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Modified Solution for Neutrosophic Linear Programming Problems with Mixed Constraints

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A B S T R A C T

Neutrosophic Linear Programming (NLP) issues is presently extensive applications in science and engineering. The primary commitment right now to manage the NLP problem where the coefficients are neutrosophic triangular numbers with blended requirements. The current method [20] are viewed as just imbalance limitations. Notwithstanding, in our paper, we consider both blended requirements and utilize another score function to understand the strategy. To determine the progression of the current method, another strategy is proposed for tackling NLP issues. To check the better outcome, we execute various numerical models.

Keywords: Neutrosophic linear programming, Crisp linear programming, Triangular neutrosophic numbers, Score function.

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1. Introduction

In Operation Research (OR) inquire about logical models Linear Programming (LP) is a noteworthy instrument for handling the numerical issues. The central point is the best outcome for enhancing the advantage and restricting the cost. Regardless of the way, it has been investigated and developed for more than seven decades by various examiners, and from the alternate points of view, it is up 'till now, accommodated to develop new techniques in order to fit this current reality issues inside the arrangement of LP. In the standard system, the parameters of the immediate programming models must be particularly described and correct. Normally, an enormous bit of information isn't deterministic and right now as an ability to choose a decent decision subject to this weakness. It is a difficult test to all authorities for taking decision when the data are uncertain to overcome these issues. Zadeh [1] first introduced the fuzzy set theory. Thusly, various researchers has demonstrated their attentiveness to various sorts of Fuzzy Liner Programming (FLP) issue and proposed diverse system for dealing with FLP issue. By far, examiners, have taken the diverse kind of FLP

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issues to be explicit: (1) the target capacities and requirements are fully fuzzy and called completely fully fuzzy with nonnegative fuzzy factors, (2) only target capacities are fuzzy with nonnegative fuzzy factors, and (3) constraints are fuzzy and unlimited fuzzy numbers. If the parameters and constraints are fuzzy numbers then it is called fully fuzzy numbers. General class of Fully Fuzzy Linear Programming (FFLP) was introduced by Buckley and Feuring [26]. Many authors [2, 21-27] considered FLP implies the constraints were fuzzy or just variables are fuzzy. However, number of researchers [3, 4, 5, 9, 10, 11, 28-34] have considered the FFLP issue with imbalance limitations. Regardless, the rule weight of the plan procured by the present systems is that it doesn't satisfy the objectives absolutely. Dehghan et al. [32] proposed sensible methodologies to solve a Fully Fuzzy Linear System (FFLS) that is proportional to the remarkable systems. Lotfi et al. [33] proposed a procedure for symmetric triangular fuzzy number, gained another system for dealing with FFLP issues by changing over two relating LPs. To overcome these obstruction, Kumar et al. [28] proposed another system for finding the fuzzy ideal arrangement of FFLP issue with uniformity imperatives. After that, Edalatpanah [10, 11, 29], Das [5-9], and Das et al. [4] has portrayed to deal with FFLP issue with the assistance of situating limit and lexicographic methodology.

So far, intuitionistic fuzzy hypothesis was presented by Atanassov [35], which utilized some mathematician in like way to show powerlessness in streamlining issues. In any case, these two musings can basically explore insufficient data, not wide data. Regardless, Smarandache [12] took care of this issue by including a self-administering indeterminacy selection to intuitionistic fuzzy sets and this framework is called neutrosophic set. Neutrosophic is the subordinate of neutrosophy and it joins neutrosophic set, neutrosophic probability/estimation, and neutrosophic method of reasoning. Neutrosophic theory was applied in various fields of sciences to disentangle the issues related to indeterminacy. Neutrosophic hypothesis was applied in numerous fields of sciences to take care of the issues identified with indeterminacy. Abdel-Baset et al. [15, 16] Maiti et al. [17], and Pramanik [18, 19, 35] proposed NLP techniques dependent on Neutrosohic Sets (NS) idea. In like manner, Abdel-Baset [15] introduced the NLP models where their parameters are addressed with trapezoidal neutrosophic numbers and presented a technique for getting them. Hussian et al. [20] proposed another method by using score function for handling NLP issue. Mohamed et al. [37] by introducing another score function, proposed a novel method for neutrosophic number programming issues. Edalatpanah [13, 14] proposed a technique for dealing with triangular NLP issue.

