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A Novel Approach for Ranking Functions to Solve Fuzzy Transportation Problems

Alaa Shnaishel Cheetar
Dept. of Financial Banking, College of Administration & Economics, Mustansiriyah University, Baghdad, Iraq.
Email: alaash1973@uomustansiriyah.edu.iq, ORCID https://orcid.org/0000-0002-7665-433X.
Fathala Ali Chachan
Dept. of Financial Banking, College of Administration & Economics, Mustansiriyah University, Baghdad, Iraq.
Email: fathala@uomustansiriyah.edu.iq, ORCID https://orcid.org/0000-0003-1751-2486.

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Correspondence:
Researcher name:
Alaa Shnaishel Cheetar

Email: :
alaash1973@uomustansiriyah.edu.iq

Abstract

Transportation costs are modelled as trapezoidal fuzzy values, and we propose a novel approach to address this issue in an uncertain setting. Supply, demand, and transportation unit costs could all start to seem odd for various real-world reasons. We can display these erroneous values as fuzzy numbers. Fuzzy numbers and values have found widespread application in many domains, including AI and experimental sciences. We used the magnitude ranking function to convert trapezoidal fuzzy numbers into crisp values, and then we developed the first fundamental solution to the fuzzy transportation problem. Next, the max-min method was implemented. In this numerical example, we demonstrate how fuzzy algorithms can be applied in a novel way to solve transportation problems.

1. Introduction

Transportation models can be utilised in logistics and supply chain management to lessen the development of inefficient algorithms that address transportation difficulties when the cost coefficients, supply, and demand are known with precision. The real world is full of uncertainty and unpredictability because of the randomness of life's events. Therefore, external factors that are difficult for us to predict affect both the cost coefficients and supply and demand.” The concept of fuzziness was proposed” by Bellman & Zadeh [1]” to address such unclear circumstances. The basic transportation problem was first raised by Chanas et al [2]. The transportation problem was initially formulated and systematically approached using linear programming by Dantzig [3].

Researchers have developed a new fuzzy approach to addressing the multi-objective transportation problem. Liu & Kao [4].The transportation problem was solved using a new algorithm. Throughout this examination, the results obtained showed that by Arockiasironmani & S. Santhi[5].

Using the proposed algorithm yielded better preliminary results compared to known methods. With supply and demand represented as trapezoidal fuzzy numbers, Gani & Razak [6] introduced the fuzzy transportation problem in 2006, which involves a two-stage cost-minimising process. In two phases, they aim to reduce transportation expenses. In 2011, Kumar et al. [7] investigated a novel approach for completely fuzzy linear systems with trapezoidal fuzzy numbers. In the transportation problem, defuzzification of trapezoidal fuzzy numbers began in 2010. Fuzzy transportation problems were first addressed by Kumar et al [8] using extended trapezoidal fuzzy numbers. An alternative approach to the North West Corner technique for transportation problem resolution was proposed by

