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Application of Hexagonal Fuzzy Number in Finding the Expected Time Duration in a Transportation Network Problem

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***Abstract**: In this paper, expected time duration in a transportation problem for the critical path was determined by applying the new ranking method. This article proposed to solve the fuzzy transportation problem using hexagonal Fuzzy number. The transportation problem is solved using new proposed ranking method of hexagonal Fuzzy Number. The proposed transportation is formulated to a crisp transportation problem and Solved by using ranking of hexagonal Fuzzy number. Numerical examples are illustrated for the new proposed ranking method. This paper intends to introduce a different ranking approach for obtaining the expected time of the fuzzy project network. In the under consideration network problem, the activity time duration is calculated by applying some operations to the fuzzy hexagonal number. This ranking method is derived from centroid method for hexagonal fuzzy numbers and it proposes an advanced ranking approach by applying the centroid of the hexagonal fuzzy number. In this paper the hexagon is separated into two triangles and one polygon. By applying the right angle and polygon centroid formula for triangle and polygon, we can calculate the centroid of each triangle and polygon and hence find out the centroid of the centroid. Also the some changes are made to introduce the new ranking method of hexagonal Fuzzy Number.*

Keywords: Fuzzy hexagonal number, ranking function, centroid, proposed ranking method, expected time, the centroid of centroid, fuzzy transportation problem

I. INTRODUCTION

Transportation problem is the optimization problem. When the coefficients of cost, the coefficients of supply and the coefficients demand quantities are known exactly, then supply chain for reducing the cost efficient algorithms have been developed for solving the transportation problem. If in a transportation problem, the cost transportation cost, demand and supply quantities are fuzzy quantities, then the transportation problem is a fuzzy transportation problem. The method used for the optimization, is to rank the fuzzy objective values of the objective function by some ranking method for numbers to find the best alternative. On the basis of this idea the proposed ranking method with the help of α solution has been adopted a transform the fuzzy transportation problem into a crisp transportation problem.

In real transportation problem situation a risk assessment features and analytical study with the problem that the information which necessary for constructing a calculation accuracy. So that the cost for getting this information seems too high, hence performance of risk features form constructing a decision making in the study and accuracy that this model is not a small process of the real problem. Fuzzy set theory offers the possibility to construct decision models, with such vague decision models, vague data is used to reach the result. Many risk models fuzzy components are proposed in literature, but only fuzzy utilities are important for practical application. When track to apply when the accuracy less combined to that numerical result small then the information cost.

Let a_i be the number of units of a product available at source i and b_j be the number of units of the product required at destination j. Let C_{ij} be the cost of transporting one unit from source i to destination j and let x_{ij} be the amount of quantity carried or shipped from origin i to destination j. Also let T_{ij} time of transportation from the source i to the

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destination j. Now if there is a path from the source i to the destination j through the sub destinations l, m, n. Then we can find the total time taken from the source i to the destination j as $T_{total}= T_{il}+ T_{lm} +T_{mn} + T_{nj}$.

The concepts of fuzzy sets were first introduced by Zadeh [1]. Since its inception several ranking procedures of fuzzy numbers have been developed so for. Many authors presented various approaches for solving the fuzzy transportation problems [3]. Some of the fuzzy number ranking approaches have been reviewed and compared by Bortolan and Degani [2]. Presently Chen and H Wang [4] reviewed the existing method for ranking fuzzy numbers and find the drawbacks in some aspects such as lengthy calculations and indiscrimination and finding not so easy to interpret the methods. As of now none of the fuzzy ranking lessen calculations due to which they are tedious to handle. Ranking normal fuzzy number was first introduced by Jain [5] for decision making in fuzzy situations. Since then remarkable efforts are made on the development of numerous methodologies. The development in ordering fuzzy numbers can even be found in [6],[7],[8],[9],[10].Fuzzy numbers must be ranked before a decision is taken by a decision maker.

