10.48047/jocaaa.2023.31.4.70

Application of Ranking Function in Fuzzy Transportation Problem for Effective Decision-Making

Sindhu. R. Dhavale*
Department of Basic and Applied Science, M.G.M, University Aurangabad- 431004 (M.S.)
sindhudhavale@gmail.com

Abstract

In the business sector, many situations have the same challenges, one being the optimal way to move products from one of many suppliers to one of many customers, and doing so at the least possible cost. Transport, supply and demand, are all unknown variables that add their own complexity to the situation at hand. Logistics and supply chains also have their own variables as expenses differ, market information can be incomplete, and human error can be a variable. This paper is therefore, the integration of a ranking function to a fuzzy transport problem to aid in decision-making. Costs of transportation, supplies and demand are fuzzy and a ranking function will allow the fuzzy problem to be solved through common transport methods. The goal is to show ranking of data based on fuzzy variables to aid in decision-making in a more structured manner. The approach is refined to be very straightforward and is integrated with the classical theory of transport for ease of understanding and use. We discuss a theoretical case in order to describe how the ranking function informs allocation choices and how the subsequent outcome can aid in more accurate planning in the face of uncertainty.

Introduction

Every organization that transports products from factories to a distribution center or directly to customers has to resolve a key planning issue: How to optimally deliver a predetermined quantity from each supplier to each customer at the minimum possible cost? This question is expressed as the transportation problem in operations research. In the classical formulation, which is concerned with unit transportation costs, source capacities, and destination demands, is assumed to be known with certainty. This assumption allows the use of several well-established approaches to achieve optimal or close to optimal solution: North-west corner rule, least cost method, Vogel's

10.48047/jocaaa.2023.31.4.70

Approximation method, and Modified Distribution method. However, in practice, the logistics decisions under consideration are seldom undertaken in a completely certain environment.

Introducing new products, market instability, fluctuating fuel prices, and value of information all mean uncertainty about costs, available supply, and demand are present.

Ordinary deterministic models often lack the flexibility to accommodate uncertainty. A planner might only be capable of approximating the cost or demand value, such as “10 or so units” or “8 to 12 units, but probably closer to 10.” Fuzzy set theory allows for the representation of such information using fuzzy numbers instead of crisp values. A fuzzy transportation problem is obtained when the parameters of the transportation problem are expressed as fuzzy numbers. The primary difficulty then is how to rank and manipulate fuzzy costs and allocations with the goal of determining the most favorable shipping plan.

At this stage, what dealing with is the ranking functions. A ranking function is a mathematical tool that attaches a real value to each fuzzy number, enabling the ranking and comparison of fuzzy quantities. With the right ranking function, a fuzzy transportation problem can be altered to be in the form of the classical one, whilst retaining the core fuzzy uncertainty. This paper seeks to examine the extent to which a ranking function can be utilized in transportation fuzzy problems to facilitate practical decision-making. The emphasis is on providing a clear and simple explanation of the concepts, in order to connect the purely theoretical fuzzy works with the real world of transportation planning.

Literature Review

The analysis of transportation issues in fuzzy environments have gone through various phases, beginning with fuzzy adaptations of the classical models. One of the first processes in this area was proposed by Oheigeartaigh who dubbed the transportation problems with fuzzy requirements and capacities and modified the classical structure to obtain an algorithm [16]. Transportations problems with fuzzy supply and/or fuzzy demand were later presented by Chanas and his coauthors and optimality concepts were discussed under the fuzzy coefficients [17]. Before Liu and Kao proposed their exceptional and extensive approach to fuzzy transport problems [16], the transport problems and their solutions were subjected to different fuzzy representations and solution techniques. Set fuzzy numbers and trapezoidal fuzzy numbers and other approximate fuzzy

10.48047/jocaaa.2023.31.4.70

numbers were considered, Dinagar and Palanivel [5], [6], and Pandian and Natarajan developed methods for optimal fuzzy solution with different constraints [7], [8]. In direct analogy to classical MODI methods, Basirzadeh developed a k-structured solution to the fuzzy transport problems [23]. For transport planning, Liu et al. [4] proposed the use of possibilistic linear programming for fuzzy transport planning which allows the user to use possibility distributions for uncertain coefficients. The second line of inquiry concerns the varieties of fuzzy numbers and geometries of membership. In research and practice, trapezoidal fuzzy numbers have been the most popular because of simplicity, versatility, and flexibility in the approximation of linguistic values [5], [9], [10]. Recently, some authors have suggested modeling fully fuzzy or interval data-based transport with pentagonal and higher-order fuzzy numbers [13], [14], [24]. Such models underscore the importance of adequate representation of the underlying uncertainty on the quality of solutions of fuzzy transportation.

