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An Application Model for Linear Programming with an Evolutionary Ranking Function

Rasha Jalal Mitlif

Department of Applied Sciences, Branch of Mathematics and Computer Applications, University of Technology, Baghdad, Iraq.

rasha.j.mitlif@uotechnology.edu.iq

ORCID ID: https://Orcid.org/0000-0001- 5033-8753

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Abstract

One of the most important methodologies in operations research (OR) is the linear programming problem (LPP). Many real-world problems can be turned into linear programming models (LPM), making this model an essential tool for today's financial, hotel, and industrial applications, among others. Fuzzy linear programming (FLP) issues are important in fuzzy modeling because they can express uncertainty in the real world. There are several ways to tackle fuzzy linear programming problems now available. An efficient method for FLP has been proposed in this research to find the best answer. This method is simple in structure and is based on crisp linear programming. To solve the fuzzy linear programming problem (FLPP), a new ranking function (RF) with the trapezoidal fuzzy number (TFN) is devised in this study. The fuzzy quantities are de-fuzzified by applying the proposed ranking function (RF) transformation to crisp value linear programming problems (LPP) in the objective function (OF). Then the simplex method (SM) is used to determine the best solution (BS). To demonstrate our findings, we provide a numerical example (NE).

Keywords: Linear programming (LP), Trapezoidal Fuzzy Number (TFN), Ranking Function (RF), Simplex method (SM).

1. Introduction

Many approaches exist to address mathematical issues in operation research, and these methods help reduce the complexity. LP is a powerful decision-making tool. This is commonly used in real-world problems using the applied operational research approach. The theory of fuzzy sets (FS) has been used in various fields, including industrial applications, systems theory, organizational theory, and mathematical modeling. Ranking fuzzy numbers (RFN) is a critical decision-making method in a fuzzy environment. [1], the idea of a fuzzy set was originally introduced as a way of dealing with uncertainty caused by imprecision rather than randomness. [2] were the first to establish the concept of FLP. In linguistic multi-criteria decision-making situations, fuzzy number ranking is extremely important. Many researchers [3-8] applied different kinds of fuzzy linear programming problems with ranking functions. One of the important types of fuzzy numbers is trapezoidal fuzzy. It used many articles with different methods.

[9] introduced the Trapezoidal Fuzzy Number Linear Programming. [10], the ranking function methods were used to solve fuzzy fractional linear programming problems. [11], using symmetric trapezoidal fuzzy numbers to solve a type of FLP problem has been presented. [12] used LPP with some Multi-Choice Fuzzy Parameters (FP). [13] suggested A New Approach for Solving the Type-2-Fuzzy Transportation Problem. [14] studied analytical preparations' level-dependent weighted average value of discrete trapezoidal fuzzy numbers. [15] presented a new method for determining the tolerance level and aspiration level based on Zimmermans approach. In [16], a Generalized Model for Fuzzy Linear Programs with TFN was discussed in this paper.The objective of this paper is to explain a novel RF for solving the fuzzy linear programming problems by simplex method by comparing it to other ranking functions.

This paper is separated into (6) sections. Section one contains the introduction. In section two, we recall the basic definitions. Section three introduces trapezoidal fuzzy numbers (TFN). In section four, we concept RF. Section five suggests the evolutionary Maleki ranking function. In section six, the proposed case study, finally, the paper arrives at a conclusion.

2. Basic Definitions

The background and foundations for fuzzy set theory are given in this section.

Definition 2.1 Fuzzy Set (FS) [17]: A membership function (MF) translating elements of a domain, space, or the universe of discourse $\mathcal{U}$ to the unit interval [0,1] characterizes a fuzzy set, i.e. $A = \{(M_A(x);\ x \in X)\}$. $M_A(x)\colon \mathcal{U} \to [0,1]$ is a mapping that represents x's degree of membership value (MV) of x in X in the fuzzy set A.

