



Neutrosophic Fuzzy Numbers and its Impact on Transportation Problem

Krishnaveni G.¹, Balaganesan M.², Melita Vinoliah E.^{3*}, Sudha G.⁴

¹ Department of Mathematics, College of Engineering and Technology, SRM Institute of Science and Technology, Kattankulathur- 603203, Chengalpattu, Tamil Nadu, India

² Department of Mathematics, College of Engineering and Technology, SRM Institute of Science and Technology, Kattankulathur- 603203, Chengalpattu, Tamil Nadu, India

^{3*} Department of Mathematics, College of Engineering and Technology, SRM Institute of Science and Technology, Kattankulathur- 603203, Chengalpattu, Tamil Nadu, India

⁴ Department of Mathematics, College of Engineering and Technology, SRM Institute of Science and Technology, Kattankulathur- 603203, Chengalpattu, Tamil Nadu, India

Emails: krishnag2@srmist.edu.in; balaganm@srmist.edu.in; melitav@srmist.edu.in; sudhag@srmist.edu.in

Abstract

The neutrosophic fuzzy set offers us a broad outline for combining several existing sets into one. Indeterminate and unpredictable data cannot be dealt with by either the fuzzy set theory or intuitionistic fuzzy set theory. The computing techniques of neutrosophic sets are valid for software development for many uses. The transportation problem profoundly depends on the neutrosophic fuzzy set. Most of the time, the data provided is indeterminate and inconsistent. At this point of time, we cannot make use of the fuzzy set and intuitionistic fuzzy set to get deal with this indeterminacy. Here, we have solved numerically to reflect the impact of neutrosophic pentagonal numbers and neutrosophic octagonal numbers. The efficiency of the method is applied is also compared with the other methods.

Keywords: Neutrosophic Fuzzy Sets; Transportation Problem; Fuzzy optimal Solution

1. Introduction

Operations research deals with developing and managing information systems primarily from a scientific viewpoint, usually in circumstances where it is necessary to allocate limited resources. Operation managers rely on the linear programming (LP) mathematical modelling approach to decide which route to use when solving the problem. The transportation problem is modelled in linear programming using a unique type of linear programming modelling method. Hitchcock [1] was the first to use a simplex method with parameters in crisp form to solve the transportation problem. By transforming them into a mathematical programming problem, it is widely utilised to tackle real-world problems.

In view of lowering the overall transportation cost (or maximizing the profit), it is to deal with the distribution of a particular product which may be raw or finished out of several sources to different locations as the unit transport costs are provided in a precise manner. In order make it to the destination faster, Li Zhenping [2] solved the problem of transportation in 1999. To find more effective starting solutions, Vogel's Approximation approach (VAM), a well-known transportation approach in the literature, was examined by Korukoglu and Balli [3] in 2011.

Komala and Vanitha Sree [4] solved a transportation problem in crisp form using Allocation Table method in 2019. One or more choice factors are uncertain in real life and there exists a variety of circumstances that cannot always be described precisely. As a result, we are unable to adequately address the transportation problems using the conventional, traditional techniques. Consequently, fuzzy transport problems provide a improved way to model

and resolve real-world problems. Balasubramanian and Subramanian [5] solved the fuzzy transportation problem in an efficient manner.

The fuzzy set theory Zadeh invented the fuzzy set theory in 1965, which proved useful in resolving situations involving uncertainty. Ashok Kumar and his colleagues [7] have successfully resolved the issue of uncertainty. While fuzzy numbers may not always be suitable due to the intricacies, lack of complete information, and numerous sources of data in real-life situations. Das et.al [8] addressed the linear software design problem in a fuzzy environment. Atanassov created IFS as an postponement of fuzzy sets. IFS can be utilized to tackle problems that involve both membership and non-membership.

Mahmoodirad et.al [10] addressed the intuitionistic transportation problematic by utilising triangular fuzzy numbers. In order to address the uncertainty and indecisiveness inherent in real-world problems, Shailendra Kumar Bharati [11] proposed a novel approach to ranking the transportation problem using interval-valued intuitionistic fuzzy sets. In 1988, Smarandache [12] presented the concept of the neutrosophic set (NS), which serves as an extension of the classical set, fuzzy set (FS), and IFS. The purpose of this extension is to tackle issues related to insufficient knowledge or undefined variables that cannot be resolved using any form of fuzzy sets. Aggarwal &

Gupta [13] have examined the sensitivity analysis in the context of intuitionistic fuzzy transportation problem. Abdel-Basset et.al [14] utilised the notion of neutrosophic set to address the issue of vagueness in linear programming problems. Singh and Yadav (2015) addressed the issue by taking into account the uncertainty in an intuitionistic setting.

