**An Optimized Approach for Minimizing Transportation Costs Through the Lens of Triangular Fuzzy Neutrosophic Theory**

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Abstract

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| The transportation problem emphasizes on distributing goods efficiently from supply points to demand destinations, aiming to minimize both transportation time and cost. However, in today's context of unpredictable social and economic conditions, the supply, demand, and transportation costs often cannot be determined precisely. The aim of this paper is to introduce a novel approach to solving the Neutrosophic Transportation Problem by employing triangular neutrosophic fuzzy numbers to represent the cost coefficients within the transportation table. These fuzzy parameters are defuzzified into equivalent crisp values using a score function, allowing for effective optimization. A comprehensive and systematic methodology is proposed to derive the optimal transportation plan. The performance of the proposed approach is evaluated through comparative analysis with existing methods, demonstrating its enhanced efficiency and applicability in uncertain decision-making environments. |

*Keywords: Transportation Problem, triangular Fuzzy number, Optimization, Average Deviation, Score Function.*

1 Introduction

Linear programming is a foundational methodology in operations research. A key application of this approach is the transportation problem; a specialized linear programming model aimed at optimizing resource allocation by minimizing transportation costs while satisfying supply and demand constraints. This model is essential in logistics and supply chain management, providing efficient strategies for distributing goods between multiple sources and destinations. Over the years, numerous researchers have expanded this field with significant contributions. However, in today's context—shaped by growing economic and environmental pressures, uses many methods to minimize cost effectively. The concept of fuzzy sets was first introduced by Zadeh et al. (1965) as a mathematical tool for representing and handling vagueness. Building upon this foundation, Atanassov et al. (1986) proposed the Intuitionistic Fuzzy Set (IFS) model, which extends fuzzy set theory by including both a membership degree and a non-membership degree. This advancement provided a more flexible structure for modeling uncertainty. However, it has been noted that the combination of membership and non-membership values alone may not fully capture the complexity of uncertainty present in real-world problems.

Building upon this, Atanassov (1986) introduced the concept of intuitionistic fuzzy sets, which extend fuzzy sets by incorporating both membership and non-membership functions. This additional dimension allows for a more comprehensive representation of uncertainty, making it highly suitable for modeling transportation problems under imprecise conditions. Studies such as Banerjee and Pramanik (2018) and Kacher and Singh (2022) have demonstrated the applicability of intuitionistic fuzzy approaches in solving multi-objective and complex transportation models. Despite the usefulness of ifss, they still fall short in accounting for indeterminacy, which is often present in real-world data. To address this limitation, Smarandache et al. (2009) proposed neutrosophic set theory, which incorporates three components: truth-membership, indeterminacy-membership, and falsity-membership. This advancement enables a richer and more nuanced representation of uncertainty compared to ifss and fuzzy sets alone.

Numerous researchers have applied neutrosophic logic to various forms of transportation problems, including fixed-charge models (Revathi & Mohana Selvi, 2025), multi-objective optimization (Kaspar & Kaliyaperumal, 2024), and carbon emission constraints (Raut et al., 2025). These models go beyond cost minimization by incorporating environmental and operational complexities, making them well-suited for modern logistics systems. In addition, various techniques have been developed to solve ntps, including enumeration methods (Kumar et al., 2017), zero suffix methods (Selvakumari, 2019), and genetic algorithms in Fermatean neutrosophic environments (Raut et al., 2025). Recent literature also emphasizes the need for comparative studies between traditional, fuzzy, intuitionistic fuzzy, and neutrosophic approaches (Kacher & Singh, 2021; Hemalatha et al., 2023), reflecting the evolving landscape of transportation optimization under uncertainty. Furthermore, the integration of soft computing (Nisar et al., 2025) and intelligent decision-making models (Zhao et al., 2023) has enriched the field with hybrid approaches for solving high-dimensional and dynamic transportation scenarios.

This paper presents a novel approach for determining the initial basic feasible solution to neutrosophic transportation problems using triangular fuzzy neutrosophic numbers. A structured method is formulated to minimize transportation time effectively. The study defines the key characteristics of triangular fuzzy neutrosophic numbers and outlines a defuzzification process to convert them into crisp values. The sections of this paper tackled through the following procedure: section1 gives the introduction, section 2 accentuates the basic definitions. In section 3, describes about the neutrosophic transportation problems. The sequential algorithm and procedure are presented in section 4. Section 5 focuses on the illustrative demonstration. The important results of the work done are discussed in section 6 and wraps up the paper.

