A Novel Methodology for Decipher Mixed Constraint Fuzzy Linear Programming Problem

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Abstract: In this paper a mixed nature LP model is taken for study. In real life very often we come across mixed type LPP, and the irony is these type of LP Problems are difficult to be solved by usual techniques. Therefore, we have made an effort to develop a new approach of simplex technique to obtain an optimum result of mixed nature FLP models of trapezoidal, as well as trivial FN. This method is very stress-free to decipher mixed nature FLP models. At times it has less iterations than the existing simplex technique. And an attempt is made to showcase the same with few numericals.

Keywords: Fuzzy number, Simplex technique, Fuzzy ranking method, Trivial fuzzy numbers, Fuzzy linear programming problem, Mixed trapezoidal fuzzy numbers.

Abbreviation
Fuzzy Set **(FS)**,
Fuzzy Zero **(FZ),**
Fuzzy Number **(FN)**,
Trapezoidal Fuzzy Number **(TFN).**
Linear Programming Problem **(LPP)**,
Fuzzy Linear Programming Problem **(FLPP),**

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1. Introduction

One of the easiest approaches to perform optimization is LP as it aids us to decipher some of the multifaceted optimization models by making a few simple assumptions. Optimization methods and algorithms have gained the significance over time to optimize the model. Fuzzy numbers in LPP have evolved as a result of real life uncertainties. There may be such situations wherein we are forced to opt for different kinds of fuzzy numbers in LPP. As the conditions are not identical in varying conditions, several factors are not clear exactly. As a result of uncontrollable factors we used to come across mixed type constraint problem. Also, these kind of models are having very few evidences in literature.

Discovered an optimal solution of LPP **(Ghadle et al., 2013)** proposed other procedure for simplex, Big-M and dual simplex technique. **(Thakre et al., 2016)** suggested an innovative method to solve FLPP with trapezoidal FN using ranking technique, multiplication and addition operators of trapezoidal FN. **(Mitlif et al., 2021)** a novel ranking function of simplex method is developed for LPP to find the optimal solution for LP models which includes three variables or less for solar cell application. **(Ali and Qureshi, 2020)** suggested a new iterative process to find the exact solution of maximization and minimization in LPP in dual simplex method and simplex method. In this algorithm developed pivot rule. To decipher FLPP using ranking technique, **(Bhattacharyyaand Majumdar, 2019)**offered some innovative systems based on the centroid of triangular and trapezoidal FN. **(Bhardwaj and Kumar, 2015)**revealed that the FFLPP with inequality constraints are difficult to be converted into FFLPP with equality constraints.

Very recently, **(Ghadle et al., 2021)**various Big-M methods were compared by using the maximization and minimization FLPP with triangular and pentagonal IFN. **(Nasseri and Mahmoudi, 2019)**studied **(Ezzati et al., 2015)**some definitions relevant to Fuzzy Set Theory and offered an innovative technique for solving fully FLPP, and thereby converting it to crisp LPP. **(Ezzati et al., 2015)** offered the innovative system only to discover the fuzzy optimum result of fully FLPP by equality constraints.

Present paper proposes an innovative simplex algorithm for mixed trapezoidal and Trivial FN to convert the given FN into crisp number. Thereby, optimal solution has been achieved.

2. Preliminaries

This segment contains some basic but important definitions for the sequel. **(Deshmukh et al, 2020) (Shugani et al., 2012) (Ahemed et al., 2015).**

2.1 FN

A real FN $\tilde{A}$ is a FN subset of real number R whose membership function $\mu_{\tilde{A}}$ fulfills the subsequent situations,

- $\mu_{\tilde{A}}(x)$ is a continuous function from R to a closed subset [0, 1].
- $\mu_{\tilde{A}}(x)$ is stricly increasing on $[d_1, d_2]$.
- $\mu_{\tilde{A}}(x)$ is stricly decreasing on $[d_3, d_4]$.

where $d_1 < d_2 < d_3 < d_4$ and $X \in [d_1, d_4]$.

