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An approach to fuzzy transportation problem using Triacontakaidigon fuzzy number with alpha cut ranking technique

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Abstract

One of the particular issues with linear programming is transportation. These are optimization efforts whose goal is to reduce the overall cost of moving goods or people through intricate logistical systems. To reduce the overall transit costs involved in distribution, the problem can be solved by optimizing the delivery system of the specific entity (such as any goods, a person, or a material) from sources (suppliers) to destinations (customers). When evacuating a region, transportation concerns are used to determine the best route for evacuees to take from boarding points to evacuation centers. Particular attention is paid to the travel distance and the overall cost of moving one person.Finding the right number of items to send from each warehouse to each customer while keeping costs to a minimum is the goal of this problem's solution. In this study, a novel fuzzy number called the Triacontakaidigon Fuzzy Number and its membership function are introduced. In terms of both form and computation, the triacontakaidigon fuzzy number is more complex than the triangular and trapezoidal fuzzy numbers. A fuzzy ranking approach is an efficient tool for addressing the fuzzy transportation problem, as demonstrated by numerical examples.

Subject Classification: *(2010)* 03*E*72; 97*P*80;

Keywords: *FTP, Triacontagaidigon fuzzy number, Alpha cut, Least cost method.*

1. Introduction

The transportation problem, a subset of the linear programming problem, is highly well known and involves moving a commodity from several supply sources to different demand destinations while keeping the overall transportation costs to a minimum. But in reality, there are

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a number of variables that might affect supply, demand, and unit life transportation costs. Fuzzy numbers may be a better representation of these uncertain data. All of the parameters in a fuzzy transportation problem are fuzzy numbers. Fuzzy numbers might be triangular or trapezoidal, normal or aberrant. As a result, certain hazy numbers cannot be directly compared. One of the essential topics is ranking such numbers based on comparisons between two or more fuzzy numbers, and one of the main issues has been determining how to rank fuzzy numbers. Comparing between two or multi fuzzy numbers and ranking such numbers is one of the important subjects, and how to set the rank of fuzzy numbers has been one of the main problems. Several authors like Pandian et al. [8], Ahmed A and Ahmed[1], Sarbjit Singh[12] applied different approaches to solve the transportation problems. Finding a way was encouraged at the transportation table by Javad Sadeghi[2]. Narayanamoorthy et al. [6] applied fuzzy Russell's method, Kenan Karagaul et al. [3] used a novel approximation method to solve fuzzy transportation problem. A new approach for the transportation problem is proposed by Pulkit Rathi et al.[9] that is based on the idea of bear hibernation and takes into account repeated organ donations. Stefan M. Stefanov's[10] suggested that strategy for resolving the convex generalized nonlinear transportation problem is to find a fuzzy optimal solution. Employing the centroid ranking technique, R. K. Saini et al.[11] suggested using Trapezoidal Shaped Generalized Fuzzy Numbers to solve unbalanced transportation problems. By utilizing the ranking of fuzzy numbers, we introduced a Triacontakaidigon fuzzy number-based transportation problem in this study.

2. Preliminaries [4,5,7]

In this section, we give the preliminaries that are required for this study.

Definition 2.1: A fuzzy set A is defined by $A = \{(x, \mu_A(x)) : x \in A, \mu_A(x) \in [0,1]\}$. Here x is crisp set A and $\mu_A(x)$ is membership function in the interval [0, 1]

Definition 2.2: The fuzzy number A is fuzzy set whose membership function must satisfy the following conditions.

(i) A fuzzy set A of the universe of discourse x is convex.

(ii) A fuzzy set A of the universe of discourse x is normal fuzzy set if $x_i \in X$ exists.

(iii) $\mu_A(x)$ is piecewise continuous.

