International Journal of Applied Engineering Research, ISSN 0973-4562 Volume 13, Number 16 (2018) pp. 12702–12709

A New Ranking on Generalized Octagonal Fuzzy Numbers

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Abstract: In decision making a ranking of fuzzy number have an important role. In this paper, we proposed the ranking of generalized octagonal fuzzy numbers. The proposed method is based on incentre of centroids by using Euclidean distance. We solve generalized octagonal fuzzy linear programming problem by alternative simplex method to determine the optimal solution. Using the numerical examples we compared our proposed approach with different approaches.

Keywords: Ranking function, centroid points, generalized octagonal fuzzy numbers, fuzzy linear programming problem.

INTRODUCTION

Fuzzy logic is a form of many valued logic. It deals with reasoning that is approximate rather than fixed and gives an exact solution. In classical set theory where binary sets have two valued logic true or false. In fuzzy logic true value of variables that range in 0 and 1. The idea of fuzzy logic was first introduced by Zadeh [6]. Klir et al. [3] apply his logic in fuzzy sets and fuzzy logic.

Today, fuzzy logic is used in many application to make human life easier. It is used in the washing machine, smart phone, air conditioners, traffic control system, automatic gear control system, camera, T.V sets, automobile engine, vacuum cleaner etc.

Ranking method is used in many decision problems to express fuzzy numbers in crisp value. Due to overlapping of fuzzy numbers, there is difficulty to find which number is smaller and which is larger. We determine correct ordering of fuzzy numbers by using the ranking function.

Fuzzy linear programming is one of the most frequently applied operations research technique which solves many real life problems. The concept of fuzzy linear programming problem was first introduced by Tanaka et al.[4]. Fuzzy linear programming problem was further research by various authors. Amit kumar et al.[1] proposed new ranking method for comparing generalized trapezoidal fuzzy numbers and proposed a new generalized simplex algorithm for solving FLP problems with fuzzy parameters.

PRELIMINARY

Definition 1. [2] Fuzzy number:
A fuzzy number is a generalization of a regular real number and which does not refer to a single value but rather to a connected a set of possible values, where each possible value has its weight between 0 and 1. This weight is called the membership function.
A fuzzy number is a convex normalized fuzzy set on the real line R such that:

1) There exist at least one $x \in R$ with $\mu_{\tilde{A}}(x) = 1$
2) $\mu_{\tilde{A}}(x)$ is piecewise continuous.

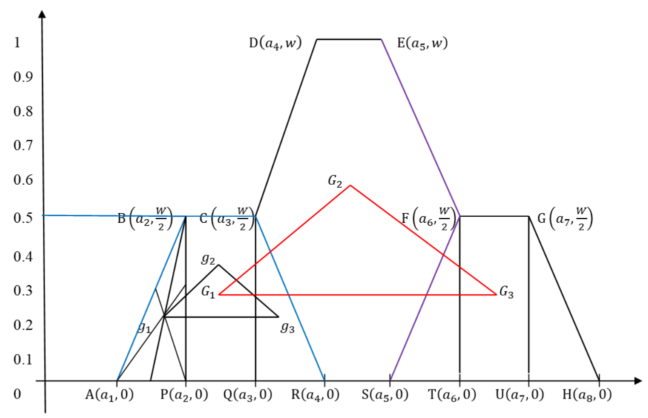
Definition 2. Generalized fuzzy number:
A fuzzy set A is defined on universal set of real numbers is said to be generalized fuzzy number if its membership function has the following attributes:

1) $\mu_{\tilde{A}}(x) : R \rightarrow [0, 1]$ is continuous;
2) $\mu_{\tilde{A}}(x) = 0$ for all $x \in (-\infty, a] \bigcup [d, \infty)$;
3) $\mu_{\tilde{A}}(x)$ is strictly increasing on [a,b] and strictly decreasing on $[c, d]$;
4) $\mu_{\tilde{A}}(x) = w$ for all $x \in [b, c]$, where $0 < w \leq 1$.