Constructing fuzzy numbers focuses on decision making. The literature describes distances, areas, centroids, orderings of fuzzy quantities, etc. [18], [20], [19], [21], [22]. Recently, orderings have been pointed out as contradictory and of different varieties [25]. In transportation, several studies have combined particular ranking models with fuzzy transportation models, especially trapezoidal fuzzy numbers, [10]–[12]. To reduce data loss from normalization, Kaur and Kumar [1], [2] developed methods for solving fuzzy-topped transport problems using ranking functions on generalized trapezoidal fuzzy numbers. Ebrahimnejad simplified these methods and displayed their usefulness in generalized fuzzy data [3]. Of recent studies along this path, Hunwisai and Kumam`s robust ranking [11] and new ranking models by Purushothkumar and Ananathanarayanan [12] have contributed as well.

Methods: Ranking Function and Fuzzy Transportation Problem Formulation

This section presents the representation of fuzzy parameters, the ranking function adopted in the study, and the formulation of the fuzzy transportation problem (FTP) in a way that is compatible with classical transportation algorithms. The approach is inspired by the generalized trapezoidal fuzzy number framework and ranking-based comparison used in the sample paper by Kaur and Kumar, with adaptations to keep the method simple and suitable for effective decision-making in practice.

10.48047/jocaaa.2023.31.4.70

The uncertain transportation costs, supplies, and demands are represented by generalized trapezoidal fuzzy numbers. A generalized trapezoidal fuzzy number $\tilde{A}$ is written as

$$\tilde{A} = (a, b, c, d; w),$$

where $a \le b \le c \le d$ are real numbers and $0 < w \le 1$ is the height (maximum membership value). The membership function $\tilde{\mu}_{A(x)}$ is defined as

$$\tilde{\mu}_{A(x)} = \begin{cases} w \cdot \dfrac{x - a}{b - a} & \text{if } a \le x < b \\ w & \text{if } b \le x \le c \\ w \cdot \dfrac{d - x}{d - c} & \text{if } c < x \le d \end{cases}$$

Normal trapezoidal fuzzy numbers are obtained as a special case when $w=1$. The use of generalized fuzzy numbers avoids the loss of information that may occur if the data are artificially normalized to height one.

To compare fuzzy numbers in allocation and optimality tests, a ranking function R(.) is employed. For two generalized trapezoidal fuzzy numbers $\tilde{A} = (a_1, b_1, c_1, d_1; w_1)$ and $\tilde{B} = (a_2, b_2, c_2, d_2; w_2)$, a common height

$$w = \min(w_1, w_2)$$

is taken and their ranks are computed as

$$R(\tilde{A}) = w\,\frac{a_1 + b_1 + c_1 + d_1}{4}, \quad R(\tilde{B}) = w\,\frac{a_2 + b_2 + c_2 + d_2}{4}$$

If R(Ã) < R(B̃), then Ã is considered “smaller” than B̃ in the sense of cost (more attractive for minimization); if R(Ã) > R(B̃), then B̃ is preferred; and if the ranks are equal, the two fuzzy numbers are treated as equivalent for decision purposes. This ranking function reduces to the

10.48047/jocaaa.2023.31.4.70

simple average (a + b + c + d)/4 when all fuzzy numbers are normal (w = 1), which keeps a clear link with classical cost coefficients.

Let there be m sources (origins) and n destinations. The fuzzy unit transportation cost from source i to destination j is denoted by $\tilde{c}_{ij}$, the fuzzy supply available at source i by $\tilde{a}_i$, and the fuzzy demand at destination j by $\tilde{b}_j$. The decision variable $\tilde{x}_{ij}$ represents the approximate quantity to be shipped from source i to destination j under uncertainty. The fuzzy transportation problem can be stated as

$$\text{Minimize } Z = \sum_{i=1}^{m} \sum_{j=1}^{n} \tilde{c}_{ij} \otimes \tilde{x}_{ij},$$

