INTERVAL VALUED NEUTROSOPHIC LINEAR PROGRAMMING WITH TRAPEZOIDAL NUMBERS

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***Abstract:*-In the real world problems, we are always dealing with uncertainty in almost all fields of approach. Neutrosophic sets helps us to deal with problems where inconsistent data are available. Application of Neutrosophic sets to real world problems, which are the generalized form of fuzzy sets is a platform where we can overcome this concept of uncertainty and obtain optimal results which can be relied on. In this paper, interval valued neutrosophic numbers are used to take into account the uncertainty in a still deeper way and Interval valued neutrosophic linear programming problem is solved with the help of the proposed ranking function and optimal results are obtained.**

***Keywords*-Neutrosophic set, trapezoidal Neutrosophic number, Interval valued neutrosophic linear programming, membership degree(truth, falsity, indeterminacy).**

I.INTRODUCTION:

Linear Programming has found its usage in solving many real world problems. A linear programming problem consists of a objective function, one or more constraints with the variables being non-negative integers. The constraints may be either in equality or inequality form. Rather than just considering the cost objectives, coefficients of constraints as just mere crisp values, we consider as neutrosophic numbers. Zadeh first introduced the concept of fuzzy set theory. Later fuzzy sets were generalized as intuitionistic sets by Atanassov and intuitionistic fuzzy set theory came into existence which was then further generalized as neutrosophic sets. In neutrosophic sets, each neutrosophic number is assigned a truth membership degree, a falsity membership degree and an indeterminacy membership degree. Hence, indeterministic data can be easily dealt with. Moreover, using interval values for the truth, indeterminacy and falsity membership degree helps us to deal with riskiness in data in an easier way. Therefore, interval valued linear programming problem with neutrosophic trapezoidal numbers is used in this paper inorder to obtain good optimal results.

II. LITERATURE REVIEW:

L.A.Zadeh[22] introduced the concept of fuzzy sets where crisp values were fuzzified and membership values were assigned to the crisp values. This was further generalized by Atanassov[6] who brought in a new concept of intuitionistic fuzzy sets where crisp values were assigned membership and non-membership values . Together with Gargov, Atanassov[7] introduced interval valued intuitionistic fuzzy sets, where the membership and non-membership degree were given interval values ranging from [0,1]. In order to deal with the indeterminacy the lies in a problem, Smarandache[17],[18],[19] put forward the concept of neutrosophy, which is a generalized form of the intuitionistic fuzzy set, which takes into consideration the truth, false and indeterminacy membership degree. This led to some more accuracy to work with real world problems. Many researchers have worked using the concept of intuitionistic fuzzy sets and neutrosophic sets and have proposed ranking functions in order to find the best optimal solution possible. Wang et.al[23] proposed the concept of Single valued neutrosophic sets and further Deli.et.al[9],[10] proposed a ranking method and applied to multi attribute decision making problems. J Chen[8] worked on single valued neutrosophic weighted aggregation operators to find the optimal solution in the case of multiple attribute decision making. A lot of ranking methods were proposed to get the optimal solution. Li[13],[14]proposed ranking methods taking into use the triangular intuitionistic fuzzy numbers. In the same way, Abdel Basset et.al[1],[2],[3],[4]researched on triangular neutrosophic numbers and trapezoidal neutrosophic numbers and applied linear programming to solve decisions. Rezvani[16] introduced a new ranking method with trapezoidal fuzzy numbers. Akyar et.al[5] discussed about ranking triangular fuzzy numbers. A Kumar et.al[12] found a new method to solve fully fuzzy linear programming problem. Umamageswari et.al[21] introduced a ranking function for single valued neutrosophic trapezoidal numbers to solve transportation problems. Kiran Khatter[11] discussed on interval trapezoidal neutrosophic set for prioritization of non- functional requirements. A.H.Nafei et.al[15] discussed about a new method for solving interval neutrosophic linear programming problem using triangular numbers.