Considering the Neutrosophic Fuzzy Sets, Rajesh Kumar Saini et.al [16] they studied the unbalanced NTP and provided a novel MRCM approach for the best solution with the idea of a single valued twelve-component trapezoidal neutrosophic number and also in 2022 [17] they solved the interval valued trapezoidal neutrosophic numbers.

Hai-Long et.al [18] have defined a closure space under neutrosophic environment. Ali et.al [19] extended the cubic set to the neutrosophic set. Shunmugapriya and Uthra [20] have proposed different ranking function in neutrosophic numbers in a flow shop scheduling problem. Radhika and Arun Prakash [21] proposed the ranking of pentagonal neutrosophic number which helps us to solve the assignment problem.

Sapan Kumar Das [22] discussed the neutrosophic transportation issue that has been resolved using Pentagonal Neutrosophic numericals. They also established a score function and utilised it to find the IBFS. Their proposed solution can be computed easily when used to a real-world issue. Varalakshmi and Srinivasan [23] solved the pentagonal neutrosophic number in a new approach. Sankar Prasad Mondal and Manimohan Mandal [24] describe the properties of pentagonal neutrosophic number.

Muhammad Saqlain and Florentin Smarandache [25] describes the different representation of octagonal neutrosophic number. Anandhi and Arthi [26] has resolved transportation problem using Octagonal Neutrosophic Numbers (ONN). Their approach is more economical when dealing with the viewpoint of an analyst in our day-to-day life. Pachamuthu and Charles Rabinson [27] obtained the optimal solution using nanogon number. Ahmad and Adhami [28] have successfully resolved the transshipment problem by incorporating fuzzy parameters. Chatterjee et.al [29] introduced similarity measurements for single valued Neutrosophic sets. Ebrahimnejad and Verdegay [30] conducted optimisation of the fuzzy transportation problem, resulting in improved decision-making capabilities. Jun et.al [31] have examined the concept of cubic neutrosophic set.

Maiti et.al [32] have introduced a goal programming approach for solving multi-objective linear programming problems using neutrosophic numbers. Mondal and Pramanik [33] have shown the practicality, validity, and efficiency of the proposed decision-making method by successfully solving a multi-attribute group decision-making problem related to investment potential. Pramanik et.al [34] introduced a novel approach to address neutrosophic multi-attribute group decision-making difficulties. Souhail Dhouib, aged [353, successfully addressed the traveling salesman problem using the neutrosophic fuzzy parameter. Additionally, Said Broumi conducted several sorts of neutrosophic analysis [36], [37]. Broumi et. al studied the IVF Neutrosophic Shortest Path Problem [38].

In this study, we address and successfully resolve a transportation problem within a neutrosophic framework using an effective approach. This paper discusses the operations and implementation of the single-valued neutrosophic set. Subsequently, the other sections of the article are addressed in the following manner: Section 2 emphasizes the fundamental definitions. The transportation problem is formulated in section 3. The algorithm is presented in

section 4, while section 5 provides a numerical example as an illustrative demonstration. The thesis is ended in section 6 with the presentation of applications.

2. Preliminaries

2.1 Fuzzy Sets

Consider U to be the discourse of the universe \tilde{A} be the fuzzy set which is defined as $\tilde{A} = \{(x, \mu_{\tilde{A}}(x)) : x \in U\}$ where, $\mu_{\tilde{A}} : U \rightarrow [0,1]$ represents the membership function of the set \tilde{A} and it indicates the degree of membership of x in \tilde{A} .

2.2 Fuzzy Number

A fuzzy set \tilde{A} defined on the set of real numbers \mathbb{R} is said to be a fuzzy number if its membership function $\mu_{\tilde{A}} : \mathbb{R} \rightarrow [0,1]$ satisfies the following conditions,

1. \tilde{A} is convex, (i.e) $\mu_{\tilde{A}}(\lambda x_1 + (1-\lambda)x_2) \geq \min\{\mu_{\tilde{A}}(x_1), \mu_{\tilde{A}}(x_2)\}$, $\lambda \in [0,1]$, for all $x_1, x_2 \in \mathbb{R}$
2. \tilde{A} is normal, (i.e) there exists an $x \in \mathbb{R}$ such that $\mu_{\tilde{A}}(x) = 1$.
3. \tilde{A} is piecewise continuous.

