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العدد الثالث والعشرون
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An optimal fuzzy zero point method for solving fuzzy transportation problem

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Abstract

One of the first uses for Linear Programming (LP) issues was the transportation problem. In order to cut costs, transportation models are widely used in transportation and the supply chain. When the demand, cost and supply amounts, and other relevant information are precisely known, effective techniques have been created to solve the transportation problem. In the real world, unpredictability and imprecisions are unavoidable due to certain events. For the purpose of solving fuzzy transportation problems, an optimal fuzzy zero point technique is suggested in this study. The approach makes exact assumptions about the product's availability, demand, and transportation cost. The suggested method uses generalized trapezoidal fuzzy numbers to describe transportation costs, product availability, and demand. The suggested approach is relatively simple to comprehend and apply to actual transportation issues because it is a direct extension of the classical method. It will be an essential tool for decision-makers when they are dealing with a variety of logistical issues with fuzzy features.

Keywords: Transportation Problem; Fuzzy Transportation Problem (FTP); Fuzzy Optimal Solution; Fuzzy Zero Point Method (FZPM); Trapezoidal Fuzzy Numbers;

Introduction

Among the most well-known issues in LP is the transportation problem. Given the state of world economics and the present marketplace, the transportation of products is becoming more and more crucial, and understanding the system of transportation is essential for a business's efficient and cost-efficient functioning as well as for cutting costs and enhancing service. They make sure that raw materials and finished commodities are moved effectively and are available when needed (Mathur, Srivastava, and Paul 2018). The problem of transportation involves moving goods from diverse sources to numerous locations. Finding the ideal quantity of a commodity to convey from multiple supplier sites to different consumption points while keeping the overall expense of transportation to a minimum is the objective of the transportation problem. The standard transportation problem belongs to a subclass of LP problems where every constraint is associated with the equivalence form. It is frequently applied in the management of inventories, communication networks, general planning, employee organizing, and people assignments, among other fields. Figure 1 depicts the basic structure of the transportation problem. The problem of transportation could be divided into linear and nonlinear types based on the characteristics of the cost factor (Kumar 2020).

The key elements of the transportation problem involve costs per unit, or the expense of moving a single unit from a certain supplying location to a specific demand site, as well as the quantities that are accessible at the supply points and the quantities that are needed at request regions. Whenever demand, supply, and cost factors are exactly recognized effective models have been created to solve transportation problems. As a specific instance of a LP challenge, the problem of transportation enables researchers to identify the ideal route for shipping among sources and recipients. The response to the problem will enable to decide how many units should be carried from a certain source to a particular location in order to maximize profit while minimizing expenses, time, or both. A transportation problem is considered to have imprecise quantities when it comes to transportation costs, supplies, and consumption. The data that is accessible in real-world issues is either inadequate or perhaps just provided as hazy representations. This requires modeling the issue using the given data, which may be accomplished by employing the theory of fuzzy sets (Malini 2019).