In this paper a new method is presented for the ranking of generalized fuzzy hexagonal numbers. To illustrate this proposed method, as the proposed ranking method is very direct and simple and includes easy calculations. So it is very easy to understand. It is derived from the centroid fuzzy ranking method and is easy to find out the fuzzy optimal solution of fuzzy transportation problems occurring in the real life situations.

II. LITERATURE REVIEW

In the current dynamic system of market, companies must find the most efficient means of sending products to customers in the quantities requested by the customers as soon as possible and at the lowest cost; this is the well-known transportation network problem of the present world. The some of the transportation problems has been widely studied and solved to some extent [20] and then generalized to more than two indexes [18, 26, 27]. Based on its typology [18], transportation problem can be classified into four groups: 2-index, 3-index, 4-index, and n-index. Previously, many efficient algorithms have been developed to identify the optimal total cost when the demands, offers, and unitary costs are known. Chen [10] introduced the concept of generalized fuzzy numbers to deal problems with unusual fuzzy membership function. A new fuzzy algorithm that is called fuzzy zero point method to find optimal solution of a fuzzy transportation problem was introduced by Pandian and Natarajan [11] in which fuzzy trapezoidal numbers were used. A fuzzy transportation problem was solved by Kaur and Kumar [12], [13] with the application of generalized trapezoidal fuzzy numbers. Ranking of fuzzy heptagon number using zero suffix method was proposed by Chandra sekaran S., Kokila G., Junu Saju [14]. A comparative study of the methods Russell's Method, Least Cost Method and North West corner Method was introduced in [15] with heptagonal fuzzy numbers. Arun Patil & S. B. Chandgude [16] proposed the method of fuzzy modified distribution for finding out the optimal solution for minimizing the cost of total fuzzy transportation and also the advantages of the method introduced were discussed briefly.

A risk decision making tool with Fuzzy Transportation problem was investigated by
M. Sangeetha [17]. P. Malini and Dr. M. Ananthanarayanan [18] presents a new ranking method of trapezoidal fuzzy numbers and by which they convert the fuzzy transportation problem to a crisp valued transportation problem which then can be solved by MODI method to find the optimal solution of the transportation problem. Results obtained by P. Malini and Dr. M. Ananthanarayanan [18] give the optimum cost by applying the trapezoidal fuzzy numbers for the fuzzy transportation problem. S. Nareshkumar and S. Kumaraghuru[19] presented the closed, non–empty and bounded feasible region of the transportation problem by the application of fuzzy trapezoidal numbers which ensures the existence of an optimal solution to the balanced transportation problem. R. Pavithra and G. M. Rosario [20] represented costs of a fuzzy transportation problem as hexagonal fuzzy numbers and introduced the suitable deffuzification method to find the minimum transportation cost for the fuzzy transportation problem. Amrita Sarkar, G. Sahoo and U. C. Sahoo [21] presented an analysis of the results achieved using fuzzy logic technique to model complex traffic and transportation processes. Dr. A. Sahaya Sudha and S. Karunambigai [22] considered a fuzzy transportation problem in which the values of transportation costs are represented as heptagonal fuzzy numbers. They used the proposed method to solve the fuzzy transportation problem. Fuzzy transportation problem can be converted into a crisp valued Transportation Problem using a new ranking method.

Preliminaries

Fuzzy set: A fuzzy set is an ordered pair $\{x, \mu_{\tilde{F}}(x); x\in X\}$, X is the universe of discourse and $\mu_{\tilde{F}}(x)$ is a function from X to [0,1]

Normal fuzzy set: A fuzzy set $\tilde{F}$ defined on the set of the universe of discourse X is called a normal fuzzy set if there exist at least one $x \in X$ such that $\mu_{\tilde{F}}(x) = 1$.

Support of a fuzzy set: The support of a fuzzy set in the universal set X is the set that contains all the elements of X that have a non- zero membership grade in $\tilde{F}$. i.e., Supp $(\tilde{F}) = \{x \in X / \mu_{\tilde{F}}(x) > 0$.