2.3 Neutrosophic Fuzzy Sets

Let U be the universal set then the Neutrosophic Fuzzy Set \tilde{A} is characterized by $\tilde{A} = \{(x, \mu_{\tilde{A}}(x), \varphi_{\tilde{A}}(x), \nu_{\tilde{A}}(x)) : x \in U\}$ where the truth membership function $\mu_{\tilde{A}}(x)$, the indeterminate membership function $\varphi_{\tilde{A}}(x)$, the falsity membership function $\nu_{\tilde{A}}(x)$ values lie between the real numbers $[0,1]$.

2.4 Pentagonal Neutrosophic Number

Pentagonal Neutrosophic Number (PNN) is defined as

$$\tilde{A} = \langle [a, b, c, d, e; \mu], (a_1, b_1, c_1, d_1, e_1; \varphi), (a_2, b_2, c_2, d_2, e_2; \gamma) \rangle \text{ where } \mu, \varphi, \gamma \in [0,1].$$

Truth membership function: $(\mu_{\tilde{A}}) : \square \rightarrow [0, \mu_{\tilde{A}}]$, Indeterminacy membership function: $(\varphi_{\tilde{A}}) : \square \rightarrow [\gamma_{\tilde{A}}, 1]$

Falsity membership function: $(\gamma_{\tilde{A}}) : \square \rightarrow [\varphi_{\tilde{A}}, 1]$.

2.5 Graphical Representation

A single valued Pentagonal Neutrosophic Number can be represented graphically by

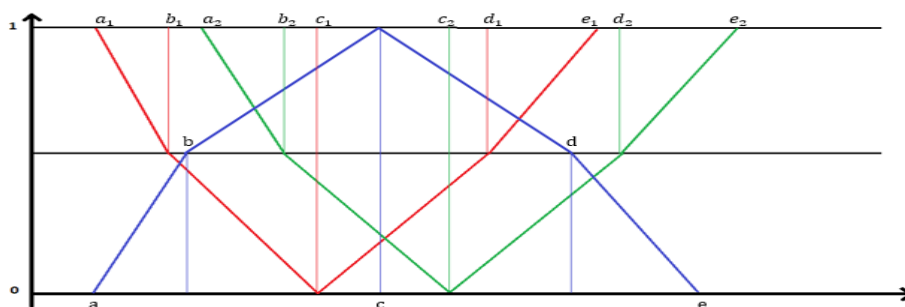


Figure 1: Graphical Representation of Pentagonal Neutrosophic Number

Here the blue line indicates the truth membership function. Similarly, the red and green line indicates the false and indeterminacy membership function.

2.6 Octagonal Neutrosophic Number

An octagonal neutrosophic number is defined by

$$\tilde{A} = \left\langle \left[(a, b, c, d, e, f, g, h; \mu), (a_1, b_1, c_1, d_1, e_1, f_1, g_1, h_1; \varphi), \right. \right. \\ \left. \left. (a_2, b_2, c_2, d_2, e_2, f_2, g_2, h_2; \gamma) \right] \right\rangle \text{ where } \mu, \varphi, \gamma \in [0, 1].$$

“Condition 1:

Truth membership of the function: $(\mu_{\tilde{A}}) : \square \rightarrow [0, \mu_{\tilde{A}}]$, Indeterminacy membership of the function:

$(\varphi_{\tilde{A}}) : \square \rightarrow [\gamma_{\tilde{A}}, 1]$, Falsity membership of the function: $(\gamma_{\tilde{A}}) : \square \rightarrow [\varphi_{\tilde{A}}, 1]$

Condition 2:

$\mu_{\tilde{A}}$: Truth membership of the function is strictly a non-decreasing continuous function on the interval $[a, e]$

$\varphi_{\tilde{A}}$: Indeterminacy membership of the function is a severely non-decreasing continuous function on the interval $[a_1, e_1]$

$\gamma_{\tilde{A}}$: Falsity membership functions are strictly non-decreasing for continuous function on the interval $[a_2, e_2]$