2.2 Trapezoidal FN

A FN $\tilde{A} = (d_1, d_2, d_3, d_4)$ is believed to be a TFN if its membership function is given by the subsequent expression:

$$\mu_{\tilde{A}}(x) = \begin{cases} \dfrac{(x - d_1)}{(d_2 - d_1)} & \text{for} d_1 \le x \le d_2 \\ 1, & \text{for} d_2 \le x \le d_3 \\ \dfrac{(d_4 - x)}{(d_4 - d_3)}, & \text{for} d_3 \le x \le d_4 \\ 0 & \text{otherwise} \end{cases}$$

2.3 Trivial Trapezoidal FN

A FN $\tilde{A} = (d_1, d_2, d_3, d_4)$ is believed to be a trivial TFN when and only when

i) $d_1 = d_2 = d_3 = d_4$

ii) It's membership function is specified by,

$$\mu_{\tilde{A}}(x) = \begin{cases} 1, & \text{When } x = a \\ 0, & \text{otherwise} \end{cases}$$

2.4 Charactertics of TFN

1. A TFN $\tilde{A} = (d_1, d_2, d_3, d_4)$ is believed to be non-negative (non-positive) TFN i.e. $\tilde{A} \ge 0 (\tilde{A} \le 0)$ if and only if $d_1 \ge 0$ $(d_3 \le 0)$. A TFN is believed to be positive (negative) TFN i.e. $\tilde{A} > 0 (\tilde{A} < 0)$ when and only when $d_1 > 0$ $(d_3 < 0)$.

2. Two TFN $\tilde{A}_1 = (d_1, d_2, d_3, d_4)$ and $\tilde{A}_2 = (b_1, b_2, b_3, b_4)$ are said to be equal i.e. $\tilde{A}_1 = \tilde{A}_2$.

3. A zero TFN is symbolized by $\tilde{0} = (0, 0, 0, 0)$.

4. A TFN $\tilde{A} = (d_1, d_2, d_3, d_4)$ is a triangular FN if $d_2 = d_3$.

2.5 α-cut of TFN

Let $\tilde{A} = (d_1, d_2, d_3, d_4)$ be a trapezoidal FN. Then its α-cut is given by $(\alpha_\alpha^L, \alpha_\alpha^U) = [(d_2 - d_1)\alpha + d_1, d_4 - (d_4 - d_3)\alpha], where\ \alpha \in [0, 1]$.

2.6 FZ

A TFN $\tilde{A} = (d_1, d_2, d_3, d_4)$ is believed to be FZ if $R(\tilde{A}) = 0$.

2.7 Ranking Function

If $\tilde{A} = (d_1, d_2, d_3, d_4)$ is a FN then the Robust ranking is defined by,

$$R(\tilde{A}) = \int_0^1 0.5\,(\alpha_\alpha^L,\ \alpha_\alpha^U)d\alpha, \qquad \dots\dots..(2.7.1)$$

where $(\alpha_\alpha^L,\ \alpha_\alpha^U)$ is the α-cut of the TFN $\tilde{A}$.

For any two FN $\tilde{A}_1, \tilde{A}_2$ we have the following comparison

- $\tilde{A}_1 < \tilde{A}_2$ if and only if $R(\tilde{A}_1) < R(\tilde{A}_2)$
- $\tilde{A}_1 > \tilde{A}_2$ if and only if $R(\tilde{A}_1) > R(\tilde{A}_2)$
- $\boldsymbol{\tilde{A}_1 = \tilde{A}_2}$ **if and only if** $\boldsymbol{R(\tilde{A}_1) = R(\tilde{A}_2)}$

3. Proposed Simplex Algorithm

An algorithm is given to discoverthe result of Mixed FLPP by Simplex technique,

Step 1: Create the mixed Fuzzy LPP.

Step 2: Convert all real numbers as trapezoidal FN using the definition of trivial TFN.

Step 3 : The objective function of FLPP must be of Maximization type. convert it to a Maximization type providedit is of Minimization type, then by using the result Min Z= -Max(-Z).

Step 4: Convert all "≥" type constraints in to " ≤ " by multiplying both sides by -1. Also convert the inequality constraints to equality by addition of slack variable and achieve an IBS.