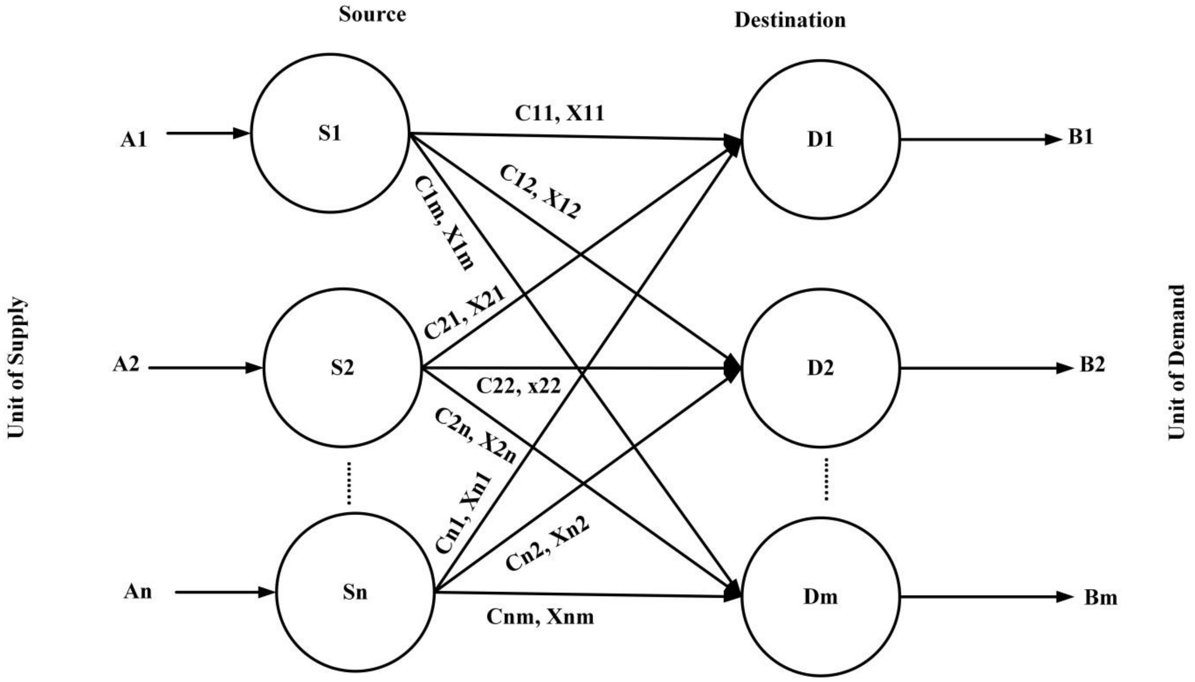

Figure 1: **Basic structure of transportation problem**

Problems specific to transportation arise in optimization. These are connected to actual, logistically organized actions. Transportation of a single manufactured item in several supplies to a number of distinct locations is an issue. The objective is to minimize the overall transportation costs for goods that will fulfill consumption at multiple locations (Mitlif, Rasheed, and Shihab 2020). The accessibility, requirements, and unit price of transportation might not be required to be known in real-time applications. Fuzzy numbers are the name given to these ambiguous facts. Each of the selected variables in the fuzzy transportation problem is an ambiguous integer. The aim of FTP is to identify the timetable for fuzzy transporting that minimizes overall fuzzy transportation expenses whilst fulfilling fuzzy accessibility and fuzzy need (Karthy and Ganesan 2019). Organizations are under pressure to discover new ways to produce as well as supply value-added services to clients for emerge greater in today's highly competitive marketplace. It became increasingly difficult to determining how and when to supply goods in large numbers to clients in a cost-effective way. Modeling of transport offers a strong foundation to handle the task. It guarantees the timely flow of both raw materials and completed commodities (Venkatachalapathy and Samuel 2016).

The problem of transportation is a subset of linear programs with equality or disparity as the constraints that Hitchcock initially defined in 1941. In its traditional form, the issue seeks to reduce the overall expense of conveying a good that is needed at different locations but is accessible at certain points (Ahmed et al. 2016). The STP/3D-transportation problem was initially introduced by Haley in 1962. The STP is the procedure of moving specific goods from their production locations (sources) to the various request locations (destinations), employing a variety of conveyances and taking into account various transportation abilities and expenses, fixed charge expenses, etc. to ensure that the overall cost of transportation is as low as possible. A lack of knowledge regarding the transit system or unanticipated issues like strikes, natural catastrophes, celebrations, etc. causes ambiguity when addressing real-world issues. Therefore, it is crucial for practical reasons that the transportation problem takes into account the aforementioned unpredictable surroundings (Jana and others 2020).

Numerous problems, including planning, manufacturing, expenditures, plant setting, control of inventory, and personnel planning, might be affected by transportation difficulties. The premise that the transportation expenses and worth of supply and requests are described in an accurate way, or in a clear surrounding, is how transportation problems are often handled. Various programs help people solve challenges in daily life. The quantity of expenses, supply, and demand make up the dimensions of the transportation problem. Transportation-related concerns with an item's worth frequently arise amid ambiguity and have a tendency to vary over time. This occurs as a result of a lack of knowledge about the importance of these issues. The number of expenses, inventory, and demand for value are the factors contributing to the transportation challenge (Satheeshkumar et al. 2017). The FZPM and the approach with the zero suffixes are two techniques used to discover the best way to save transportation expenses.