Condition 3:

$\mu_{\tilde{A}}$: The truth membership function is a strictly non-increasing continuous function on the interval $[e, h]$

$\varphi_{\tilde{A}}$: Indeterminacy membership function is a strictly non-increasing continuous function on the interval $[e_1, h_1]$

$\gamma_{\tilde{A}}$: Falsity membership function is a strictly non-increasing continuous function on the interval $[e_2, h_2]$ ”

Graphical Representation:

A single-valued Octagonal Neutrosophic Number can be represented graphically by

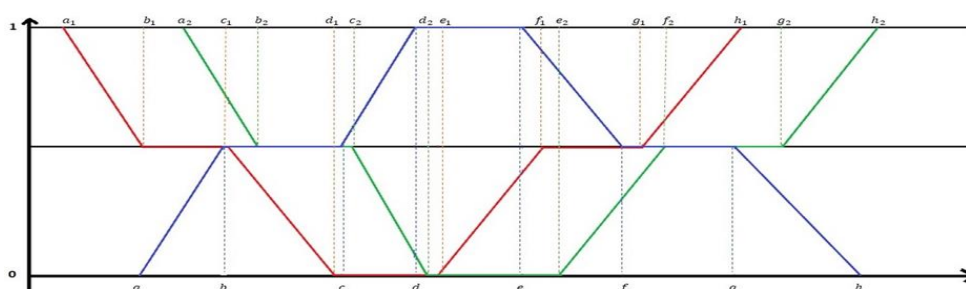


Figure 2: Graphical Representation of Octagonal Neutrosophic Number

Here the blue line indicates the truth membership function. Similarly, the red and green line indicates the false and indeterminacy membership function.

3. Score Function

The truth membership value, falsity membership value, and hesitation membership value determine a neutrosophic number. The score function is used to compare or transform a neutrosophic number to its crisp form.

3.1 Pentagonal Neutrosophic number

Let us consider the single-valued Pentagonal Neutrosophic Number (PNN) as $\tilde{F}_{pen} = (F_1, F_2, F_3, F_4, F_5; \pi, \sigma, \rho)$ then the mean of the PNN components is represented by $\frac{(F_1 + F_2 + F_3 + F_4 + F_5)}{5}$ and the score function of membership value is $\frac{(2 + \pi - \sigma - \rho)}{3}$. Thus, for an PNN $\tilde{F}_{pen} = (F_1, F_2, F_3, F_4, F_5; \pi, \sigma, \rho)$ the score function is $\tilde{T} = \frac{1}{15}(F_1 + F_2 + F_3 + F_4 + F_5)(2 + \pi - \sigma - \rho), T \in \square$.

3.2 Octagonal Neutrosophic number

Let's look at a single-valued Octagonal Neutrosophic Number (ONN) which is in the form $\tilde{F}_{oct} = (F_1, F_2, F_3, F_4, F_5, F_6, F_7, F_8; \pi, \sigma, \rho)$, then the mean of the PNN components is represented by $\frac{(F_1 + F_2 + F_3 + F_4 + F_5 + F_6 + F_7 + F_8)}{8}$ and the score function of the membership value is $\frac{(2 + \pi - \sigma - \rho)}{3}$. Thus, for an ONN $\tilde{F}_{oct} = (F_1, F_2, F_3, F_4, F_5, F_6, F_7, F_8; \pi, \sigma, \rho)$, the score function is given by $\tilde{T} = \frac{1}{24}(F_1 + F_2 + F_3 + F_4 + F_5 + F_6 + F_7 + F_8)(2 + \pi - \sigma - \rho), T \in \square$.

4. Arithmetic Operations

4.1 Octagonal Neutrosophic Number:

Let $\tilde{S}_1 = \langle (p_1, p_2, p_3, p_4, p_5, p_6, p_7, p_8)\pi_{\tilde{\sigma}_1}, \mu_{\tilde{\sigma}_1}, \rho_{\tilde{\sigma}_1} \rangle$ and $\tilde{S}_2 = \langle (q_1, q_2, q_3, q_4, q_5, q_6, q_7, q_8)\pi_{\tilde{\sigma}_2}, \mu_{\tilde{\sigma}_2}, \rho_{\tilde{\sigma}_2} \rangle$ be two octagonal neutrosophic numbers and $\alpha \geq 0$. "Then the following operational relations holds:

