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AN OPTIMAL SOLUTION OF NONAGONAL FUZZY ASSIGNMENT PROBLEM USING AVERAGE RANKING METHOD

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Abstract: The specific case of transportation problem is an assignment problem. The goal of optimal assignment is assign equal number of task to equal number of persons with a minimum cost (time) or maximum profit (sales). In fuzzy assignment problem, the distance (time) are fuzzy values. In this article, a new ranking procedure proposed for ranking the nonagonal fuzzy numbers. The best solution of the nonagonal fuzzy assignment problem is obtained from proposed ranking technique which is compared with existing solution.

Keywords and Phrases: Average ranking method, Existing ranking method, Nonagonal fuzzy number.

2020 Mathematics Subject Classification: 03B52, 03E72, 90C06, 90C70.

1. Introduction

The specific case of transportation is an assignment problem. The goal of optimal assignment is assigning task to resources in which the total time (distance) is minimum. The concept of fuzzy introduced in real life situations by L. A. Zadeh [30]. C. J. Lin and U. P. Wen [15] applied labeling technique in fuzzy assignment problem. Stefan Chanas et al [3] solved the transportation problem with fuzzy approach. H. Basirzadeh [1] approached a different ranking technique for ranking the fuzzy numbers. Stefan Chanas and Dorota Kuchta [4] found an ideal solution of the fuzzy transportation problem. Assignment and travelling salesman problem in fuzzy nature discussed by Amit Kumar and Anila Gupta [14] with various membership functions. L. Sutha et al [26] solved the transportation problem with nonagonal fuzzy number. P. Ghadle Kirtiwant and M. Muley Yogesh [11] discussed the applications of assignment problem in travelling salesman problem. A. Felix et al [10] proposed a arithmetic operations of nonagonal fuzzy numbers. K. Deepika and S. Rekha [6] derived a new ranking function of nonagonal fuzzy numbers. P. Pandian and K. Kavitha [19] applied a technique for solving the fuzzy assignment problem. D. Selvi et al [24] ranked the fuzzy numbers by using magnitude method. B. Queen Mary and D. Selvi [20] ordered the fuzzy number using centroid ranking method. Emrouznejad et al [9] developed a new formulation for fuzzy assignment problem. S. Narayanamoorthy and P. Vidya [18] adopted a new technique to solve the fuzzy assignment problem. K. Sangeetha et al [22] ranked trapezoidal fuzzy number by using ranking method and solved the unbalanced fuzzy assignment problem. R. Jahirhussain and P. Jayaraman [13] found an optimal solution of assignment with fuzzy cost via robust ranking method. S. Menaka devi et al [16] ranked the heptagonal fuzzy number using robust ranking method.

Anchal Choudhary et al [5] solved assignment problem with fuzzy values. A. Venkatesh and A. Britto Manoj [29] discussed the applications of assignment problem in balanced diet control for human with nonagoonal fuzzy number. S. Dhanasekar et al [8] used diagonal algorithm to solve the fuzzy hexagonal assignment problem. N. Ruth Naveena and A. Rajkumar [21] introduced a reverse order nonagonal fuzzy number. V. R. Bindu Kumari and R. Govindarajan [2] discussed performance of single server queuing model in nonagonal fuzzy numbers. G. Santhi and M. Ananthanarayanan [23] ranked the fuzzy numbers using standard deviation method. P. Ghadle Kirtiwant and M. Muley Yoges [12] discussed the applications of assignment problem in laptop selection using matlab. Y. L. P. Thorani and N. Ravi Shankar [28] proposed a multi-objective assignment problem with fuzzy cost and defuzzified using centre of centroid method. S. Dhanasekar and S. Hariharan [7] presented a new for method for solving fuzzy assignment problem. R. Srinivasan et al [25] discussed the comparative study of fuzzy assignment problem with various ranking techniques. L. Suzane Raj et al [27] solved fuzzy assignment problem using best candidate method. S. Muruganandam and, K. Hema [17] approached a genetic algorithm to solve fuzzy assignment problem. In this article, a new ranking procedure proposed for ranking the nonagonal fuzzy numbers. An optimal solution of the fuzzy assignment problem is obtained with the help of proposed ranking method.