Definition 2.3: An α-cut of fuzzy set A is classical set defined as ${}^{\alpha}[A] = \{x \in X / \ \mu_A(x) \geq \alpha\}$

Definition 2.4: A fuzzy set A is convex fuzzy set iff each of it's ${}^{\alpha}A$ is convex set.

Definition 2.5: Mathematical formulation of a fuzzy transportation problem

$$\text{Minimize } \tilde{\mathcal{Z}} = \sum_{i=1}^{m} \sum_{j=1}^{n} \tilde{c}_{ij} \tilde{x}_{ij}$$

$$\text{Subject to the constraints } \sum_{i=1}^{m} \tilde{x}_{ij} = \tilde{s}_i \text{ for } i = 1, 2, \ldots m$$

$$\sum_{j=1}^{n} \tilde{x}_{ij} = \tilde{t}_j \text{ for } j = 1, 2, \ldots n$$

where $\tilde{x}_{ij} \geq 0$ for all i and j

Definition 2.6: A fuzzy number ${}^{TCD}\mathcal{F} = (\tau_{k_1}, \tau_{k_2}, \tau_{k_3}, \tau_{k_4}, \tau_{k_5}, \tau_{k_6}, \tau_{k_7}, \tau_{k_8}, \tau_{k_9}, \tau_{k_{10}} :\ldots\ldots\ldots, \tau_{k_{32}})$ is a Triacontakaidigon fuzzy number with its membership function $\psi_{{}^{TCD}\mathcal{F}}(x)$ is defined as