Definition 3. Membership Function:
A fuzzy number A is said to be a generalized octagonal fuzzy number denoted by $\tilde{A}_H = (a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8; k, w)$ where $a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8$ are real numbers and its membership function μ_A is given by,

$$\mu_A(x) = \begin{cases} 0, & for \quad x < a_1, \\ k\left(\frac{x-a_1}{a_2-a_1}\right), & for \quad a_1 \leq x \leq a_2 \\ k, & for \quad a_2 \leq x \leq a_3 \\ k + (w-k)\left(\frac{x-a_3}{a_4-a_3}\right), & for \quad a_3 \leq x \leq a_4 \\ w, & for \quad a_4 \leq x \leq a_5 \\ k + (w-k)\left(\frac{a_6-x}{a_6-a_5}\right), & for \quad a_5 \leq x \leq a_6 \\ k, & for \quad a_6 \leq x \leq a_7 \\ k\left(\frac{a_8-x}{a_8-a_7}\right), & for \quad a_7 \leq x \leq a_8 \\ 0, & for \quad x \geq a_8. \end{cases}$$

PROPOSED METHOD



The centroid point of an octagonal fuzzy number is considered to be the balancing point of the octagon. Divide the octagon into three plane figures. These three plane figures are a trapezium ABCR, a hexagon RCDEFS and again a trapezium SFGH respectively. Let the centroid of three plane figures be G_1, G_2 and G_3 respectively.

The incenter of centroids G_1, G_2 and G_3 is taken as the point of reference to define the ranking of generalised octagonal fuzzy number. The reason for selecting this point as a point of reference is that each centroid points are balancing points of each individual plane fig. and the incenter of these centroids points as a much more balancing point for generalized octagonal fuzzy number. Therefore this point would be better than the centroid point of octagon. Consider a generalized octagonal fuzzy number $\tilde{A}_H = (a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8; w)$ the centroid of these plane figures is,

$$G_1 = \left(\frac{a_1 + 2a_2}{3} + \frac{a_2 + a_3}{2} + \frac{2a_3 + a_4}{3}, \frac{w}{6} + \frac{w}{4} + \frac{w}{6}\right)$$
$$= \left(\frac{2a_1 + 7a_2 + 7a_3 + 2a_4}{18}, \frac{7w}{36}\right)$$

Similarly,

$$G_2 = \left(\frac{a_1 + 2a_4 + 2a_5 + a_6}{6}, \frac{w}{2}\right)$$

$$G_3 = \left(\frac{2a_5 + 7a_6 + 7a_7 + 2a_8}{18}, \frac{7w}{36}\right)$$

The equation of the line G_1, G_3 is $Y = \frac{w}{5}$ and G_2 does not lie on the line G_1 and G_3. Thus G_1, G_2 and G_3 are non-collinear and they form a triangle.

Incentre of octagonal fuzzy number:
We define the incentre $I_{\tilde{A}_H}(\bar{x_0}, \bar{y_0})$ of triangle with vertices G_1, G_2 and G_3 of the generalized octagonal fuzzy numbers $\tilde{A}_H = (a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8; w)$ as

$$I_{\tilde{A}_H}(\bar{x_0}, \bar{y_0}) =$$

$$\left(\frac{\alpha_{\tilde{A}_H}\left(\frac{2a_1+7a_2+7a_3+2a_4}{18}\right) + \beta_{\tilde{A}_H}\left(\frac{a_1+2a_4+2a_5+a_6}{6}\right)}{\alpha_{\tilde{A}_H} + \beta_{\tilde{A}_H} + \gamma_{\tilde{A}_H}} + \frac{\gamma_{\tilde{A}_H}\left(\frac{2a_5+7a_6+7a_7+2a_8}{18}\right)}{\alpha_{\tilde{A}_H} + \beta_{\tilde{A}_H} + \gamma_{\tilde{A}_H}}, \frac{\alpha_{\tilde{A}_H}\left(\frac{7w}{36}\right) + \beta_{\tilde{A}_H}\left(\frac{w}{2}\right) + \gamma_{\tilde{A}_H}\left(\frac{7w}{36}\right)}{\alpha_{\tilde{A}_H} + \beta_{\tilde{A}_H} + \gamma_{\tilde{A}_H}}\right) \quad (1)$$

where,

$$\alpha_{\tilde{A}_H} = \left(\frac{\sqrt{(4a_8 + 14a_7 + 8a_6 - 8a_5 - 12a_4 - 6a_1)^2 + 121w^2}}{36}\right),$$

$$\beta_{\tilde{A}_H} = \Big(\frac{\sqrt{(2a_8 + 7a_7 + 7a_6 + 2a_5 - 2a_1 - 7a_2 - 7a_3 - 2a_4)^2}}{18}\Big),$$

and

$$\gamma_{\tilde{A}_H} = \Big(\frac{\sqrt{(6a_6 + 12a_5 + 8a_4 + 2a_1 - 14a_2 - 14a_3)^2 + 121w^2}}{36}\Big).$$

The ranking of generalized octagonal fuzzy number:
The ranking of generalized octagonal fuzzy number $\tilde{A}_H = (a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8; w)$ which maps the set of all fuzzy numbers to a set of real numbers is defined as,

$$R(\tilde{A}_H) = \sqrt{\bar{x_0}^2 + \bar{y_0}^2}.$$

This is the Euclidean distance from the incentre of centroids.