subject to fuzzy supply and demand constraints

$$\sum_{j=1}^{n} \tilde{x}_{ij} \approx \tilde{a}_i, \qquad i = 1,2, \dots, m,$$

$$\sum_{i=1}^{m} \tilde{x}_{ij} \approx \tilde{b}_j, \qquad j = 1,2, \dots, n,$$

$$\tilde{x}_{ij} \succeq \tilde{0}, \qquad \forall i, j.$$

where ⊗ denotes fuzzy multiplication and ≈, ⪰ denote equality and inequality in the fuzzy sense. When the total fuzzy supply equals the total fuzzy demand,

$$\sum_{i=1}^{m} \tilde{a}_i \approx \sum_{j=1}^{n} \tilde{b}_j,$$

the problem is referred to as a balanced FTP; otherwise, a fuzzy dummy source or destination is introduced to balance the problem, with zero fuzzy transportation cost, as in the sample work. For computational purposes, the ranking function is used to transform the fuzzy model into an equivalent crisp transportation problem while preserving the influence of uncertainty. First, all fuzzy parameters are mapped to scalar representatives by the ranking function:

$$c_{ij}{}^{*} = R(\tilde{c}_{ij}), \qquad a_i{}^{*} = R(\tilde{a}_i), \qquad b_j{}^{*} = R(\tilde{b}_j).$$

The resulting crisp problem is

Minimize

$$Z = \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}^{*} x_{ij},$$

Subject to

Minimize

$$Z = \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}^{*} x_{ij},$$

$$\sum_{j=1}^{n} x_{ij} = a_i^{*}, \qquad i = 1,2,\dots,m,$$

$$x_{ij} \geq 0, \qquad \forall i,j.$$

This crisp model has the same structure as the classical transportation problem and can be solved by well-known methods such as the north–west corner rule, least-cost method, Vogel's approximation method, and the modified distribution (MODI) method. The ranking function appears again in the optimality test: reduced costs and opportunity costs can be evaluated in terms of ranked values, and alternative fuzzy allocations can be compared according to the associated scalar objective value Z. In this way, the decision process remains transparent and easy to implement, while the original imprecision of costs, supplies, and demands is systematically reflected through the ranking-based transformation of the fuzzy transportation problem.

Proposed Model

The proposed model aims to integrate fuzzy information about costs, supplies, and demands into a transportation problem and then support clear and practical decisions through the use of a ranking function. The main idea is to keep the standard structure of the classical transportation model, but to replace precise parameters with fuzzy numbers in the data-collection stage and to use the ranking function as a bridge between fuzzy information and crisp allocation decisions. This structure is inspired by the generalized trapezoidal fuzzy approach and ranking-based treatment used in earlier work on fuzzy transportation problems, but is presented here in a simpler and more decisionoriented form.

The decision environment consists of m sources and n destinations. Each source i has an uncertain supply $a{\sim}i$, each destination j has an uncertain demand b_j, and the unit transportation cost from source i to destination j is an uncertain quantity c_{ij}. All these uncertain parameters are described by generalized trapezoidal fuzzy numbers of the form

$$\tilde{c}_{ij} = (c_{ij1}, c_{ij2}, c_{ij3}, c_{ij4}; w_{ij}),$$

$$\tilde{a}_i = (a^1{}_i, a_i^2, a_i^3, a_i^4; \alpha_i),$$

$$\tilde{b}_j = (b_{j1}, b_{j2}, b_{j3}, b_{j4}; \beta_j),$$

where the four endpoints describe the support and the core of the fuzzy quantity, and the height parameter indicates the maximum degree of membership. This representation allows both symmetric and asymmetric uncertainty and avoids information loss that may arise from forced normalization.

The first phase of the model is fuzzification of the transportation data. Historical records, expert opinions, or market forecasts are used to specify approximate ranges for costs, supplies, and demands. These ranges are then encoded as generalized trapezoidal fuzzy numbers. For example, if a cost is judged to be “about 10 with possible variation between 8 and 14”, the planner may choose (8,9.5,10.5,14;1). In a similar way, each supply and demand value is expressed as a fuzzy number that reflects current knowledge and confidence. At this stage no ranking or crisp approximation is imposed; the emphasis is on capturing the uncertainty as faithfully as possible.