To vanquish these weaknesses, the main aim in this paper is proposed for discovering NLP issue with both consistency and disproportion limitations. We propose linear programming problem based on neutrosophic environment and the neutrosophic sets specify three independent parameters: Truth-membership degree, indeterminacy degree, and falsity degree. We also transform the NLP problem into a crisp LP model by using ranking function. This crisp LP issue is explained by any standard methodologies.

The remainder of the paper is made by the present moment: Crucial considerations and documentations are open in Section 2. In Section 3, the general sort of NLP issue is introduced. Another system to deal with NLP issue is introduced in Section 4. In Section 5, some numerical models are given to reveal the practicality of the proposed strategy. A relative examination is talked about in stipulation 6. The paper has been concluded in the last part.

2. Preliminaries

Right now, present some essential definition and number juggling procedure on neutrosophic sets.

Definition 1. [12]. Assume X be a space of objectives and v∈*X*. A neutrosophic set N in *X* may be defined via three membership functions for truth, indeterminacy along with falsity and denoted by $\tau_I(v)$, $\varsigma_I(v)$ and $\zeta_I(v)$ are real standard or real nonstandard subsets of $[0^-,1^+]$. That is $\tau_I(v): X \to \left]0^-,1^+\right[$, $\varsigma_I(v): X \to \left]0^-,1^+\right[$ and $\zeta_I(v): X \to \left]0^-,1^+\right[$. There is no limitation on the sum of $\tau_I(v)$, $\varsigma_I(v)$ and $\zeta_I(v)$, so $0^- \le \sup\tau_I(v) + \sup\varsigma_I(v) + \sup\zeta_I(v) \le 3^+$.

Definition 2. [13]. A Single-Valued Neutrosophic Set (SVNS) I through *X* taking the form $I = \{v, \tau_I(v), \varsigma_I(v), \zeta_I(v); v \in X\}$, where X be a space of discourse, $\tau_I(v): X \to [0,1]$, $\varsigma_I(v): X \to [0,1]$ and $\zeta_I(v): X \to [0,1]$ with $0 < \tau_I(v) + \varsigma_I(v) + \zeta_I(v) < 3$ for all $v \in X$. $\tau_I(v)$, $\varsigma_I(v)$ and $\zeta_I(v)$ respectively represents truth membership, indeterminacy membership and falsity membership degree of v to I.

Definition 3. A Triangular Neutrosophic Number (TNNs) is signified via $I = <(b^1, b^2, b^3), (\alpha, \delta, \lambda)>$ is an extended version of the three membership functions for the truth and indeterminacy, and falsity of s can be defined as follows [17]:

$$\tau_I(v) = \begin{cases} \dfrac{\left(v - b^1\right)}{\left(b^2 - b^3\right)}\alpha & b^1 \le v < b^2, \\ \alpha & v = b^1, \\ \dfrac{\left(b^3 - v\right)}{\left(b^3 - b^2\right)}\alpha & b^2 \le v < b^3, \\ 0 & \text{something else.} \end{cases}$$

$$\varsigma_I(v) = \begin{cases} \dfrac{\left(b^2 - v\right)}{\left(b^2 - b^3\right)}\delta, & b^1 \le v < b^2, \\ \delta, & v = b^2, \\ \dfrac{\left(v - b^3\right)}{\left(b^3 - b^1\right)}\delta, & b^2 \le v < b^3, \\ 1, & \text{something else.} \end{cases}$$

$$\zeta_I(v)=\begin{cases}\dfrac{\left(b^1-v\right)}{\left(b^2-b^1\right)}\lambda, & b^1\le v<b^2,\\ \lambda, & v=b^2,\\ \dfrac{\left(v-b^3\right)}{\left(b^3-b^2\right)}\lambda, & b^2\le v<b^3,\\ 1, & \text{something else.}\end{cases}$$