This paper introduces interval valued trapezoidal numbers in a neutrosophic environment and we solve the interval valued neutrosophic linear programming problem (IVNLPP). A new ranking function is proposed to convert the interval valued trapezoidal neutrosophic number to its crisp form to solve IVNLPP. In section 2, some basic definitions are discussed. In section 3, a new ranking function is proposed and the algorithm to solve the IVNLPP is presented. In section 4, some numerical examples are presented to assure that the proposed ranking method is the best. The examples were taken from the research article by A.H.Nafei et.al. In section 5, the optimal results obtained are compared with the existing method and the efficiency of this method is put forth. In section 6. Conclusions are discussed.

III. PRELIMINARIES AND BASIC DEFINITIONS

Definition 1:[4] A single valued neutrosophic set A through X taking the form A= $\{x, T_A(x), I_A(x), F_A(x); x \in X\}$ where X be a space of discourse, $T_A(x): X \to [0,1]$, $I_A(x): X \to [0,1]$ and $F_A(x): X \to [0,1]$ with $0 < T_A(x) + I_A(x) + F_A(x) < 3$ for all $x \in X$. $T_A(x)$, $I_A(x)$ and $F_A(x)$ represent the truth membership degree, indeterminacy membership degree and falsity membership degree respectively.

Definition 2: A neutrosophic number A is an extended version of the fuzzy set on R with the following truth, falsity and indeterminacy membership functions.

$$T_A(x)=\begin{cases}\dfrac{x-a_1}{a_2-a_1} & a_1\le x\le a_2\\ T_A & a_2\le x\le a_3\\ \dfrac{a_4-x}{a_4-a_3} & a_3\le x\le a_4\\ 0 & x>a_4\end{cases}$$

$$I_A(x)=\begin{cases}\dfrac{a_1-x}{a_2-a_1} & \delta a_1+(1-\delta)a_2\le x\le a_2\\ I_A & a_2\le x\le a_3\\ \dfrac{x-a_3}{a_4-a_3} & a_3\le x\le (1-\delta)a_3+\delta a_4\\ 1 & otherwise\end{cases}$$

$$F_A(x)=\begin{cases}\dfrac{a_1-x}{a_2-a_1} & a_1\le x\le a_2\\ F_A & a_2\le x\le a_3\\ \dfrac{x-a_3}{a_4-a_3} & a_3\le x\le a_4\\ 1 & otherwise\end{cases}$$

where δ is the maximum degree of indeterminacy and $a_1< a_2< a_3< a_4$ and $\delta \in (0,1)$. a_1, a_2, a_3, a_4 are the upper bound, first median, second median and lower bound of the trapezoidal neutrosophic number respectively.

Definition 3:Let $A=[(a_1,a_2,a_3,a_4);\mu_A,\vartheta_A,\gamma_A]$ and $B=[(b_1,b_2,b_3,b_4);\mu_B,\vartheta_B,\gamma_B]$ be two trapezoidal neutrosophic numbers, where $\mu_A,\vartheta_A,\gamma_A$ and $\mu_B,\vartheta_B,\gamma_B$ are the truth membership degree, indeterminacy membership degree and falsity membership degree of the trapezoidal neutrosophic number A and B respectively. The mathematical operations between A and B are defined as:

$$A+B=[(a_1+b_1,a_2+b_2,a_3+b_3,a_4+b_4);\mu_A\wedge\mu_B,\vartheta_A\vee\vartheta_B,\gamma_A\vee\gamma_B]$$
$$A-B=[(a_1-b_1,a_2-b_2,a_3-b_3,a_4-b_4);\mu_A\wedge\mu_B,\vartheta_A\vee\vartheta_B,\gamma_A\vee\gamma_B]$$

$$kA=\begin{cases}[(ka_1,ka_2,ka_3,ka_4);\mu_A,\vartheta_A,\gamma_A] & k>0\\ [(ka_4,ka_3,ka_2,ka_1);\mu_A,\vartheta_A,\gamma_A] & k<0\end{cases}$$

where '$\wedge$' and '$\vee$' are the minimum and maximum operators respectively.