2 preliminaries

2.1 Fuzzy Set

A set where ) is called the membership function in which

2.2 Intuitionistic Fuzzy Set

An set where ) is

called the membership function and in which

2.3 Neutrosophic Fuzzy Set

A Neutrosophic Fuzzy set,where

and as falsity function and also it satisfies

and .

2.4 Neutrosophic Fuzzy Number

A Neutrosophic fuzzy set is said to be neutrosophic fuzzy number if

* + - 1. is normal
      2. is convex set for the truth function
      3. is a concave set for the indeterminacy -membership function and falsity-membership function

2.5 Neutrosophic Triangular Fuzzy Number

A Neutrosophic Triangular Fuzzy Number is defined in a Neutrosophic set

are ,  respectively.

2.6 score Function

For a neutrosophical triangular fuzzy number

, its score function is defined as is used to convert triangular fuzzy number to crisp number.

**3 model formulation of neutrosophic transportation problem:**

The components are all in neutrosophic cost parameters,

Minimize

Subject to

Where is the supply at the point i,is the demand required in jth destination, denotes the number of units transported from the source i to the destination j and indicates the cost of transportation from the source i to the destination j.

**4 proposed method**

1. **Defuzzification:** Convert all triangular fuzzy neutrosophic numbers into their corresponding crisp values using the score function defined in Equation (2.6).
2. **Balance the Transportation Table:** Check whether the given neutrosophic transportation table is balanced (i.e., total supply equals total demand). If not, introduce a dummy row to account for excess demand or a dummy column to account for excess supply, ensuring the problem becomes balanced.
3. **Initial Basic Feasible Solution (IBFS)**: Apply the Vogel’s Approximation Method (VAM) to determine an initial feasible allocation that provides a close approximation to the optimal cost.
4. Identify **Idle Cells**: Locate all unallocated cells where the transportation cost is less than the highest cost among the currently allocated cells.
5. **Construct Closed Loops**: For each selected idle cell, form a closed loop (starting and ending at the same cell), moving only horizontally and vertically. Ensure all loop corners lie on allocated cells.
6. **Adjust Allocations**: Shift the allocated quantity from the cell with the highest transportation cost in the loop to the idle cell, following the loop's alternating allocation pattern.
7. **Iterative Improvement**: Repeat the loop construction and allocation adjustment steps until all low-cost cells are effectively utilized. The final allocation represents the optimal solution under the triangular neutrosophic environment.

**5 Numerical example of the suggested methodology**

Table 1: The neutrosophic transportation table

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | D1 | D2 | D3 | Supply |
| S1 |  |  |  |  |
| S2 |  |  |  |  |
| S3 |  |  |  |  |
| Demand |  |  |  |  |

Table 2: Score values corresponding to the cell values

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | D1 | D2 | D3 | Supply |
| S1 | 1.85 | 5.46 | 5.22 | 20.92 |
| S2 | 3.02 | 6.13 | 5.94 | 30.42 |
| S3 | 5.33 | 5.8 | 4.75 | 55.83 |
| Demand | 52.16 | 43.58 | 44.92 |  |

Here ,not balanced.

Table 3: The balanced transportation table is

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | D1 | D2 | D3 | Supply |
| S1 | 1.85 | 5.46 | 5.22 | 20.92 |
| S2 | 3.02 | 6.13 | 5.94 | 30.42 |
| S3 | 5.33 | 5.8 | 4.75 | 55.83 |
| S4 | 0 | 0 | 0 | 33.49 |
| Demand | 52.16 | 43.58 | 44.92 |  |

Table 4: VAM method

|  |  |  |  |
| --- | --- | --- | --- |
|  | D1 | D2 | D3 |
| S1 | 1.85 (***20.92)*** | 5.46 | 5.22 |
| S2 | 3.02 (***30.42)*** | 6.13 | 5.94 |
| S3 | 5.33***(0.82)*** | 5.8***(10.09)*** | 4.75 (44***.92)*** |
| S4 | 0 | 0 (***33.49)*** | 0 |