$$\begin{aligned} \tilde{S}_1 + \tilde{S}_2 &= \langle (p_1 + q_1, p_2 + q_2, p_3 + q_3, p_4 + q_4, p_5 + q_5, p_6 + q_6, p_7 + q_7, p_8 + q_8); \max\{\pi_{\tilde{\sigma}_1}, \pi_{\tilde{\sigma}_2}\}, \min\{\mu_{\tilde{\sigma}_1}, \mu_{\tilde{\sigma}_2}\}, \min\{\sigma_{\tilde{\sigma}_1}, \sigma_{\tilde{\sigma}_2}\} \rangle \\ \tilde{S}_1 - \tilde{S}_2 &= \langle (p_1 - q_1, p_2 - q_2, p_3 - q_3, p_4 - q_4, p_5 - q_5, p_6 - q_6, p_7 - q_7, p_8 - q_8); \max\{\pi_{\tilde{\sigma}_1}, \pi_{\tilde{\sigma}_2}\}, \min\{\mu_{\tilde{\sigma}_1}, \mu_{\tilde{\sigma}_2}\}, \min\{\sigma_{\tilde{\sigma}_1}, \sigma_{\tilde{\sigma}_2}\} \rangle \\ \alpha \tilde{S}_1 &= \langle (\alpha p_1, \alpha p_2, \alpha p_3, \alpha p_4, \alpha p_5, \alpha p_6, \alpha p_7, \alpha p_8); 1 - (1 - \pi_{\tilde{\sigma}_1})^\alpha, \mu_{\tilde{\sigma}_1}^\alpha, \sigma_{\tilde{\sigma}_1}^\alpha \rangle \\ \tilde{S}_1^\alpha &= \langle (p_1^\alpha, p_2^\alpha, p_3^\alpha, p_4^\alpha, p_5^\alpha, p_6^\alpha, p_7^\alpha, p_8^\alpha); \pi_{\tilde{\sigma}_1}^\alpha, (1 - \mu_{\tilde{\sigma}_1})^\alpha, (1 - \sigma_{\tilde{\sigma}_1})^\alpha \rangle \end{aligned}$$

5. Formulation of Fuzzy Transportation Problem

"Minimize: $\tilde{z} = \sum_{i=1}^m \sum_{j=1}^n \tilde{c}_{ij} x_{ij}$

Subject to $\sum_{j=1}^n x_{ij} = a_i; \quad i = 1, 2, 3, \dots, m.$

$$\sum_{i=1}^m x_{ij} = b_j; \quad j = 1, 2, 3, \dots, n.$$

$$x_{ij} \geq 0 \quad \text{for all } i, j."$$

where, m is the total number of sources, n is the number of destinations, a_i is the amount of supply at source i , b_j - amount of demand at destination j , c_{ij} is the fuzzy transportation cost and x_{ij} - amount to be transported from supply i and to destination j .

Theorem 1

At every stage of a non-degenerate feasible solution, the number of basic variables for the transportation problem is $m+n -1$.

6. Algorithm

Step 1: Initially convert assumed fuzzy neutrosophic number hooked on crisp number by means of the ranking function.

Step 2: If the transportation problem is not balanced, create a dummy row or column to make it so. Otherwise, check to determine if the problem is balanced.

Step 3: Pick the cost cell with the lowest odd cost out of all those in the transportation problem. If there isn't an odd cost, divide the value by two until there is at least an odd cost.

Step 4: A new table is formed where, the selected minimum odd cost is subtracted from each of the odd cost is subtracted from each of the odd cost value of the given problem.

Step 5: From the new table obtained, identify the maximum cost and assign the smallest of supply. If there in a tie, break at arbitrarily.

Step 6: Continue with Step 5 until there is no more supply or demand.

Optimality test:

We evaluate a transportation problem's initial basic feasible solution for its effectiveness. The possible solution of $(m+n-1)$ allocation in independent positions is subject to the optimality test.

7. Flowchart



Figure 3: Flow chart of the proposed method

8. Numerical Example

8.1 Example 1

A leading company has three dress-delivery facilities in India. The garments are to be transported to three warehouses and the data is represented as pentagonal neutrosophic fuzzy numbers. The following table presents the transportation sources and demands [30].

