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Transportation Problem with Nanogonal Intuitionistic Fuzzy Numbers Solved Using Ranking Technique and Russell's Method

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***Abstract*- We introduces nanogonal intuitionistic fuzzy number with its membership and non-membership functions. We define a solution methodology for transportation problem in an intuitionistic fuzzy environment in which cost are represented by nanogonal intuitionistic fuzzy numbers. Further, using a ranking technique called Accuracy function for nanogonal intuitionistic fuzzy numbers and Russell's Method, an illustrative example is given.**

I. INTRODUCTION

The theory of fuzzy set introduced by Zadeh[10] in 1965 has achieved good real life application in many fields. Atanassov[1,2] proposed the concept of intuitionistic fuzzy sets in 1986.He found that it is useful in vague concept. Degree of membership and the degree of non-membership of an element in the set has separated in intuitionistic fuzzy set. Klir[6] has proved theory based applications in fuzzy environment. Transportation problem is a particular class of linear programming, which is associated with day-to-day activities in our real life. Transportation problem was originally introduced by Hitchcock [5] in 1941. An intuitionistic fuzzy set is a powerful tool to deal with such vagueness. Felix.A ,Christopher.S and Victor Devadoss.[4]A developed , "A Nanogonal Fuzzy Number and its arithmetic operation".Ponnivalavan.K and Pathinathan.T [8]studied "Intuitionistic Pentagonal Fuzzy Number".Pramila.K and Uthra.G[9] obtained "Optimal Solution of an Intuitionistic Fuzzy Transportation Problem". The purpose of this paper is to introduce nanogonal intuitionistic fuzzy number in a more simplified way which is easy to handle and as a natural interpretation. Also, we find the optimal solution for intuitionistic fuzzy transportation problem using nanogonal intuitionistic fuzzy number.

II. PRELIMINARIES

2.1. Definition:[3]
Intuitionistic Fuzzy Set:-
Let X be a universal set. An intuitionistic fuzzy Set A in X is defined as an object of the form $A' = \{(x, \mu_{A'}(x), \vartheta_{A'}(x)): x \in X\}$ where the functions $\mu_A: X \to [0,1]$, $\vartheta_A: X \to [0,1]$ define the degree of membership and the degree of non-membership of the element $x \in X$ to the set A' respectively and for every $x \in X$ in A',$0 \le \mu_A(x) + \vartheta_A(x) \le 1$ holds.

2.2. Definition:[4]
A nanogonal fuzzy number A' of an intuitionistic fuzzy set is defined as $a_1, b_1, c_1, d_1, e_1, f_1, g_1, h_1, i_1$re real numbers and its membership function $\mu_{A'}(x)$ is given by,

$$\mu_{A'}(x) = \begin{cases} \left(\frac{x-a_1}{4(b_1-a_1)}\right) & , \quad a_1 \le x \le b_1 \\ \frac{1}{4} + \left(\frac{x-b_1}{4(c_1-b_1)}\right) & , \quad b_1 \le x \le c_1 \\ \frac{1}{2} + \left(\frac{x-c_1}{4(d_1-c_1)}\right) & , \quad c_1 \le x \le d_1 \\ \frac{3}{4} + \left(\frac{x-d_1}{4(e_1-d_1)}\right) & , \quad d_1 \le x \le e_1 \\ 1 - \left(\frac{x-e_1}{4(f_1-e_1)}\right) & , \quad e_1 \le x \le f_1 \\ \frac{3}{4} - \left(\frac{x-f_1}{4(g_1-f_1)}\right) & , \quad f_1 \le x \le g_1 \\ \frac{1}{2} - \left(\frac{x-g_1}{4(h_1-g_1)}\right) & , \quad g_1 \le x \le h_1 \\ \left(\frac{i_1-x}{4(i_1-h_1)}\right) & , \quad h_1 \le x \le i_1 \\ 0 & , \quad \text{Otherwise} \end{cases}$$

2.3.Defintion: [3]

Intuitionistic fuzzy Number:-

An intuitionistic fuzzy subset $A' = \{(x_i, \mu_{A'}(x), \vartheta_{A'}(x)/x_i \in X\}$, of the real line R is called an intuitionistic fuzzy number if the following condition holds.

i)There exists $m \in R$, $\mu_{A'}(m) = 1$ and $\vartheta_{A'}(m) = 0$, (m is the mean value of A')

ii)$\mu_{A'}$ is a continuous mapping from R to the closed interval [0,1] for all $x \in R$, the relation $0 \le \mu_{A'} + \vartheta_{A'} \le 1$ holds.