Where, $0\le \tau_I(v)+\varsigma_I(v)+\zeta_I(v)\le 3, v\in I.$ Additionally, when $b^1\ge 0,$ I is called a nonnegative TNN. Similarly, when $b^1<0,$ I becomes a negative TNN.

Definition 5. (Arithmetic Operation). Suppose $A_1{}^I=<(b^1{}_1,b^2{}_1,b^3{}_1),(\alpha_1,\delta_1,\lambda_1)>$ and $A_2{}^I=<(b^1{}_2,b^2{}_2,b^3{}_2),(\alpha_2,\delta_2,\lambda_2)>$ be two TNNs. Then the arithmetic relations are defined as [13]:

$$A_1{}^I\oplus A_2{}^I=<(b^1{}_1+b^1{}_2,b^2{}_1+b^2{}_2,b^3{}_1+b^3{}_2),(\alpha_1\wedge\alpha_2,\delta_1\vee\delta_2,\lambda_1\vee\lambda_2)>.$$

$$A_1{}^M-A_2{}^M=<(b^1{}_1-b^3{}_2,b^2{}_1-b^2{}_2,b^3{}_1-b^1{}_2),(\alpha_1\wedge\alpha_2,\delta_1\vee\delta_2,\lambda_1\vee\lambda_2)>.$$

$$A_1{}^M\otimes A_2{}^M=<(b^1{}_1b^1{}_2,b^2{}_1b^2{}_2,b^3{}_1b^3{}_2),(\alpha_1\wedge\alpha_2,\delta_1\vee\delta_2,\lambda_1\vee\lambda_2)>,\ \text{if } b^1{}_1>0,b^2{}_1>0.$$

$$\lambda A_1{}^M=\begin{cases}<(\lambda b^1{}_1,\lambda b^2{}_1,\lambda b^3{}_1),(\alpha_1,\delta_1,\lambda_1)>, & \text{if } \lambda>0\\ <(\lambda b^3{}_1,\lambda b^2{}_1,\lambda b^1{}_1),(\alpha_1,\delta_1,\lambda_1)>, & \text{if } \lambda<0\end{cases}.$$

$$\frac{A_1{}^M}{A_2{}^M}=\begin{cases}\left\langle(\frac{b^1{}_1}{b^3{}_2},\frac{b^2{}_1}{b^2{}_2},\frac{b^3{}_1}{b^1{}_2});\alpha_1\wedge\alpha_2,\delta_1\wedge\delta_2,\lambda_1\wedge\lambda_2\right\rangle(b^3{}_1>0,b^3{}_2>0)\\ \left\langle(\frac{b^3{}_1}{b^3{}_2},\frac{b^2{}_1}{b^2{}_2},\frac{b^1{}_1}{b^1{}_2});\alpha_1\wedge\alpha_2,\delta_1\wedge\delta_2,\lambda_1\wedge\lambda_2\right\rangle(b^3{}_1<0,b^3{}_2>0)\\ \left\langle(\frac{b^3{}_1}{b^1{}_2},\frac{b^2{}_1}{b^2{}_2},\frac{b^1{}_1}{b^3{}_2});\alpha_1\wedge\alpha_2,\delta_1\wedge\delta_2,\lambda_1\wedge\lambda_2\right\rangle(b^3{}_1<0,b^3{}_2<0)\end{cases}.$$

Definition 6. (Arithmetic Operation). Assume A^M and B^M be two TNNs. Then the ranking function is [20]:

- $A^M\le B^M$ if and only if $\Re(A^M)\le\Re(B^M).$
- $A^M<B^M$ if and only if $\Re(A^M)<\Re(B^M).$

Where $\Re(.)$ is a ranking function.