Table 8.1: Transportation Problem with Neutrosophic numbers

| Factories | Chennai (C) | Orissa (O) | Delhi (D) | Supply |
|-----------|------------------------|-------------------------|-------------------------|------------------------|
| Asha (A) | (5,10,13,14,18;1,0,0) | (1,2,3,4,5;1,0,0) | (2,6,8,10,14;1,0,0) | (2,11,23,34,45; 1,0,0) |
| Omm (O) | (3,4,5,6,7;1,0,0) | (1,5,6,7,11;1,0,0) | (1,4,5,9,16;1,0,0) | (10,47,52,65,76;1,0,0) |
| Disha (D) | (3,6,9,12,15;1,0,0) | (2,5,7,8,8;1,0,0) | (1,1,1,1,1;1,0,0) | (3,18,56,76,87; 1,0,0) |
| Demand | (11,16,51,67,75;1,0,0) | (20,40,60,80,100;1,0,0) | (15,30,45,75,110;1,0,0) | |

Solution

The score function is applied to the given fuzzy transportation problem.

Table 8.2 Transportation with the score function

| Factories | C | O | D | Supply |
|---------------|----|----|----|--------|
| A | 12 | 3 | 8 | 23 |
| O | 5 | 6 | 7 | 50 |
| D | 9 | 6 | 1 | 48 |
| Demand | 44 | 60 | 55 | |

The cost cell with the lowest odd cost out of all the other costs in the transportation problem is picked. A new table is formed where the selected minimum odd cost is deducted from each of the odd cost is subtracted from each of the odd cost values of the given problem. From the new table obtained, the maximum cost is identified and the minimum supply is allocated. Step 5 is continued pending there is no more stream. The following is the final allocation table.

Table 8.3 Original Allocation Table

| Factories | C | O | D | Supply |
|---------------|--------|--------|--------|--------|
| A | 12 | 3 (23) | 8 | 23 |
| O | 5 (44) | 6 (6) | 7 | 50 |
| D | 9 | 6 | 1 (48) | 48 |
| Dummy | 0 | 0 (31) | 0 (7) | 38 |
| Demand | 44 | 60 | 55 | 159 |

The Minimum Transportation cost obtained is Rs.418.

The solution obtained is non-degenerate.

8.2 Example 2

A leading company operates with 3 units for the delivery of automotive spare components. The cost of transportation of the spare parts to three locations to their destinations which involves octagonal neutrosophic numbers and the circumstances imposed on the transference problem are given below.

Table 8.3: Transportation Problem with Octagonal Neutrosophic numbers

| Factory | Meryin (M) | Lancy (L) | Versoix (V) | Supply |
|-------------------|---------------------------------|-------------------------------------|-------------------------------------|---------------------------------|
| Kelvin (K) | (5,10,13,14,18,20,22,24;1,0,0) | (1,2,3,4,5,6,7,8;1,0,0) | (2,6,8,14,14,16,18,20;1,0,0) | (2,11,23,34,45,56,67,78;1,0,0) |
| Peter (P) | (3,4,5,6,7,8,9,10;1,0,0) | (1,5,6,7,11,12,13,17;1,0,0) | (1,4,5,9,16,17,19,21;1,0,0) | (10,47,52,65,76,80,84,85;1,0,0) |
| David (D) | (3,6,9,12,15,18,21,24;1,0,0) | (2,5,7,8,8,9,9,10;1,0,0) | (1,1,1,1,1,1,1,1;1,0,0) | (3,18,56,76,87,90,92,95;1,0,0) |
| Demand | (11,16,51,67,75,79,81,83;1,0,0) | (20,40,60,80,100,120,140,160;1,0,0) | (15,30,45,75,110,115,120,125;1,0,0) | |

Solution:

Table 8.4 Crisp transportation table with a ranking function

| Factory | M | L | V | Supply |
|---------------|--------|------|--------|--------|
| K | 15.75 | 4.5 | 12.25 | 39.5 |
| P | 6.5 | 9 | 11.5 | 62.375 |
| D | 13.5 | 7.25 | 1 | 64.62 |
| Demand | 57.875 | 90 | 79.375 | |

The given problem is a balanced one. The cost cell with the lowest odd cost out of all the other costs in the transportation problem is picked. A new table is formed where, the selected minimum odd cost is deducted from each of the odd cost is subtracted from each of the odd cost value of the given problem. From the new table obtained, the maximum cost is identified and the smallest of supply is billed. Step 5 is sustained until there is no more supplementary demand. The following is the final allocation table.

