



THE SCIENTIFIC TEMPER

AUGUST 2026 Vol. 17 (8): 6740-6749

ISSN: 0976-8653, E-ISSN: 2231-6396

DOI: 10.58414/SCIENTIFICTEMPER.2026.17.8.2517

A WEB OF SCIENCE JOURNAL

RESEARCH ARTICLE

Resilient Supply Chain Logistics: A Neutrosophic Absolute Width Optimization Approach

DHANALAKSHMI GANESAN¹, KALAIARASI KALAICHELVAN²

¹PG & Research Department of Mathematics, Cauvery College for Women (Autonomous), (Affiliated to Bharathidasan University), Tiruchirappalli 620018, Tamil Nadu, India; ghanalakshmi.matphd@cauverycollege.ac.in (D.G.);

²Assistant Professor, PG & Research Department of Mathematics, Cauvery College for Women (Autonomous), (Affiliated to Bharathidasan University), Tiruchirappalli 620018, Tamil Nadu, India; kkalaiarasi.maths@cauverycollege.ac.in (K.K.)

Corresponding author: kkalaiarasi.maths@cauverycollege.ac.in

ABSTRACT

Modern supply chains suffer cost volatility, traffic ambiguity, and disruption threats that old transportation models cannot fully address. This study proposes a Resilient Supply Chain Logistics framework based on a Neutrosophic Absolute Width (NAW) Optimization Approach, in which transportation costs are modelled using Pentagonal Neutrosophic Fuzzy Numbers (PNFNs) that capture truth (reliability), indeterminacy (uncertainty), and untruth (disruption risk). The innovative NAW defuzzification technique turns these Neutrosophic costs into crisp representative values while maintaining uncertainty spread, allowing for practical decision-making. The framework, which is presented as a transportation optimization issue and solved using Vogel's Approximation Method (VAM) and the MODI technique, is validated through a real case study. Direct costs, uncertainty-related expenses, and disruption losses have been reduced, improving supply chain resilience and supporting sustainability goals aligned with SDGs 9 (Industry, Innovation, and Infrastructure), 12 (Responsible Consumption and Production), and 13 (Climate Action).

Keywords: Resilient supply chain, Neutrosophic Transportation model, Absolute width method, Pentagonal Neutrosophic fuzzy numbers, Uncertainty optimization, Risk-aware logistics, MODI method, Sustainable transportation planning, Fuzzy and Neutrosophic operations research, Industrial logistics optimization.

INTRODUCTION

In an increasingly interconnected global economy, efficient supply chain logistics systems are essential for maintaining industrial competitiveness. Transportation operations are frequently affected by fluctuating fuel prices, varying traffic conditions, demand uncertainty, travel-time variability, and unexpected road disruptions. Traditional transportation models generally rely on deterministic cost parameters and therefore may not adequately represent the

uncertainty inherent in real-world logistics environments, potentially leading to inefficient or risky transportation decisions. Fuzzy transportation models have been developed to overcome this limitation by representing transportation costs, supplies, and demands as fuzzy numbers, thereby incorporating imprecision directly into the optimization process (Kaur & Kumar, 2011; Samuel & Venkatachalapathy, 2011).

Pentagonal fuzzy numbers (PFNs) provide a more flexible representation of uncertainty than triangular and trapezoidal fuzzy numbers because their five parameters allow asymmetric dispersion around a central value. This flexibility is particularly useful for representing uncertain transportation and inventory costs in industrial systems (Kalaierasi et al., 2018). Recent developments have further demonstrated the applicability of pentagonal fuzzy numbers to inventory management and supply chain decision-making. Kalaierasi et al. (2018) developed a fuzzy inventory model using pentagonal fuzzy numbers, while Kalaierasi and Swathi (2024) incorporated fuzzy inventory management with deep learning techniques to improve demand forecasting and supply chain efficiency. These studies demonstrate the usefulness of higher-order fuzzy representations in dealing with uncertain operational parameters.