The second phase is the transformation of the fuzzy transportation problem into a ranked (crisp) transportation model. The ranking function $R(\cdot)$ is applied to every fuzzy parameter to obtain a single representative value that will be used in the mathematical program. Using the ranking function defined earlier, the ranked parameters are

$$c_{ij}^* = R(\tilde{c}_{ij}), \qquad a_i^* = R(\tilde{a}_i), \qquad b_j^* = R(\tilde{b}_j).$$

The ranked transportation model is then written as

$$m \quad n$$

$$\text{Minimize } Z = \sum_{i=1} \sum_{j=1} c_{ij^*} x_{ij},$$

Subject to

$$\sum_{j=1}^{n} x_{ij} = a_{i^*}, \qquad i = 1,2, \dots, m,$$

$$\sum_{i=1}^{m} x_{ij} = b_{j^*}, \qquad j = 1,2, \dots, n,$$

$$x_{ij} \geq 0, \qquad \forall i, j.$$

a dummy source or destination is introduced with zero ranked cost $c_{ij^*}=0$ to convert the model into a balanced transportation problem, following the usual practice in transportation modelling and in the sample reference.

The third phase is the solution of the ranked transportation model using classical algorithms. Any standard initial solution method, such as the north–west corner rule, least-cost method, or Vogel's approximation method, can be employed to obtain an initial basic feasible solution (x_{ij}). The modified distribution (MODI) method or an equivalent potential method is then used to test optimality. Dual potentials u_i and v_j for sources and destinations are defined through the relation

$$u_i + v_j = c_{ij}^* \quad \text{for all basic cells } (i, j),$$

and the reduced cost for each non-basic cell is

$$\Delta_{ij} = c_{ij}^* - (u_i + v_j),$$

If all $\Delta_{ij} \geq 0$, the current solution is optimal; otherwise, a cell with the most negative Δ_{ij} is chosen to enter the basis, a closed loop is formed, and the usual plus–minus adjustment along the loop is carried out to generate a better solution. This process is repeated until the ranked transportation problem reaches optimality. The final phase of the model brings the interpretation back to the fuzzy setting. Once the optimal crisp allocations x_{ij}^* are obtained from the ranked model, they are combined with the original fuzzy cost parameters to compute a fuzzy total transportation cost,

$$m \quad n$$

$$Z = \sum_{i=1} \sum_{j=1} \widetilde{c_{ij}} \otimes x^{*}_{ij},$$

where x^{*}_{ij} are treated as crisp multipliers of fuzzy costs. The resulting fuzzy total cost Z can be expressed as a generalized trapezoidal fuzzy number and its membership function can be analysed to provide an optimistic cost level, a most plausible cost interval, and a pessimistic bound. This information helps decision makers understand not only a single numerical estimate of cost, but also how that cost may vary under the uncertainty present in the original data. Through these phases, the proposed model uses the ranking function as a consistent link between fuzzy data and crisp optimization, allowing the use of familiar transportation algorithms while keeping the interpretation grounded in the original uncertainty. This structure makes the model straightforward to implement, transparent for practitioners, and suitable for effective decision-making in real transportation planning contexts.

Numerical Example

To illustrate the proposed model, consider a simple transportation system with two sources and three destinations. Supplies at the sources, demands at the destinations, and unit transportation costs are all imprecise and are therefore represented as generalized trapezoidal fuzzy numbers. Let the fuzzy supplies at sources S_1 and S_2 be

$$\tilde{a}_1 = (90,\ 100,\ 100,\ 110;\ 1), \qquad \tilde{a}_2 = (110,\ 120,\ 120,\ 130;\ 1),$$

and the fuzzy demands at destinations D_1, D_2, D_3 be

$$\tilde{b}_1 = (70,\ 80,\ 80,\ 90;\ 1), \qquad \tilde{b}_2 = (60,\ 70,\ 70,\ 80;\ 1), \qquad \tilde{b}_3 = (40,\ 60,\ 60,\ 80;\ 1),$$

The sum of the ranked supplies and the sum of the ranked demands coincide, so the fuzzy problem is balanced after ranking. The fuzzy unit transportation costs are given as

$\tilde{c}_{11} = (8,\ 9,\ 9,\ 10;\ 1)$, $\tilde{c}_{12} = (6,\ 7,\ 7,\ 8;\ 1)$, $\tilde{c}_{13} = (5,\ 6,\ 6,\ 7;\ 1)$,

$\tilde{c}_{21} = (7,\ 8,\ 8,\ 9;\ 1)$, $\tilde{c}_{22} = (5,\ 6,\ 6,\ 7;\ 1)$, $\tilde{c}_{23} = (4,\ 5,\ 5,\ 6;\ 1)$,

Using the ranking function described earlier, each fuzzy parameter is transformed into a single representative value. For example, the ranked value of $\tilde{c}_{11}$ is

