A New Method for Solving Fuzzy Transportation Problem Using Hexadecagonal Fuzzy Numbers

U.Jayalakshmi[1], K.Mohana[2]

[1]*PG Scholar, Department of mathematics, Nirmala College for woman, Coimbatore, Tamilnadu*

[2]*Assistant professor, Department of mathematics, Nirmala College for woman, Coimbatore, Tamilnadu*

***Abstract-* In this paper, proposed to solve the Fuzzy Transportation Problem using hexadecagonal Fuzzy number. The transportation problem is solved using proposed Ranking Method of hexadecagonal Fuzzy Number. The Proposed transportation is formulated to a crisp Transportation Problem and Solved by using Vogel's approximation method and using Ranking of hexadecagonal Fuzzy number. Numerical examples for the fuzzy proposed ranking method an effective tool for handling the balanced transportation problem.**

Index Terms- Hexadecagonal fuzzy number, fuzzy number, fuzzy transportation problem, proposed ranking method and ranking method.

I. INTRODUCTION

The transportation problem is one of the earliest applications of linear programming problems. Transportation models have wide applications in logistics and supply chain for reducing the cost efficient algorithms have been developed for solving the transportation problem when the cost coefficients and the supply and demand quantities are known exactly. A fuzzy transportation problem is a transportation problem in which the transportation cost, supply and demand quantities are fuzzy quantities. The method 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 a solution has been adopted a transform the fuzzy transportation problem. The idea is to transform a problem with fuzzy parameters in the form of Linear programming problem and solve it by the Vogel Approximation Method.

2. PRELIMINARIES

2.1 Fuzzy set:[5]

Let X = {x} denote a collection of objects denoted generically by x. Then a fuzzy set $\widetilde{A}$ in X is a set of ordered pairs $\widetilde{A} = \{(x, \mu_{\widetilde{A}}(x); x \in X\}$ where $\mu_{\widetilde{A}}(x)$ is termed as the grade of membership of x in A and $\mu_{\widetilde{A}} : X \rightarrow M$ is a function from X to a space M which is called membership space. When M contains only two points, 0 and 1, A is non fuzzy and its membership function becomes identical with the characteristic function of a non fuzzy set.

2.2 Normal set:[5]

A Fuzzy set $\widetilde{A}$ of universe set X is normal if and only if $\sup_{x \in X} \mu_{\widetilde{A}}(x) = 1$.

2.3 Support of fuzzy set:[11]

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 A

i.e., Supp(A) = {x ϵ X / (x)> 0.

2.4 Fuzzy Number:[11]

A fuzzy set A defined on the set of real numbers R is said to be a fuzzy number if its membership function: $R \rightarrow 0{,}1$ has the following properties

i. A must be normal & convex fuzzy set.

ii. αA $m$ust be a closed interval for every $\alpha \in (0,1]$.

iii. The support of , must be bounded.

3. BASIC DEFINITION ON HEXADECAGONAL FUZZY NUMBERS

Definition:

An hexadecagonal fuzzy number denoted by $M_0^{HD}(\tilde{A})$ is to be ordered quadruple

$$M_0^{HD}(\tilde{A}) = (l_1(r), s_1(t), h_1(u), f_1(v), l_2(r), s_2(t), h_2(u), f_2(v))$$

For $r \in [0, k_1]$, $t \in [k_1, k_2]$, $s \in [k_2, k_3]$, $h \in [k_3, \omega]$.