Definition4:A ranking function R on A(R) is a mapping from A(R) to the real line, where natural ordering exists.

Let $A=[(a_1,a_2,a_3,a_4);\mu_A,\vartheta_A,\gamma_A]$ and $B=[(b_1,b_2,b_3,b_4);\mu_B,\vartheta_B,\gamma_B]$ be two trapezoidal neutrosophic numbers, then ranking between them is defined as

i) If $R(A) > R(B)$, then $A > B$
ii) If $R(A) < R(B)$, then $A < B$
iii) If $R(A) = R(B)$, then $A = B$

Definition 5:[23] Let X be a space of discourse, an interval neutrosophic set (INS) A through X taking the form $A=\{x,T_A(x),I_A(x),F_A(x);x\in X\}$ where $T_A(x),I_A(x),F_A(x)\subseteq[0,1]$ and $0<\text{Sup}\,T_A(x)+SupI_A(x)+SupF_A(x)\le 3$ for all $x\in X$. $T_A(x),I_A(x),F_A(x)$ represents the truth membership, indeterminacy membership and falsity membership respectively.

Definition 6:An interval valued trapezoidal neutrosophic set $A=[(a_1,a_2,a_3,a_4);[\mu_A^L,\mu_A^U],[\vartheta_A^L,\vartheta_A^U],[\gamma_A^L,\gamma_A^U]]$ and $B=[(b_1,b_2,b_3,b_4);[\mu_B^L,\mu_B^U],[\vartheta_B^L,\vartheta_B^U],[\gamma_B^L,\gamma_B^U]]$ be two interval valued trapezoidal numbers with $[\mu_A^L,\mu_A^U],[\vartheta_A^L,\vartheta_A^U],[\gamma_A^L,\gamma_A^U]$ and $[\mu_B^L,\mu_B^U],[\vartheta_B^L,\vartheta_B^U],[\gamma_B^L,\gamma_B^U]$ being the upper and lower bound for the truth, indeterminacy and falsity membership degrees for the sets A and B. The mathematical operations between A and B can be represented as:

$$A+B=[(a_1+b_1,a_2+b_2,a_3+b_3,a_4+b_4);[\mu_A^L+\mu_B^L-\mu_A^L\mu_B^L,\mu_A^U+\mu_B^U-\mu_A^U\mu_B^U],[\vartheta_A^L\vartheta_B^L,\vartheta_A^U\vartheta_B^U],[\gamma_A^L\gamma_B^L,\gamma_A^U\gamma_B^U]]$$
$$A-B=[(a_1-b_1,a_2-b_2,a_3-b_3,a_4-b_4);[\mu_A^L+\mu_B^L-\mu_A^L\mu_B^L,\mu_A^U+\mu_B^U-\mu_A^U\mu_B^U],[\vartheta_A^L\vartheta_B^L,\vartheta_A^U\vartheta_B^U],[\gamma_A^L\gamma_B^L,\gamma_A^U\gamma_B^U]]$$

IV. PROPOSED METHOD AND ALGORITHM

In this section, we propose a new ranking method to solve interval valued trapezoidal neutrosophic linear programming problems. To obtain the optimum solution, the following steps are to be followed.

Step 1:The Linear programming problem can be of maximization or minimization problems. Also, either the cost or the coefficients a_{ij} or the constants on the right hand side can be neutrosophic numbers or else, all the cost objectives, coefficients and right hand side values can be trapezoidal neutrosophic numbers.

The T_A, I_A, F_A i.e., the truth, indeterminacy and falsity membership values are taken as interval valued and we need to take care that in most of the cases, we adopt the maximum degree for truth membership and the minimum degree for indeterminacy and falsity membership.