Step 5 : Formulate given FLPP in standard form and then obtain IBFS.

Step 6 : Using Ranking Function (2.8.1).

Step 7: To find the Pivot Column,

a) In first iteration, find the pivot column by selecting Max$\left[\tilde{c}_j\ Max(\tilde{y}_{ij})\right]$, for entering vector.

b) In further iterations, find the pivot column by selecting max$\sum \tilde{y}_{ij},\ \forall \tilde{y}_{ij} \geq 0$, for entering vector.

Step 8: To find the pivot Row,

Pick the largest coefficient of decision variables.

a) If the largest coeffficient is exclusive, then the number corresponding to this row and column marks the pivotal number.

b) Use tie-breaking technique if the largest coefficient is not unique.

Step 9: Use traditional simplex technique for this table.

Step 10: Overlook corresponding row and column. Go to step 7 and 8 for left over numbers and replicate similar approach till the finest result is achieved or there will be an indication of unbounded solution.

Step 11: If all rows and columns are overlooked, then present result is an optimum result.

4. Numerical Examples:

Example 4.1

Explain mixed type FLP model:

Maximize $\tilde{Z} = (4,6,8,10)\tilde{y}_1 + (3,5,7,9)\tilde{y}_2 + (4,6,8,10)\tilde{y}_3 + (6,8,10,12)\tilde{y}_4$

Subject to:
$$4\tilde{y}_1 + 5\tilde{y}_2 + 5\tilde{y}_3 + (4,6,8,10)\tilde{y}_4 \leq (97,99,101,103)$$
$$5\tilde{y}_1 + 5\tilde{y}_3 + (1,3,5,7)\tilde{y}_4 \leq (87,89,91,93)$$
$$6\tilde{y}_1 + (3,5,7,9)\tilde{y}_2 + 4\tilde{y}_3 + (1,3,5,7)\tilde{y}_4 \leq (97,99,101,103)$$
$$\tilde{y}_1, \tilde{y}_2, \tilde{y}_3, \tilde{y}_4 \geq 0$$

Answer:

By usingstep-2, here, the specified mixed FLP model coefficient of variable contains eleven TFN and remaining are real numbers. Hence, using the definition of trivial TFN to transform real values as TFN, we convert the whole problem into fully FLP model as: (By **step-2**)

Maximize $\tilde{Z} = (4,6,8,10)\tilde{y}_1 + (3,5,7,9)\tilde{y}_2 + (4,6,8,10)\tilde{y}_3 + (6,8,10,12)\tilde{y}_4$

Subject to: $(4,4,4,4)\tilde{y}_1 + (5,5,5,5)\tilde{y}_2 + (5,5,5,5)\tilde{y}_3 + (4,6,8,10)\tilde{y}_4 \leq (97,99,101,103)$

$$(5,5,5,5)\tilde{y}_1 + (5,5,5,5)\tilde{y}_3 + (1,3,5,7)\tilde{y}_4 \leq (87,89,91,93)$$

$$(6,6,6,6)\tilde{y}_1 + (3,5,7,9)\tilde{y}_2 + (4,4,4,4)\tilde{y}_3 + (1,3,5,7)\tilde{y}_4 \leq (97,99,101,103)$$

$$\tilde{y}_1, \tilde{y}_2, \tilde{y}_3, \tilde{y}_4 \geq 0$$

Standard form of fully FLP model:

Maximize $\tilde{Z} = (4,6,8,10)\tilde{y}_1 + (3,5,7,9)\tilde{y}_2 + (4,6,8,10)\tilde{y}_3 + (6,8,10,12)\tilde{y}_4 + 0\tilde{y}_5 + 0\tilde{y}_6 + 0\tilde{y}_7$