α−cut: Given a fuzzy set $\tilde{F}$ defined on X and any number $\alpha \in [0, 1]$ the α - Cut, $\alpha\tilde{F}$ is the crisp Set $\alpha\tilde{F} = \{x \in X / \mu_{\tilde{F}}(x) \geq \alpha, \alpha\in[0,1]$.

Fuzzy Number: A fuzzy set $\tilde{F}$ defined on the set of real numbers R is said to be a fuzzy number if its membership function $\mu_{\tilde{F}}(x) : X \rightarrow [0,1]$ has the following properties

$\tilde{F}$ is convex and normal fuzzy set.

$\alpha\tilde{F}$ is a closed interval for every $\alpha\in(0,1]$.

The support of $\tilde{F}$ must be bounded.

Generalized Hexagonal Fuzzy Number (HFN)

A generalized hexagonal fuzzy number represented by $\tilde{A}_H = (p, q, r, s, t, u, \omega)$ where p, q, r, s, t, u are real numbers and its membership function $\mu_{\tilde{A}_H}(x)$ is given by

$$\mu_{\tilde{A}_H}(x) = \begin{cases} \frac{1}{2}\left(\frac{x-p}{q-p}\right) & for\ p \leq x \leq q \\ \frac{1}{2} + \frac{w}{2}\left(\frac{x-q}{r-q}\right) & for\ q \leq x \leq r \\ w & for\ r \leq x \leq s \\ 1 - \frac{w}{2}\left(\frac{x-s}{t-s}\right) & for\ s \leq x \leq t \\ \frac{1}{2}\left(\frac{u-x}{u-t}\right) & for\ t \leq x \leq u \\ 0 & otherwise \end{cases}$$

Pictorial representation of the generalized hexagonal fuzzy number is shown in figure 1 below

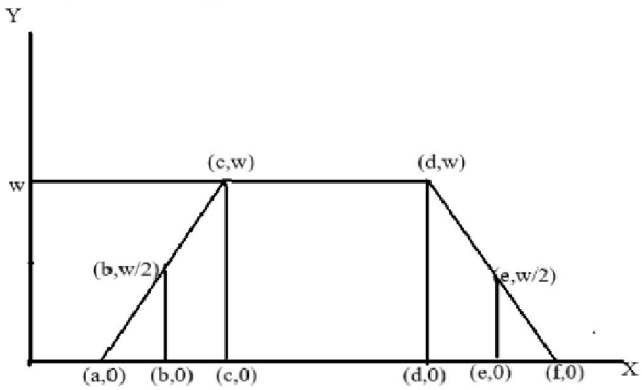

Figure1: Generalized Hexagonal Fuzzy Number

Ordering of Hexagonal Fuzzy Number

Let $\tilde{A}_H = (a_1, a_2, a_3, a_4, a_5, a_6)$ and $\tilde{B}_H = (b_1, b_2, b_3, b_4, b_5, b_6)$ be in fuzzy real number be the set of real Hexagonal fuzzy numbers

$\tilde{A}_H \cong \tilde{B}_H$ iff $a_i = b_i$, $i = 1,2,3,4,5,6$

$\tilde{A}_H \leq \tilde{B}_H$ iff $a_i \leq b_i$, $i = 1,2,3,4,5,6$

$\tilde{A}_H \geq \tilde{B}_H$ iff $a_i \geq b_i$, $i = 1,2,3,4,5,6$

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Ranking of hexagonal fuzzy number

An effective approach for comparing fuzzy numbers is to use a ranking function

$\mathcal{R}: FN(R) \longrightarrow R$,

Where $FN(R)$ is a collection of fuzzy numbers that maps each fuzzy number to a real number.

For any two hexagonal fuzzy numbers $\tilde{A}_H = (a_1, a_2, a_3, a_4, a_5, a_6)$ and $\tilde{B}_H = (b_1, b_2, b_3, b_4, b_5, b_6)$ have the following comparison.