$$\psi_{TCD\,\mathcal{F}}(x)=\begin{cases} 0, \text{ for } x<\tau_{k_1} \\ \rho_1^\circ\left(\frac{x-\tau_{k_1}}{\tau_{k_2}-\tau_{k_1}}\right), \text{ for } \tau_{k_1}\le x\le\tau_{k_2} \\ \rho_1^\circ, \text{ for } \tau_{k_2}\le x\le\tau_{k_3} \\ \rho_1^\circ+(\rho_2^\circ-\rho_1^\circ)\left(\frac{x-\tau_{k_3}}{\tau_{k_4}-\tau_{k_3}}\right), \text{ for } \tau_{k_3}\le x\le\tau_{k_4} \\ \rho_2^\circ, \text{ for } \tau_{k_4}\le x\le\tau_{k_5} \\ \rho_1^\circ+\rho_3^\circ-\rho_2^\circ)\left(\frac{x-\tau_{k_5}}{\tau_{k_6}-\tau_{k_5}}\right), \text{ for } \tau_{k_5}\le x\le\tau_{k_6} \\ \rho_3^\circ, \text{ for } \tau_{k_6}\le x\le\tau_{k_7} \\ \rho_3^\circ+(\rho_4^\circ-\rho_3^\circ)\left(\frac{x-\tau_{k_7}}{\tau_{k_8}-\tau_{k_7}}\right), \text{ for } \tau_{k_7}\le x\le\tau_{k_8} \\ \rho_4^\circ, \text{ for } \tau_{k_8}\le x\le\tau_{k_9} \\ \rho_4^\circ+(\rho_5^\circ-\rho_4^\circ)\left(\frac{x-\tau_{k_9}}{\tau_{k_{10}}-\tau_{k_9}}\right), \text{ for } \tau_{k_9}\le x\le\tau_{k_{10}} \\ \rho_5^\circ, \text{ for } \tau_{k_{10}}\le x\le\tau_{k_{11}} \\ \rho_5^\circ+(\rho_6^\circ-\rho_5^\circ)\left(\frac{x-\tau_{k_{11}}}{\tau_{k_{12}}-\tau_{k_{11}}}\right), \text{ for } \tau_{k_{11}}\le x\le\tau_{k_{12}} \\ \rho_6^\circ, \text{ for } \tau_{k_{12}}\le x\le\tau_{k_{13}} \\ \rho_6^\circ+(\rho_7^\circ-\rho_6^\circ)\left(\frac{x-\tau_{k_{13}}}{\tau_{k_{14}}-\tau_{k_{13}}}\right), \text{ for } \tau_{k_{13}}\le x\le\tau_{k_{14}} \\ \rho_7^\circ, \text{ for } \tau_{k_{14}}\le x\le\tau_{k_{15}} \\ \rho_7^\circ+(1-\rho_7^\circ)\left(\frac{x-\tau_{k_{15}}}{\tau_{k_{16}}-\tau_{k_{15}}}\right), \text{ for } \tau_{k_{15}}\le x\le\tau_{k_{16}} \\ 1, \text{ for } \tau_{k_{16}}\le x\le\tau_{k_{17}} \\ \rho_7^\circ+(1-\rho_7^\circ)\left(\frac{\tau_{k_{17}}-x}{\tau_{k_{18}}-\tau_{k_{17}}}\right), \text{ for } \tau_{k_{17}}\le x\le\tau_{k_{18}} \\ \rho_7^\circ, \text{ for } \tau_{k_{18}}\le x\le\tau_{k_{19}} \\ \rho_6^\circ+(\rho_7^\circ-\rho_6^\circ)\left(\frac{\tau_{k_{19}}-x}{\tau_{k_{20}}-\tau_{k_{19}}}\right), \text{ for } \tau_{k_{19}}\le x\le\tau_{k_{20}} \\ \rho_6^\circ, \text{ for } \tau_{k_{20}}\le x\le\tau_{k_{21}} \\ \rho_5^\circ+(\rho_6^\circ-\rho_5^\circ)\left(\frac{\tau_{k_{21}}-x}{\tau_{k_{22}}-\tau_{k_{21}}}\right), \text{ for } \tau_{k_{21}}\le x\le\tau_{k_{22}} \\ \rho_5^\circ, \text{ for } \tau_{k_{22}}\le x\le\tau_{k_{23}} \\ \rho_4^\circ+(\rho_5^\circ-\rho_4^\circ)\left(\frac{\tau_{k_{23}}-x}{\tau_{k_{24}}-\tau_{k_{23}}}\right), \text{ for } \tau_{k_{23}}\le x\le\tau_{k_{24}} \\ \rho_4^\circ, \text{ for } \tau_{k_{24}}\le x\le\tau_{k_{25}} \\ \rho_3^\circ+(\rho_4^\circ-\rho_3^\circ)\left(\frac{\tau_{k_{25}}-x}{\tau_{k_{26}}-\tau_{k_{25}}}\right), \text{ for } \tau_{k_{25}}\le x\le\tau_{k_{26}} \\ \rho_3^\circ, \text{ for } \tau_{k_{26}}\le x\le\tau_{k_{27}} \\ \rho_2^\circ+(\rho_3^\circ-\rho_2^\circ)\left(\frac{\tau_{k_{27}}-x}{\tau_{k_{28}}-\tau_{k_{27}}}\right), \text{ for } \tau_{k_{27}}\le x\le\tau_{k_{28}} \end{cases}$$

$$\psi_{TCD\mathcal{F}}(x)=\begin{cases}\rho_2^\circ, \text{ for } \tau_{k_{28}} \le x \le \tau_{k_{29}}\\ \rho_1^\circ+(\rho_2^\circ-\rho_1^\circ)\left(\dfrac{\tau_{k_{30}}-x}{\tau_{k_{30}}-\tau_{k_{29}}}\right), \text{ for } \tau_{k_{29}} \le x \le \tau_{k_{30}}\\ \rho_1^\circ, \text{ for } \tau_{k_{30}} \le x \le \tau_{k_{31}}\\ \rho_1^\circ\left(\dfrac{\tau_{k_{32}}-x}{\tau_{k_{32}}-\tau_{k_{31}}}\right), \text{ for } \tau_{k_{31}} \le x \le \tau_{k_{32}}\\ 0, \text{ for } x > \tau_{k_{32}}\end{cases}$$

where $\tau_{k_1}, \tau_{k_2}, \tau_{k_3}, ..., \tau_{k_{32}}$ and $\rho_1^\circ, \rho_2^\circ, ..., \rho_7^\circ$ are real numbers with $0 \le \rho_1^\circ \le \rho_2^\circ \le \rho_3^\circ \le \rho_4^\circ \le \rho_5^\circ \le \rho_6^\circ \le \rho_7^\circ \le 1$