The membership and the non-membership function of $\tilde{A}'$ is of the following form.

$$\mu_{A'}(x) = \begin{cases} 0 & for \quad -\alpha < x < m - \alpha \\ l_1(x) & for \quad x \in [m-\alpha, m] \\ 1 & for \quad x = m \\ h_1(x) & for \quad x \in [m, m+\beta] \\ 0 & for \quad m + \beta \le x < \alpha \end{cases}$$

where $l_1(x)$ and $h_1(x)$ are strictly increasing and decreasing functions in $[m-\alpha, m]$ and $[m, m+\beta]$ respectively.

$$\vartheta_{A}'(x) = \begin{cases} 1 & for \quad -\alpha < x < m - \alpha' \\ l_2(x) & for \quad x \in [m - \alpha', m]; 0 \le f_1(x) + f_2(x) \le 1 \\ 0 & for \quad x = m \\ h_2(x) & for \quad x \in [m, m+\beta']; 0 \le h_1(x) + h_2(x) \le 1 \\ 1 & for \quad m + \beta' \le x \le \alpha \end{cases}$$

Here , m is the mean value of A' , α *and* β are called left and right spreads of membership and non-membership function of $\mu_{A'}(x)$ respectively.α' *and* β' are called left and right spreads of membership and non-membership function of $\vartheta_{A'}(x)$ respectively.

Symbolically, the intuitionistic fuzzy number is represented as $A' = (m; \alpha, \beta; \alpha', \beta')$.

2.4.Russell's Method:- [7]

There are many methods to find the basic feasible solution; one among them is Russell's Method for solving transportation problem. Russell's method is probably the better one since it generates a near optimal initial feasible solution. Here in this paper Russell's method is suitably modified and used for solving intuitionistic fuzzy transportation problem.

III. NANOGONAL INTUITIONISTIC FUZZY NUMBER[NIFN]

3.1.Definition:

A nanogonal intuitionistic fuzzy number A' of an intuitionistic fuzzy set is defined as $A' = \{(a_1, b_1, c_1, d_1, e_1, f_1, g_1, h_1, i_1), (a_2, b_2, c_2, d_2, e_2, f_2, g_2, h_2, i_2)\}$ where all $a_1, b_1, c_1, d_1, e_1, f_1, g_1, h_1, i_1, a_2, b_2, c_2, d_2, e_2, f_2, g_2, h_2, i_2$ are real numbers and its membership function $\mu_{A'}(x)$, non-membership function $\vartheta_{A'}(x)$ are given by ,

$$\mu_{A'}(x) = \begin{cases} \left(\frac{x - a_1}{4(a_2 - a_1)}\right) & , \quad a_1 \le x \le a_2 \\ \frac{1}{4} + \left(\frac{x - a_2}{4(a_3 - a_2)}\right) & , \quad a_2 \le x \le a_3 \\ \frac{1}{2} + \left(\frac{x - a_3}{4(a_4 - a_3)}\right) & , \quad a_3 \le x \le a_4 \\ \frac{3}{4} + \left(\frac{x - a_4}{4(a_5 - a_4)}\right) & , \quad a_4 \le x \le a_5 \\ 1 - \left(\frac{x - a_5}{4(a_6 - a_5)}\right) & , \quad a_5 \le x \le a_6 \\ \frac{3}{4} - \left(\frac{x - a_6}{4(a_7 - a_6)}\right) & , \quad a_6 \le x \le a_7 \\ \frac{1}{2} - \left(\frac{x - a_7}{4(a_8 - a_7)}\right) & , \quad a_7 \le x \le a_8 \\ \left(\frac{a_9 - x}{4(a_9 - a_8)}\right) & , \quad a_8 \le x \le a_9 \\ 0 & , \quad \text{Otherwise} \end{cases}$$