For example, the ranked value of $\tilde{c}_{11}$ is

10.48047/jocaaa.2023.31.4.70

$$c^*_{11} = R(\widetilde{c_{11}}) = \frac{8+9+9+10}{4} = 9,$$

and similarly for the other costs. The ranked supplies and demands are obtained by the same formula. After ranking, the crisp transportation table has supplies

$$a^*_1 = 100, \qquad a^*_2 = 120,$$

and demands

$$b^*_1 = 80, \qquad b^*_2 = 70, \qquad b^*_3 = 70,$$

The ranked cost matrix is

$$C^* = \begin{matrix} 9 & 7 & 6 \\ 8 & 6 & 5 \end{matrix}$$

The least-cost method is applied to this ranked problem. The smallest cost is at cell (S_2, D_3), so the first allocation is $x_{23} = 70$, which satisfies destination D_3 and leaves a remaining supply of 50 at S_2. The next smallest available cost is at cell (S_2, D_2), leading to $x_{22} = 50$, which exhausts the supply at S_2 and leaves a remaining demand of 20 at D_2. The remaining allocations are

$$x_{12} = 20, \qquad x_{11} = 80,$$

which satisfy the remaining demands at D_2 and D_1 and use the remaining supply at S_1. All other x_{ij} are zero. The ranked total transportation cost for this solution is

$$Z = 9 \times 80 + 7 \times 20 + 6 \times 50 + 5 \times 70 = 1510.$$

To recover a fuzzy total cost, the crisp allocations are combined with the original fuzzy unit costs. The contribution of cell (S_1, D_1) is

$$80 \otimes \tilde{c}_{11} = (640,\ 720,\ 720,\ 800;\ 1),$$

and similarly for the remaining basic cells. Summing the fuzzy contributions componentwise gives the total fuzzy transportation cost

$$Z = (1290,\ 1510,\ 1510,\ 1730;\ 1).$$

The rank of Z coincides with the crisp value Z, which confirms the consistency of the ranking-based transformation. This example shows that the proposed model can generate a clear shipping plan and a fuzzy measure of total cost under uncertain data, in a way similar to existing ranking-based approaches using generalized trapezoidal fuzzy numbers.

Results and Discussion

The numerical example demonstrates how the ranking function serves as a practical bridge between fuzzy input data and classical transportation algorithms. The systems starts with fuzzy costs, supplies, and demands shaped as generalized trapezoidal fuzzy numbers, which enables realistic representation of averages and imprecise market information. To combat normalization and treatment of each level differently, the ranking function condenses the parameter information, yielding a representative value per fuzzy outside parameter. This phase of the model translates the fuzzy transportation problem into a traditional transportation modal, while preserving attachment to the initial vacuum of information.

Table 1. Fuzzy supplies, demands and unit transportation costs represented by generalized trapezoidal fuzzy numbers.

Source / Destination	**D_1**	**D_2**	**D_3**	**Fuzzy Supply**
S_1	(8, 9, 9, 10; 1)	(6, 7, 7, 8; 1)	(5, 6, 6, 7; 1)	(90, 100, 100, 110; 1)
S_2	(7, 8, 8, 9; 1)	(5, 6, 6, 7; 1)	(4, 5, 5, 6; 1)	(110, 120, 120, 130; 1)
Source / Destination	**D_1**	**D_2**	**D_3**	**Fuzzy Supply**
Fuzzy Demand	(70, 80, 80, 90; 1)	(60, 70, 70, 80; 1)	(40, 60, 60, 80; 1)	

Table 1 presents the fuzzy input data for the numerical example. Supplies, demands, and unit transportation costs are expressed as generalized trapezoidal fuzzy numbers of the form $(a,b,c,d;w)$. This representation captures the minimum, core, and maximum plausible values for each parameter together with the associated membership height. The table shows that both sources and all destinations are subject to uncertainty, and the fuzzy costs reflect approximate expert judgements for each transportation route.