2.7 *Ranking of Triacontakaidigon fuzzy number*

Let $\mathcal{S}$ be a normal Triacontakaidigon fuzzy number. The value $M(\mathcal{S})$, called as the measure of $\mathcal{S}$ is calculated as

$$^{TC}M(\mathcal{S})=\frac{1}{2}\begin{bmatrix}\int_0^{\rho_1^\circ}(A_1+A_2)dA+\int_{\rho_1^\circ}^{\rho_2^\circ}(P_1+P_2)dP+\int_{\rho_2^\circ}^{\rho_3^\circ}(B_1+B_2)dB+\\ \int_{\rho_3^\circ}^{\rho_4^\circ}(Q_1+Q_2)dQ+\int_{\rho_4^\circ}^{\rho_5^\circ}(C_1+C_2)dC+\int_{\rho_5^\circ}^{\rho_6^\circ}(R_1+R_2)dR+\\ \int_{\rho_6^\circ}^{\rho_7^\circ}(D_1+D_2)dD+\int_{\rho_7^\circ}^{1}(S_1+S_2)dS\end{bmatrix}$$

where $0 \le \rho_1^\circ \le \rho_2^\circ \le \rho_3^\circ \le \rho_4^\circ \le \rho_5^\circ \le \rho_6^\circ \le \rho^\circ \le 1$

$$^{TC}M(\mathcal{S})=\frac{1}{4}\begin{bmatrix}(\tau_{k_1}+\tau_{k_2}+\tau_{k_{31}}+\tau_{k_{32}})\rho_1^\circ+(\tau_{k_3}+\tau_{k_4}+\tau_{k_{29}}+\tau_{k_{30}})(\rho_2^\circ-\rho_1^\circ)+\\ (\tau_{k_5}+\tau_{k_6}+\tau_{k_{27}}+\tau_{k_{28}})(\rho_3^\circ-\rho_2^\circ)+(\tau_{k_7}+\tau_{k_8}+\tau_{k_{25}}+\tau_{k_{26}})(\rho_4^\circ-\rho_3^\circ)+\\ (\tau_{k_9}+\tau_{k_{10}}+\tau_{k_{23}}+\tau_{k_{24}})(\rho_5^\circ-\rho_4^\circ)+(\tau_{k_{11}}+\tau_{k_{12}}+\tau_{k_{21}}+\tau_{k_{22}})(\rho_6^\circ-\rho_5^\circ)+\\ (\tau_{k_{13}}+\tau_{k_{14}}+\tau_{k_{19}}+\tau_{k_{20}})(\rho_7^\circ-\rho_6^\circ)+(\tau_{k_{15}}+\tau_{k_{16}}+\tau_{k_{17}}+\tau_{k_{18}})(1-\rho_7^\circ)\end{bmatrix}$$

where $0 \le \rho_1^\circ \le \rho_2^\circ \le \rho_3^\circ \le \rho_4^\circ \le \rho_5^\circ \le \rho_6^\circ \le \rho_7^\circ \le 1$

we take the values for $\rho_1^\circ=\frac{1}{8}, \rho_2^\circ=\frac{2}{8}, \rho_3^\circ=\frac{3}{8}, \rho_4^\circ=\frac{4}{8}, \rho_5^\circ=\frac{5}{8}, \rho_6^\circ=\frac{6}{7}, \rho_7^\circ=\frac{7}{8}$.