Subject to: $(4,4,4,4)\tilde{y}_1 + (5,5,5,5)\tilde{y}_2 + (5,5,5,5)\tilde{y}_3 + (4,6,8,10)\tilde{y}_4 + (1,1,1,1)\tilde{y}_5 = (97,99,101,103)$

$$(5,5,5,5)\tilde{y}_1 + (5,5,5,5)\tilde{y}_3 + (1,3,5,7)\tilde{y}_4 + (1,1,1,1)\tilde{y}_6 = (87,89,91,93)$$

$$(6,6,6,6)\tilde{y}_1 + (3,5,7,9)\tilde{y}_2 + (4,4,4,4)\tilde{y}_3 + (1,3,5,7)\tilde{y}_4 + (1,1,1,1)\tilde{y}_7 = (97,99,101,103)$$

$$\tilde{y}_1, \tilde{y}_2, \tilde{y}_3, \tilde{y}_4, \tilde{y}_5, \tilde{y}_6, \tilde{y}_7 \geq 0$$

Step 6: Using (2.8.1)

Maximize $\tilde{Z} = 7\tilde{y}_1 + 6\tilde{y}_2 + 7\tilde{y}_3 + 9\tilde{y}_4 + 0\tilde{y}_5 + 0\tilde{y}_6 + 0\tilde{y}_7$

Subject to: $4\tilde{y}_1 + 5\tilde{y}_2 + 5\tilde{y}_3 + 7\tilde{y}_4 + \tilde{y}_5 = 100$

$$5\tilde{y}_1 + 5\tilde{y}_3 + 4\tilde{y}_4 + \tilde{y}_6 = 90$$

$$6\tilde{y}_1 + 6\tilde{y}_2 + 4\tilde{y}_3 + 4\tilde{y}_4 + \tilde{y}_7 = 100$$

$\tilde{y}_1, \tilde{y}_2, \tilde{y}_3, \tilde{y}_4, \tilde{y}_5, \tilde{y}_6, \tilde{y}_7 \geq 0$

Table 1. Initial Iteration

By using **Step-7, step-8 and step-9**

		$\tilde{c}_j$	7	6	7	9	0	0	0
$\tilde{c}_B$	$\tilde{y}_B$	$\tilde{x}_B$	$\tilde{y}_1$	$\tilde{y}_2$	$\tilde{y}_3$	$\tilde{y}_4$	$\tilde{y}_5$	$\tilde{y}_6$	$\tilde{y}_7$
0	$\tilde{y}_5$	100	4	5	5	7^*	1	0	0
0	$\tilde{y}_6$	90	5	0	5	4	0	1	0
0	$\tilde{y}_7$	100	6	6	4	4	0	0	1
		$\tilde{c}_j\ Max(\tilde{y}_{ij})$	42	36	35	63			

↑

Table 2. First Iteration

$\tilde{c}_B$	$\tilde{y}_B$	$\tilde{x}_B$	$\tilde{y}_1$	$\tilde{y}_2$	$\tilde{y}_3$	$\tilde{y}_4$	$\tilde{y}_5$	$\tilde{y}_6$	$\tilde{y}_7$
9	$\tilde{y}_4$	100/7	4/7	5/7	5/7	1	1/7	0	0
0	$\tilde{y}_6$	230/7	19/7	−20/7	15/7	0	−4/7	1	0
0	$\tilde{y}_7$	300/7	$26/7^*$	22/7	8/7	0	−4/7	0	1
		$\sum \tilde{y}_{ij}$	$^{49}/_{7}$	$^{27}/_{7}$	$^{28}/_{7}$	1	1/7	1	1

↑

Table 3. Second Iteration

$\tilde{c}_B$	$\tilde{y}_B$	$\tilde{x}_B$	$\tilde{y}_1$	$\tilde{y}_2$	$\tilde{y}_3$	$\tilde{y}_4$	$\tilde{y}_5$	$\tilde{y}_6$	$\tilde{y}_7$
9	$\tilde{y}_4$	$100/13$	0	$3/13$	$7/13$	1	$3/13$	0	$-2/13$
0	$\tilde{y}_6$	$20/13$	0	$-67/13$	$17/13^*$	0	$-2/13$	1	$-19/26$
7	$\tilde{y}_1$	$150/13$	1	$11/13$	$4/13$	0	$-2/13$	0	$7/26$
		$\sum \tilde{y}_{ij}$	1	$^{14}/_{13}$	$^{28}/_{13}$	1	$^{3}/_{13}$	1	$^{7}/_{26}$
					↑				