$\tilde{A}_H \cong \tilde{B}_H$ iff $\mathcal{R}(\tilde{A}_H) = \mathcal{R}(\tilde{B}_H)$

$\tilde{A}_H \leq \tilde{B}_H$ iff $\mathcal{R}(\tilde{A}_H) \leq \mathcal{R}(\tilde{B}_H)$

$\tilde{A}_H \geq \tilde{B}_H$ iff $\mathcal{R}(\tilde{A}_H) \geq \mathcal{R}(\tilde{B}_H)$

Centroid ranking method of hexagonal fuzzy number is used to find out the new proposed ranking in linear hexagonal fuzzy number. we suggest it as a successful method for calculating the rank of hexagonal fuzzy numbers. The centroid ranking in the hexagonal fuzzy number diagram is represented in Figure 3.

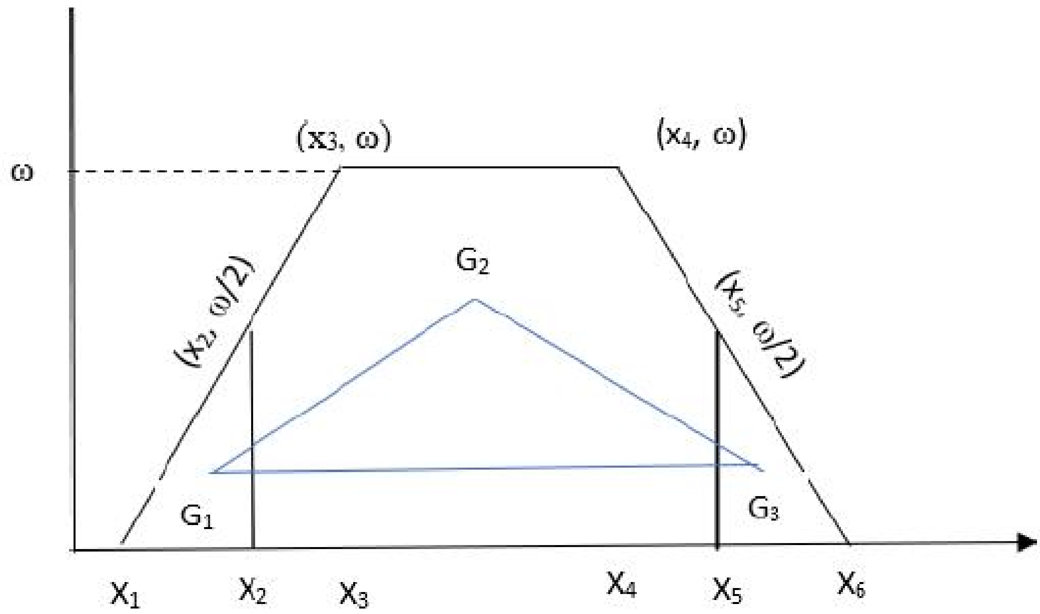

Figure3: Centroid ranking method

In the above figure 3, the hexagon is split into two right angles and one polygon. By applying the centroid formula of right triangle and polygon, calculate the centroid of triangles and polygon, respectively. The balancing point of hexagon in Figure 3 is taken as the circumcentre of the centroid pints of the triangles and a polygon of the hexagonal fuzzy number. The circumcentre of the triangle formed by the centroid of these three-plane figures together with some changes is taken as the ranking of generalized hexagonal fuzzy numbers. Let G_1 , G_2 and G_3 be the centroid of the three plane figures.

G_1 is the centroid of the right triangle with vertices $(x_1, 0)$, $(x_2, 0)$, $(x_2, \frac{\omega}{2})$.