Table 8.5 Original Allocation Table

| Factory | M | L | V | Supply |
|---------------|-------------|-----------|-----------|--------|
| K | 15.75 | 4.5(39.5) | 12.25 | 39.5 |
| P | 6.5(57.875) | 9(4.5) | 11.5 | 62.375 |
| D | 13.5 | 7.25 | 1(64.62) | 64.62 |
| Dummy | 0 | 0(46) | 0(14.755) | 60.755 |
| Demand | 57.875 | 90 | 79.375 | 227.25 |

The Minimum Transportation cost obtained is Rs.659.06

The solution obtained is non-degenerate.

9. Result and Analysis

In this research the Neutrosophic Transportation Problem has been solved by Allocation for Table Method to find out the Initial Basic Feasible Solution. Further a comparison study has been done with respect to the existing methods.

| Methods | Example 1 | Example 2 |
|------------------------------|-----------|-----------|
| Existing method | 418 | 659.06 |
| North West Corner | 758 | 1489.68 |
| Least Cost Method | 418 | 749.78 |
| Vogel's Approximation method | 418 | 670.31 |
| Column Minima method | 418 | 1257.31 |
| Proposed Method (ATM method) | 373 | 659.06 |
| MODI Method | 373 | 659.06 |

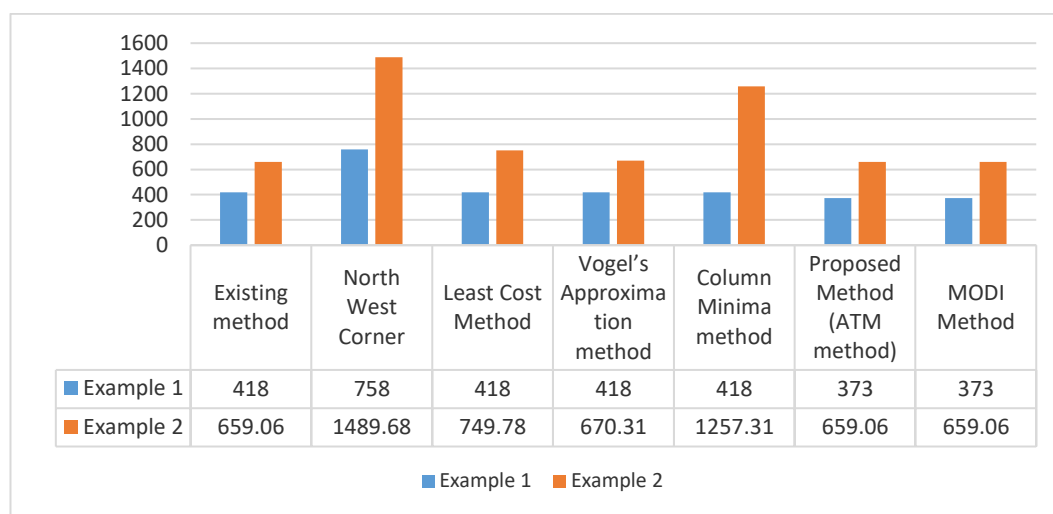


Figure 4: Result and Analysis Examples

10. Applications of Neutrosophic fuzzy sets

An important aspect of applied mathematical modeling is the theory of uncertainty. Nowadays, the idea of a neutrosophic number is highly well-liked. For a researcher who studies decision-making and uncertainty, the development and de-neutrosophication of the associated number can be crucial. The neutrosophic fuzzy set plays a vital role in the transportation problem. Most of the time, the data provided is indeterminate and inconsistent. At this point, we cannot make use of the fuzzy set and intuitionistic fuzzy set to deal with this indeterminacy. Here we have solved numerically to reflect the impact of neutrosophic pentagonal numbers and neutrosophic octagonal numbers. Some more applications of neutrosophic fuzzy sets are in image processing, security data, GIS Topology, and in databases.

11. Conclusion

In this research, we proposed the best approach for a neutrosophic transportation problem under pentagonal and octagonal numbers. From a logical point of view, this method is the most precise and consumes less time in our daily life situation. Further, we have done a comparative study of the various transportation methods.

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