N. M. Sharma & Bhadane [9]. When dealing with transportation problems involving triangular fuzzy numbers for both demand and supply, N. M. Sharma & Bhadane [10] proposed a ranking approach using a cut. Voskoglou [11] presented two models for decision-making problems in a fuzzy environment. The first model used the classic Bellman and Zadeh criteria, while the second model was a case of parametric decision-making, using a hybrid method based on elastic sets, grey numbers, and neutral sets. Sharma & Tyagi [12] presented a study of the two-objective transport problem using fuzzy numbers with interval values, and the artificial insemination two-objective transport problem is transformed into a clear two-objective transport problem using signed-distance classification. Arian Latif Jasim Muhammad [13] We propose a new method for determining the primary possible fuzzy basic solution and the optimal fuzzy solution for transportation problems with generalised trapezoidal fuzzy numbers. The studies by K. Nathiya & K. R. Balasubramanian [15] place distinct emphasis. The Robust ranking method is utilised in the transportation problem to model fuzzy demand and supply data as trapezoidal fuzzy numbers. Laxminarayan Sahoo [16] has devised an algorithm to address the transportation problem utilising Fermatian fuzzy parameters and has also resolved the issue using the established method. Wajahat Ali and Shakeel Javaid[17] proposed a mathematical model of the multi-objective transportation problem (MOTP) incorporating FFPs, which is similarly transformed into a crisp form using NFFSF under fermatean fuzzy environments (FFE). They extend this approach to develop a mathematical model of a multi-level, multi-objective solid transportation problem (MLMOSTP) using FFPs under FFE. Veena Yadahalli and M. Saradha [18] used the ranking method to convert the fuzzy transportation problem into an exact-value transportation problem. which uses the strong ranking strategy to simplify the fuzzy transportation problem and produce a workable initial basic solution. The fuzzy optimal solution is then obtained by applying the MODI approach. V. Vidhya, K. Ganesan [19] put out a novel approach to find the fuzzy transportation problem's first workable basic solution. Fuzzy trapezoidal numbers, which are more realistic and broader, were used to represent transportation costs, supply, and demand. The ranking technique was used to convert the fuzzy transportation problem with trapezoidal numbers into a precise transportation problem. Other real-world issues, such as assignment difficulty and project scheduling, can also be addressed with the suggested approach.

2. Paper importance

The significance of the research lies in introducing a novel algorithm to address transportation issues in a scientific and straightforward manner, with its efficacy demonstrated through practical implementation. The primary issue is to refine and enhance the heuristic method provided in this paper. Furthermore, it is feasible to propose a novel algorithm that can improve the solution in identifying the ideal one, particularly by incorporating advanced data analysis techniques and real-time feedback mechanisms to optimise transportation efficiency.

3. Paper aims

A new approach, the max-min method, was used to solve the fuzzy transportation problem using the ranking function. Where supply, demand, and transportation costs per unit are fuzzy numbers in the form of trapezoids. The proposed method yields the best results, as verified by comparison with other methods such as the Northwest Corner, LCM, VAM, and SSM. An illustrative example was provided to better understand the given algorithm.

4. Theoretical Concepts

Definitions used in the fuzzy linear programming problem are given below.

4.1. Fuzzy set theory

addresses notions along a continuum rather than within rigid classifications. It recognises that numerous real-world problems are intricate and ambiguous, and offers a method to describe and address uncertainty with greater sophistication.

4.1.1. Crisp set

Elements can only ever be in or out of a crisp set; the set's membership is absolute. A characteristic function that clearly assigns values of 1 or 0 determines this. To illustrate the point, mashed potatoes are not sweets, but jelly beans are. A characteristic of crisp sets is this significant difference.

4.1.2. Fuzzy set

A fuzzy set expands a traditional set's binary membership {0,1} to a spectrum in the interval [0,1]. Partially included items are permitted in fuzzy sets. Let a be the set that applies very were in mathematics. A fuzzy set in Y is defined as A(x, $\mu\widetilde{A}$ (x)) where $\mu\breve{A}(x)$ is the function for membership, and x is an element of α. is a member of the set $\tilde{A}$.

4.2. membership function

The grade of membership of x in A is denoted by the evaluation function $\mu\tilde{J}(x)$. 1. Keep in mind that the membership function of $\tilde{A}$ is an indicator function for $\tilde{A}$, and it indicates the extent to which f is a member of $\tilde{A}$.

4.2.1. Types of membership function

An important part of using fuzzy logic is picking the right membership function. The onus is on the user to choose a function that competently captures the meaning of the fuzzy idea.

Membership functions that are commonly utilised comprise:

1. Membership function that is linear.
2. Membership function that is triangular.
3. The membership function has a trapezoidal shape.
4. A membership function that is sigmoid.
5. Membership function of the π type.
6. A membership function that is Gaussian.

4.3. Fuzzy number [14][8][13][5]

1. Fuzzy numbers are defined as fuzzy sets $\tilde{A}$ on the set of real numbers R, where the membership function meets certain criteria. The function $\mu\tilde{A} \oint R \to [0,1]$ is continuous. s.
2. For every $x \in (-\infty, a)\ \emptyset\ (d, \infty)$, $\mu\tilde{A}(x) = 0$.
3. On the interval $[a, b]$, it is strictly increasing, whereas on the interval $[c, d]$, it is strictly decreasing.
4. For any $x \in [b, c]$, where $a < b < c$, $\mu\tilde{A}\ (x) = 1.\ > d$.