$$\vartheta_{A}'(x) = \begin{cases} 1 - \left(\frac{x - b_1}{4(b_2 - b_1)}\right) & , \quad b_1 \le x \le b_2 \\ \frac{3}{4} - \left(\frac{x - b_2}{4(b_3 - b_2)}\right) & , \quad b_2 \le x \le b_3 \\ \frac{1}{2} - \left(\frac{x - b_3}{4(b_4 - b_3)}\right) & , \quad b_3 \le x \le b_4 \\ \frac{1}{4} - \left(\frac{x - b_4}{4(b_5 - b_4)}\right) & , \quad b_4 \le x \le b_5 \\ \left(\frac{x - b_5}{4(b_6 - b_5)}\right) & , \quad b_5 \le x \le b_6 \\ \frac{1}{4} + \left(\frac{x - b_6}{4(b_7 - b_6)}\right) & , \quad b_6 \le x \le b_7 \\ \frac{1}{2} + \left(\frac{x - b_7}{4(b_8 - b_7)}\right) & , \quad b_7 \le x \le b_8 \\ 1 - \left(\frac{b_9 - x}{4(b_9 - b_8)}\right) & , \quad b_8 \le x \le b_9 \\ 0 & , \quad Otherwise \end{cases}$$

3.2. Arithmetic Operations of NIFN:-

Let

$A' = \{(a_1, b_1, c_1, d_1, e_1, f_1, g_1, h_1, i_1), (a_2, b_2, c_2, d_2, e_2, f_2, g_2, h_2, i_2,)\}$

and

$B' = \{(a_3, b_3, c_3, d_3, e_3, f_3, g_3, h_3, i_3), (a_4, b_4, c_4, d_4, e_4, f_4, g_4, h_4, i_4,)\}$

be two nanogonal intuitionistic fuzzy numbers , then the arithmetic operations are as follows:

Addition:-

$$A' + B' = \{(a_1 + a_3, b_1 + b_3, c_1 + c_3, d_1 + d_3, e_1 + e_3, f_1 + f_3, g_1 + g_3, h_1 + h_3, i_1 + i_3), (a_2 + a_4, b_2 + b_4, c_2 + c_4, d_2 + d_4, e_2 + e_4, f_2 + f_4, g_2 + g_4, h_2 + h_4, i_2 + i_4)\}$$

Subtraction:-

$$A' - B' = \{(a_1 - i_3, b_1 - h_3, c_1 - g_3, d_1 - f_3, e_1 - e_3, f_1 - d_3, g_1 - c_3, h_1 - b_3, i_1 - a_3), (a_2 - i_4, b_2 - h_4, c_2 - g_4, d_2 - f_4, e_2 - e_4, f_2 - d_4, g_2 - c_4, h_2 - b_4, i_2 - a_4)\}$$

3.2.Ranking of NIFN based on Accuracy Function:-

Accuracy function of a nanogonal intuitionistic fuzzy number

$A' = \{(a_1, b_1, c_1, d_1, e_1, f_1, g_1, h_1, i_1), (a_2, b_2, c_2, d_2, e_2, f_2, g_2, h_2, i_2)\}$ is defined as

$$H(A)' = (a_1 + a_2, b_1 + b_2, c_1 + c_2, d_1 + d_2, e_1 + e_2, f_1 + f_2, g_1 + g_2, h_1 + h_2, i_1 + i_2)/9$$

IV. PROPOSED ALGORITHM

1. In intuitionistic fuzzy transportation problem, the quantities are reduced into an integer using the ranking method called Accuracy Function.
2. In the reduced IFTP, identify the row and column difference considering the least two numbers of the respective row and column.
3. Select the maximum among the difference (if more than one, then select any one) and allocate the respective demand / supply to the minimum value of the corresponding row or column.
4. We take a difference of the corresponding supply and demand of the allocated cell which leads either of one to zero, eliminating corresponding row or column (eliminate both row or column if both demand and supply is zero).
5. Repeat the steps 2,3 and 4 until all the rows and columns are eliminated.
6. Finally total minimum cost is calculated as sum of the product of the cost and the allocated value.