Definition 7. Let $I=<(b^1,b^2,b^3),(\alpha,\delta,\lambda)>$ be a triangular neutrosophic number, where they are represented lower, median and upper bound of triangular neutrosophic number, respectively. Also, α,δ,λ denote the truth degree, indeterminacy degree and falsity degree of a triangular number. The score function of this number is:

$$S(I)=\frac{b_1+b_3+2b_2}{4}+|\alpha-\delta-\lambda|.$$

Here, we present a new type of ranking function:

3. NLP Model

In this section, LP problem with neutrosophic factors is defined as the following:

$$\text{Max } Z=\sum_{j=1}^{n}\tilde{c}_j x_j, \qquad \textbf{\textit{(1)}}$$

Subject to

$$\sum_{j=1}^{n}\tilde{a}_{ij}x_j\le\tilde{b}_i,\ i=1,2,\dots,m,$$
$$x_j\ge 0,\ j=1,2,\dots,n.$$

Where x_j is non-negative neutrosophic triangular numbers and $\tilde{c}_j,\tilde{a}_{ij},\tilde{b}_i$ represented the neutrosophic numbers.

In our neutrosophic model we want to maximize the degree of acceptance and minimize the degree of rejection and indeterminacy of the neutrosophic objective function and constraints. Now the problem can be written as follows:

$$\begin{aligned}&\max T(x),\\&\min F(x),\\&\min I(x),\end{aligned} \qquad \textbf{\textit{(2)}}$$

Subject to

$$\begin{aligned}&T(x)\ge F(x),\\&T(x)\ge I(x),\\&0\le T(x)+I(x)+F(x)\le 3,\\&T(x),I(x),F(x)\ge 0,\\&x\ge 0.\end{aligned}$$

The problem can be written to the equivalent form as follows:

$$\max\alpha,\min\delta,\min\lambda, \qquad \textbf{\textit{(3)}}$$

Subject to

$$\begin{aligned}&\alpha\le T(x),\\&\lambda\ge F(x),\\&\delta\ge I(x),\\&\alpha\ge\lambda,\\&\alpha\ge\delta,\\&0\le\alpha+\delta+\lambda\le 3,\\&x\ge 0.\end{aligned}$$

Where α represents the minimal degree of acceptation, δ represents the maximal degree of rejection, and λ represents the maximal degree of indeterminacy.

Now the model can be changed into the following model:

$$\max(\alpha-\delta-\lambda), \tag{4}$$

Subject to

$$\begin{aligned}&\alpha \le T(x),\\ &\lambda \ge F(x),\\ &\delta \ge I(x),\\ &\alpha \ge \lambda,\\ &\alpha \ge \delta,\\ &0 \le \alpha+\delta+\lambda \le 3,\\ &x \ge 0.\end{aligned}$$

Finally, the model can be written as:

$$\min(1-\alpha)+\delta+\lambda, \tag{5}$$

Subject to

$$\begin{aligned}&\alpha \le T(x),\\ &\lambda \ge F(x),\\ &\delta \ge I(x),\\ &\alpha \ge \lambda,\\ &\alpha \ge \delta,\\ &0 \le \alpha+\delta+\lambda \le 3,\\ &x \ge 0.\end{aligned}$$

4. Proposed Method

Right now, here we solve the model (1), we propose the following algorithm:

Step 1. Construct the problem as the model (1).

Step 2. Consider $\tilde{b} = \langle b^l, b^m, b^r; T_b, I_b, F_b \rangle, \tilde{c} = \langle c^l, c^m, c^r; T_c, I_c, F_c \rangle$ and using Definition 5, the LP problem (1) can be transformed into problem (2).

$$\text{Max (or Min)} Z = \sum_{j=1}^{n} (c_j^l, c_j^m, c_j^r) x_j, \tag{6}$$

Subject to

$$\sum (a_{ij1}, a_{ij2}, a_{ij3}; T_a, I_a, F_a) x_j \le (b_i^l, b_i^m, b_i^r; T_b, I_b, F_b),\ i = 1,2,\ldots,m,$$

$$x_j \ge 0,\ j = 1,2,\ldots,n.$$

Step 3. Create the decision set which includes the highest degree of truth-membership and the least degree of falsity and indeterminacy memberships.