4.3.1. Fuzzy triangular number

Any fuzzy number whose membership function is specified by is referred to as a triangular fuzzy number.

$$\mu(x) = \begin{cases} 1 & \text{if} \quad x \le \alpha \\ \dfrac{x-\alpha}{\beta-\alpha} & \text{if} \quad \alpha \le x \le \beta \\ \dfrac{\gamma-x}{\gamma-\beta} & \text{if} \quad \beta \le x \le \gamma \\ 0 & \text{if} \quad Otherwise \end{cases} \tag{1}$$

4.3.2. Fuzzy trapezoidal number

$$\mu(x) = \begin{cases} 0 & \text{if} \quad x < \alpha \\ \dfrac{x-\alpha}{\beta-\alpha} & \text{if} \quad \alpha \le x \le \beta \\ 1 & \text{if} \quad \beta \le x \le \gamma \\ \dfrac{\delta-x}{\delta-\gamma} & \text{if} \quad \gamma \le x \le \delta \\ 0 & \text{if} \quad x > \delta \end{cases} \tag{2}$$

A fuzzy number is said to have a trapezoidal membership function if and only if.

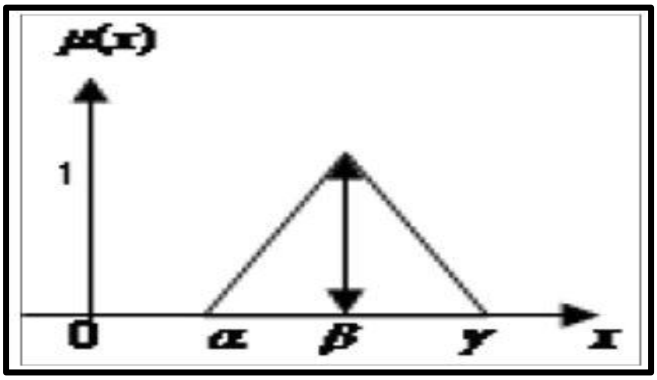

Figure (1): Show the function trapezoidal fuzzy number curve

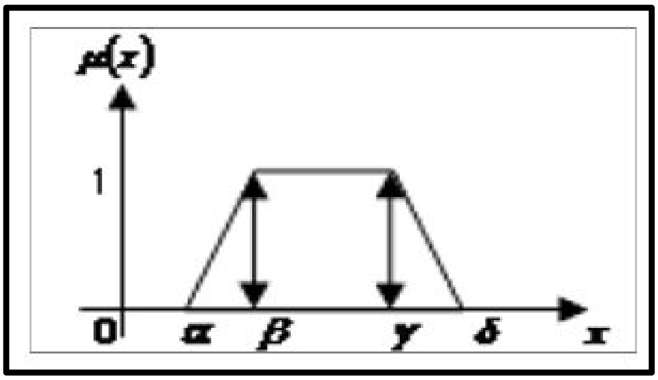

Figure (2): Show the function triangular fuzzy number curve

4.3.3. Arithmetic procedures with triangular fuzzy numbers:[5]

Let $\bar{\alpha} = (\alpha_1, \alpha_2, \alpha_3)$ and $\bar{\beta} = (b_1, b_2, b_3)$, be triangular fuzzy numbers, then

$$\bar{\alpha} + \bar{B} = (\alpha_1 + b_1, \alpha_2 + b_2, \alpha_3 + b_3)$$

Subtraction: (3)

$$\bar{\alpha} - \bar{B} = (\alpha_1 - b_3, \alpha_2 - b_2, \alpha_3 - b_1)$$

Multiplication:

$$\bar{\alpha} * \bar{B} = \{\min(\alpha_1 b_1, \alpha_1 b_3, \alpha_3 b_1, \alpha_3 b_3), \alpha_2 b_2, \max(\alpha_1 b_1, \alpha_1 b_3, \alpha_3 b_1, \alpha_3 b_3)\}$$