Table 4. Third Iteration

$\tilde{c}_B$	$\tilde{y}_B$	$\tilde{x}_B$	$\tilde{y}_1$	$\tilde{y}_2$	$\tilde{y}_3$	$\tilde{y}_4$	$\tilde{y}_5$	$\tilde{y}_6$	$\tilde{y}_7$
9	$\tilde{y}_4$	$120/17$	0	$40/17$	0	1	$5/17$	$-7/17$	$5/34$
7	$\tilde{y}_3$	$20/17$	0	$-67/17$	1	0	$-2/17$	$13/17$	$-19/34$
7	$\tilde{y}_1$	$190/17$	1	$35/17$	0	0	$-2/17$	$-4/17$	$15/34$

Since all the rows and columns are ignore and ignored and all values of x_B are positive.

Optimal solution is $\tilde{y}_1 = \frac{190}{17}$, $\tilde{y}_3 = \frac{20}{17}, \tilde{y}_4 = \frac{120}{17}$ and Maximize $\tilde{Z} = 150$

Example 4.2

Explain mixed type FLP model:

Minimize $\tilde{Z} = -(1,3,5,7)\tilde{y}_1 - (3,5,7,9)\tilde{y}_2 - (0,2,4,6)\tilde{y}_3$

Subject to: $(0,2,4,6)\tilde{y}_1 + 5\tilde{y}_2 \leq (3,5,7,9)$

$$4\tilde{y}_1 + (0,2,4,6)\tilde{y}_2 \leq (2,4,6,8)$$

$$(0,2,4,6)\tilde{y}_2 + 6\tilde{y}_3 \leq (2,4,6,8)$$

$$\tilde{y}_1, \tilde{y}_2, \tilde{y}_3 \geq 0$$

Answer:

Here the given mixed FLP model coefficient of variable contains three real number and the remaining are TFN. So using the definition of trivial TFN to transform the real values as TFN, we convert the whole problem into fully FLP model shown in below: (By **step-2**)

Minimize $\tilde{Z} = -(1,3,5,7)\tilde{y}_1 - (3,5,7,9)\tilde{y}_2 - (0,2,4,6)\tilde{y}_3$

Subject to: $(0,2,4,6)\tilde{y}_1 + (5,5,5,5)\, \tilde{y}_2 \leq (3,5,7,9)$

$$(4,4,4,4)\tilde{y}_1 + (0,2,4,6)\tilde{y}_2 \leq (2,4,6,8)$$

$$(0,2,4,6)\tilde{y}_2 + (6,6,6,6)\tilde{y}_3 \leq (2,4,6,8)$$

$$\tilde{y}_1, \tilde{y}_2, \tilde{y}_3 \geq 0$$

Standard form of fully FLP model:

Maximize $\tilde{Z} = (1,3,5,7)\tilde{y}_1 + (3,5,7,9)\tilde{y}_2 + (0,2,4,6)\tilde{y}_3 + 0\tilde{y}_4 + 0\tilde{y}_5 + 0\tilde{y}_6$

Subject to: $(0,2,4,6)\tilde{y}_1 + (5,5,5,5)\tilde{y}_2 + (1,1,1,1)\tilde{y}_4 \leq (3,5,7,9)$

$$(4,4,4,4)\tilde{y}_1 + (0,2,4,6)\tilde{y}_2 + (1,1,1,1)\tilde{y}_5 \leq (2,4,6,8)$$

$$(0,2,4,6)\tilde{y}_2 + (6,6,6,6)\tilde{y}_3 + (1,1,1,1)\tilde{y}_6 \leq (2,4,6,8)$$

$$\tilde{y}_1, \tilde{y}_2, \tilde{y}_3, \tilde{y}_4, \tilde{y}_5, \tilde{y}_6 \geq 0$$

Step 6: Using (2.8.1)

Maximize $\tilde{Z} = 4\tilde{y}_1 + 6\tilde{y}_2 + 3\tilde{y}_3 + 0\tilde{y}_4 + 0\tilde{y}_5 + 0\tilde{y}_6$