1. $l_1(r)$ is a bounded left continuous non-decreasing function over $[0, \omega_1]$, $[0 \leq \omega_1 \leq k_1]$

2. $s_1(t)$ is a bounded left continuous non-decreasing function over $[k_1, \omega_2]$, $[k_1 \le \omega_2 \le k_2]$
3. $h_1(u)$ is a bounded left continuous non-decreasing function over $[k_2, \omega_3]$, $[k_2 \le \omega_3 \le k_3]$
4. $f_1(v)$ is a bounded left continuous non-decreasing function over $[k_3, \omega_4]$, $[k_3 \le \omega_4 \le \omega]$
5.) $l_2(r)$ is a bounded left continuous non-increasing function over $[0, \omega_1]$, $[0 \le \omega_1 \le k_1]$
6. $s_2(t)$ is a bounded left continuous non-increasing function over $[k_1, \omega_2]$, $[k_1 \le \omega_2 \le k_2]$
7. $h_2(u)$ is a bounded left continuous non-increasing function over $[k_2, \omega_3]$, $[k_2 \le \omega_3 \le k_3]$
8. $f_2(v)$ is a bounded left continuous non-increasing function over $[k_3, \omega_4]$, $[k_3 \le \omega_4 \le \omega]$

3.1.1 Remark:

If ω=1 , then the above defined number is called a normal hexadecagonal fuzzy number.

3.3 Definition:

If $\tilde{A}$ be an hexadecagonal fuzzy number, then the α-cut of $\tilde{A}$ is

$$[A]_\alpha = \{x / \tilde{A}(x) \ge \alpha\}$$

$$= \begin{cases} l_1(\alpha), l_2(\alpha) \text{ for } \alpha \in (0, k_1] \\ s_1(\alpha), s_2(\alpha) \text{ for } \alpha \in (k_1, k_2] \\ h_1(\alpha), h_2(\alpha) \text{ for } \alpha \in (k_2, k_3] \\ f_1(\alpha), f_2(\alpha) \text{ for } \alpha \in (k_3, 1] \end{cases}$$

the hexadecagonal fuzzy number is convex as their α-cut in the classical sense.

3.3.1 Remark:

A fuzzy number is called positive(negative) is denoted by $\tilde{A} > 0 (\tilde{A} < 0)$ if its membership function $\mu_{\tilde{A}}(x) = 0 \; \forall \; x \le 0 (\forall \; x \ge 0)$

3.3.2 Remark:

Two hexadecagonal fuzzy numbers $\tilde{A} = (a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8, a_9, a_{10}, a_{11}, a_{12}, a_{13}, a_{14}, a_{15}, a_{16})$ and $\tilde{B} = (b_1, b_2, b_3, b_4, b_5, b_6, b_7, b_8, b_9, b_{10}, b_{11}, b_{12}, b_{13}, b_{14}, b_{15}, b_{16})$ are said to be equal iff $a_1 = b_1, a_2 = b_2, a_3 = b_3, a_4 = b_4, a_5 = b_5, a_6 = b_6, a_7 = b_7, a_8 = b_8, a_9 = b_9, a_{10} = b_{10}, a_{11} = b_{11}, a_{12} = b_{12}, a_{13} = b_{13}, a_{14} = b_{14}, a_{15} = b_{15}, a_{16} = b_{16}$.

3.4 Arithmetic operation on hexadecagonal fuzzy number:Let

$\tilde{A}_{HD} = (a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8, a_9, a_{10}, a_{11}, a_{12}, a_{13}, a_{14}, a_{15}, a_{16})$ and

$\tilde{B}_{HD} = (b_1, b_2, b_3, b_4, b_5, b_6, b_7, b_8, b_9, b_{10}, b_{11}, b_{12}, b_{13}, b_{14}, b_{15}, b_{16})$ be two hexadecagonal fuzzy numbers then addition and subtraction can be performed as

$\tilde{A}_{HD} + \tilde{B}_{HD} = (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4, a_5 + b_5, a_6 + b_6, a_7 + b_7, a_8 + b_8, a_9 + b_9, a_{10} + b_{10}, a_{11} + b_{11}, a_{12} + b_{12}, a_{13} + b_{13}, a_{14} + b_{14}, a_{15} + b_{15}, a_{16} + b_{16})$.