Steps for finding the rank of fuzzy numbers
Let

$$\tilde{A}_H = (a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8; w_1)$$

and

$$\tilde{B}_H = (b_1, b_2, b_3, b_4, b_5, b_6, b_7, b_8; w_2)$$

be two generalized octagonal fuzzy numbers then,

Step 1: Find $\alpha_{\tilde{A}_H}, \beta_{\tilde{A}_H}, \gamma_{\tilde{A}_H}$ and $\alpha_{\tilde{B}_H}, \beta_{\tilde{B}_H}, \gamma_{\tilde{B}_H}$.

Step 2: Find $I_{\tilde{A}_H}(\bar{x_0}, \bar{y_0})$ and $I_{\tilde{B}_H}(\bar{x_0}, \bar{y_0})$.

Step 3: Find $R(\tilde{A}_H) = \sqrt{\bar{x_0}^2 + \bar{y_0}^2}$
and $R(\tilde{B}_H) = \sqrt{\bar{x_0}^2 + \bar{y_0}^2}$
and using the following the ranking of generalized octagonal fuzzy numbers,

1. $If \quad R(\tilde{A}_H) > R(\tilde{B}_H) then \quad \tilde{A}_H > \tilde{B}_H$
2. $If \quad R(\tilde{A}_H) < R(\tilde{B}_H) then \quad \tilde{A}_H < \tilde{B}_H$
3. $If \quad R(\tilde{A}_H) \approx R(\tilde{B}_H) then \quad \tilde{A}_H \approx \tilde{B}_H$

NUMERICAL EXAMPLES

Let

$$\tilde{A}_H = (0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8; 0.3)$$

and

$$\tilde{B}_H = (0.2, 0.4, 0.6, 0.8, 1, 1.2, 1.4, 1.6; 0.6)$$

be two generalized octagonal fuzzy numbers.

Step 1:

$$\alpha_{\tilde{A}} = \Big(\frac{\sqrt{(4a_8 + 14a_7 + 8a_6 - 8a_5 - 12a_4 - 6a_1)^2 + 121w^2}}{36}\Big)$$
$$\alpha_{\tilde{A}_H} = \Big(\frac{\sqrt{(4 \times 0.8 + 14 \times 0.7 + 8 \times 0.6 - 8 \times 0.5 - 12 \times 0.4 - 6 \times 0.1)^2 + 121 \times (0.3)^2}}{36}\Big)$$
$$\alpha_{\tilde{A}_H} = 0.25$$

$$\alpha_{\tilde{B}_H} = \Big(\frac{\sqrt{(4 \times 1.6 + 14 \times 1.4 + 8 \times 1.2 - 8 \times 1 - 12 \times 0.8 - 6 \times 0.2)^2 + 121 \times (0.6)^2}}{36}\Big)$$
$$\alpha_{\tilde{B}_H} = 0.50$$

$$\beta_{\tilde{A}} = \Big(\frac{\sqrt{(2a_8 + 7a_7 + 7a_6 + 2a_5 - 2a_1 - 7a_2 - 7a_3 - 2a_4)^2}}{18}\Big)$$
$$\beta_{\tilde{A}_H} = \Big(\frac{\sqrt{(2 \times 0.8 + 7 \times 0.7 + 7 \times 0.6 + 2 \times 0.5 - 2 \times 0.1 - 7 \times 0.2 - 7 \times 0.3 - 2 \times 0.4)^2}}{18}\Big)$$
$$\beta_{\tilde{A}_H} = 0.4$$

$$\beta_{\tilde{B}_H} = \Big(\frac{\sqrt{(2 \times 1.6 + 7 \times 1.4 + 7 \times 1.2 + 2 \times 1 - 2 \times 0.2 - 7 \times 0.4 - 7 \times 0.6 - 2 \times 0.8)^2}}{18}\Big)$$
$$\beta_{\tilde{B}_H} = 0.8$$