However, conventional fuzzy approaches generally represent uncertainty through a single membership function and therefore do not explicitly distinguish between reliable information, indeterminate information, and potentially false or risk-associated information. To overcome this limitation, neutrosophic set theory introduces three independent components—truth, indeterminacy, and falsity—providing a richer framework for representing incomplete, inconsistent, and uncertain information. Das et al. (2019) demonstrated the applicability of neutrosophic soft matrices to decision-making problems involving uncertain and imprecise information. In transportation and logistics applications, the three-component representation provides an appropriate structure for modeling situations in which some transportation costs are known with high confidence, some are subject to uncertainty, and others are associated with possible disruptions or unreliable information.

The application of neutrosophic concepts to transportation optimization has received increasing attention. Karak et al. (2023) proposed a solution technique for transportation problems in a neutrosophic environment, demonstrating the potential of neutrosophic representations for transportation decision-making under uncertainty. Similarly, recent work by Kalaierasi et al. (2025) investigated pentagonal fuzzy numbers within a neutrosophic fuzzy inventory management framework, further demonstrating the relevance of pentagonal and neutrosophic representations for inventory systems involving uncertain consumption and supply conditions. These developments indicate that the integration of pentagonal fuzzy and neutrosophic concepts can provide a more comprehensive representation of uncertainty in supply chain systems.

Nevertheless, an important methodological challenge remains in converting neutrosophic information into suitable crisp values for transportation optimization without losing the information contained in the uncertainty spread. Existing ranking and defuzzification approaches generally emphasize the central tendency of a fuzzy number. Kaur and Kumar (2011), for example, developed a ranking-function-based approach for solving fuzzy transportation problems, while Roushan et al. (2023) proposed a pentagonal type-2 fuzzy variable defuzzification model with an application to humanitarian supply chains. Although such methods are effective in obtaining representative crisp values, the transformation process may reduce the explicit representation of uncertainty width and risk-related information. Consequently, there is a need for a defuzzification mechanism that considers both the representative cost and the associated spread of uncertainty.

The optimization stage is equally important in obtaining an efficient transportation plan. Vogel's Approximation Method (VAM) is widely used to obtain an initial basic feasible solution because it considers the penalty associated with selecting a non-minimum-cost route. Korukoğlu and Ballı (2011) proposed an improved VAM for transportation problems, demonstrating the effectiveness of penalty-based allocation. Samuel and Venkatachalapathy (2011) further adapted VAM to fuzzy transportation problems, illustrating the applicability of classical transportation procedures in uncertain environments. Once an initial feasible solution is obtained, the Modified Distribution (MODI) method can be employed to evaluate optimality through transportation potentials and opportunity costs. Thus, integrating an appropriate uncertainty-reduction mechanism with VAM and MODI provides a computationally efficient framework for transportation optimization.

Motivated by these developments, this study proposes a Resilient Supply Chain Logistics framework based on a Neutrosophic Absolute Width Optimization Approach. The proposed approach represents transportation costs using Pentagonal Neutrosophic Fuzzy Numbers (PNFNs), in which the truth component represents reliable transportation costs, the indeterminacy component represents uncertainty arising from traffic, travel-time variability, and fluctuating operating conditions, and the falsity component represents potential disruption and route-related risk. A Neutrosophic Absolute Width (NAW) mechanism is then employed to transform the three neutrosophic components into a representative risk-adjusted transportation

cost while retaining information about their uncertainty spread.

The resulting transportation model is formulated as a linear programming transportation problem and solved using Vogel's Approximation Method (VAM) to obtain an initial basic feasible solution and the Modified Distribution (MODI) method to test and improve optimality. The MODI procedure evaluates the opportunity costs of unoccupied cells and identifies whether further reduction in the total transportation cost is possible. If an improving cell exists, a closed transportation loop is constructed and the allocations are systematically adjusted until all opportunity costs satisfy the optimality condition. Consequently, the proposed hybrid scheme integrates neutrosophic uncertainty representation, absolute-width-based transformation, and classical transportation optimization into a unified framework.

The proposed approach is demonstrated through an industrial steel-rod distribution application in which supply is transported from Salem-based production and storage facilities to major destination markets such as Chennai, Coimbatore, and Tiruchirappalli. The framework provides not only an optimal transportation allocation but also a component-wise interpretation of truth, indeterminacy, and falsity contributions. This enables decision-makers to identify routes associated with higher uncertainty or risk and to develop more resilient transportation strategies.