3. Numerical Example

Consider the following transportation problem with three sources and three destinations, the values in the body of the matrix Table 1 represents the unit transportation cost. In Table 2, the ranking of the triacontakaidigon fuzzy number is calculated. Converted the given fuzzy supplies and fuzzy demands into a crisp value problem by using the measure given in Tables 3 and 4 respectively. Total fuzzy supplies and demands are represented in Table 5 simultaneously and in Table 6, the fuzzy transportation problem is converted into crisp valued fuzzy transportation problem by using the measure.

Table 1

Fuzzy transportation problem

	Destination			**Supply**
Source	(-11,-10,-7,-6,-5,-4,-3,-2,-1,0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22)	(-12,-11,-10,-9,-8,-7,-6,-5,-4,-3,-2,-1,0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19)	(1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,20,22,23,24,25,26,27,28,29,30,31,32)	(-3,-2,-1,0,1,2,3,4,5,6,7,8,9,10,12,13,15,17,18,19,20,21,22,24,25,26,27,28,29,30,31,32,33)
	(-10,-9,-8,-7,-6,-5,-4,-3,-2,-1,0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,20,22,23)	(-7,-6,-5,-4,-3,-2,-1,0,1,2,3,4,5,6,7,9,11,12,13,15,17,19,20,21,23,24,25,26,27,28,29,30)	(0,1,2,3,4,5,6,7,8,9,10,11,12,14,15,16,18,20,22,23,24,25,26,27,28,29,30,31,32,33,34,35)	(-13,-12,-11,-10,-9,-8,-7,-6,-4,-3,-2,-1,0,1,2,3,4,5,6,7,8,9,10,11,12,14,16,18,20,21,22,23)
	(1,2,3,4,5,6,7,8,9,10,12,13,15,17,19,21,23,25,27,29,31,33,35,39,41,42,43,45,46,47,48,49)	(1,3,5,7,9,11,12,13,15,17,19,21,23,25,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44)	(-9,-8,-7,-6,-5,-4,-3,-2,-1,0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,22,23,24)	(1,2,3,4,6,7,9,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35)
Demand	(3,4,5,6,7,8,9,10,12,13,15,17,19,21,23,25,27,29,31,33,35,39,41,42,43,45,46,47,48,49)	(-1,-5,-7,-9,-11,-12,-13,-14,-15,-17,19,20,22,24,26,28,30,32,34,36,38,40,42,44,46,48,50,52,54,56,58,60)	(2,3,5,7,8,9,10,11,13,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37)	

Table 2

Ranking of fuzzy transportation problem

a_11	-11,-10,-7,-6,-5,-4,-3,-2,-1,0,1,2,3,4,5,6,7,8,9,10,11,12, 13,14,15,16,17,18,19,20,21,22	$\mu_{Tc}(a_{11}) = 18.5$
a_12	-12,-11,-10,-9,-8,-7,-6,-5,-4,-3,-2,-1,0,1,2,3,4,5,6,7,8,9,10, 11,12,13,14,15,16,17,18,19	$\mu_{Tc}(a_{12}) = 24$
a_13	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,20,22,23,24, 25,26,27,28,29,30,31,32	$\mu_{Tc}(a_{13}) = 24.8$
a_21	-10,-9,-8,-7,-6,-5,-4,-3,-2,-1,0,1,2,3,4,5,6,7,8,9,10,11,12,13, 14,15,16,17,18,20,22,23	$\mu_{Tc}(a_{21}) = 30.5$
a_22	-7,-6,-5,-4,-3,-2,-1,0,1,2,3,4,5,6,7,9,11,12,13,15,17,19,20,21, 23,24,25,26,27,28,29,30	$\mu_{Tc}(a_{22}) = 25.4$
a_23	0,1,2,3,4,5,6,7,8,9,10,11,12,14,15,16,18,20,22,23,24,25,26, 27,28,29,30,31,32,33,34,35	$\mu_{Tc}(a_{23}) = 23.8$
a_31	1,2,3,4,5,6,7,8,9,10,12,13,15,17,19,21,23,25,27,29,31,33, 35,39,41,42,43,45,46,47,48,49	$\mu_{Tc}(a_{31}) = 27.7$
a_32	1,3,5,7,9,11,12,13,15,17,19,21,23,25,27,28,29,30,31,32,33, 34,35,36,37,38,40,41,42,43,44	$\mu_{Tc}(a_{32}) = 15.5$
a_33	-9,-8,-7,-6,-5,-4,-3,-2,-1,0,1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,22,23,24	$\mu_{Tc}(a_{33}) = 36$