$\tilde{A}_{HD} - \tilde{B}_{HD} = (a_1 - b_1, a_2 - b_2, a_3 - b_3, a_4 - b_4, a_5 - b_5, a_6 - b_6, a_7 - b_7, a_8 - b_8, a_9 - b_9, a_{10} - b_{10}, a_{11} - b_{11}, a_{12} - b_{12}, a_{13} - b_{13}, a_{14} - b_{14}, a_{15} - b_{15}, a_{16} - b_{16})$.

3.4 Hexadecagonal Fuzzy Numbers:[5]

A generalized fuzzy numbers $\tilde{A}_{HD} = (a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8, a_9, a_{10}, a_{11}, a_{12}, a_{13}, a_{14}, a_{15}, a_{16})$ is said to be hexadecagonal fuzzy number if its membership function $\mu_{\tilde{A}_{HD}}(x)$ is given below:

$$\mu_{\tilde{A}_{HD}}(x) = \begin{cases} 0 & x \le a_1 \\ \frac{1}{4}\left(\frac{x - a_1}{a_2 - a_1}\right) & a_2 \le x \le a_3 \\ \frac{1}{2}\left(\frac{x - a_3}{a_4 - a_3}\right) & a_3 \le x \le a_4 \\ \frac{1}{2} & a_4 \le x \le a_5 \\ \frac{3}{4}\left(\frac{x - a_5}{a_6 - a_5}\right) & a_5 \le x \le a_6 \\ \frac{3}{4} & a_6 \le x \le a_7 \\ \left(\frac{x - a_7}{a_8 - a_7}\right) & a_7 \le x \le a_8 \\ 1 & a_8 \le x \le a_9 \\ \left(\frac{a_{10} - x}{a_{10} - a_3}\right) & a_9 \le x \le a_{10} \\ \frac{3}{4} & a_{10} \le x \le a_{11} \\ \frac{3}{4}\left(\frac{a_{12} - x}{a_{12} - a_{11}}\right) & a_{11} \le x \le a_{12} \\ \frac{1}{2} & a_{12} \le x \le a_{13} \\ \frac{1}{2}\left(\frac{a_{14} - x}{a_{14} - a_{13}}\right) & a_{13} \le x \le a_{14} \\ \frac{1}{4} & a_{14} \le x \le a_{15} \\ \frac{1}{4}\left(\frac{a_{16} - x}{a_{16} - a_{15}}\right) & a_{15} \le x \le a_{16} \\ 0 & a_{16} \le x \end{cases}$$

where $0 < k_1 < k_2 < k_3 < 1$

4. RANKING OF HEXADECAGONAL FUZZY NUMBER

Let $\tilde{A}$ be a normal hexadecagonal fuzzy number. The value

$$M_0^{HD}(\tilde{A}) = \frac{1}{2}\int_0^{k_1}(l_1(r)+l_2(r))dr + \frac{1}{2}\int_{k_1}^{k_2}(g_1(s)+g_2(s))dr + \frac{1}{2}\int_{k_2}^{k_3}(h_1(t)+h_2(t))dr + \frac{1}{2}\int_{k_3}^{1}(f_1(h)+f_2(h))dr$$

$$M_0^{HD}(\tilde{A}) = \frac{1}{4}\left[(a_1+a_2+a_{15}+a_{16})k_1 + (a_3+a_4+a_{13}+a_{14})(k_2-k_1) + (a_5+a_6+a_{11}+a_{12})(k_3-k_2) + (a_7+a_8+a_9+a_{10})(1-k_3)\right]$$