4.3.4. Arithmetic procedures with trapezoidal fuzzy numbers: [5]

Let" $\bar{\alpha} = (\alpha_1, \alpha_2, \alpha_3, \alpha_4)$ and $\bar{\beta} = (b_1, b_2, b_3, b_4)$ be trapezoidal fuzzy numbers, then

$$\bar{\alpha} + \bar{\beta} = (\alpha_1 + b_1, \alpha_2 + b_2, \alpha_3 + b_3, \alpha_4 + b_4)$$

Subtraction:

$$\bar{\alpha} - \bar{B} = (\alpha_1 - b_4, \alpha_2 - b_3, \alpha_3 - b_2, \alpha_4 - b_1) \quad (4)$$

Multiplication:

$$\bar{\alpha} * \bar{\beta} = \{\min(\alpha_1 b_1, \alpha_1 b_4, \alpha_4 b_1, \alpha_4 b_4), \min(\alpha_2 b_2, \alpha_3 b_2, \alpha_2 b_3, \alpha_3 b_3)$$
$$\max(\alpha_2 b_2, \alpha_3 b_2, \alpha_2 b_3, \alpha_3 b_3), \max(\alpha_1 b_1, \alpha_1 b_4, \alpha_4 b_1, \alpha_4 b_4)\}$$

4.4. Definition: Hierarchical Formula

Let $\bar{\alpha} = (\alpha_1, \alpha_2, \alpha_3, \alpha_4)$ be a trapezoidal fuzzy number, then
$\bar{V} = (x_0 - \alpha, x_0, \gamma_0, \gamma_0 + \alpha)$ with parametric form $\bar{V} = (\underline{V}(h), \bar{V}(h))$
Where $\underline{V}(h) = (X_0 - \alpha + \alpha h)$ and $\bar{V}(h) = (y_0 + \beta - \beta h)$ are defined as

$$\mathrm{Mag}(\bar{V}) = \frac{1}{2}\left[\int_0^1 \left(\underline{V}(h) + \bar{V}(h) + X_0 + \gamma_0\right)\right] hdh. \text{ Where } h \in [0,1] \quad (5)$$

The magnitude of the trapezoidal fuzzy number
$\bar{V} = (\alpha_1, \alpha_2, \alpha_3, \alpha_4)$ is given by Mag $\bar{V} = \frac{\alpha_1 + 2\alpha_2 + 2\alpha_3 + \alpha_4}{6}$

4.5 Formulation in Mathematics

Let's look at a fuzzy number-based transportation problem with m fuzzy suppliers and n fuzzy destinations. Assume further that $\breve{C}_{ij}$ is the cost of shipping a single product unit from the i th fuzzy source to the j th fuzzy destination. Assume that the ith source's fuzzy supply and the j th destination's fuzzy demand is, respectively $\breve{a}_i$ and $\breve{b}_j$.Assume that xij is the amount sent from the fuzzy source (i) to fuzzy destination (j).

$$\text{Min } z = \sum_{i=1}^{m} \sum_{j=1}^{n} \breve{C}_{ij} x_{ij}$$

Subject to (6)

$\sum_{j=1}^{n} x_{ij} = \breve{a}_i, \quad i = 1,2, \dots \dots$ m.

$\sum_{i=1}^{m} x_{ij} = \breve{b}_j, \quad j = 1,2, \dots \dots .$ n.

$\sum_{i=1}^{m} \breve{a}_i = \sum_{j=1}^{n} \breve{b}_j; \quad i = 1,2, \dots \dots$ m; $j = 1,2, \dots \dots$ n and $x_{ij} \geq 0$.