The proposed framework also contributes to sustainable industrial logistics. By improving transportation allocation and reducing unnecessary transportation effort, the model promotes efficient utilization of fuel, vehicles, infrastructure, and other logistics resources. Accordingly, the study primarily supports Sustainable Development Goal 9 (SDG 9: Industry, Innovation and Infrastructure) through resilient and innovative industrial logistics planning. It additionally contributes to SDG 12 (Responsible Consumption and Production) through improved resource efficiency and reduced logistics waste, and supports SDG 13 (Climate Action) by providing a framework that can facilitate more efficient transportation and consequently reduce fuel-intensive logistics operations.

The principal contribution of this study is therefore the integration of Pentagonal Neutrosophic Fuzzy Numbers, Neutrosophic Absolute Width, VAM, and MODI into a unified transportation optimization framework. Unlike conventional fuzzy ranking and defuzzification approaches that primarily focus on obtaining a representative central value, the proposed

framework explicitly incorporates truth, indeterminacy, falsity, and uncertainty spread into the transportation decision process. This provides a mathematically tractable and practically interpretable approach for resilient and sustainable supply chain logistics under uncertain operating conditions.

PRELIMINARIES

This section deals with the important ideas of Neutrosophic pentagonal fuzzy numbers and the absolute width concept, which form the mathematical basis for the suggested transportation method.

NEUTROSOPHIC SET

Let X be a universe of a Neutrosophic set B and it can be characterized by three independent membership functions:

$$B = \{(x, T_B(x), I_B(x), F_B(x)) : x \in X\} \quad (1)$$

where $T_B(x)$ = degree of membership truth, $I_B(x)$ = degree of membership indeterminacy, $F_B(x)$ = degree of membership falsity, also lies in the interval $0 \leq T_B(x), I_B(x), F_B(x) \leq 1$, $0 \leq T_B(x) + I_B(x) + F_B(x) \leq 3$.

PENTAGONAL NEUTROSOPHIC FUZZY NUMBER (PNFN)

A Pentagonal Neutrosophic Fuzzy Number is defined as

$$\underline{K} = ((h_1, h_2, h_3, h_4, h_5), (i_1, i_2, i_3, i_4, i_5), (j_1, j_2, j_3, j_4, j_5)) \quad (2)$$

and it is denoted by $\underline{K}$, where $(h_1, h_2, h_3, h_4, h_5)$ denotes the membership of the truth pentagonal fuzzy number, $(i_1, i_2, i_3, i_4, i_5)$ denotes the membership of the indeterminacy pentagonal fuzzy number, $(j_1, j_2, j_3, j_4, j_5)$ denotes the membership of the falsity pentagonal fuzzy number.

NEUTROSOPHIC ABSOLUTE WIDTH (NAW) METHOD

Consider a pentagonal fuzzy number $(h_1, h_2, h_3, h_4, h_5)$, the absolute width value is determined by

$$AW = h_3 + \frac{(h_3 - h_1) + (h_5 - h_3)}{2} \quad (3)$$

Given a pentagonal fuzzy number extending to this neutrosophic pentagonal fuzzy number, it can be written

$$AW_T = h_3 + \frac{(h_3 - h_1) + (h_5 - h_3)}{2}, AW_I = i_3 + \frac{(i_3 - i_1) + (i_5 - i_3)}{2} \text{ and } AW_F = j_3 + \frac{(j_3 - j_1) + (j_5 - j_3)}{2} \text{ then define the Neutrosophic Absolute Width cost is}$$

$$K^* = AW_T + AW_I + AW_F \quad (4)$$

METHODOLOGY FOR SOLVING THE NEUTROSOPHIC TRANSPORTATION MODEL USING PENTAGONAL FUZZY NUMBER

Step 1: First verify that the given problem is balanced. Then calculate the number of allocations.

Step 2: First, list transport costs, supplies, and demands, then compute row/column penalties by subtracting the smallest cost from the next smallest and select the row/column with the highest penalty. In that row/column, allocate as much as possible to the lowest-cost cell (min of supply or demand), update the table and repeat until all supplies and demands are met, yielding the initial basic feasible solution.