2. Nonagonal Fuzzy Number

A fuzzy number $\widetilde{A}$ is a nonagonal fuzzy number defined by $\widetilde{A}_{NFN}$=$(\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6, \alpha_7, \alpha_8, \alpha_9)$ where $\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6, \alpha_7, \alpha_8, \alpha_9 \in$ The membership function of nonagonal fuzzy number is defined by

$$\mu_{\widetilde{A}}(x) = \begin{cases} 0 & y < \alpha_1 \\ \omega\left(\frac{y-\alpha_1}{a_2-a_1}\right) & \alpha_1 \leq y \leq \alpha_2 \\ \omega & \alpha_2 \leq y \leq \alpha_3 \\ \omega + (1-\omega)\left(\frac{y-\alpha_3}{\alpha_4-\alpha_3}\right) & \alpha_3 \leq y \leq \alpha_4 \\ \omega + (1-\omega)\left(\frac{y-\alpha_4}{\alpha_5-\alpha_4}\right) & \alpha_4 \leq y \leq \alpha_5 \\ \omega + (1-\omega)\left(\frac{\alpha_5-y}{\alpha_6-\alpha_5}\right) & \alpha_5 \leq y \leq \alpha_6 \\ \omega + (1-\omega)\left(\frac{\alpha_7-y}{\alpha_7-\alpha_6}\right) & \alpha_6 \leq y \leq \alpha_7 \\ \omega & \alpha_7 \leq y \leq \alpha_8 \\ \omega\left(\frac{\alpha_9-y}{\alpha_9-\alpha_8}\right) & \alpha_8 \leq y \leq \alpha_9 \\ 0 & y > \alpha_9 \end{cases}$$

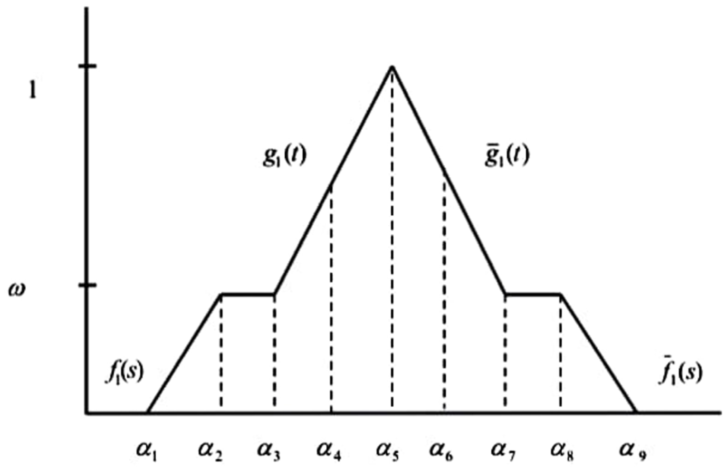

Figure 1: Graphical Representation of Nonagonal Fuzzy Number

2.1. Operations on Nonagonal Fuzzy Number

Let $\widetilde{A}_{NFN}$=$(\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6, \alpha_7, \alpha_8, \alpha_9)$ and $\widetilde{B}_{NFN}$=$(\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7, \beta_8, \beta_9)$ be two nonagonal fuzzy numbers then the addition, subtraction can be defined as,

$\widetilde{A}_{NFN} + \widetilde{B}_{NFN}$=$[\alpha_1 + \beta_1, \alpha_2 + \beta_2, \alpha_3 + \beta_3, \alpha_4 + \beta_4, \alpha_5 + \beta_5, \alpha_6 + \beta_6, \alpha_7 + \beta_7, \alpha_8 + \beta_8, \alpha_9 + \beta_9]$

$\widetilde{A}_{NFN} - \widetilde{B}_{NFN}$=$[\alpha_1 - \beta_9, \alpha_2 - \beta_8, \alpha_3 - \beta_7, \alpha_4 - \beta_6, \alpha_5 - \beta_5, \alpha_6 - \beta_4, \alpha_7 - \beta_3, \alpha_8 - \beta_2, \alpha_9 - \beta_1]$

3. Ranking Methods

3.1. Existing Ranking Method

The existing ranking technique for ranking the nonagonal fuzzy number is given by

$$\mathscr{R}(\widetilde{A}) = \frac{1}{4}\{(\alpha_1+\alpha_2+\alpha_8+\alpha_9)\omega+(\alpha_3+\alpha_4+2\alpha_5+\alpha_6+\alpha_7)(1-\omega)\}, \text{ where } 0 < \omega < 1 \tag{3.1.1}$$

3.2. Average Ranking Method

The average ranking technique for nonagonal fuzzy number is defined by

$$\mathscr{R}(\widetilde{a}) = \frac{\alpha_1 + \alpha_2 + \alpha_3 + \alpha_4 + \alpha_5 + \alpha_6 + \alpha_7 + \alpha_8 + \alpha_9}{9} \tag{3.2.1}$$

4. Advantages of Proposed Ranking Method (Average Ranking Method)

Ranking of fuzzy number plays an important role in decision-making problems. Ranking method is applied to the fuzzy number for converting the fuzzy values into crisp values. The presented ranking method is new and flexible one for nonagonal fuzzy numbers. The proposed ranking method (3.2.1) is simple and easy to calculate rank of fuzzy numbers which also give the optimum solution to the given problem.