Step 4. By using score function, each single valued triangular neutrosophic number will convert to a crisp number.

Step 5. Find the optimal solution to the crisp linear programming model.

Step 6. From Step 5, we use LINGO/MATLAB to take care of the fresh LP issue and get the ideal arrangement.

5. Numerical Example

Here, we select a case of [20] to represent the model and to measure the efficiency of our proposed model, we solved three numerical examples.

Example-1.

$$\begin{aligned} &\max \tilde{5}x_1 + \tilde{3}x_2, \\ \text{s.t.} \\ &\tilde{4}x_1 + \tilde{3}x_2 \le \tilde{12}, \\ &\tilde{1}x_1 + \tilde{3}x_2 \le \tilde{6}, \\ &x_1, x_2 \ge 0. \end{aligned}$$

Where

$$\begin{aligned} &\tilde{5} = <(4,5,6);(0.5,0.8,0.3)>, \\ &\tilde{3} = <(2.5,3,3.2);(0.6,0.4,0)>, \\ &\tilde{4} = <(3.5,4,4.1);(0.75,0.5,0.25)>, \\ &\tilde{3} = <(2.5,3,3.2);(0.2,0.8,0.4)>, \\ &\tilde{1} = <(0,1,2);(0.15,0.5,0)>, \\ &\tilde{3} = <(2.8,3,3.2);(0.75,0.5,0.25)>, \\ &\tilde{12} = <(11,12,13);(0.2,0.6,0.5)>, \\ &\tilde{6} = <(5.5,6,7.5);(0.8,0.6,0.4)>. \end{aligned}$$

By using the score function proposed in ***Definition 7*** the above problem can be converted to crisp model as follows:

$$\begin{aligned} &\max\ 5.06x_1 + 3.12x_2, \\ \text{s.t.} \\ &3.9x_1 + 3.92x_2 \le 12.9, \\ &1.35x_1 + 3x_2 \le 6.45, \\ &x_1, x_2 \ge 0. \end{aligned}$$

By following the steps that presented in the last section, the optimal solution of the above problem is $x_1 = 3.31, x_2 = 0$ and the objective solution is $Z = 16.73$.

Example-2.

$$\max \tilde{25}x_1 + \tilde{48}x_2,$$
$$\text{s.t.}$$
$$15x_1 + 30x_2 \le 45000,$$
$$24x_1 + 6x_2 \le 24000,$$
$$21x_1 + 14x_2 < 28000,$$
$$x_1, x_2 \ge 0.$$

Where

$$\tilde{25} = <(19,25,33);(0.8,0.1,0.4)>,$$
$$\tilde{48} = <(44,48,54);(0.75,0.25,0)>.$$

By using the score function proposed in ***Definition 7***, the above problem can be converted to crisp model as follows:

$$\max\ 25.8x_1 + 49x_2,$$
$$\text{s.t.}$$
$$15x_1 + 30x_2 \le 45000,$$
$$24x_1 + 6x_2 \le 24000,$$
$$21x_1 + 14x_2 \le 28000,$$
$$x_1, x_2 \ge 0.$$

By following the steps that presented in the last section the optimal solution of the above problem is $x_1 = 500, x_2 = 1250$ and the objective solution is $Z = 74150$.