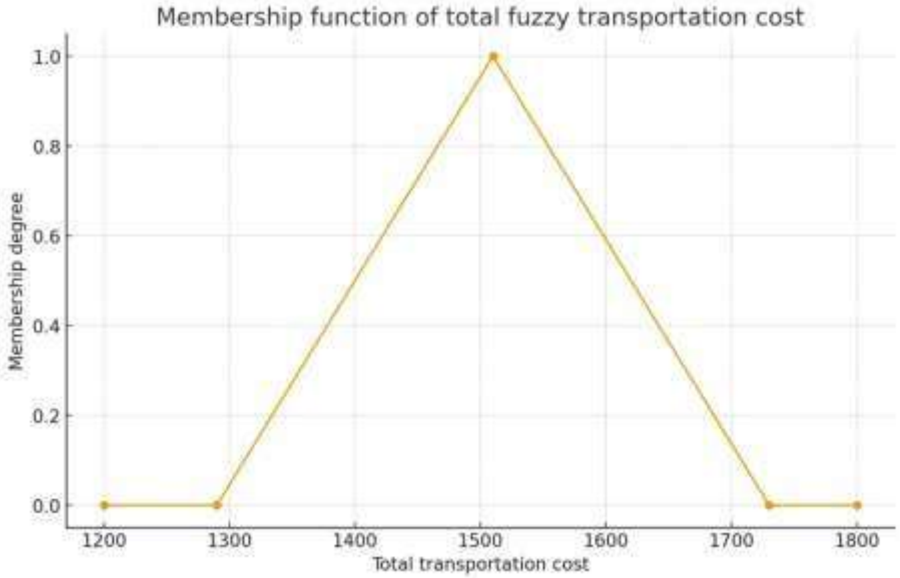
10.48047/jocaaa.2023.31.4.70

Table 2. Ranked supplies, demands, costs and optimal allocation obtained using the proposed ranking-function-based model.

Source / Destination	**D₁**	**D₂**	**D₃**	**Ranked Supply**
S_1	9 → 80	7 → 20	6 → 0	100
S_2	8 → 0	6 → 50	5 → 70	120
Ranked Demand	80	70	70	

Table 2 reports the ranked transportation problem and the corresponding optimal allocation. The ranked supplies and demands are obtained by applying the ranking function to the fuzzy quantities in Table 1. Each cell shows the ranked unit cost for the respective route together with the optimal shipment level. All source supplies are fully utilized and all destination demands are exactly satisfied, confirming feasibility of the solution. The associated crisp total transportation cost is 1510 units. When the optimal allocation is combined with the original fuzzy unit costs, the resulting total transportation cost is expressed as the generalized trapezoidal fuzzy number $Z=(1290,1510,1510,1730;1)$.

Figure 1. Membership function of the total fuzzy transportation cost



10.48047/jocaaa.2023.31.4.70

Figure 1 illustrates the membership function of the total fuzzy transportation cost Z. The lower and upper supports at 1290 and 1730 units represent optimistic and pessimistic cost levels, while the plateau around 1510 units corresponds to the most plausible cost range. This graphical representation shows that the crisp cost obtained from the ranked model lies at the core of the fuzzy cost band, confirming the internal consistency of the proposed ranking-function-based approach.

Figure 2: Bar Chart of Optimal Shipments on Each Route

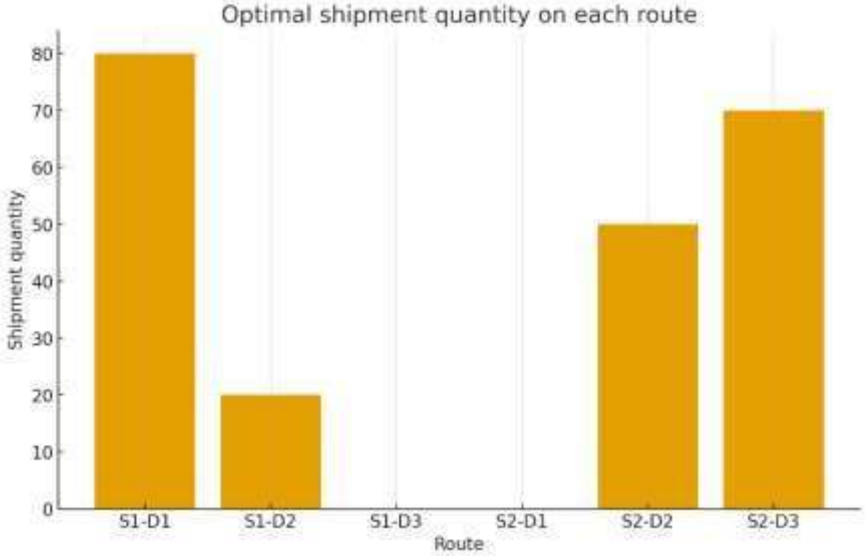


Figure 2 presents the optimal shipment quantities on each route derived from the ranked transportation model. The majority of the flow is assigned to the relatively cheaper routes $S1{\rightarrow}D1$, $S1{\rightarrow}D2$, $S2{\rightarrow}D2$, and $S2{\rightarrow}D3$, while the more expensive routes $S1{\rightarrow}D3$ and $S2{\rightarrow}D1$are not used. This pattern is consistent with the ranked cost structure in Table 2 and confirms that the proposed approach effectively directs shipments toward lower-cost paths while satisfying all supply and demand constraints.