$$\gamma_{\tilde{A}} = \Big(\frac{\sqrt{(6a_6 + 12a_5 + 8a_4 + 2a_1 - 14a_2 - 14a_3)^2 + 121w^2}}{36}\Big)$$
$$\gamma_{\tilde{A}_H} = \Big(\frac{\sqrt{(6 \times 0.6 + 12 \times 0.5 + 8 \times 0.4 + 2 \times 0.1 - 14 \times 0.2 - 14 \times 0.3)^2 + 121 \times (0.3)^2}}{36}\Big)$$
$$\gamma_{\tilde{A}_H} = 0.19$$

$$\gamma_{\tilde{B}_H} = \Big(\frac{\sqrt{(6 \times 1.2 + 12 \times 1 + 8 \times 0.8 + 2 \times 0.2 - 14 \times 0.4 - 14 \times 0.6)^2 + 121 \times (0.6)^2}}{36}\Big)$$
$$\gamma_{\tilde{B}_H} = 0.38$$

Step 2:
From equation of incentre of octagonal fuzzy numbers we get,

$$I_{\tilde{A}_H}(\bar{x_0}, \bar{y_0}) = \Big(\frac{0.25(\frac{2\times0.1+7\times0.2+7\times0.3+2\times0.4}{18}) + 0.4(\frac{0.1+2\times0.4+2\times0.5+0.6}{6}) + 0.19(\frac{2\times0.5+7\times0.6+7\times0.7+2\times0.8}{18})}{0.25 + 0.4 + 0.19},$$
$$\frac{0.25(\frac{7\times0.3}{36}) + 0.4(\frac{0.3}{2}) + 0.19(\frac{7\times0.3}{36})}{0.25 + 0.4 + 0.19}\Big)$$
$$= (0.42, 0.10)$$

$$I_{\tilde{B}_H}(\bar{x_0}, \bar{y_0}) = \Big(\frac{0.50(\frac{2\times0.2+7\times0.4+7\times0.6+2\times0.8}{18}) + 0.8(\frac{0.2+2\times0.8+2\times1+1.2}{6}) + 0.38(\frac{2\times1+7\times1.2+7\times1.4+2\times1.6}{18})}{0.50+0.8+0.38}, \frac{0.50(\frac{7\times0.6}{36}) + 0.8(\frac{0.6}{2}) + 0.38(\frac{7\times0.6}{36})}{0.50+0.8+0.38}\Big) = (0.84, 0.20)$$

Step 3:

$$R(\tilde{A}_H) = \sqrt{(0.42)^2 + (0.10)^2} = 0.44$$
$$R(\tilde{B}_H) = \sqrt{(0.84)^2 + (0.20)^2} = 0.86.$$

Here $R(\tilde{A}_H) < R(\tilde{B}_H) \Rightarrow \tilde{A}_H < \tilde{B}_H$.

Dr. S. Chandrasekaran, G. Golika and Juno Saju [8] approach:

$$R(\tilde{A}) = \Big(\frac{2a_1 + 3a_2 + 4a_3 + 5a_4 + 5a_5 + 4a_6 + 3a_7 + 2a_8}{28}\Big) \times \Big(\frac{7}{28}\Big)$$

$$R(\tilde{A}_H) = \Big(\frac{2\times0.1 + 3\times0.2 + 4\times0.3 + 5\times0.4 + 5\times0.5 + 4\times0.6 + 3\times0.7 + 2\times0.8}{28}\Big)\Big(\frac{7}{28}\Big) = 0.11.$$

Similarly,

$$R(\tilde{B}_H) = \Big(\frac{2\times0.2 + 3\times0.4 + 4\times0.6 + 5\times0.8 + 5\times1 + 4\times1.2 + 3\times1.4 + 2\times1.6}{28}\Big)\Big(\frac{7}{28}\Big) = 0.23.$$

Here, $R(\tilde{A}_H) = 0.11 < R(\tilde{B}_H) = 0.23 \Rightarrow \tilde{A}_H < \tilde{B}_H$.