VAM USES AN ITERATIVE PROCESS

In each iteration is defined as follows:

1. First we find the two lowest cost for each row and each column penalties. For the selected row or column, we have to find the highest penalty = second smallest value - smallest value.
2. Identify which row or column has the most penalty value.
3. Finally determine the cell with the lowest value in the selected row or column, and allocate the greatest possible value to that cell and also not exceeding the available supply or demand.
4. After each allocation, finally update the supply and demand cost values. Omitting any row or column where supply or demand has been fully satisfied, and repeat the process we get all the allocations are made.

MODI METHOD

Step 1: Assign potentials u_i and v_j such that for all basic cells: $C_{ij}^* = u_i + v_j$

Step 2: Compute opportunity cost for each non-basic cell: $\Delta_{ij} = C_{ij}^* - (u_i + v_j)$

Step 3: If all $\Delta_{ij} \geq 0$, the solution is optimal obtained. Otherwise, select the most negative Δ_{ij} and construct a closed loop. Adjust allocations along the loop with the complete process.

Step 4: Repeat until optimality is reached. These four steps followed and applying MODI method, we get a new improved solution for the Pentagonal Neutrosophic transportation cost.

Step 3: After initial basic feasible solution then apply VAM method to get a pentagonal fuzzy transportation total cost. Finally applying MODI Method to get an optimal solution.

MATHEMATICAL EXAMPLE FOR SOLVING THE NEUTROSOPHIC TRANSPORTATION MODEL USING PENTAGONAL FUZZY NUMBER

A steel rod plant in Salem that supplies construction steel to Chennai, Coimbatore, and Trichy –where transportation costs vary due to fuel prices, traffic, toll delays, and vehicle breakdowns—is used to illustrate the concept. The problem is transformed into a typical linear transportation model by modelling these uncertainties using pentagonal Neutrosophic fuzzy numbers, which are subsequently transformed into crisp values using the Neutrosophic Absolute Width (NAW) method. The process involves three steps: (i) Establishing an Initial Basic Feasible Solution; (ii) Utilising Vogel's Approximation approach (VAM) to refine it; and (iii) Using the MODI approach to evaluate and optimize optimality.

PENTAGONAL FUZZY TRANSPORTATION COST MATRIX

Consider a transportation steel rod factory (network) with i sources and j destinations. Therefore here supply at source M_i and demand at destination N_j and x_{ij} as quantity transported from source i to destination j . Each transportation cost is expressed as a Neutrosophic Pentagonal Fuzzy Number "NPFN": as shown in Equation (2.2)

Table 1. Pentagonal fuzzy transportation cost matrix

	N_1	N_2	N_3
M_1	(6,7,8,9,10)	(5,6,7,8,9)	(8,9,10,11,12)
M_2	(7,8,9,10,11)	(4,5,6,7,8)	(6,7,8,9,10)
M_3	(5,6,7,8,9)	(7,8,9,10,11)	(4,5,6,7,8)

Each component satisfies: $0 \leq h_k, i_k, j_k \leq 1, k \in 1,2,3,4,5$. As shown in Table 1 as a pentagonal fuzzy transportation cost matrix. Our method is to use absolute width matrix of the supplies and demands directly (by using pentagonal fuzzy

supply/demands): $M_1 = 40, M_2 = 35, M_3 = 25, N_1 = 30, N_2 = 45, N_3 = 25$.

Table 2. Fuzzy transportation problem with demand and supply

	N_1	N_2	N_3	Supply
M_1	10	9	12	40
M_2	11	8	10	35
M_3	9	11	8	25
Demand	30	45	25	100

As shown in Table 2 which satisfies the balancing requirement. Pentagonal fuzzy supply = Pentagonal fuzzy demand = 100. The given pentagonal fuzzy transportation problem is balanced.