Definition 2.2 Fuzzy Number (FN) [18]: To be considered a fuzzy number (FN), a fuzzy set (FS) $\tilde{A}$ on R must have at least three properties:

i. $\tilde{A}$ Must be a standard fuzzy set (FS).
ii. Every ɕ ∈ [0, 1] must have a closed interval in $\tilde{A}$.
iii. The support of $\tilde{A}$ must be constrained.

Definition 2.3 Linear Programming Problem (LPP) [19]:

A linear programming (LP) problem is defined as:

$Max\ t = ç\, x$

Subject to

$Q\, x \ \leq y$

$x \geq 0$

Where $ç = (ç_1, ç_2, \dots, ç_n)$, $y = (y_1, y_2, \dots, y_m)^{\,T}$ and $Q = [r_{ij}]_{m*n}$.

Definition 2.4 Fuzzy Linear Programming Problem (FLPP) [20]:

The following is the description of a fuzzy number linear programming (FLP) problem:

$Max\ \tilde{f} = \tilde{c}\, \sigma$

Subject to

$\mathcal{A}\, \sigma \ \leq w$

$\sigma \geq 0$

Where $w \in \mathcal{J}^m$, $\sigma \in \mathcal{J}^n, \mathcal{A} \in \mathcal{J}^{m*n}, \tilde{c} \in F(\mathcal{J})$.

3. Trapezoidal Fuzzy Numbers (TFN)[21]:

A trapezoidal fuzzy number (TFN) is defined as: $\tilde{A} = (q^l, q^u, \alpha, \beta)$ which is said to be a TFN if its membership function (MF) is:

$$M_A X = \begin{cases} \frac{j-(q^l-\alpha)}{\alpha}, & q^l - \alpha \leq j \leq q^l \\ 1\,, & q^l \leq j \leq q^u \\ \frac{(q^u+\beta)-j}{\beta}, & q^u \leq j \leq q^u + \beta \\ 0\,, & other\ wise \end{cases}$$

4. Ranking function (RF)[22]:

A ranking function (RF), where a natural order exists, is the function $\mathcal{J}: F(\mathcal{J}) \rightarrow \mathcal{J}$ that maps each fuzzy number (FN) onto the real line (RL).

If $\check{p}, \check{r} \in F(\mathcal{J})$ is real, then

a) $\check{p} \ \geq \check{r}$ if and only if $\mathcal{J}(\check{p}) \geq \mathcal{J}(\check{r})$;
b) $\check{p} > \check{r}$ if and only if $\mathcal{J}(\check{p}) > \mathcal{J}(\check{r})$;
c) $\check{p} = \check{r}$ if and only if $\mathcal{J}(\check{p}) = \mathcal{J}(\check{r})$;
d) $\check{p} \leq \check{r}$ if and only if $\mathcal{J}(\check{p}) \leq \mathcal{J}(\check{r})$.

If a ranking function R such that $\mathcal{J}(k\,\check{p} + \check{r}) = k\,\mathcal{J}(\check{p}) + \mathcal{J}(\check{r})$.

For any $\check{p}, \check{\mathfrak{r}} \in F(\mathcal{J})$, $k \in \mathcal{J}$ then $\mathcal{J}$ is a linear ranking function (LRF) on $F(\mathcal{J})$.

The Maleki's ranking function (RF) suggestion for an LRF is as bellow [23]and [24]:

$$\mathcal{J}(\tilde{A}) = \frac{1}{2}(q^l + q^u) + \frac{1}{4}(\beta - \alpha).$$

5. Evolutionary Maleki Ranking Function

In this section, we propose a new ranking function that depends on the idea of The Maleki's ranking function with a new weight $\left(\frac{15}{16}\right)$. Assume $\tilde{a} = (q^l, q^u, \alpha, \beta)$ is a trapezoidal fuzzy number, and use the following formula to find the ranking function of $\tilde{a}$.