P. Malini and M. Ananthanarayann [7] approach:

$$R(\tilde{A}) = \Big(\frac{3a_1 + 6a_2 + 4a_3 + 5a_4 + 5a_5 + 4a_6 + 6a_7 + 3a_8}{36}\Big)$$
$$R(\tilde{A}_H) = \Big(\frac{3\times0.1 + 6\times0.2 + 4\times0.3 + 5\times0.4 + 5\times0.5 + 4\times0.6 + 6\times0.7 + 3\times0.8}{36}\Big) = 0.45.$$

Similarly,

$$R(\tilde{B}_H) = \Big(\frac{3\times0.2 + 6\times0.4 + 4\times0.6 + 5\times0.8 + 5\times1 + 4\times1.2 + 6\times1.4 + 3\times1.6}{36}\Big) = 0.9.$$

Here, $R(\tilde{A}_H) = 0.45 < R(\tilde{B}_H) = 0.9 \Rightarrow \tilde{A}_H < \tilde{B}_H$.

Dr. Sreelekha Menon [9] approach:

$$R(A) = \frac{1}{4}[(a_1 + a_2 + a_7 + a_8)k + (a_3 + a_4 + a_5 + a_6)(1 - k)]$$

$$R(\tilde{A}_H) = \frac{1}{4}\Big[(0.1 + 0.2 + 0.7 + 0.8)(0.3) + (0.3 + 0.4 + 0.5 + 0.6)(1 - 0.3)\Big] = 0.45$$

$$R(\tilde{B}_H) = \frac{1}{4}\Big[(0.2 + 0.4 + 1.4 + 1.6)(0.6) + (0.6 + 0.8 + 1 + 1.2)(1 - 0.6)\Big] = 0.9.$$

Here, $R(\tilde{A}_H) = 0.45 < R(\tilde{B}_H) = 0.9 \Rightarrow \tilde{A}_H < \tilde{B}_H$.

A comparison of ranking results for a different approach:

Approaches	$Ex.1$
Dr. Chandrasekaran	$\tilde{A}_H < \tilde{B}_H$
Dr. P.Malini	$\tilde{A}_H < \tilde{B}_H$
Dr. Sreelekha Menon	$\tilde{A}_H < \tilde{B}_H$
Proposed approach	$\tilde{A}_H < \tilde{B}_H$

V. Example of fuzzy linear programming problem:

$$Maximize\ \tilde{z} = (11, 13, 15, 17, 19, 21, 23, 25; 0.5)\tilde{x_1} + (31, 33, 35, 37, 39, 41, 43, 45; 0.3)\tilde{x_2}$$

Subject to,

$$82\tilde{x_1} + 100\tilde{x_2} \leq (71, 72, 73, 74, 75, 76, 77, 78; 0.8)$$
$$72\tilde{x_1} + 12\tilde{x_2} \leq (3, 6, 9, 12, 15, 18, 21, 24; 1)$$
$$\tilde{x}_1, \tilde{x}_2 \geq 0.$$

Solution:
Using incentre of centroid ranking function we get,

$$Maximize\ \tilde{z} = 17.29\tilde{x_1} + 37.32\tilde{x_2}$$

Subject to,

$$82\tilde{x_1} + 100\tilde{x_2} \leq 74.17$$
$$72\tilde{x_1} + 12\tilde{x_2} \leq 12.50$$
$$\tilde{x}_1, \tilde{x}_2 \geq 0.$$

FLPP in standard form:

$$Maximize\tilde{z} = 17.29\tilde{x_1} + 37.32\tilde{x_2} + 0\tilde{s}_1 + 0\tilde{s}_2$$

Subject to,

$$82\tilde{x}_1 + 100\tilde{x}_2 + \tilde{s}_1 = 74.17$$
$$72\tilde{x}_1 + 12\tilde{x}_2 + \tilde{s}_2 = 12.50$$
$$\tilde{x}_1, \tilde{x}_2, \tilde{s}_1, \tilde{s}_2 \geq 0.$$

Using method [5] we get, simplex table:

C_B	BVS	X_B	$\tilde{x}_1$	$\tilde{x}_2$	$\tilde{s}_1$	$\tilde{s}_2$
0	$\tilde{s}_1$	74.17	82	100	1	0
0	$\tilde{s}_2$	12.50	72	12	0	1
37.32	$\tilde{x}_2$	0.74	0.82	1	0.01	0
0	$\tilde{s}_2$	3.62	62.16	0	-0.12	1
37.32	$\tilde{x}_2$	0.69	0	1	0.01	-0.02
17.29	$\tilde{x}_1$	0.06	1	0	-0.001	0.02