Table (1): The problem of transportation with fuzzy logic is shown clearly in the fuzzy transportation

	1	⋯	N	Supply
1	c_{11}	⋯	c_{1n}	α_1
⋮	⋮	⋯	⋮	⋮
M	c_{m1}	⋯	c_{mn}	α_m
Demand	b_1	⋯	b_n	

4.6. Algorithm for Maximum Minimum Diameter Proposed

Step 1: After determining that total demand equals total supply, we proceed to step 2 of building the transportation table.

Step 2: We apply the magnitude ranking tool to the provided transportation problem, transforming imprecise cost estimates into concrete figures.

Step 3: After that, we divide the sum of the row-wise differences in the cost matrix by the total number of columns.

Step 4: For each row in the cost matrix, take the absolute value of each column and divide it by the difference between its maximum and minimum.

Step 5: We assign the specific cell in the provided matrix after finding the maximum of the resulting values and the corresponding minimum cost value. Imagine if the largest resultant value is not the only one. Anyone can be chosen.

Step 6: Repeat procedures 1–5 until all assignments are finished.

5. Experimental Work

The General Company for Grain Manufacturing is responsible for transporting the produced flour at the lowest possible cost and in a manner that meets actual distribution demand for citizens and fulfils the needs of the local market. There are five factories, each with five warehouses distributed by governorates, where wheat flour is stored. Due to the inability to accurately predict required quantities, it is impossible to determine them precisely, which, in turn, affects demand. Below are the quantity details in tables (2) and (3). With transportation costs in Table 4.

Table (2): The available capacities for wheat flour production

	Capacity (1000 ton)
Factory1	(32,36,48,40)
Factory2	(22,24,25,30)
Factory3	(31,33,34,36)
Factory4	(16,20,21,22)
Factory5	(27,29,31,33)

Table (3): Storage capacities by governorate

	Demand (1000 ton)
Store 1 Kirkuk	(40,45,48,50)
Store 2 Anbar	(33,34,35,39)
Store 3 Wasit	((23,24,25,29)
Store 4 Najaf	(15,17,19,21)
Store 5 Karbala	(22,24,26,28)

Table (4): Transportation expenses between the production facility and the warehouse (thousand dinars).

	Store 1 Kirkuk	Store 2 Anbar	Store 3 Wasit	Store 4 Najaf	Store 5 Karbala
Factory1	(100,125,150,200)	(150,175,200,250)	(75,120,125,130)	(100,110,130,135)	(200,210,230,250)
Factory2	(90,100,115,125)	(100,120,220,250)	(150,175,190,200)	(200,250,260,275)	(100,105,120,125)
Factory3	(100,110,130,140)	(150,170,190,210)	(125,150,175,200)	(100,150,200,230)	(200,260,300,310)
Factory4	(200,245,250,300)	(200,225,250,275)	(100,130,150,170)	(210,250,270,300)	(100,145,200,210)
Factory5	(130,135,140,150)	(100,200,300,350)	(100,150,200,230)	(100,150,170,190)	(200,210,230,250)

Table (5): transform trapezoidal fuzzy numbers into precise values utilizing the magnitude ranking function.

	Store 1 Kirkuk	Store 2 Anbar	Store 3 Wasit	Store 4 Najaf	Store 5 Karbala	SUPLY
Factory1	(141.67)	(191.67)	(115.83)	(119.16)	(261.67)	(40)
Factory2	(107.5)	(171.67)	(180)	(249.16)	(112.5)	(25)
Factory3	(120)	(180)	(162.5)	(210)	(271.67)	(34)
Factory4	(248.3)	(237.5)	(138.3)	(258.3)	(166.67)	(20)
Factory5	(138.3)	(241.67)	(180)	(155)	(221.67)	(30)
DEMAND	(46)	(35)	(25)	(18)	(25)	

Discover the highest value that results, discover the lowest value that corresponds to the cost, then assign that value to the specific cost cell in the provided matrix. If there is more than one possible maximum result, we are free to choose any one. The solution tables from (5-1) to (5-6) represent the solution steps, as shown below.