5. Formulation of the Problem

The assignment problem can be easily defined in the assignment table

Persons	Jobs			
	1	**2**	...	**n**
1	$\widetilde{D}_{11}$	$\widetilde{D}_{12}$		$\widetilde{D}_{1n}$
2	$\widetilde{D}_{21}$	$\widetilde{D}_{22}$		$\widetilde{D}_{2n}$
...	...	...	...	...
m	$\widetilde{D}_{m1}$	$\widetilde{D}_{m2}$		$\widetilde{D}_{mn}$

The mathematical formulation of the problem can be expressed as

$$minimize\ \widetilde{\omega}^{**} = \sum_{m=1}^{k}\sum_{n=1}^{k} \widetilde{D}_{mn}\widetilde{y}_{mn}$$

with the constraints

$$\sum_{m=1}^{k} \widetilde{y}_{mn} = 1,\ m = 1, 2, ..., k$$
$$\sum_{n=1}^{k} \widetilde{y}_{mn} = 1,\ n = 1, 2, ..., k$$

where $\widetilde{y}_{mn}$ is the decision variable and $\widetilde{D}_{mn}$ is the fuzzy value which denotes distance from of n^{th} task to m^{th} resource . Before solving the given problem, we first apply the ranking method to the given fuzzy problem for ordering the fuzzy values.

6. Numerical Illustration

Example 1. In this example we consider assignment problem with nonagonal fuzzy numbers which consists of four tasks and four workers. The cost matrix $\widetilde{D}_{ij}$ those values are nonagonal numbers. The aim of the problem is to find an optimum allocation which is to be minimized distance (time). The mathematical formulation of fuzzy assignment problem is

Table 1: Nonagonal Fuzzy Assignment Problem

	$\mathbf{W}_1$	$\mathbf{W}_2$	$\mathbf{W}_3$	$\mathbf{W}_4$
$\mathbf{R}_1$	(1,2,3,4,5, 6,7,8,9)	(2,4,6,8,10,12, 14,16,18)	(1,3,5,7,9, 11,13,15,17,)	(3,6,9,12,15,18, 21,24,27)
$\mathbf{R}_2$	(2,5,8,9,10 11,14,17,18)	(3,4,5,6,7 8,9,10,11)	(7,8,9,11,12, 13,14,15)	(5,6,7,8,9, 10,11,12,13)
$\mathbf{R}_3$	(4,6,8,10,12,14, 16,18,20)	(6,8,10,12,14, 16,18,20,22)	(9,10,11,12,13, 14,15,16,17)	(5,7,9,11,13 15,17,19,21)
$\mathbf{R}_4$	(0,1,2,3,4,5, 6,7,8,9)	(1,4,7,10,13, 16,19,22,25)	(2,4,6,8,10,12 14,16,18)	(10,11,12,13,14 15,16,17,18)

Minimize $\widetilde{Z}^* = \mathscr{R}(1,2,3,4,5,6,7,8,9)\ \widetilde{y}_{11} + \mathscr{R}(2,4,6,8,10,12,14,16,18)\ \widetilde{y}_{12} + \mathscr{R}(1,3,5,7,9,11,13,15,17)\ \widetilde{y}_{13} + \mathscr{R}(3,6,9,12,15,18,21,24,27)\ \widetilde{y}_{14} + \mathscr{R}(2,5,8,9,10,11,14,17,18)\ \widetilde{y}_{21} + \mathscr{R}(3,4,5,6,7,8,9,10,11)\ \widetilde{y}_{22} + \mathscr{R}(7,8,9,10,11,12,13,14,15)\ \widetilde{y}_{23} + \mathscr{R}(5,6,7,8,9,10,11,12,13) + \mathscr{R}(4,6,8,10,12,14,16,18,20)\ \widetilde{y}_{24} + \mathscr{R}(6,8,10,12,14,16,18,20,22)\ \widetilde{y}_{31} + \mathscr{R}(9,10,11,12,13,14,15,16,17)\ \widetilde{y}_{32} + \mathscr{R}(5,7,9,11,13,15,17,19,21)\ \widetilde{y}_{33} + \mathscr{R}(0,1,2,3,4,5,6,7,8,9)\ \widetilde{y}_{34} + \mathscr{R}(1,4,7,10,13,16,19,22,25)\ \widetilde{y}_{42} + \mathscr{R}(2,4,6,8,10,12,14,16,18)\ \widetilde{y}_{43} + \mathscr{R}(10,11,12,13,14,15,16,17,18)\ \widetilde{y}_{44}$.