This indicates that the most plausible total cost is 1510 units, with an optimistic bound of 1290 units and a pessimistic bound of 1730 units under the assumed uncertainty. In the example, the ranked total cost is identical to the rank of the corresponding fuzzy total cost. This property supports a coherent interpretation of the solution: the crisp objective value used during optimization can be read as the central or most representative value of a fuzzy band of possible total costs. In this case, the planner receives a finalized logistic strategy and an ambiguous

10.48047/jocaaa.2023.31.4.70

boundary that outlines the best and worst-case pricing scenarios. A combination such as this is very important in scenarios where a clear choice is needed, and the risk or uncertainty must also be explained so that stakeholders can fully understand what is happening.

The primary fuzzy optimization methods, especially pertaining to transportation models, are less difficult than other techniques, perhaps due to construction of the transportation problem model of rank order techniques. Since the transportation problem model is a rank model the least cost, Vogel and modified distribution methods can all be employed as is. This characteristic lowers the learning curve for users and makes them usable in less analytically sophisticated environments. As such this model is congruent with the spirit of previous efforts extending transportation to fuzzy models using ranking and other simple comparators. Unintended consequences abound for using a single ranking function, limitations can be obvious. This may be the case where different ranking rules produce scalar descriptions (fuzzy numbers) that can in some cases lead to different shipping plans, costs or both. The ranking function selection plays a vital role and reflects the decision maker's perspective about risk, uncertainty or both. The model employs a ranking function using simple averages which is a low rank function but more elaborate functions for ranking can be tolerated in the particular case.

When decisions are exceptionally crucial or when different stakeholders have diverse perspectives on assessing fuzzy quantities, sensitivity analysis concerning the ranking function becomes a natural extension.

Conclusion

The study has presented a ranking-function-based model for handling fuzzy transportation problems in situations where costs, supplies, and demands are imprecise. Generalized trapezoidal fuzzy numbers were used to describe uncertain parameters, allowing both the support and the height of the membership functions to reflect the confidence level of the decision maker. A simple but consistent ranking function was then applied to transform the fuzzy transportation problem into a classical transportation model with ranked parameters, without discarding the underlying fuzzy interpretation.

By retaining the standard structure of the transportation model, the proposed approach permits direct use of well-known solution methods. Initial feasible solutions can be obtained by the leastcost rule or other classical techniques, and optimality can be checked by the modified

10.48047/jocaaa.2023.31.4.70

distribution method in the usual way. When a solution is optimally ranked, the original fuzzy costs are merged with the unambiguous distributions, resulting in a fuzzy total cost. The outcome, possessing the dual endings of a concrete numerical objective value and a plausible cost range, achieved a more confident and transparent public value.

References

[1] A. Kaur and A. Kumar, “A new method for solving fuzzy transportation problems using ranking function,” *Applied Mathematical Modelling*, vol. 35, no. 12, pp. 5652–5661, 2011.

[2] A. Kaur and A. Kumar, “A new approach for solving fuzzy transportation problems using generalized trapezoidal fuzzy numbers,” *Applied Soft Computing*, vol. 12, no. 3, pp. 1201–1213, 2012.

[3] A. Ebrahimnejad, “A simplified new approach for solving fuzzy transportation problems with generalized trapezoidal fuzzy numbers,” *Applied Soft Computing*, vol. 19, pp. 171–176, 2014.

[4] T.-F. Liang, C.-S. Chiu, and H.-W. Cheng, “Using possibilistic linear programming for fuzzy transportation planning decisions,” *Hsiuping Journal*, vol. 11, pp. 93–112, 2005.

[5] D. S. Dinagar and K. Palanivel, “On trapezoidal membership functions in solving transportation problem under fuzzy environment,” *International Journal of Computer and Physical Sciences*, vol. 1, pp. 1–12, 2009.