Step 2: Using the proposed ranking function, we convert the interval valued trapezoidal neutrosophic number to its crisp value using the function defined below:

Let $A=[(a_1,a_2,a_3,a_4);[\mu_A^L,\mu_A^U],[\vartheta_A^L,\vartheta_A^U],[\gamma_A^L,\gamma_A^U]]$ where a_1,a_2,a_3,a_4 are the lower bound, first median, second median and upper bound respectively. The ranking function for interval valued neutrosophic number A is defined as follows:

$$R(A)=\int_{\mu_A^L}^{\mu_A^U} 0.5(a^L,a^U)\,d\alpha+\int_{\vartheta_A^L}^{\vartheta_A^U} 0.5(a^L,a^U)\,d\alpha+\int_{\gamma_A^L}^{\gamma_A^U} 0.5(a^L,a^U)\,d\alpha$$

where a^L, a^U represent the α - level cut of the neutrosophic number A

Step 3: Making use of the proposed ranking function, the trapezoidal interval valued neutrosophic numbers are converted to its crisp form. Thus the interval valued linear programming problem is converted into a linear programming problem.

Step 4: The linear programming problem is solved using the standard methods and the optimal solution is obtained.

V.NUMERICAL EXAMPLE:

In this section, inorder to prove that the proposed ranking function gives an optimized result, we consider two examples that has been already worked out by Amir Hossein Nafei et.al. Nafei worked on interval valued neutrosophic linear programming with triangular numbers. Here, the interval neutrosophic numbers are taken as trapezoidal interval neutrosophic numbers by taking the values as lower bound, first median, second median and upper bound in order.

Example 1:

In this example, we consider a fully interval valued neutrosophic linear programming problem. Here, the cost objectives, the constraints and the values on the right hand side of the constraints are taken as interval valued neutrosophic numbers. The interval valued neutrosophic numbers are denoted by a tilde ($\tilde{a}$) on the top of the number.

$$Max Z=\tilde{7}x_1+\tilde{6}x_2+1\tilde{4}x_3$$

$$s.t\quad 1\tilde{5}x_1+\tilde{1}x_2\ \tilde{\leq}\ 1\tilde{0}$$

$$\tilde{9}x_1+\tilde{4}x_2+\tilde{8}x_3\ \tilde{\leq}\ \tilde{2}$$

$$1\tilde{9}x_2+1\tilde{1}x_3\ \tilde{\leq}\ \tilde{4}$$

$$x_1,x_2,x_3\geq 0$$

$\tilde{7} = \langle (1,3,10,13),[0.7,0.9],[0.1,0.4],[0.2,0.4] \rangle$

$\tilde{6} = \langle (2,3,9,10),[0.2,0.6],[0.2,0.5,[0.1,0.8] \rangle$

$1\tilde{4} = \langle (7,8,20,21),[0.5,0.7],[0.4,0.6],[0.3,0.4] \rangle$

$1\tilde{5} = \langle (14,14.5,15.5,16),[0.6,0.8],[0.1,0.4],[0.4,0.9] \rangle$

$\tilde{1} = \langle (0,0.5,1.5,2),[0.2,0.7],[0.1,0.6],[0.8,0.9] \rangle$

$1\tilde{0} = \langle (5,7,12,15),[0.1,0.5],[0.1,0.4],[0.6,0.9] \rangle$

$\tilde{9} = \langle (4,6,11,14),[0.4,0.5],[0.5,0.8],[0.4,0.8] \rangle$

$\tilde{4} = \langle (1,2,5,7),[0.1,0.9],[0.4,0.5],[0.3,0.4] \rangle$

$\tilde{8} = \langle (6,7,9,10),[0.7,0.8],[0.5,0.6],[0.1,0.6] \rangle$

$\tilde{2} = \langle (1,1.5,2.5,3),[0.3,0.6],[0.1,0.9],[0.4,0.6] \rangle$

$1\tilde{9} = \langle (5,12,26,33),[0.5,0.9],[0.3,0.5],[0.7,0.8] \rangle$

$1\tilde{1} = \langle (8,9,12,14),[0.6,0.8],[0.4,0.9],[0.6,0.9] \rangle$

$\tilde{4} = \langle (0,2,6,8),[0.3,0.7],[0.1,0.2],[0.1,0.3] \rangle$

Using the proposed ranking function, the given interval neutrosophic linear programming problem is converted into crisp LPP as follows:

$$MaxZ = 5.05x_1 + 8.4x_2 + 7x_3$$

$$\begin{aligned} s.t \quad & 15x_1 + 1.1x_2 \le 10.1 \\ & 7.5x_1 + 3.7x_2 + 5.6x_3 \le 2.6 \\ & 13.3x_2 + 11.3x_3 \le 2.8 \\ & x_1, x_2, x_3 \ge 0 \end{aligned}$$

The above LPP is converted into standard form by adding slack variables to the constraints and is solved using simplex method. The optimal solution thus obtained is:

x_1=0.2428, x_2 =0.2105, x_3=0, Z=2.9945

Example 2:

In a computer manufacturing plant, we need to produce four basic units, such as RAMs, graphics cards, hard drives and CPUs to produce each computer. All productions have to get through four parts. These four parts include design, fabrication, probe and assembly. The favorable time for each unit manufactured and its profit is presented in Table 1. The minimum production amount for supplementing monthly products is given in Table 2. The purpose of the company is producing products in this limit for maximizing the general profit.

TABLE 1

PRODUCTS	DESIGN	FABRICATION	PROBE	ASSEMBLY	UNIT PROFIT
P_1	0.2	0.5	0.1	0.1	$\tilde{14}$ \$
P_2	0.5	3	2	0.6	$\tilde{7}$ \$
P_3	0.4	4	4	0.8	$\tilde{5}$ \$
P_4	1	2	0.2	0.2	$\tilde{8}$ \$

TABLE 2

SECTOR	CAPACITY	PRODUCTS	MINIMUM PRODUCTION LEVEL
DESIGN	$\tilde{1300}$	P_1	$\tilde{100}$
FABRICATION	$\tilde{3340}$	P_2	$\tilde{280}$
PROBE	$\tilde{1800}$	P_3	$\tilde{194}$
ASSEMBLY	$\tilde{2100}$	P_4	$\tilde{400}$

The trapezoidal values and the degrees of the truth, indeterminacy and falsity membership functions for each interval neutrosophic number is given as:

$$\tilde{14} = \langle (12,13,15,16),[0.3,0.7],[0.2,0.8],[0.2,0.9] \rangle$$
$$\tilde{7} = \langle (2,4.5,9.5,12),[0.1,0.6],[0.4,0.7],[0.6,0.8] \rangle$$
$$\tilde{5} = \langle (4,4.5,5.5,6),[0.2,0.6],[0.4,0.9],[0.3,0.4] \rangle$$
$$\tilde{8} = \langle (3,5.5,10.5,13),[0.2,0.5],[0.3,0.8],[0.6,0.9] \rangle$$
$$\tilde{1300} = \langle (1000,1150,1450,1600),[0.1,0.6],[0.2,0.7],[0.3,0.8] \rangle$$
$$\tilde{3340} = \langle (3215,3277.5,3402.5,3465),[0.7,0.9],[0.2,0.7],[0.4,0.9] \rangle$$

$$\tilde{1800} = \langle (1390,1595,2005,2210),[0.4,1],[0.2,0.6],[0.1,0.2] \rangle$$
$$\tilde{2100} = \langle (1818,1959,2305,2510),[0.3,0.7],[0.1,0.6],[0.4,0.8] \rangle$$
$$\tilde{100} = \langle (99,99.5,100.5,101),[0.1,0.7],[0.2,0.6],[0.3,0.4] \rangle$$
$$\tilde{280} = \langle (230,255,305,330),[0.7,0.9],[0.1,0.2],[0.2,0.5] \rangle$$
$$\tilde{194} = \langle (184,189,199,204),[0.1,0.6],[0.3,0.7],[0.1,0.7] \rangle$$
$$\tilde{400} = \langle (200,300,500,600),[0.1,0.4],[0.2,0.6],[0.4,0.8] \rangle$$