Optimal solution is

$$\tilde{x}_1 = 0.06, \tilde{x}_2 = 0.69, Maximize \tilde{z} = 26.79$$

Using centroid ranking function to example (V)

$$\left(\frac{2a_1 + 7a_2 + 10a_3 + 8a_4 + 8a_5 + 10a_6 + 7a_7 + 2a_8}{54} \times \frac{8w}{27}\right)$$

we get,

$$Maximize\,\tilde{z} = 2.67\tilde{x}_1 + 3.38\tilde{x}_2$$

Subject to

$$82\tilde{x}_1 + 100\tilde{x}_2 \leq 17.66$$
$$72\tilde{x}_1 + 12\tilde{x}_2 \leq 4$$
$$\tilde{x}_1, \tilde{x}_2 \geq 0.$$

FLPP in standard form,

$$Maximize\,\tilde{z} = 2.67\tilde{x}_1 + 3.38\tilde{x}_2 + 0\tilde{s}_1 + 0\tilde{s}_2$$

Subject to

$$82\tilde{x}_1 + 100\tilde{x}_2 + \tilde{s}_1 = 17.66$$
$$72\tilde{x}_1 + 12\tilde{x}_2 + \tilde{s}_2 = 4$$
$$\tilde{x}_1, \tilde{x}_2, \tilde{s}_1, \tilde{s}_2 \geq 0.$$

Using method [5] we get,
Simplex table:

C_B	BVS	X_B	$\tilde{x}_1$	$\tilde{x}_2$	$\tilde{s}_1$	$\tilde{s}_2$
0	$\tilde{s}_1$	17.66	82	100	1	0
0	$\tilde{s}_2$	4	72	12	0	1
3.38	$\tilde{x}_2$	0.18	0.82	1	0.01	0
0	$\tilde{s}_2$	1.84	62.16	0	-0.12	1
3.38	$\tilde{x}_2$	0.16	0	1	0.01	-0.02
2.67	$\tilde{x}_1$	0.03	1	0	-0.002	0.02

Optimal solution is $\tilde{x}_1$=0.03, $\tilde{x}_2$=0.16, Maximize $\tilde{z}$ =0.62

Comparison table of proposed ranking method and centroid ranking method:

Method	$\tilde{x}_1$	$\tilde{x}_2$	$\tilde{z}$
Proposed ranking method	0.06	0.69	26.79
Centroid ranking method	0.03	0.16	0.62

CONCLUSION

We introduced a new ranking method for generalized octagonal fuzzy numbers with Euclidean distance by the incentre of centroids. The advantage of our proposed ranking method is to rank fuzzy set which is non-normal and also gives the correct ordering of generalized and normal octagonal fuzzy numbers. The proposed ranking method gives best optimal solution than the existing method. It is more advanced method than a ranking method based on centroid concept. This ranking function is easy to apply in real life problem.

REFERENCES

[1] Amit kumar, P. Singh and J. Kaur, Generalized simplex algorithm to solve fuzzy linear programming problems with ranking of generalized fuzzy numbers, Turkish Journal of fuzzy systems, 1(2010), 80–103.

[2] A. Hamoud and K. Ghadle, Modified Adomian decomposition method for solving fuzzy Volterra-Fredholm integral equations, J. Indian Math. Soc., 85, (1-2) (2018), 52–69.

International Journal of Applied Engineering Research, ISSN 0973-4562 Volume 13, Number 16 (2018) pp. 12702–12709
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[3] G. Klir and Boyuan, Fuzzy sets and fuzzy logic theory and application, Prentice Hall Inc-574, 1995.
[4] H. Tanaka and K. Asai, Fuzzy linear programming problem with fuzzy numbers, Fuzzy sets and system, 13(1984), 1–10.
[5] K. P. Ghadle, T. S. Pawar and N. W. Khobragade, Solution of linear programming problem by new approach, International Journal of engineering and Innovative Technology, 3(2013), 301–307.
[6] L. A. Zadeh, Fuzzy set, Information and Control, 8(1965), 338–353.
[7] P. Malini and M. Ananthanarayanan, Solving fuzzy transportation problem using ranking of octagonal fuzzy numbers, International Journal of Pure and Applied Mathematics, 110(2016), 275–282.
[8] S. Chandrasekaran, G. Gokila and Juno Saju, Ranking of octagonal fuzzy numbers for solving multi objective fuzzy linear programming problem with simplex method and graphical Method, International Journal of Scientific Engineering and Applied Science (IJSEAS), 1(2015), 504–515.
[9] S. Menon, Solving fuzzy maximal flow problem using octagonal fuzzy number, International Journal of Engineering Research and Applications, 6(2016), 66–74.