Subject to: $3\tilde{y}_1 + 5\tilde{y}_2 + \tilde{y}_4 = 6$

$4\tilde{y}_1 + 3\tilde{y}_2 + \tilde{y}_5 = 5$

$3\tilde{y}_2 + 6\tilde{y}_3 + \tilde{y}_6 = 5$

$\tilde{y}_1, \tilde{y}_2, \tilde{y}_3, \tilde{y}_4, \tilde{y}_5, \tilde{y}_6 \geq 0$

Table 1. Initial Iteration

By using **step-7, step-8 and step-9**

		$\tilde{c}_j$	4	6	3	0	0	0
$\tilde{c}_B$	$\tilde{y}_B$	$\tilde{x}_B$	$\tilde{y}_1$	$\tilde{y}_2$	$\tilde{y}_3$	$\tilde{y}_4$	$\tilde{y}_5$	$\tilde{y}_6$
0	$\tilde{y}_4$	6	3	5	0	1	0	0
0	$\tilde{y}_5$	5	4	3	0	0	1	0
0	$\tilde{y}_6$	5	0	3	6	0	0	1
		$\tilde{c}_j\ Max(\tilde{y}_{ij})$	16	30	18			

↑

Table 2. First Iteration

$\tilde{c}_B$	$\tilde{y}_B$	$\tilde{x}_B$	$\tilde{y}_1$	$\tilde{y}_2$	$\tilde{y}_3$	$\tilde{y}_4$	$\tilde{y}_5$	$\tilde{y}_6$
6	$\tilde{y}_2$	$6/5$	$3/5$	1	0	$1/5$	0	0
0	$\tilde{y}_5$	$7/5$	$11/5$	0	0	$-3/5$	1	0
0	$\tilde{y}_6$	$7/5$	$-9/5$	0	6^{*}	$-3/5$	0	1
		$\sum \tilde{y}_{ij}$	$13/5$	1	6	$1/5$	1	1

↑

Table 3. Second Iteration

$\tilde{c}_B$	$\tilde{y}_B$	$\tilde{x}_B$	$\tilde{y}_1$	$\tilde{y}_2$	$\tilde{y}_3$	$\tilde{y}_4$	$\tilde{y}_5$	$\tilde{y}_6$
6	$\tilde{y}_2$	$6/5$	$3/5$	1	0	$1/5$	0	0
0	$\tilde{y}_5$	$7/5$	$11/5^{*}$	0	0	$-3/5$	1	0
3	$\tilde{y}_3$	$7/30$	$-9/30$	0	1	$-3/30$	0	$1/6$
		$\sum \tilde{y}_{ij}$	$13/5$	1	1	$1/5$	1	$1/6$

↑

Table 4. Third Iteration

$\tilde{c}_B$	$\tilde{y}_B$	$\tilde{x}_B$	$\tilde{y}_1$	$\tilde{y}_2$	$\tilde{y}_3$	$\tilde{y}_4$	$\tilde{y}_5$	$\tilde{y}_6$
6	$\tilde{y}_2$	$9/11$	0	1	0	$4/11$	$-3/11$	0
4	$\tilde{y}_1$	$7/11$	1	0	0	$-3/11$	$5/11$	0
3	$\tilde{y}_3$	$14/33$	0	0	1	$-2/11$	$3/22$	$1/6$

Since all the rows and columns are ignore and ignored and all values of x_B are positive.

Optimal solution is $\tilde{y}_1 = \frac{7}{11}$, $\tilde{y}_2 = \frac{9}{11}$, $\tilde{y}_3 = \frac{14}{33}$ and Minimize $\tilde{Z} = \frac{288}{33}$

5. Conclusion:

Present paper recommends an innovative technique for obtaining the finest solution of mixed trapezoidal FLP problems. It has been evaluated too. We witnessed the lesser iterations or at the most equal iterations for both the cases to obtain the solution, i.e. for Maximization and Minimization type of cases by our modified method. This suggested method is easy to apply for solving FLPP of mixed type. This method consumes less time as calculation of net evaluation is not needed.

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