4.1.An Illustrative Example:-

Consider a 3x3 nanogonal intuitionistic fuzzy number,

	D_1	D_2	D_3	Supply
S_1	[(1,3,5,7,10,11,13,16,18) (0,3,4,6,11,13,14,17,19)]	[(2,4,5,9,11,12,13,15,18) (0,2,6,9,10,14,16,16,18)]	[(2,3,4,8,10,13,16,18,19) (1,3,8,10,12,13,14,16,19)]	30
S_2	[(1,3,6,9,13,14,16,17,18) (1,3,9,12,13,14,15,16,18)]	[(2,3,5,7,10,11,12,13,16) (2,3,4,8,10,14,16,17,18)]	[(2,4,6,7,8,9,10,11,13) (1,3,6,8,12,13,15,16,18)]	35
S_3	[(3,5,9,15,16,16,17,18,20) (3,8,10,15,16,16,17,19,20)]	[(3,4,7,9,12,15,17,18,20) (5,6,10,13,14,15,18,19,20)]	[(3,4,5,6,8,9,10,11,15) (2,4,5,7,9,11,13,15,16)]	45
Demand	40	50	20	110

Since $\sum Demand = \sum Supply$. The problem is a balanced transportation problem. Using the proposed algorithm, the solution of the problem is as follows:

Applying Accuracy function on nanogonal intuitionistic fuzzy number,

[(1,3,5,7,10,11,13,16,18),(0,3,4,6,11,13,14,17,19)]

we have,

$H(A')$ =[1+0+3+3+5+4+7+6+10+11+11+13+13+14 +16+17+18+19] / 9 =19

$H(A')$=[2+0+4+2+5+6+9+9+11+10+12+14+13+16+ 15+16+18+18] / 9 = 20

$H(A')$=[2+1+3+3+4+8+8+10+10+12+13+13+16+14 +18+16+19+19] / 9 =21

$H(A')$=[1+1+3+3+6+9+9+12+13+13+14+14+16+15 +17+16+18+18] / 9 =22

$H(A')$=[2+2+3+3+5+4+7+8+10+10+11+14+12+16+ 13+17+16+18] / 9 =19

$H(A')$=[2+1+4+3+6+6+7+8+8+12+9+13+10+15+11 +16+13+18] / 9 =18

$H(A')$=[3+3+5+8+9+10+15+15+16+16+16+16+17+ 17+18+19+20+20] / 9 =27

$H(A')$=[3+5+4+6+7+10+9+13+12+14+15+15+17+1 8+18+19+20+20] / 9=25

$H(A')$=[3+2+4+4+5+5+6+7+8+9+9+11+10+13+11+ 15+15+16] / 9=17

REDUCED TEBLE:-

	D_1	D_2	D_3	Supply
S_1	19	20	21	30
S_2	22	19	18	35
S_3	27	25	17	45
Demand	40	50	20	110

Solution: Step 1:-

	D_1	D_2	D_3		
S_1	19	20	21	30	(1)
S_2	22	19	18	35	(1)
S_3	27	25	20 17	25 45	(8)
	40	50	20	110	
	(3)	(1)	(1)		

And finally,

	D_1	D_2	D_3		
S_1	30 19	20	21	30	(1)
S_2	22	35 19	18	35	(1)
S_3	10 27	15 25	20 17	45	(8)
	40	50	20	110	
	(3)	(1)	(1)		

$The\ Optimal\ Solution\ is\ (20 \times 17) + (30 \times 19) + (35 \times 19) + (10 \times 27) + (15 \times 25) = 2220$

V. CONCLUSION

A method for finding the optimal solution in an intuitionistic fuzzy environments has been proposed. We have used accuracy function ranking method and Russell's method to find the optimal solution for nanogonal intuitionistic transportation problem. Thus this method provides an applicable optimal solution which helps the decision maker while they are handling real life transportation problem having intuitionistic fuzzy parameters.

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