$$\mathcal{J}(\tilde{A}) = \frac{15}{16}.\mathrm{g}^5 \int_0^1 \frac{[inf\ \tilde{q}_{\mathrm{g}} + sup\ \tilde{q}_{\mathrm{g}}]}{\mathrm{g}^5}\ d\mathrm{g}$$

$$\mathcal{J}(\tilde{A}) = \frac{15}{16}.\mathrm{g}^5 \int_0^1 \frac{[(q^l - \alpha\,\mathrm{g})\,d\mathrm{g} + (q^u + \beta\,\mathrm{g})d\mathrm{g}]}{\mathrm{g}^5}$$

$$\mathcal{J}(\tilde{A}) = \frac{15}{16} \int_0^1 \frac{[(q^l\mathrm{g}^5 - \alpha\,\mathrm{g}^6)\,d\gamma + (q^u\mathrm{g}^5 + \beta\,\mathrm{g}^6)d\gamma]}{\mathrm{g}^5}$$

$$\mathcal{J}(\tilde{A}) = \frac{15}{16} \left. \frac{[q^l \frac{\mathrm{g}^6}{6} - \alpha \frac{\mathrm{g}^7}{7} + q^u \frac{\mathrm{g}^6}{6} + \beta \frac{\mathrm{g}^7}{7}]}{\frac{\mathrm{g}^6}{6}} \right|_0^1$$

$$\mathcal{J}(\tilde{A}) = \frac{15}{16} \frac{[q^l \frac{1}{6} - \alpha \frac{1}{7} + q^u \frac{1}{6} + \beta \frac{1}{7}]}{\frac{1}{6}}$$

$$\mathcal{J}(\tilde{A}) = \frac{15}{16} \frac{[\frac{1}{6}(q^l + q^u) + \frac{1}{7}(\beta - \alpha)]}{\frac{1}{6}}$$

$$\mathcal{J}(\tilde{A}) = \frac{15}{16} [(q^l + q^u) + \frac{6}{7}(\beta - \alpha)]$$

$$\mathcal{J}(\tilde{A}) = \frac{15}{16} [q^l + q^u] + \frac{90}{112} [\beta - \alpha]$$

6. Case Study

To apply for trapezoidal fuzzy number in linear programming problem, we have data from monthly production of the yogurt section in the abo ghreeb factory in the general company for the food products for the problem below and expressing the types of yogurt product (yogurt, diet yogurt, shenena, and diet shenena).

The objective function represents the types of yogurt products.

$\mathfrak{J}_1$: represent yogurt.

$\mathfrak{J}_2$: represent diet yogurt.

$\mathfrak{J}_3$: represent shenena.

$\mathfrak{J}_4$: represent diet shenena.

The constraints represent the basic materials (milk powder, skim milk powder, salt, starter, and water).

The following steps can be used to find the fuzzy optimal solution (FOS) to the chosen FLPP:

Step1. The practical LPP is:

$Max\ S = 69\,\mathfrak{J}_1 + 15\,\mathfrak{J}_2 + 463\,\mathfrak{J}_3 + 11\,\mathfrak{J}_4$

Subject to

$160\,\mathfrak{J}_1 + 70\,\mathfrak{J}_2 + 1000\,\mathfrak{J}_3 + 70\,\mathfrak{J}_4 \leq 3600000$

$1000\,\mathfrak{J}_2 + 1000\,\mathfrak{J}_3 \leq 200000$

$15\,\mathfrak{J}_3 + 15\,\mathfrak{J}_4 \leq 500$

$30\,\mathfrak{J}_1 + 30\,\mathfrak{J}_2 + 30\,\mathfrak{J}_3 + 30\,\mathfrak{J}_4 \leq 18000$

$840\,\mathfrak{J}_1 + 930\,\mathfrak{J}_4 \leq 15000$

$\mathfrak{J}_1, \mathfrak{J}_2, \mathfrak{J}_3, \mathfrak{J}_4 \geq 0$

Step 2. Now the problem is solved by the simplex method, and get the optimal solution (OS) is as:

$\mathfrak{J}_1 = 17.857\ , \mathfrak{J}_2 = 166.667\ , \mathfrak{J}_3 = 33.333\ , \mathfrak{J}_4 = 0\ , Max\ Z = 19.165480$

Step 3. In this problem, we take two cases in the following trapezoidal fuzzy number :