The initial basic feasible solution is obtained by least cost method.

Table 3

Fuzzy supplies are noted as follows

$\mathcal{S}_1$	-3,-2,-1,0,1,2,3,4,5,6,7,8,9,10,12,13,15,17,19,20,21,22,24,25,26,27, 28,29,30,31,32,33	15
$\mathcal{S}_2$	-13,-12,-11,-10,-9,-8,-7,-6,-4,-3,-2,-1,0,1,2,3,4,5,6,7,8,9,10,11,12, 14,16,18,20,21,22,23	28.44
$\mathcal{S}_3$	1,2,3,4,6,7,9,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27, 28,29,30,31,32,33,34,35	18.97

Table 4

Fuzzy demand are noted as follows

$\mathcal{D}_1$	3,4,5,6,7,8,9,10,12,13,15,17,19,21,23,25,27,29,31,33,35, 39,41,42,43,45,46,47,48,49	18.01
$\mathcal{D}_2$	-1,-5,-7,-9,-11,-12,-13,-14,-15,-17,19,20,22,24,26,28,30, 32,34,36,38,40,42,44,46,48,50,52,54,56,58,60	23.59
$\mathcal{D}_3$	2,3,5,7,8,9,10,11,13,15,16,17,18,19,20,21,22,23,24,25, 26,27,28,29,30,31,32,33,34,35,36,37	20.81

Table 5

Total fuzzy supply and the total fuzzy demands are shown as follows

$\mathcal{S}$	-5,-6,-7,-11,22,26,38,39,40,41,60,61,69,70,71,72,79,80,82,83,84, 85,86,87,89,90,92,94,95,96,97,98	62.41
$\mathcal{D}$	-2,-3,-4,6,8,10,22,32,42,53,61,69,71,77,78,79,80,81,82,83,84,85, 87,88,89,90,91,92,93,94,96,98	62.9

Table 6

The crisp valued transportation is as follows

	Destination			Supply
Source	5.5	3.5	16.5	15
	5.65	11.47	17.65	28.44
	23.59	25.63	6.22	18.97
Demand	18.01	23.59	20.81	

	Destination			Supply
Source	5.5	$\boxed{3.5}$ 15	16.5	15
	$\boxed{5.65}$ 18.01	$\boxed{11.47}$ 8.59	$\boxed{17.65}$ 1.84	28.44
	23.59	25.63	$\boxed{18.97}$ 6.22	18.97
	0	0	0	0.49
Demand	18.01	23.59	20.81	62.9

	Destination			Supply
Source	5.5	$\boxed{3.5}$ 15	16.5	~~15~~ 0
	5.65	11.47	17.65	28.44
	23.59	25.63	6.22	18.97
Demand	18.01	~~23.59~~ 8.59	20.81	

	Destination			Supply
Source	$\boxed{5.65}$ 18.01	11.47	17.65	~~28.44~~ 10.43
	23.59	25.63	6.22	18.97
Demand	~~18.01~~ 0	8.59	20.81	

	Destination		Supply
Source	11.47	17.65	10.43
	25.63	$\boxed{6.22}$ 18.97	~~18.97~~ 0
Demand	8.59	~~20.81~~ 1.84	