6.1. Ranking of Nonagonal Fuzzy Number Using Average Ranking Method

To find the best solution of given nonagonal fuzzy value given in Table 1, first we convert the fuzzy values into the crisp values using (3.2.1) as shown in Table 2.

Table 2: Crisp assignment problem of the equivalent Nonagonal fuzzy assignment problem

	$\mathbf{W}_1$	$\mathbf{W}_2$	$\mathbf{W}_3$	$\mathbf{W}_4$
$\mathbf{R}_1$	5	10	9	15
$\mathbf{R}_2$	10.4	7	10.9	9
$\mathbf{R}_3$	12	14	13	13
$\mathbf{R}_4$	4	13	10	14

Applying the Hungarian method to the given problem, we find the optimal assignment schedule and the optimum assignment cost. The optimal assignment

schedule is given by $R_1 \to W_3,\ R_2 \to W_4,\ R_3 \to W_1,\ R_4 \to W_2$.
The optimal allocation is given by
$\widetilde{D}_{13}+\widetilde{D}_{22}+\widetilde{D}_{34}+\widetilde{D}_{41}= \mathscr{R}(1,3,5,7,9,11,13,15,17)\widetilde{y}_{13} + \mathscr{R}(3,4,5,6,7,8,9,10,11)\widetilde{y}_{22}$
$+ \mathscr{R}(5,7,9,11,13,15,17,19,21)\widetilde{y}_{34} + \mathscr{R}(0,1,2,3,4,5,6,7,8,9)\widetilde{y}_{41}$
The optimal assignment cost (crisp form) = 9+13+7+4 = 33 units.

6.2. Ranking of Nonagonal Fuzzy Number Using Existing Ranking Method

Using existing ranking method (3.1.1), the nonagonal fuzzy cost (Table 1) is transformed into crisp cost which is shown in Table 3.

Table 3: Crisp assignment problem of the equivalent Nonagonal fuzzy assignment problem

	$\mathbf{W}_1$	$\mathbf{W}_2$	$\mathbf{W}_3$	$\mathbf{W}_4$
$\mathbf{R}_1$	6.3	12.5	11.3	18.8
$\mathbf{R}_2$	13	8.8	13.8	11.3
$\mathbf{R}_3$	15	17.5	16.3	16.3
$\mathbf{R}_4$	5	16.3	12.	17.5

Applying the Hungarian method to the given problem, we find the optimal assignment schedule and the optimum assignment cost. The optimal assignment schedule is given by
$\widetilde{D}_{13}+\widetilde{D}_{22}+\widetilde{D}_{34}+\widetilde{D}_{41}= \mathscr{R}(1,3,5,7,9,11,13,15,17)\widetilde{y}_{13} + \mathscr{R}(3,4,5,6,7,8,9,10,11)\widetilde{y}_{22}$
$+ \mathscr{R}(5,7,9,11,13,15,17,19,21)\widetilde{y}_{34} + \mathscr{R}(0,1,2,3,4,5,6,7,8,9)\widetilde{y}_{41}$
$= 13.3 + 8.81 + 6.3 + 5 = 41.4$ units.

6.3. Result

The solution is attained by using two ranking technique is listed in Table 4.

Table 4: The solution is attained by using two ranking technique

Methods	Optimal Solution
Existing ranking method (3.1.1)	41.4
Average ranking method (3.2.1)	33

From the above results, we conclude that the optimum allocation of the problem is obtained from average ranking method is minimum than that of existing ranking method.

Example 2. Let us consider nonagonal fuzzy assignment problem which consisting of three jobs and three machines. Here the objective is to find an optimum assignment cost with the minimized cost (time).