Case1: Assuming α=β the fuzzy linear programming problem (FLPP) may be written as:

$Max\ S = (65,73,4,4)\,\mathfrak{J}_1 + (13,17,2,2)\,\mathfrak{J}_2 + (460,466,3,3)\,\mathfrak{J}_3 + (9,13,2,2)\mathfrak{J}_4$

Subject to

$160\,\mathfrak{J}_1 + 70\,\mathfrak{J}_2 + 1000\,\mathfrak{J}_3 + 70\,\mathfrak{J}_4 \leq 3600000$

$1000\,\mathfrak{J}_2 + 1000\,\mathfrak{J}_3 \leq 200000$

$15\,\mathfrak{J}_3 + 15\,\mathfrak{J}_4 \leq 500$

$30\,\mathfrak{J}_1 + 30\,\mathfrak{J}_2 + 30\,\mathfrak{J}_3 + 30\,\mathfrak{J}_4 \leq 18000$

$840\,\mathfrak{J}_1 + 930\,\mathfrak{J}_4 \leq 15000$

$\mathfrak{J}_1, \mathfrak{J}_2, \mathfrak{J}_3, \mathfrak{J}_4 \geq 0$

Step 4. Convert the problem of fuzzy linear programming (FLP) to crisp the linear programming problem (CLPP) by using Maleki's ranking function (MRF)

$Max\ \mathcal{S} = 69\,\Im_1 + 15\,\Im_2 + 463\,\Im_3 + 11\,\Im_4$

Subject to

$160\,\Im_1 + 70\,\Im_2 + 1000\,\Im_3 + 70\,\Im_4 \leq 3600000$

$1000\,\Im_2 + 1000\,\Im_3 \leq 200000$

$15\,\Im_3 + 15\,\Im_4 \leq 500$

$30\,\Im_1 + 30\,\Im_2 + 30\,\Im_3 + 30\,\Im_4 \leq 18000$

$840\,\Im_1 + 930\,\Im_4 \leq 15000$

$\Im_1, \Im_2, \Im_3, \Im_4 \geq 0$

Step 5. Now find the optimal solution (OS) the in crisp linear programming problem (CLPP) by using the simplex method (SM):

$\Im_1 = 17.857\ , \Im_2 = 166.667\ , \Im_3 = 33.333\ , \Im_4 = 0\ , Max\ Z = 19.165480$

Step 6. To determine the optimal value (OV) of the above problem, we take transform TFN in the objective function (OF) to LPP by the Evolutionary Maleki ranking function (MRF)

$MAX\ \mathcal{S} = 129.375\,\Im_1 + 28.125\,\Im_2 + 868.125\,\Im_3 + 20.625\,\Im_4$

Subject to

$160\,\Im_1 + 70\,\Im_2 + 1000\,\Im_3 + 70\,\Im_4 \leq 3600000$

$1000\,\Im_2 + 1000\,\Im_3 \leq 200000$

$15\,\Im_3 + 15\,\Im_4 \leq 500$

$30\,\Im_1 + 30\,\Im_2 + 30\,\Im_3 + 30\,\Im_4 \leq 18000$

$840\,\Im_1 + 930\,\Im_4 \leq 15000$

$\Im_1, \Im_2, \Im_3, \Im_4 \geq 0$

Step 7. Finally, the optimum solution (OS) of the crisp linear programming problem (LPP) is obtained.
Thus,

$\Im_1 = 17.857\ , \Im_2 = 166.667\ , \Im_3 = 33.333\ , \Im_4 = 0\ , Max\ Z = 35.935270.$

Case2: Assuming $\alpha \neq \beta$ the FLPP may be written as:

$Max\ \mathcal{S} = (65,73,2,6)\,\Im_1 + (13,17,1,3)\,\Im_2 + (460,466,2,4)\,\Im_3 + (9,13,1,3)\,\Im_4$