[6] D. S. Dinagar and K. Palanivel, “The transportation problem in fuzzy environment,” *International Journal of Algorithms and Computational Mathematics*, vol. 2, pp. 65–71, 2009.

[7] P. Pandian and G. Natarajan, “A new algorithm for finding a fuzzy optimal solution for fuzzy transportation problems,” *Applied Mathematical Sciences*, vol. 4, no. 1, pp. 79–90, 2010.

[8] P. Pandian and G. Natarajan, “An optimal more-for-less solution to fuzzy transportation problems with mixed constraints,” *Applied Mathematical Sciences*, vol. 4, no. 28, pp. 1405–1415, 2010.

[9] N. Mathur, P. K. Srivastava, and A. Paul, “Trapezoidal fuzzy model to optimize transportation problem,” *International Journal of Modeling, Simulation, and Scientific Computing*, vol. 7, no. 3, art. no. 1650028, 2016.

10.48047/jocaaa.2023.31.4.70

[10] P. Malini and M. Ananthanarayanan, "Solving fuzzy transportation problem using ranking of trapezoidal fuzzy numbers," *International Journal of Mathematics Research*, vol. 8, no. 2, pp. 127–132, 2016.

[11] D. Hunwisai and P. Kumam, "A method for solving a fuzzy transportation problem via Robust ranking technique and ATM," *Cogent Mathematics*, vol. 4, art. no. 1283730, 2017.

[12] M. K. Purushothkumar and M. Ananathanarayanan, "Fuzzy transportation problem of trapezoidal fuzzy numbers with new ranking technique," *IOSR Journal of Mathematics*, vol. 13, no. 6, pp. 6–12, 2017.

[13] P. U. Maheswari and K. Ganesan, "Solving fully fuzzy transportation problem using pentagonal fuzzy numbers," *Journal of Physics: Conference Series*, vol. 1000, art. no. 012014, 2018.

[14] Z. A. M. S. Juman *et al.*, "Close interval approximation of pentagonal fuzzy numbers for interval data-based transportation problems," *Sustainability*, vol. 14, no. 12, art. no. 7423, 2022.

[15] S.-T. Liu and C. Kao, "Solving fuzzy transportation problems based on extension principle," *European Journal of Operational Research*, vol. 153, no. 3, pp. 661–674, 2004.

[16] M. Oheigeartaigh, "A fuzzy transportation algorithm," *Fuzzy Sets and Systems*, vol. 8, no. 3, pp. 235–243, 1982.

[17] S. Chanas, W. Kolodziejczyk, and A. Machaj, "A fuzzy approach to the transportation problem," *Fuzzy Sets and Systems*, vol. 13, no. 3, pp. 211–221, 1984.

[18] C.-H. Cheng, "A new approach for ranking fuzzy numbers by distance method," *Fuzzy Sets and Systems*, vol. 95, no. 3, pp. 307–317, 1998.

[19] P. P. B. Rao and N. R. Shankar, "Ranking fuzzy numbers with an area method using circumcenter of centroids and an index of modality," *Advances in Fuzzy Systems*, vol. 2011, art. no. 178308, 2011.

[20] B. Asady and A. Zendehnam, "Ranking fuzzy numbers by distance minimization," *Applied Mathematical Modelling*, vol. 31, no. 11, pp. 2589–2598, 2007.

[21] T.-C. Chu and C.-T. Tsao, "Ranking fuzzy numbers with an area between the centroid point and original point," *Computers & Mathematics with Applications*, vol. 43, no. 1–2, pp. 111–117, 2002.

10.48047/jocaaa.2023.31.4.70

[22] X. Wang and E. E. Kerre, "Reasonable properties for the ordering of fuzzy quantities (II)," *Fuzzy Sets and Systems*, vol. 118, no. 3, pp. 375–405, 2001.

[23] H. Basirzadeh, "An approach for solving fuzzy transportation problem," *Applied Mathematical Sciences*, vol. 5, no. 32, pp. 1549–1566, 2011.

[24] M. S. Christi Annie and B. Kasthuri, "Transportation problem with pentagonal intuitionistic fuzzy numbers solved using ranking technique and Russell's method," *International Journal of Engineering Research and Applications*, vol. 6, no. 2, pp. 82–86, 2016.

[25] M. Brunelli and J. Mezei, "How different are ranking methods for fuzzy numbers? A numerical study," *International Journal of Approximate Reasoning*, vol. 54, no. 5, pp. 627–639, 2013.