	Destination		Supply
Source	$\boxed{11.47}$ 8.59	17.65	~~10.43~~ 1.84
Demand	~~8.59~~ 0	1.84	

	Destination	Supply
Source	1.84 17.65	~~1.84~~
Demand	~~1.84~~	

The crisp value of the minimum transportation cost of the FTP is:

$(15 \times 3.5) + (5.65 \times 18.01) + (8.59 \times 11.47) + (17.65 \times 1.84)\ (18.97 \times 6.22)$

$52.5 + 101.76 + 98.53 + 32.48 + 117.99$

403.26

4. Conclusion

The transportation costs are viewed as fuzzy numbers, which are more realistic and all-encompassing in character, that describe imprecise statistics. Fuzzy transportation problem of triacontakaidigon fuzzy numbers has been transformed into crisp transportation problem using ranking technique indices. The approach may produce both the crisp and fuzzy ideal total cost as well as the optimal solution, according to numerical examples. Decision-makers who are managing logistical and supply chain issues in a fuzzy environment will therefore find this useful.

References

[1] Ahmed, M.M., Khan, A.R., Uddin, M.S., Ahmed, F., A new approach to solve transportation problems. *Open J. Optimization*, Vol 5, No.1, pp. 22–30, 2016.

[2] Javad Sadeghi, A method for solving the transportation problem, *Journal of Statistics and Management Systems*, Vol. 21 No. 5, pp. 817-837 (2018). DOI: 10.1080/09720.

[3] Kenan Karagul and YusufSahin, A novel approximation method to obtain initial basic feasible solution of transportation problem, *Journal of King Saud University - Engineering Sciences*, Vol 32. No. 3 pp. 211-218 (2020).

[4] Kaur. A and Kumar A, A new method for solving fuzzy transportation problems using ranking function, *Appl. Math. Model.* 35, Vol. pp. 5652-5661 (2011).

[5] Kumar. A, Amarpreet. K, Application of classical transportation methods for solving fuzzy transportation problems, *Journal of Transportation Systems Engineering and Information Technology,* Vol.11 No. 5, pp. 68-80 (2011).

[6] Narayanamoorthy S, Saranya S and Maheswari S, A Method for Solving Fuzzy Transportation Problem using Fuzzy Russell's Method, *I. J. Intelligent Systems and Applications,* Vol. 02, pp. 71-75 (2013).

[7] Mathur. M, PK Srivastava, A Paul, Algorithms for solving fuzzy transportation problem, *International Journal of Mathematics in Operational Research*, Vol. 12, No. 2, pp.190 (2018).

[8] Pandian. P and Nagarajan. G, A new algorithm for finding a fuzzy optimal solution for fuzzy transportation problem, *Applied Mathematics Sciences*, Vol 4 No. 2, pp. 79-90 (2010).

[9] Pulkit Rathi, Sugandha Rathi and Kamlesh Gupta, An optimization approach for transportation problem of transplant organ using self-adaptive bear hibernation algorithm, *Journal of Information and Optimization Sciences*, Vol 41. No 2, pp. 567-576 (2020). DOI: 0.1080/02522667.2020.1733189.

[10] Stefan M. Stefanov, Characterization of the optimal solution of the convex generalized nonlinear transportation problem, *Journal of Interdisciplinary Mathematics,* Vol. 22 No.5, pp 745-756 (2019). DOI: 10.1080/09720502.2019.1668151.

[11] R K Saini, Atul Sangal and Om Prakash, Unbalanced Transportation Problems in Fuzzy Environment using Centroid Ranking Technique, *International Journal of Computer Applications*, Vol 110, No.11, pp. 27-33 (2015).

[12] Sarbjit Singh , Note on Transportation Problem with New Method for Resolution of Degeneracy, *Universal Journal of Industrial and Business Management*, Vol. 3, No. 1, pp. 26-36 (2015).

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