G_2 is the centroid of the polygon with vertices $(x_2, 0)$, $(x_2, \frac{\omega}{2})$, (x_3, ω), (x_4, ω), $(x_5, \frac{\omega}{2})$, $(x_6, 0)$

G_3 is the centroid of the right triangle with vertices $(x_5, 0)$, $(x_5, \frac{\omega}{2})$, $(x_6, 0)$

The centroid of these three planes is

$G_1 = (\frac{x_1+2x_2}{3}, \frac{w}{6})$, $G_2 = (\frac{2x_2+x_3+x_4+2x_5}{6}, \frac{w}{2})$, $G_3 = (\frac{2x_5+x_6}{3}, \frac{w}{6})$ respectively

The circumcentre of G_1, G_2, and G_3 is

$$G_{\tilde{A}_H} = (\frac{2x_1+6x_2+x_3+x_4+6x_5+2x_6}{18}, \frac{5w}{18})$$

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A hexagonal fuzzy number is denoted by $\tilde{E}_H$ and is defined as $\tilde{E}_H = (a_1, a_2, a_3, a_4, a_5, a_6)$ where $a_1, a_2, a_3, a_4, a_5, a_6$ real numbers and its membership function are $\mu_{\tilde{A}_H}(x)$ is given below. It will be also obtained from general one by putting $\omega = 1$.

$$\mu_{\tilde{A}_H}(x) = \begin{cases} 0 \; for \; x < a_1 \\ \frac{1}{2}\left(\frac{x - a_2}{a_3 - a_2}\right) \; for \; a_1 \le x \le a_2 \\ \frac{1}{2} + \frac{1}{2}\left(\frac{x - a_2}{a_3 - a_2}\right) \; for \; a_2 \le x \le a_3 \\ 1 \; for \; a_3 \le x \le a_4 \\ 1 - \frac{1}{2}\left(\frac{x - a_4}{a_5 - a_4}\right) \; for \; a_4 \le x \le a_5 \\ \frac{1}{2}\left(\frac{a_6 - x}{a_6 - a_5}\right) \; for \; a_5 \le x \le a_6 \\ 0 \; for \; x > a_6 \end{cases}$$

New ranking function

Therefore, for the generalized Hexagonal fuzzy number $\tilde{A}_H = (a_1, a_2, a_3, a_4, a_5, a_6)$, we proposed here a new ranking function that is given by

$$\mathcal{R}(\tilde{A}_H) = \left(\frac{2x_1 + 6x_2 + x_3 + x_4 + 6x_5 + 2x_6}{18}\right)$$

Transportation Problem

It is the point of concern for both the sender and the receiver to reach the commodities on time in any transportation problem. Transportation problem with regard to expected time is a real world problem. As the expected time between the source and destination depends upon the various factors like connection between the source and the destination, It is of four types (1) by road (2) By train (3) by air (4) by sea ships, Weather as the harsh weather affects the transportation time and manpower etc. Some of the factors are vague such as weather as it is not crisp and in way obstacles like checking or scanning at various junctions.

Consider transportation with *m* fuzzy sources and *n* fuzzy destinations. Let T_{ij} be the expected time between the ith source and the jth destination. That is, T_{ij} is the time of a commodity to reach to the destination from the source. The above fuzzy transportation problem can be stated in the matrix form as shown table 1

Table 1

	1	2	…	n
1	T_{11}	T_{12}	…	T_{1n}
2	T_{21}	T_{21}	…	T_{2n}
3	T_{31}	T_{32}	…	T_{3n}
….	…	…	…	…
m	T_{m1}	T_{m2}	…	T_{mn}

Procedure for the problem

Solution of the problem includes some steps that are

Let the fuzzy time between the two consecutive source and destination be a hexagonal fuzzy number

Find the $\mathcal{R}(T_{21})$ for all the hexagonal fuzzy numbers, It is a crisp value

Find all the paths between the source and the destination

Find expected time of all the paths that is a crisp value

The path that has maximum crisp value is the critical path

Numerical example

Consider the following fuzzy transportation problem. We consider a network with a set of fuzzy events $\tilde{A}$ = {1, 2, 3, 4, 5} and the fuzzy activity time represented as a hexagonal fuzzy number for each activity in table 2. Furthermore, the project network diagram is represented in figure 3.

