5)	0	~~1.5~~	0
O3	3	4	3	3.5	1
R	5.5	~~3.5~~ 2	2.5		
Penality	1	3(Max)	3		

Table 5.29 Eliminate O2

	D2	D3	D4	A	Penality
O1	1(5.5)	3	4	~~6.5~~ 1	2(Max)
O3	3	4	3	3.5	0
R	~~5.5~~	2	2.5		
Penality	2	1	1		

Table 5.30 Eliminate D2

	D3	D4	A	Penality
O1	3 (1)	4	~~1~~	1(Max)
O3	4	3	3.5	1
R	~~2~~ 1	2.5		
Penality	1	1		

Table 5.31 Eliminate O1

	D3	D4	A	Penality
O3	4(1)	3(2.5)	3.5	1
R	1	2.5		
Penality	4	3		

Table 5.32

	D1	D2	D3	D4	A
O1	2.5	3.5(5.5)	11.5(1)	7.5	6.5
O2	1.5	0.5	6.5(1.5)	1.5	1.5
O3	5.5(7.5)	8.5	15.5(1)	9.5(2.5)	11
R	7.5	5.5	3.5	2.5	

Soln be z = (3.5*5.5) + (11.5*1) +(6.5*1.5) + (5.5*7.5)+ (15.5*1) + (9.5*2.5)=**121**

Table 5.33 Comparison table:

Method	No.of iterations	IBFS
FVAM	8	134.5
FNM	6	**121**
FZSM	8	134.5
FMAM	7	**121**

6. CONCLUSION

The proposed methods fuzzy new method provides an FIBFS for a fuzzy transportation problem that gives better results. The proposed methods FNM & FMAM is easy to understand and apply with the help a numerical problem. .

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