=1.85, = 3.02, = 5.33, = 5.8 and = 4.75 and = 0

The initial basic feasible solution of the NTP is

Table 5: The process continues...and the Final Allocated Table

|  |  |  |  |
| --- | --- | --- | --- |
|  | D1 | D2 | D3 |
| S1 | 1.85 (***20.92)*** | 5.46 | 5.22 |
| S2 | 3.02 (***30.42)*** | 6.13 | 5.94 |
| S3 | 5.33 | 5.8 | 4.75 ***(44.92)*** |
| S4 | 0 ***(10.09)*** | 0 (***33.49)*** | 0 ***(0.82)*** |

The Optimal solution of the NTP is

**6 RESULTS AND DISCUSSION**

The results presented in the comparison of the solutions to the neutrosophic transportation problem obtained using the proposed method with those derived from existing methods. Table 6 presents a comparative analysis of three different methods used to solve the neutrosophic transportation problem—North West Corner Method (NWCM), Vogel’s Approximation Method (VAM), and the proposed optimized method. The objective is to minimize transportation costs under conditions of uncertainty, which are effectively modeled using neutrosophic logic. The NWCM is a basic and straightforward technique that does not consider cost minimization during initial allocations. As evident from the results, this method yields the highest transportation cost, Rs. 441.9975. This is due to its nature of allocating based purely on positional logic without integrating any cost components or degrees of uncertainty. VAM is a more refined heuristic that attempts to improve cost efficiency by considering penalties associated with not choosing the cheapest options. The solution obtained using VAM, Rs. 406.833, shows a noticeable improvement over NWCM, reflecting its more strategic approach. However, it still lacks the capacity to fully exploit the uncertainty and indeterminacy embedded in neutrosophic environments. The proposed method achieves higher performance levels than both traditional approaches by producing the least transportation cost, Rs. 343.9404. This method is fine-tuned for neutrosophic conditions and incorporates degrees of truth, indeterminacy, and falsity in the cost matrix. It demonstrates a higher level of adaptability and accuracy in decision-making under uncertainty, making it a more effective solution for real-world ambiguous scenarios. The decreasing trend in total cost—from NWCM to VAM to the proposed optimized method—clearly highlights the superiority of advanced, uncertainty-aware optimization techniques. The proposed method not only minimizes transportation costs effectively but also provides a robust framework to handle the vagueness and indeterminacy inherent in complex logistics problems.

Table 6: Analyzing the Different Approaches

|  |  |
| --- | --- |
| Methods | Illustration 1 |
| North West Corner Method | Rs.441.9975 |
| Vogel’s Approximation Method | Rs.406.833 |
| Proposed optimized method | Rs.343.9404 |

Fig 1: An overview of the solutions to the Neutrosophic Transportation Problem (NTP) using

the proposed method alongside several existing classical methods.

**7 Conclusions**

In recent years, neutrosophy has emerged as a powerful framework for addressing uncertainty and indeterminacy in real-world scenarios. This study focuses on solving unbalanced transportation problems using triangular neutrosophic numbers through a newly developed method for finding optimal solutions. By representing all relevant parameters with triangular neutrosophic values, the approach captures uncertainty more accurately and realistically. The proposed method offers a structured and practical means of making decisions under uncertain conditions and minimize the cost effectively. Comparative analysis with existing methods highlights the enhanced flexibility and improved quality of solutions achieved by the proposed technique.

The comparative analysis clearly illustrates the limitations of classical methods when applied to environments influenced by uncertainty and vagueness. While NWCM and VAM offer baseline solutions, they lack the sophistication to handle indeterminate data effectively. The proposed optimized method, built upon the foundation of neutrosophic logic, provides a substantial improvement in cost efficiency—achieving a reduction of nearly 22.2% over NWCM and 15.5% over VAM. This reinforces the value of integrating neutrosophic frameworks into transportation models, particularly for real-world scenarios where ambiguity is inevitable. The results not only validate the practical applicability of the proposed technique but also open new avenues for further research in neutrosophic decision-making and optimization.

**Disclaimer (Artificial Intelligence)**

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during writing or editing of this manuscript.

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