where $0<k_1<k_2<k_3<1$

6.NUMERICAL EXAMPLE

6.1 Consider the following transportation problem

	D_1	D_2	D_3	Supply
O_1	(-3,-2,-1,0,1,2,3,4,5,6,7 8,9,10,11,12)	(5,10,15,20,25,30,35,40,45, 50,55,60,65,70,75,80)	(0,1,2,3,4,5,6,7,8,9,10, 11,12,13,14,15)	(2,3,5,6,8,9,11,12,14 ,15,17,18,20,23,24)
O_2	(5,6,7,8,9,10,11,12,13, 14,15,16,17,18,19,20)	(-5,-4,-3,-2,-1,0,1,2,3,4,5, 6,7,8,9,10)	(1,2,3,4,5,6,7,8,9,10, 11,12,13,14,15,16)	(0,2,4,6,8,10,12,14, 16,18,20,22,24,26, 28,30)
O_3	(2,3,4,5,6,7,8,9,10,11, 12,13,14,15,16,17)	(-9,-7,-5,-3,-1,0,1,3,5,7,9, 11,13,15,17,19)	(-10,-8,-6,-4,-2,0,2,4, 6,8,10,12,14,16,18,20)	(-3,-1,1,3,5,7,9,11, 13,15,17,19,21,23, 25,27)
Demand	(-8,-6,-4,-2,0,2,4,6,8, 10,12,14,16,18,20,22)	(-3,-1,1,3,5,7,9,11,13,15, 17,19,21,23,25,27)	(4,8,12,16,20,24,28,32,36,40,44,4 8,52,56,60,64)	

Solution:

since $\sum \text{demand} \neq \sum \text{supply}$

Therefore the problem is an unbalanced transportation problem.

And take the value of $K_1 = 0.25$, $K_2 = 0.5$, $K_3 = 0.75$

$$M_0^{HD} = \frac{1}{4}\left[(-3-2+11+12)(0.25) + (-1+0+9+10)(0.5-0.25) + (1+2+7+8)(0.75-0.5) + (3+4+5+6)(0.75)\right]$$

$$= \frac{1}{4}\left[4.5+4.5+4.5+4.5\right]$$

$$= 4.5$$

$$M_0^{HD} = \frac{1}{4}\left[\begin{array}{l}(5+10+75+80)(0.25) + (15+20+65+70)(0.5-0.25) + (25+30+55+60)(0.75-0.5) + \\ (35+40+45+50)(1-0.75)\end{array}\right]$$

$$= \frac{1}{4}[25.5+25.5+25.5+25.5]$$

$$= 25.5$$

$$M_0^{HD} = \frac{1}{4}\left[(0+1+14+15)(0.25) + (2+3+12+13)(0.5-0.25) + (4+5+10+11)(0.75-0.5) + (6+7+8+9)(1-0.75)\right]$$

$$= \frac{1}{4}\left[7.5+7.5+7.5+7.5\right]$$

$$= 7.5$$

$$M_0^{HD} = \frac{1}{4}\left[(2+3+23+24)(0.25) + (5+6+20+21)(0.5-0.25) + (8+9+17+18)(0.75-0.5) + (11+12+14+15)(1-0.75)\right]$$