The FTP is regarded as a specific class of fuzzy LP issues. It is crucial to compute FTP while working with fuzzy numbers. To describe a fresh, sophisticated approach for locating a fuzzy, ideal FTP response. An optimum solution is one that can be achieved that minimizes or increases an objective response. It indicates a superior choice among all possible outcomes (Pandian and Natarajan 2010). Vogel's approximate approach was employed to arrive at a basic, workable fuzzy response (Thamaraiselvi and Santhi 2015). The goal of this research is to propose an algorithmic solution to the transportation problem that is both practical and straightforward. Needs, supply, and expenses for transportation are a few examples of transportation factors that aren't always clear-cut and may be unpredictable for a variety of factors. Thus, it could be difficult to calculate the precise values in certain situations. This kind of ambiguity could be handled using fuzzy, and numerous scholars have discussed this transportation problem using type 1 fuzzy parameters. Type 2 fuzzy parameter provides the ability to cope with uncertain/inexact/fuzzy data of any actual-life scenario in a conceptually suitable way by extending a range of freedom to current ambiguities.

The following is the study's key contribution:

- It helps to transport goods from source to destination at low cost
- This work suggests an ideal FZPM to address the fuzzy transportation problems.
- The availability, demand, and cost of transportation for the commodity are all accurate assumptions made in this study.
- It employs generalized trapezoidal fuzzy numbers to describe the price of transportation, the availability of the commodity, and the level of demand.

The organization of this study is as follows. The many approaches currently being used to address the transportation problem are described in Section 2. The structure of the suggested strategy for resolving the transportation problem is described in Section 3. It summarizes the results of the suggested system in Section 4. The findings and the plan for further research are presented in Section 5 at the end.

Related Works

Among the key issues in linear programming challenges (LPP), transportation problems (TP) focus on the issues associated with moving and distributing commodities with the goal of maximizing revenue or minimizing expenses, based on the problem category. A novel approach to resolving transportation problems was put forth in this investigation, using an objective function of the kind of profit maximization employed. This method was developed by drawing inspiration from a previously published study that addresses an identical issue using an objective function of the miniaturization kind. The effectiveness of this novel approach was evaluated based on the kinds of outcomes it produced whenever applied to a variety of real-world transportation problems, a few of which were highlighted in this report. The findings of the approach were subsequently compared between the suggested methodology and the three widely used traditional techniques, NWCM, LCM, and VAM. However, the outcomes obtained with the novel approach were those that were necessary and near the ideal response (Kadhim, Shiker, and Al-Dallal 2021).

The numerous objectives fractionated fixed-charge transporting problem (MFFTP) are addressed in this work along with a broad structure to guide decisions. To translate a multifaceted nonlinear transportation problem into its linear structure, a transformation approach is changed. The planned strategy variables are thought to be unclear. To cope with these fuzzy settings, the study uses several forms of fuzzy scales, such as potential, trustworthiness, and necessary measurements. The study uses recommended MFFTP and, utilizing the fuzzy chance-constrained rough approximate (FCRA) method, retrieves the most desirable optimum result. The original outcome is contrasted with the robustness rankings (RR) method's output. By taking into account two estimates, the study additionally employs the notion of approximate sets to enlarge and divide the MFFTP's feasible area in order to handle more data. Using those estimations, the study provides two variations of the proposed MFFTP: the lesser approximate (LA) and the upper approximate (UA). Lastly, the study presents the ideal responses to the suggested problems utilizing these frameworks. It additionally offers an actual scenario to illustrate the relevance and efficiency of the MFFTP. The work's fundamental idea is that it approaches an MFFTP utilizing two distinct types of ambiguity and broadens its practical field in search of the best solution. The developed strategy optimal solutions, derived via the FCRA approach, may be divided into two categories: "surely area" and probable area." Given that these are minimum values, the best option in the "undoubtedly area" is superior to those in the "probably area" and other situations. Finally, a description of the methodology is given, together with suggestions for the planned direction of a subsequent investigation. Another of the FCRA technique's drawbacks is how time-consuming it's to convert from a model that is fuzzy to a comparable crisp form (Midya, Roy, and Weber 2021).

Particle Swarm Optimization (PSO) has imitated the foraging behaviors of various social creatures, including a flock of birds and a group of fish. Whenever described as a computer process, this communicating socialization has provided solutions to a variety of challenging issues. PSO has changed throughout time and there are now many different variations. In order to minimize the expenses related to transportation (a parameter and stable) of transporting products while fulfilling supply/demand restrictions, PSO has been hybridized with two novel techniques in this work. It was additionally looked into to solve the issue independently using variable costs at first, and then adding fixed costs. This was shown that the suggested PSO performs better when the objective function is left unaffected. The findings from the simulation show that the suggested strategy has significantly improved in terms of effectiveness as well as efficacy when applied to various testing issues. The suggested PSO was additionally evaluated against the answers obtained by other current approaches (whether it's precise or heuristic) in order to verify the assertions. As a result of its inadequate answers, this approach is ineffective (Singh and Singh 2021).