Here, let us consider that x_1, x_2, x_3 and x_4 are the number of RAMs, graphics cards, hard drives, CPUs produced respectively. Here, the cost objectives and the values on the right hand side of the constraints are taken as interval valued trapezoidal neutrosophic numbers. The interval valued neutrosophic linear programming problem is formulated as follows:

$$MaxZ \approx \tilde{14}x_1 + \tilde{7}x_2 + \tilde{5}x_3 + \tilde{8}x_4$$

$$s.t \quad 0.2x_1 + 0.5x_2 + 0.4x_3 + 1x_4 \le \tilde{1300}$$

$$0.5x_1 + 3x_2 + 4x_3 + 2x_4 \le \tilde{3340}$$

$$0.1x_1 + 2x_2 + 4x_3 + 0.2x_4 \le \tilde{1800}$$

$$0.1x_1 + 0.6x_2 + 0.8x_3 + 0.2x_4 \le \tilde{2100}$$

$$x_1 \ge \tilde{100}$$

$$x_2 \ge \tilde{280}$$

$$x_3 \ge \tilde{194}$$

$$x_4 \ge \tilde{400}$$

$$x_1, x_2, x_3, x_4 \ge \tilde{0}$$

After converting into standard form, the LPP is solved using simplex method and the solution is found.

$$MaxZ = 23.8x_1 + 7x_2 + 5x_3 + 8.8x_4$$

$$s.t \quad 0.2x_1 + 0.5x_2 + 0.4x_3 + 1x_4 \le 1950$$

$$0.5x_1 + 3x_2 + 4x_3 + 2x_4 \le 4008$$

$$0.1x_1 + 2x_2 + 4x_3 + 0.2x_4 \le 1980$$

$$0.1x_1 + 0.6x_2 + 0.8x_3 + 0.2x_4 \le 2829.2$$

$$x_1 \ge 110.15$$

$$x_2 \ge 168$$

$$x_3 \ge 291$$

$$x_4 \ge 440$$

$$x_1, x_2, x_3, x_4 \ge 0$$

The optimal results obtained are: x_1=2920, x_2=168, x_3=291, x_4=440, Z=75999.

VI.RESULTS:

A new ranking method is proposed in this paper and making use of the interval valued trapezoidal neutrosophic number, the interval valued neutrosophic linear programming problem is solved using the simplex method. This method gave the best optimal result. In order to exhibit the efficiency of the proposed ranking method, comparison was made with the existing models and is tabulated as follows:

TABLE 3

METHOD	EXAMPLE 1	EXAMPLE 2
EXISTING METHOD	x_1=0, x_2=0, x_3=0.18, Z=2.54	x_1=1853, x_2=280.3, x_3=193.45, x_4=399.25, Z=30298.57
PROPOSED METHOD	x_1=0.24, x_2=0.21, x_3=0, Z=2.99	x_1=2920, x_2=168, x_3=291, x_4=440, Z=75999

VII. CONCLUSION:

In this paper, we have considered interval valued neutrosophic linear programming problem with trapezoidal numbers. Having taken into account the truth membership, indeterminacy membership and falsity membership degree of the trapezoidal neutrosophic number, we have dealt with the uncertainty. The proposed ranking function is desirable as it promotes an optimized result compared to the existing methods. Hence, this method can be used easily to convert the interval trapezoidal neutrosophic number to its crisp form and solve the IVNLPP using simplex method. This proposed method is efficient than the existing models.

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