Table (5.1)

1	Store 1 Kirkuk	Store 2 Anbar	Store 3 Wasit	Store 4 Najaf	Store 5 Karbala	SUPLY	$\frac{max - min}{5}$
Factory1	(141.67)	(191.67)	(115.83)	(119.16)	(261.67)	(40)	145.84/5=29.2
Factory2	(107.5)	(171.67)	(180)	(249.16)	(112.5) 25	(0)	141.66/5=28.3
Factory3	(120)	(180)	(162.5)	(210)	(271.67)	(34)	151.67/5=30.3
Factory4	(248.3)	(237.5)	(138.3)	(258.3)	(166.67)	(20)	120/5=24
Factory5	(138.3)	(241.67)	(180)	(155)	(221.67)	(30)	103.37/5=20.67
DEMAND	(46)	(35)	(25)	(18)	(0)		
$\frac{max - min}{5}$	140.8/5= 28.16	70/5=14	64.62/5= 12.9	139.14/5= 27.8	159.17/5= 31.8	↑	

Table (5.2)

2	Store 1 Kirkuk	Store 2 Anbar	Store 3 Wasit	Store 4 Najaf	SUPLY	$\frac{max - min}{4}$
Factory1	(141.67)	(191.67)	(115.83)	(119.16) 18	(22)	75.84/4=19
Factory3	(120)	(180)	(162.5)	(210)	(34)	90/4=22.5
Factory4	(248.3)	(237.5)	(138.3)	(258.3)	(20)	120/4=30
Factory5	(138.3)	(241.67)	(180)	(155)	(30)	103.37/4=25.8
DEMAND	(46)	(35)	(25)	(0)		
$\frac{max - min}{4}$	140.8/4 =32.1	60.67/4 =15.4	64.17/4 =16.04	139.14/4= 34.8	↑	

Table (5.3)

3	Store 1 Kirkuk	Store 2 Anbar	Store 3 Wasit	SUPLY	$\frac{max - min}{3}$
Factory1	(141.67)	(191.67)	(115.83)	(22)	75.84/3=25.28
Factory3	(120)	(180)	(162.5)	(34)	60/3=20
Factory4	(248.3)	(237.5)	(138.3) 20	(0)	110/3=36.7 ←
Factory5	(138.3)	(241.67)	(180)	(30)	103.37/3=34.5
DEMAND	(46)	(35)	(5)		
$\frac{max - min}{4}$	140.8/4 =32.1	60.67/4 =15.4	64.17/4 =16.04		

Table (5.4)

4	Store 1 Kirkuk	Store 2 Anbar	Store 3 Wasit	SUPLY	$\frac{max - min}{3}$
Factory1	(141.67)	(191.67)	(115.83)	(22)	75.84/3=25.28
Factory3	(120)	(180)	(162.5)	(34)	60/3=20
Factory5	(138.3) 30	(241.67)	(180)	(0)	103.37/3=34.5 ←
DEMAND	(16)	(35)	(5)		
$\frac{max - min}{3}$	21.67/3 =7.2	61.67/3 =20.5	64.17/3 =21.39		

Table (5.5)

5	Store 1 Kirkuk	Store 2 Anbar	Store 3 Wasit	SUPLY	$\frac{max - min}{3}$
Factory1	(141.67)	(191.67)	(115.83) **5**	(17)	75.84/3=25.28 ←
Factory3	(120)	(180)	(162.5)	(34)	60/3=20
DEMAND	(16)	(35)	(0)		
$\frac{max - min}{2}$	21.67/2 =10.8	11.67/2 =5.8	46.7/2 =23.35		

Table (5.6)

6	Store 1 Kirkuk	Store 2 Anbar	SUPLY	$\frac{max - min}{2}$
Factory1	(141.67)	(191.67) 17	(0)	50/2=25
Factory3	(120) 16	(180) 18	(0)	60/2=30 ←
DEMAND	(0)	(0)		
$\frac{max - min}{2}$	21.67/2 =10.8	11.67/2 =5.8		

Table (6): It refers to the optimal solution.