Example-3.

$$\max 7x_1 + 5x_2,$$
$$\text{s.t.}$$
$$\tilde{1}x_1 + \tilde{2}x_2 \le 6,$$
$$\tilde{4}x_1 + \tilde{3}x_2 \le 12,$$
$$x_1, x_2 \ge 0.$$

Where

$$\tilde{1} = <(0.5,1,2);(0.2,0.6,0.3)>,$$
$$\tilde{2} = <(2.5,3,3.2);(0.6,0.4,0.1)>,$$
$$\tilde{4} = <(3.5,4,4.1);(0.5,0.25,0.25)>,$$
$$\tilde{3} = <(2.5,3,3.2);(0.75,0.25,0.)>.$$

By using the score function proposed in ***Definition 7*** the above problem can be converted to crisp model as follows:

$$\max\ 7x_1 + 5x_2$$
$$\text{s.t.}$$
$$1.825x_1 + 3.025x_2 \le 6,$$
$$3.9x_1 + 3.425x_2 \le 12,$$
$$x_1, x_2 \ge 0.$$

By following the steps that presented in the last section the optimal solution of the above problem is $x_1 = 3.076, x_2 = 0$ and the objective solution is $Z = 21.538$.

5. Result and analysis

The proposed triangular neutrosophic number has a potential noteworthiness as it has the accompanying characteristics.

- It manages the LP issue in which all the limitations and target esteems are triangular neutrosophic numbers thus it characterizes membership, falsity, and indeterminacy of each values.
- In our proposed method, it shows that the constraints are satisfied precisely, however, in the existing method [20] the constraints are not satisfied properly.
- In our proposed method, we have solved three types of problems. First model considers the objective functions and all constraints except the variables that are neutrosophic triangular; second model considers just objective functions that are neutrosophic triangular numbers; third one is just left side of constraints that are neutrosophic triangular numbers.
- Our model represents reality efficiently than Hussian [20] model, because we consider all aspects of decision-making process in our calculations (i.e. the truthiness, indeterminacy, and falsity degree).
- Our model reduces complexity of problem, by reducing the number of constraints and variables.
- Their model is a time-consuming and complex, but our model is not.
- In our proposed model, we solved both inequality and equality constraints (mixed constraints), but in existing model [20] they have concentrated only inequality constraints.

Table 1. Comparative of NLP problem using proposed method and existing method [20].

Example	Proposed Method		Existing Method [20]	
	x_1, x_2	Z	x_1, x_2	Z
1	$x_1 = 3.31, x_2 = 0$	$Z = 16.73$	$x_1 = 0.9754, x_2 = 0$	$Z = 1.2802$
2	$x_1 = 500, x_2 = 1250$	$Z = 74150$	$x_1 = 0, x_2 = 1500$	$Z = 34218.75$
3	$x_1 = 3.076, x_2 = 0$	$Z = 21.538$	$x_1 = 4.3665, x_2 = 4.168$	$Z = 63.91$

The upside of the proposed technique over the current strategy [20] is that for utilizing the proposed strategy there is no limitation on the components of coefficient framework and the acquired outcomes precisely fulfills all the imperatives. Likewise, it is anything but difficult to apply the proposed strategy when is contrast with the current technique [20] for tackling the FFLP issues, happening, all things considered, and circumstances.

From the above table, one can see that, the proposed strategy is proficient and consistently amplify the target esteems. Subsequently, this proposed strategy can be applied to an enormous issue and genuine applications. Our NLP model right now is better than the outcome got by existing strategy [20].

7. Conclusions

This paper, concentrated on the NLP issue with the assistance of our new altered calculation and proposed a new method for solving these problems based on introducing a novel ordering approach. To outline the proposed strategy, the numerical models are understood and the upsides of the proposed technique over the current technique is likewise talked about. In our new model, we amplify the degrees of acknowledgment and limit the indeterminacy. In our proposed method, we maximize the degrees of acceptance, minimize the indeterminacy and rejection of objectives. NLP problem was transformed into a crisp LP model by using ranking functions. Several numerical examples have been used to demonstrate the capability and efficiency of the proposed method. In future, the proposed method can be extended for solving duality based LP problem.

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