Table 2

Activity	1	2	3	4	5
1	(0,0,0,0,0,0)	(3,7,11,15,19,24)	(3,5,7,9,10,12)	(0,0,0,0,0,0)	(2, 3, 5, 6, 7, 8)
2	(3,7,11,15,19,24)	(0,0,0,0,0,0)	(0,0,0,0,0,0)	(11,14,17,21,25,30)	(5,7,10,13,17,21)
3	(3,5,7,9,10,12)	(0,0,0,0,0,0)	(0,0,0,0,0,0)	(3,5,6,7,8,12)	(0,0,0,0,0,0)
4	(0,0,0,0,0,0)	(11,14,17,21,25,30)	(3,5,6,7,8,12)	(0,0,0,0,0,0)	(1, 2, 4, 6, 8, 10)
5	(2, 3, 5, 6, 7, 8)	(5,7,10,13,17,21)	(0,0,0,0,0,0)	(1, 2, 4, 6, 8, 10)	(0,0,0,0,0,0)

$\mathcal{R}(\tilde{A}_H) = (\frac{2a_1+6a_2+a_3+a_4+6a_5+2a_6}{18})$

$\mathcal{R}((0,0,0,0,0,0)) = 0$

$\mathcal{R}((3,7,11,15,19,24)) = 13.1111$

$\mathcal{R}((3,5,7,9,10,12)) = 7.5555$

$\mathcal{R}((2,3,5,6,7,8)) = 5.0555$

$\mathcal{R}((11,14,17,21,25,30)) = 19.6666$

$\mathcal{R}((5,7,10,13,17,21)) = 12.1666$

$\mathcal{R}((3,5,6,7,8,12)) = 6.7222$

$\mathcal{R}((1,2,4,6,8,10)) = 5.1111$

Expected time between all of the consecutive activities is presented in table 3.

Table 3 Expected time between activities

Activities	Expected time between activities
1-2	13.1111
1-3	7.5555
1-5	5.0555
2-4	19.6666
2-5	12.1666
3-4	6.7222
4-5	5.1111

The all possible paths of project network from the source (1) to the destination (5) and their expected time is presented in table 4. All the paths from the source (1) to the destination (5) can be determined from the fuzzy transportation network figure 3.

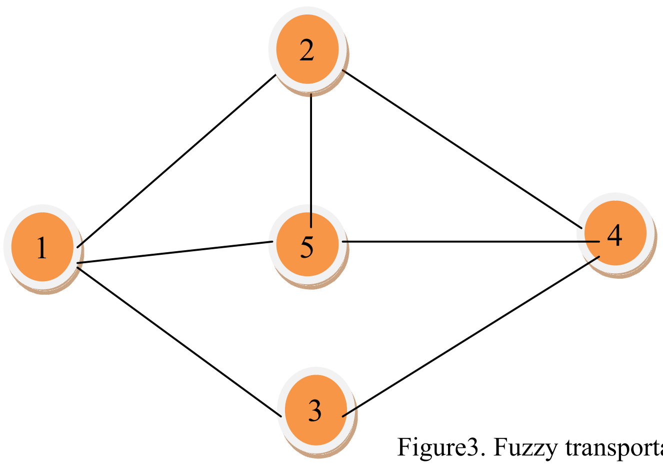

Figure3. Fuzzy transportation network

The expected time for all the paths from source (1) to destination (5) is presented by the proposed ranking method in table 4. Among all the paths from 1-5, the maximum value is 37.88. Therefore, the project completion duration is 3.88 and the critical path is 1-2-4-5.

Table 4

Paths	Expected time
1-5	5.05
1-2-5	25.27
1-2-4-5	37.88
1-3-4-5	19.38

III. CONCLUSION

In this paper, a new ranking function was introduced for the solution of a fuzzy transportation problem. Hexagonal fuzzy numbers were used in proposed ranking method. The new ranking function derived from the centroid method has been applied to calculate the expected time for critical path in the fuzzy transportation problem. Moreover, we can conclude that the solution of fuzzy problems can be obtained by proposed ranking method effectively; this fuzzy ranking technique can also be used in solving other types of problems like, fuzzy game problems, network problems, fuzzy flow problems and project schedules.

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