	Store 1 Kirkuk	Store 2 Anbar	Store 3 Wasit	Store 4 Najaf	Store 5 Karbala	SUPLY
Factory1	(141.67)	(191.67) 17	(115.83) 5	(119.16) 18	(261.67)	(40)
Factory2	(107.5)	(171.67)	(180)	(249.16)	(112.5) 25	(25)
Factory3	(120) 16	(180) 18	(162.5)	(210)	(271.67)	(34)
Factory4	(248.3)	(237.5)	(138.3) 20	(258.3)	(166.67)	(20)
Factory5	(138.3) 30	(241.67)	(180)	(155)	(221.67)	(30)
DEMAND	(46)	(35)	(25)	(18)	(25)	

$$z = (191.67 \times 17) + (115.83 \times 5) + (119.16 \times 18) + (112.5 \times 25) + (120 \times 16) + (180 \times 18) + (138.3 \times 20) + (138.3 \times 30) \quad (7)$$

z =20869.92

6. Results& Discussions

Table (7): Results and comparisons

Methods	Optimal solution	Improvement
Northwest corner method	26021.28	0.2%
LCM	22454	0.07%
VAM	21395.7	0.02%
Stepping -stone method	21395.7	0.02%
Linear programming method	20869.92	0%
Proposed method	20869.92	

The proposed method has proven its effectiveness compared to other methods such as the northwest corner method, which achieved an improvement rate of 0.2%, and the LCM, which achieved an improvement rate of 0.07%, also VAM and SSM which achieved an improvement rate of 0.02%, while it provided results that are comparable to the optimal solution using linear programming. This indicates the efficiency of the proposed method.

7. Conclusions.

In this research, an efficient and simple non-complex algorithm was presented to find the initial optimal solution using the max-min approach, where the results were compared and the algorithm's strength was examined. Therefore, this method could be of interest in future studies on real transportation problems. Where it can be practically relied upon due to the ease of calculations.

8. Supplementary material

(None).

9 Author's Contributions

Alaa Shnaishel Cheetar: Designed the research، Writing and editing. Fathala Ali Chachan: Conducted the analyses، Interpreted the results.

10. Funding

(None).

11. Data availability statement

1- The General Company for Grain Manufacturing
2- The General Company for Grain Trade

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13. Conflict of interest

The authors declare no conflict of interest

14. Declaration of generative AI use

During the preparation of this work, the authors used Google translate for grammar checking and language polishing. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication

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نهج جديد يستخدم دوال الترتيب لحل مشاكل النقل الضبابية

علاء شنيشل جيتر
العلوم المالية والمصرفية، كلية الإدارة والاقتصاد، الجامعة المستنصرية، بغداد، العراق.
Email: alaash1973@uomustansiriyah.edu.iq ORCID: https://orcid.org/0000-0002-7665-433X.
فاضلة علي جيجان
العلوم المالية والمصرفية، كلية الإدارة والاقتصاد، الجامعة المستنصرية، بغداد، العراق.
Email: fathala@uomustansiriyah.edu.iq, ORCID: https://orcid.org/0000-0003-1751-2486.

المستخلص

توصف نفقات النقل كأرقام ضبابية شبه منحرفة، وفي سياق غير متوقع، نقدم نهجًا جديدًا للتعامل مع هذه المشكلة. هناك العديد من الأسباب الواقعية التي قد تجعل أسعار وحدات النقل، والعرض، والطلب تبدو غير واضحة. من الممكن عرض هذه الأرقام غير الدقيقة كأرقام ضبابية. استخدمت مجالات مختلفة، مثل العلوم التجريبية والذكاء الاصطناعي، تستخدم الأعداد والقيم الضبابية بشكل واسع. لتطوير الحل الأساسي الأول الممكن لمشكلة النقل الضبابي، استخدمنا دالة ترتيب الحجم لتحويل الأعداد الضبابية شبه المنحرفة إلى قيم دقيقة. ثم، طبقنا استراتيجية MAX-MIN. يتم توضيح استخدام جديد للخوارزميات الضبابية في مشكلة النقل من خلال المثال العددي.

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المراسلة:
أسم الباحث: علاء شنيشل جيتر

Email: alaash1973@uomustansiriyah.edu.iq