The fractionated transportation problem, which has several objectives, is addressed in this study using a soft computation optimizing operational strategy. According to the suggested method, a mathematical representation is developed to represent the multi-objective aspiring levels fractionated transportation problem (MOFTP) dependent on the greatest worth of each and every modeling goal. To find the most ideal approach dependent on symmetric information, it additionally employed the symmetry principle in the framework. Investigation created membership ratings for the collection of symmetrical variables that were requested. To find the best option for fuzzy multi-objective fractionated transportation, this investigation also applied the notion of ranking functions in the mathematical framework. The ambition values are linked to the MOFTP goal functions in this suggested method. The work also suggests a novel method to perform concurrent optimization of the targets of the numerator functional and denominator function in fractionated situations. Additionally, a technique is devised to determine the typical expenditure for every fractional modeling target. The defuzzification approach will then be used to discover the ranked functions for every value. The study should be capable to transform the MOFTP into a bi-objective transportation problem using this way. Mathematical computations are used to clarify the offered approach in order to demonstrate its exquisite simplicity and potency (Sharma et al. 2021).

Proposed solution for Fuzzy Transportation Problem

It is demanded in traditional transportation issues that the decision-maker is certain of the precise figures relating to transportation costs, product availability, and demand. Due to unpredictable circumstances, it's possible that each of these transportation problem characteristics will not be accurately understood in real-world applications (Maity et al. 2019). When a product needs to be carried for the first time to a location and no expert is familiar with the cost of transportation, there might be the following difficulties that occur in real-world issues. When a new product is introduced to the market, there is always some degree of uncertainty regarding the demand for that specific item.

The FTP might be expressed as follows when a decision-maker is unable to determine the exact amount of transportation costs from the ith source to the jth destination but is confident about the supply and demand of the product (Gupta, Ali, and Ahmed 2018). The formulation is given in Eq.1 and Eq. 2:

$$\sum_{y=1}^{n} i_{xy} = p_x, \quad x = 1,2,\ldots,m \qquad (1)$$

$$\sum_{x=1}^{m} i_{xy} = q_y, \quad y = 1,2,\ldots,n \qquad (2)$$

where i_{xy} is the amount of components of the good, which must be transported through the xth origin to the yth destination or decision factors; p_x will be the total rate of the goods that are accessible at the xth source; q_y will be the total rate of the goods that are necessary at the yth destination; r is the approximation of the cost for transporting one unit the amount of the goods from the xth origin to the yth destination; The overall cost of fuzzy transportation is $\sum_{x=1}^{m} \sum_{y=1}^{n} r_{xy} i_{xy}$

Let u'_x and v'_y represent the fuzzy dual factors linked to the xth row and yth column constraints, accordingly. In such case, the fuzzy dual of the FTP shown in Eq. (1) will be as follows Eq.3:

$$max \sum_{x=1}^{m} p_x u'_x \oplus \sum_{y=1}^{n} q_y v'_y \tag{3}$$

Trapezoidal Fuzzy Numbers

A set made up of a single trapezoidal fuzzy number or numerous trapezoidal fuzzy numbers is referred to as a trapezoidal fuzzy set. An individually linear and trapezoidal function of membership of a trapezoidal fuzzy number may represent the fuzzy characteristics of those linguistic evaluations (Fahmi, Abdullah, and Fazli 2018). The trapezoidal numbers are widely used in real-world applications and are relatively simple to use. The fundamental design of a trapezoidal fuzzy number is depicted in Figure 2.