$$= \frac{1}{4}\left[13+13+13+13\right]$$

$$= 13$$

$$M_0^{HD} = \frac{1}{4}\left[(5+6+19+20)(0.25)+(7+8+17+18)(0.5-0.25)+(9+10+15+16)(0.75-0.5)+(11+12+13+14)(1-0.75)\right]$$
$$= \frac{1}{4}\left[12.5+12.5+12.5+12.5\right]$$
$$= 12.5$$
$$M_0^{HD} = \frac{1}{4}\left[(-5-4+9+10)(0.25)+(-3-2+7+8)(0.5-0.25)+(-1+0+5+6)(0.75-0.5)+(1+2+3+4)(1-0.75)\right]$$
$$= \frac{1}{4}\left[2.5+2.5+2.5+2.5\right]$$
$$= 2.5$$
$$M_0^{HD} = \frac{1}{4}\left[(1+2+15+16)(0.25)+(3+4+13+14)(0.25)+(5+6+11+12)(0.25)+(7+8+9+10)(0.25)\right]$$
$$= \frac{1}{4}\left[8.5+8.5+8.5+8.5\right]$$
$$= 8.5$$
$$M_0^{HD} = \frac{1}{4}\left[(0+2+28+30)(0.25)+(4+6+24+26)(0.5-0.25)+(8+10+20+22)(0.75-0.5)+(12+14+16+18)(1-0.75)\right]$$
$$= \frac{1}{4}\left[15+15+15+15\right]$$
$$= 15$$
$$M_0^{HD} = \frac{1}{4}\left[(2+3+16+17)(0.25)+(4+5+14+15)(0.5-0.25)+(6+7+12+13)(0.75-0.5)+(8+9+10+11)(0.75)\right]$$
$$= \frac{1}{4}\left[9.5+9.5+9.5+9.5\right]$$
$$= 9.5$$
$$M_0^{HD} = \frac{1}{4}\left[(-10-8+18+20)(0.25)+(-6-4+16+14)(0.25)+(-2+0+10+12)(0.25)+(2+4+6+8)(0.25)\right]$$
$$= \frac{1}{4}\left[5+5+5+5\right]$$
$$= 5$$
$$M_0^{HD} = \frac{1}{4}\left[(-9-7+17+19)(0.25)+(-5-3+13+15)(0.25)+(-1+0+9+11)(0.25)+(1+3+5+7)(0.25)\right]$$
$$= \frac{1}{4}\left[5+5+5+5\right]$$
$$= 5$$
$$M_0^{HD} = \frac{1}{4}\left[(-3-1+25+27)(0.25)+(1+3+21+23)(0.25)+(5+7+17+19)(0.25)+(9+11+13+15)(0.25)\right]$$
$$= \frac{1}{4}\left[12+12+12+12\right]$$
$$= 12$$
$$M_0^{HD} = \frac{1}{4}\left[(-8-6+20+22)(0.25)+(-4-2+16+18)(0.25)+(0+2+12+14)(0.25)+(4+6+8+10)(0.25)\right]$$
$$= \frac{1}{4}\left[7+7+7+7\right]$$
$$= 7$$

$$M_0^{HD} = \frac{1}{4}\left[(-3-1+25+27)(0.25)+(1+3+21+23)(0.25)+(5+7+17+19)(0.25)+(9+11+13+15)(0.25)\right]$$

$$= \frac{1}{4}\left[12+12+12+12\right]$$

$$= 12$$

$$M_0^{HD} = \frac{1}{4}\left[(4+8+60+64)(0.25)+(12+16+52+56)(0.25)+(20+24+44+48)(0.25)+(28+32+36+40)(0.25)\right]$$

$$= \frac{1}{4}\left[34+34+34+34\right]$$

$$= 34$$

REDUCED TABLE:

	D_1	D_2	D_3	supply
O_1	4.5	25.5	7.5	13
O_2	12.5	2.5	8.5	15
O_3	9.5	5	5	12
demand	7	12	34	

STEP 1:

	D_1	D_2	D_3	Supply	
O_1	4.5	25.5	7.5	13	(3)
O_2	12.5	$\boxed{12}$ 2.5	8.5	~~15~~ 3	(6)
O_3	9.5	5	5	12	(0)
O_4	0	0	0	13	(0)
Demand	7	~~12~~	34		
	(4.5)	(2.5)	(5)		

	D_1	D_2	D_3	Supply
O_1	$\boxed{7}$ 4.5	25.5	$\boxed{6}$ 7.5	13
O_2	12.5	$\boxed{12}$ 2.5	$\boxed{3}$ 8.5	15
O_3	9.5	5	$\boxed{12}$ 5	12
Demand	7	12	24	

The transportation cost is

=(12*2.5)+(13*0)+(7*4.5)+(3*8.5)+(6*7.5)+(12*5)

=30+0+31.5+25.5+45+60

=192

6.2 Consider the following transportation problem

And finally,

	D_1	D_2	Supply
O_1	(2,4,6,8,10,12,14,16,18,20,22,24,26,28,30,32)	(4,8,12,16,20,24,28,32,36,40,44,48,52,56,60,64)	(3,6,9,12,15,18,21,24,27,30,33,36,39,42,45,48,)
O_2	(1,2,4,5,7,8,10,11,13,14,16,17,19,20,22,23)	(1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16)	(1,3,5,7,11,13,17,19,23,29,31,37,41,43,47,53)
Demand	(5,10,15,20,25,30,35,40,45,50,55,60,65,70,75,80)	(0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15)	

Solution:

since $\sum \text{demand} = \sum \text{supply}$

Therefore the problem is balanced transportation problem.