Subject to

$160\,\Im_1 + 70\,\Im_2 + 1000\,\Im_3 + 70\,\Im_4 \leq 3600000$

$1000\,\mathfrak{J}_2 + 1000\,\mathfrak{J}_3 \quad \le 200000$

$15\,\mathfrak{J}_3 + 15\,\mathfrak{J}_4 \quad \le 500$

$30\,\mathfrak{J}_1 + 30\,\mathfrak{J}_2 + 30\,\mathfrak{J}_3 + 30\,\mathfrak{J}_4 \quad \le 18000$

$840\,\mathfrak{J}_1 + 930\,\mathfrak{J}_4 \quad \le 15000$

$\mathfrak{J}_1, \mathfrak{J}_2, \mathfrak{J}_3, \mathfrak{J}_4 \ge 0$

Step 8. Convert the problem of FLP to a crisp linear programming problem (CLPP) by using the Maleki's ranking function (MRF)

$Max\ \mathcal{S} = 70\,\mathfrak{J}_1 + 15.5\,\mathfrak{J}_2 + 463.5\,\mathfrak{J}_3 + 11.5\,\mathfrak{J}_4$

Subject to

$160\,\mathfrak{J}_1 + 70\,\mathfrak{J}_2 + 1000\,\mathfrak{J}_3 + 70\,\mathfrak{J}_4 \quad \le 3600000$

$1000\,\mathfrak{J}_2 + 1000\,\mathfrak{J}_3 \quad \le 200000$

$15\,\mathfrak{J}_3 + 15\,\mathfrak{J}_4 \quad \le 500$

$30\,\mathfrak{J}_1 + 30\,\mathfrak{J}_2 + 30\,\mathfrak{J}_3 + 30\,\mathfrak{J}_4 \quad \le 18000$

$840\,\mathfrak{J}_1 + 930\,\mathfrak{J}_4 \quad \le 15000$

$\mathfrak{J}_1, \mathfrak{J}_2, \mathfrak{J}_3, \mathfrak{J}_4 \ge 0$

Step 9. Now find the OS in CLPP by using the simplex method (SM):

$\mathfrak{J}_1 = 17.857\ , \mathfrak{J}_2 = 166.667\ , \mathfrak{J}_3 = 33.333\ , \mathfrak{J}_4 = 0\ , Max\ Z = 19.283330$

Step 10. To determine the optimal value of the above problem, we transform the trapezoidal fuzzy number in the objective function to LPP by the Evolutionary Maleki's ranking function (MRF)

$MAX\ \mathcal{S} = 132.589\,\mathfrak{J}_1 + 29.732\,\mathfrak{J}_2 + 869.732\,\mathfrak{J}_3 + 22.232\,\mathfrak{J}_4$

Subject to

$160\,\mathfrak{J}_1 + 70\,\mathfrak{J}_2 + 1000\,\mathfrak{J}_3 + 70\,\mathfrak{J}_4 \quad \le 3600000$

$1000\,\mathfrak{J}_2 + 1000\,\mathfrak{J}_3 \quad \le 200000$

$15\,\mathfrak{J}_3 + 15\,\mathfrak{J}_4 \quad \le 500$

$30\,\mathfrak{J}_1 + 30\,\mathfrak{J}_2 + 30\,\mathfrak{J}_3 + 30\,\mathfrak{J}_4 \quad \le 18000$

$840\,\mathfrak{J}_1 + 930\,\mathfrak{J}_4 \quad \le 15000$

$\mathfrak{J}_1, \mathfrak{J}_2, \mathfrak{J}_3, \mathfrak{J}_4 \ge 0$

Step 11. Finally, the OS of CLPP is obtained.
Thus,

$$\mathfrak{I}_1 = 17.857 \ , \mathfrak{I}_2 = 166.667 \ , \mathfrak{I}_3 = 33.333 \ , \mathfrak{I}_4 = 0 \ , Max\ Z = 36.314060.$$

7. Conclusion

The simplex method is an important method for solving linear programming problems. This paper proposes an evolutionary ranking function for solving the FLPP by SM. The proposed method may transform the FLPP into its equivalent crisp linear fractional programming problems (CLFPP). A practical problem was used to demonstrate the efficacy of our proposed strategy.

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