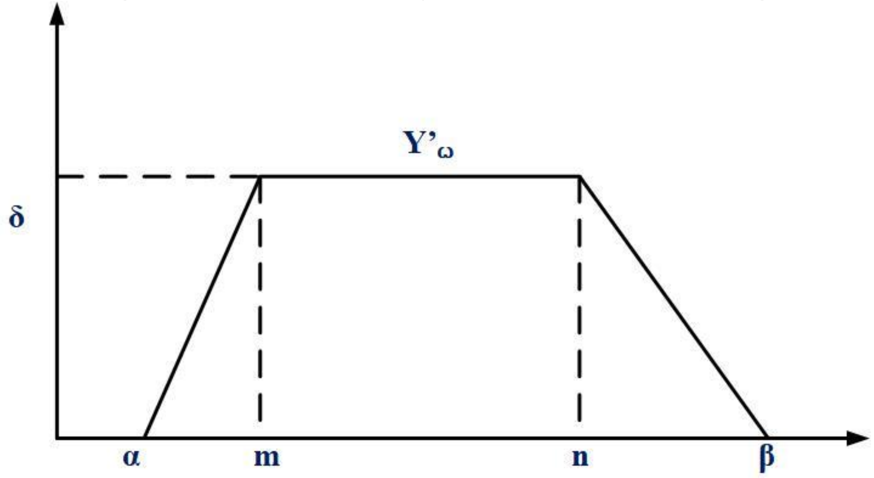

Figure 2: **Fuzzy Trapezoidal Number**

An indeterminate number L' is a trapezoidal fuzzy number, as well as its association function, is given below as (α, β, m, and n), where, these are real numbers.

$$\begin{cases} 0 & for\ i \le \alpha \\ (i-\alpha)/(m-\alpha) & for\ \alpha \le i \le m \\ 1 & for\ m \le i \le n \\ (n-i)/(\beta-n) & for\ \ n \le i \le \beta \end{cases} \tag{3}$$

The variable $M(Y')$, which is allocated to Y' is determined as follows: Let $Y' = (Y(c), Y'(c))$, (0≤ c ≤1) be a fuzzy number in accordance with the definition of a trapezoidal fuzzy number provided in Eq.3.

$$M_0^{tp}(Y') = \frac{1}{2}\int_0^1 \{Y(c) + Y'(c)\}d = \frac{1}{4}[m+n+\alpha+\beta] \tag{4}$$

It makes calculations extremely simple as given in Eq.4.

The variable $M_0^{tp}(Y')$, provided to Y'_δ might be determined as follows if Y'_δ = (Y(c), Y'(c)) = $\alpha + \frac{m-\alpha}{\delta}c, \beta + \frac{n-\beta}{\delta}c$ is an arbitrary trapezoidal fuzzy number with decision level greater than δ ϵ[0, 1].

If δ >γ, then

$$M_0^{tp}(Y') = \frac{1}{2}\int_\gamma^\delta \{Y(c) + Y'(c)\}d = \frac{1}{4}[m+n+\frac{\gamma}{\delta}(m+n-\alpha-\beta)+\alpha+\beta](\delta-\gamma) \tag{5}$$

It goes without saying that the previously stated amount will be zero if. It may also be demonstrated that the aforementioned quantities decrease to: if L’ is a trapezoidal fuzzy number ($\delta = 1$).

$$M_0^{tp}(Y') = \frac{1}{2}\int_0^1 \{Y(c) + Y'(c)\}d = \frac{1}{4}[m + n + \frac{\gamma}{1}(m + n - \alpha - \beta) + \alpha + \beta](1 - \gamma) \qquad (6)$$

The relationships may be further simplified as the two additional relations of Eq. 6 are cancelled out, if the fuzzy number is symmetrical ($\alpha = \beta$). The trapezoidal fuzzy number Y’ might be demonstrated as (α, β, m, and n) depending on the results.

Fuzzy Zero Point Method (FZPM)

The study developed an entirely novel algorithm, the FZPM, for solving fuzzy transportation problems in a single step.

The Fuzzy Zero Point Method (FZPM) proceeds as follows.

Step 1: For the provided fuzzy transportation problem, generate the fuzzy transportation table, and if it is not balanced, convert it into a balance.

Step 2: From the row minimum, take every row values from the fuzzy transportation table.

Step 3: After utilizing Step 2, subtract every column values from the column minimum in the generated fuzzy transportation table.

Step 4: Verify that every fuzzy demand in a column is smaller than the total of the fuzzy supplies where lowered costs are fuzzy zero in that column. Additionally, make sure every row's fuzzy supply is lower than the sum of every column's fuzzy demands, where decreased costs are fuzzy zero in that row. Go to Step 7 if so. The allotment table is a similar smaller table. Go to Step 5 if not.

Step 5: Demonstrate the fewest amount of vertical and horizontal lines necessary to completely hide each of the fuzzy zeros in the lowered fuzzy transportation table, assuming certainly that none of the variables in the columns, and rows will not fulfil Step 4’s requirement.

Step 6: Following are the steps to create the new revised lowered fuzzy transportation table: (i) locate the reduced fuzzy cost matrix's smallest entry that is not hidden by any lines. (ii) Subtract this entry from every one of the hidden entries and add it to each of the entries that are found at any two-line junction then proceed to Step 4.