Table 5: Nonagonal fuzzy assignment problem

	$\mathbf{M}_1$	$\mathbf{M}_2$	$\mathbf{M}_3$
$\mathbf{J}_1$	(0,1,2,3,4,5,6,7,8)	(1,3,5,7,9,11 13, 15,17)	(1,2,4,5,6,9,12,15,20)
$\mathbf{J}_2$	(2,4,6,8,10,12, 14, 16,18)	(2,3,5,7,11,13,17,19,23)	(1,2,3,4,5,6,7,8,9)
$\mathbf{J}_3$	(4,8,12,16,20,24,28,32,36)	(3,6,9,12,15,18,21,24,27)	(5,10,15,20,25,30,35,40,45)

The mathematical formulation of fuzzy assignment problem is
Minimize $\widetilde{Z}^* = \mathscr{R}(0,1,2,3,4,5,6,7,8)\widetilde{y}_{11} + \mathscr{R}(1,3,5,7,9,11,13,15,17)\widetilde{y}_{12} + \mathscr{R}(1,2,5,6,9,12,15,20)\widetilde{y}_{13} + \mathscr{R}(2,4,6,8,10,12,14,16,18)\widetilde{y}_{21} + \mathscr{R}(2,3,5,7,11,13,17,19,23)\widetilde{y}_{22} + \mathscr{R}(1,2,3,4,5,6,7,8,9)\widetilde{y}_{23} + \mathscr{R}(4,8,12,16,20,24,28,32,36)\widetilde{y}_{31} + \mathscr{R}(3,6,9,12,15,18,21,24,27)\widetilde{y}_{32} + \mathscr{R}(5,10,15,20,25,30,35,40,45)\widetilde{y}_{33}$

6.4. Ranking of Nonagonal Fuzzy Number Using Average Ranking Method

To find the solution of given nonagonal fuzzy assignment problem, first we change the fuzzy values (Table 5) into the crisp values by using (3.2.1) as shown in Table 6.

Table 6: Crisp assignment problem of the equivalent Nonagonal fuzzy assignment problem

	$\mathbf{M}_1$	$\mathbf{M}_2$	$\mathbf{M}_3$
$\mathbf{J}_1$	4	9	8.2
$\mathbf{J}_2$	10	11.1	5
$\mathbf{J}_3$	20	15	25

Applying the Hungarian algorithm to the given fuzzy assignment problem, we found an optimum allocation and the optimum assignment cost. The optimal allocation is $J_1 \to M_1,\ J_2 \to M_3,\ J_3 \to M_2$
The optimum assignment cost is $\widetilde{D}_{11} + \widetilde{D}_{23} + \widetilde{D}_{32} = \mathscr{R}(0,1,2,3,4,5,6,7,8)\widetilde{y}_{11} + \mathscr{R}(1,2,3,4,5,6,7,8,9)\widetilde{y}_{23} + \mathscr{R}(3,6,9,12,15,18,21,24,27)\widetilde{y}_{34} = 4+5+15 = 24$ units.

6.5. Ranking of Nonagonal Fuzzy Number Using Existing Ranking Method

Using existing ranking method (3.1.1), the nonagonal fuzzy cost (Table 5) is transformed into crisp cost which is shown in Table 7.

Table 7: Crisp assignment problem of the equivalent Nonagonal fuzzy assignment problem

	$\mathbf{M}_1$	$\mathbf{M}_2$	$\mathbf{M}_3$
$\mathbf{J}_1$	5	11.3	10
$\mathbf{J}_2$	12.5	13.9	6.3
$\mathbf{J}_3$	25	18.8	31.3

Applying the Hungarian algorithm to the given fuzzy assignment problem, we found an optimum allocation and the optimum assignment cost. The optimal allocation is $J_1 \to M_1$, $J_2 \to M_3$, $J_3 \to M_2$
The optimum assignment cost is $\widetilde{D}_{11} + \widetilde{D}_{23} + \widetilde{D}_{32}= \mathscr{R}(0,1,2,3,4,5,6,7,8)\widetilde{y}_{11} + \mathscr{R}(1,2,3,4,5,6,7,8,9)\widetilde{y}_{23} + \mathscr{R}(3,6,9,12,15,18,21,24,27)\widetilde{y}_{34}$ =5+6.3+18.8 = 30.1 units.

6.6. Results

The solution is attained by using two ranking technique is listed in Table 6.

Table 8: The solution is attained by using two ranking technique

Methods	Optimal Solution
Existing ranking method (3.1.1)	30.1
Average ranking method (3.2.1)	24

From the above results, we determined that the optimum allocation of the problem is obtained with the help of average ranking method is minimum than that of existing ranking method.

7. Conclusion

The ranking of fuzzy number plays an important part in decision-making problems. In decision making problems, decisions made by the decision makers based upon the ranking of fuzzy numbers. In this article, a different ordering method (Average ranking) is opted for ranking the nonagonal fuzzy number. Fuzzy value is transformed into crisp value using opted ranking technique and solved by Hungarian method. Average ranking technique is better than the prior ranking method for nonagonal fuzzy numbers. The given example shows the correctness and effectiveness of the working procedure of these ranking methods.

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