And take the value of $K_1 = 0.2$, $K_2 = 0.5$, $K_3 = 0.6$

$$M_0^{HD} = \frac{1}{4}\left[(2+4+30+32)(0.2)+(6+8+26+28)(0.5-0.2)+(10+12+22+24)(0.6-0.5)+(14+16+18+20)(1-0.6)\right]$$

$$= 17$$

$$M_0^{HD} = \frac{1}{4}\left[(4+8+60+64)(0.2)+(12+16+52+56)(0.5-0.2)+(20+24+44+48)(0.6-0.5)+(28+32+36+40)(1-0.6)\right]$$

$$= 34$$

$$M_0^{HD} = \frac{1}{4}\left[(1+2+22+23)(0.2)+(4+5+19+20)(0.5-0.2)+(7+8+16+17)(0.6-0.5)+(10+11+13+14)(1-0.6)\right]$$

$$= 12$$

$$M_0^{HD} = \frac{1}{4}\left[(1+2+15+16)(0.2)+(3+4+13+14)(0.5-0.2)+(5+6+11+13)(0.6-0.5)+(7+8+9+10)(1-0.6)\right]$$
$$= 8.5$$
$$M_0^{HD} = \frac{1}{4}\left[(3+6+45+48)(0.2)+(9+12+39+42)(0.5-0.2)+(15+18+33+36)(0.6-0.5)+(21+24+27+30)(1-0.6)\right]$$
$$= 25.5$$
$$M_0^{HD} = \frac{1}{4}\left[(1+3+47+53)(0.2)+(5+7+41+43)(0.5-0.2)+(9+13+31+37)(0.6-0.5)+(17+19+23+29)(1-0.6)\right]$$
$$= 23.45$$
$$M_0^{HD} = \frac{1}{4}\left[(5+10+75+80)(0.2)+(15+20+65+70)(0.5-0.2)+(25+30+55+60)(0.6-0.5)+(35+40+45+50)(1-0.6)\right]$$
$$= 41.5$$
$$M_0^{HD} = \frac{1}{4}\left[(0+1+14+15)(0.25)+(2+3+12+13)(0.5-0.25)+(4+5+10+11)(0.75-0.5)+(6+7+8+9)(1-0.75)\right]$$
$$= 7.5$$

REDUCED TABLE:

	D_1	D_2	Supply
O_1	17	34	25.5
O_2	12	8.5	23.5
Demand	41.5	7.5	49

Step 1:-

	D_1	D_2	Supply	
O_1	17	34	16 ~~25.5~~	(17)
O_2	12	$\boxed{7.5}$ 8.5	23.5	(3.5)
Demand	41.5	~~7.5~~	49	
	(5)	(25.5)		

And finally,

	D_1	D_2	Supply
O_1	$\boxed{25.5}$ 17	34	25.5
O_2	$\boxed{16}$ 12	$\boxed{7.5}$ 8.5	23.5
Demand	41.5	7.5	49

The transportation cost is
=(25.5*17)+(16*12)+(8.5*7.5)
=689.25

7. CONCLUSION

In this paper, a new form of a fuzzy Transportation problem as hexadecagonal fuzzy numbers using proposed ranking method. The numerical examples are solved using proposed ranking method is more optimal than other ranking method. Moreover, one can conclude that the solution of fuzzy problems can be obtained by proposed ranking methods effectively, this technique can also be used in solving other types of problems like, project schedules,game approximately, game problems and network flow problems.

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