Step 7: In the lowered fuzzy transportation table, choose a cell where reduced cost is the highest cost as α, β Choose any cell if there is more than one

Step 8: Choose the only cell in the column or row of the lowered fuzzy transportation table where low cost is fuzzy zero, also assign that cell as much space as you can. Determine the next maximum so that the cell does appear if the maximum value does not have such a cell. Choose any cell in the lowered fuzzy transportation table, where lowest cost is fuzzy zero if such a cell is absent for any amount.

Step 9: After removing the fully utilized fuzzy supply points along with all established fuzzy demand points, reform the modified fuzzy transportation table. Additionally, modify it to add the partially utilized fuzzy supply points and partially established fuzzy demand points.

Step 10: Steps 7 through 9 should be repeated until all fuzzy demand points and supply points have been completely supplied.

Step 11: The supplied fuzzy transportation problem has a fuzzy solution as a result of this allocation.

Example of Fuzzy Zero Point Method

The following example provides to show the FZPM, which is the suggested approach.

Consider the following FTP.

				Demand
	(1,2,3,4)	(0,1,2,4)	(3,5,6,8)	(5,7,8,10)
	(1,3,4,6)	(-1,0,1,2)	(5,8,9,12)	(1,5,6,10)
	(9,11,12,14)	(5,6,7,8)	(12,15,16,19)	(1,3,4,6)
	(5,7,8,11)	(0,1,2,3)	(7,9,10,12)	(1,2,3,4)
Supply	(2,6,7,12)	(0,1,2,3)	(6,10,12,17)	

Now, the overall fuzzy supply, S’= (8, 17, 21, 32) as well as the total fuzzy demand, D’= (8, 17, 21, 32). As Mag (S’) = Mag (D’), the problem is balanced.

Obtain the following simplified fuzzy transportation table after using Steps 2 through 3 of the FZPM.

				Demand
	0	(-2,0,2,5)	0	(5,7,8,10)
	(-3,0,2,5)	0	(-3,2,4,9)	(1,5,6,10)
	(-4,1,5,10)	0	(-5,2,6,13)	(1,3,4,6)
	(-3,2,6,12)	0	(-5,1,5,11)	(1,2,3,4)
Supply	(2,6,7,12)	(0,1,2,3)	(6,10,12,17)	

The following allocation table results from using Steps 4 through 6 of the FZPM.

				Demand
	-22,-5,7,25	(-37,-6,16,48)	0	(5,7,8,10)
	0	(-9,-1,4,13)	(-33,-7,9,34)	(1,5,6,10)
	0	0	0	(1,3,4,6)
	(-44,-10,13,49)	(-23,-5,7,24)	0	(1,2,3,4)
Supply	(2,6,7,12)	(0,1,2,3)	(6,10,12,17)	

The allocation is obtained, using the FZPM’s allotment rules,

				Demand
			(5,7,8,10)	(5,7,8,10)
	(1,5,6,10)			(1,5,6,10)
	(-9,0,2,11)	(0,1,2,3)	(-9,-1,3,11)	(1,3,4,6)
			(1,2,3,4)	(1,2,3,4)
Supply	(2,6,7,12)	(0,1,2,3)	(6,10,12,17)	

Thus, the optimal fuzzy solution for the FTP is i_{13}=(5,7,8,10), i_{21}= (1,5,6,10), i_{31}= (-9,0,2,11), i_{32}= (0.,1,2,3), i_{33}= (-9,-1,3,11), i_{43}= (1,2,3,4) with the fuzzy objective value k= (-275, 58,188, 575) as well as the variable of the optimum FTP, k is 131.17

Conclusion

The transportation issue was among the first LP application problems. Transportation models are frequently employed in transportation including the supply chain to save costs. There are efficient methods for resolving the transportation issue when the demand, supply and cost volumes, and other pertinent variables are exactly understood. In the real world, unpredictability and inaccuracy are unavoidable due to a few unforeseen circumstances. The paper suggested an optimal FZPM for solving FTP. The strategy bases its decisions on precise presumptions on the product's supply, demand, and transportation expenses. The proposed approach describes transportation costs, product availability, and demand using generalized trapezoidal fuzzy numbers. As the suggested method is a straightforward extension of the conventional method, it is easier to learn and implement to real transportation problems. When decision-makers are faced with a variety of logistical problems with fuzzy features, it may prove to be an important tool.

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