NEUTROSOPHIC ABSOLUTE WIDTH COST MATRIX

Table 3. Neutrosophic Absolute Width (NAW) Transportation Cost Matrix with Supply and Demand

From (Salem)/To	Chennai N_1	Coimbatore N_2	Trichy N_3	Supply
M_1	19	17	22	40
M_2	20	15	18	35
M_3	16	21	14	25
Demand	30	45	25	100

The Table 3 entries represent the per-unit transportation cost from Salem to each destination (Chennai, Coimbatore, Trichy). As the problem is balanced, all supply is fully allocated to meet demand with no surplus or shortage. Table 3 presents the crisp cost matrix derived using the Neutrosophic Absolute Width (NAW) method for steel rod distribution from Salem's manufacturing sites to target markets.

VAM ANALYSIS OF THE INITIAL BASIC FEASIBLE SOLUTION (IBFS)

To obtain the ideal shipment plan, Vogel's Approximation approach (VAM) and the Modified Distribution (MODI) approach use the matrix as input.

Table 4. Final allocation matrix for the Neutrosophic transportation model

From (Salem)/To	Chennai N_1	Coimbatore N_2	Trichy N_3	Supply
M_1	0	40	0	40
M_2	5	5	25	35
M_3	25	0	0	25
Demand	30	45	25	100

This Table 4 describes a transportation allocation plan. This is a feasible solution to the transportation problem, showing one possible way to satisfy all demands without surplus or shortage. The pentagonal optimal total cost is: $Z = 5(19) + 35(17) + 10(15) + 25(18) + 25(16) = \text{INR}1690$.

NEUTROSOPHIC ABSOLUTE WIDTH

CALCULATION AND OPTIMALITY TEST USING MODI METHOD

The components are summed to calculate each route's total cost. Table 5 lists routes with their respective cost components. The route total are 19, 17, 15, 18, and 16, respectively.

Table 5. Neutrosophic absolute width cost matrix calculations for route-wise cost component total truth, indeterminacy, and falsity.

Route	AW_T	AW_I	AW_F	Total
$M_1 \rightarrow N_1$	10	5	4	19
$M_1 \rightarrow N_2$	9	4	4	17

$M_2 \rightarrow N_2$	8	4	3	15
$M_2 \rightarrow N_3$	10	4	4	18
$M_3 \rightarrow N_1$	9	4	3	16

Each route's total cost combines multiple contribution factors for direct comparison. Costs range from 15 to 19, with Route 1 being the most expensive and Route 3 the least. This analysis supports efficient logistics and supply-chain route selection. The allocation satisfies all supply and

demand constraints. Table 6 presents the optimal shipment allocation using the NAW-VAW-MODI framework. It minimizes risk-adjusted transportation costs across Salem's steel distribution network.

Table 6. Optimal transportation allocation obtained using the proposed NAW-VAM-MODI

From (salem)/To	Chennai N_1	Coimbatore N_2	Trichy N_3	Supply
M_1	5	35	0	40
M_2	0	10	25	35
M_3	25	0	0	25
Demand	30	45	25	100

This solution highlights how the proposed hybrid optimization technique can help achieve resilient

and efficient supply chain operations.

Table 7. NAW contributions for truth, indeterminacy, and falsity contribution

Route	Units	AW_T	contribution	AW_I	contribution	AW_F	contribution
$M_1 \rightarrow N_1$	5	10	50	5	25	4	20
$M_1 \rightarrow N_2$	35	9	315	4	140	4	140
$M_2 \rightarrow N_2$	10	8	80	4	40	3	30
$M_2 \rightarrow N_3$	25	10	250	4	100	4	100
$M_3 \rightarrow N_1$	25	9	225	4	100	3	75

NEUTROSOPHIC ABSOLUTE WIDTH CONTRIBUTION TABLE

All $\Delta \geq 0 \rightarrow$ optimal. $Z_T=920$, $Z_I=405$, $Z_F=365$.
Final Neutrosophic total cost is

$Z = Z_T + Z_I + Z_F = 920 + 405 + 365 = \text{INR}1690$.
Therefore, the minimum total transportation cost is INR1690.

Table 8. Breakdown of costs

Component	Cost	Share of total	Meaning
Truth	920	54%	Base transportation expense
Indeterminacy	405	24%	Uncertainty-related cost
Falsity	365	22%	Risk and disruption cost

Table 8 shows the percentage contribution and interpretation of neutrosophic cost components. Uncertainty and risk account for INR 770, representing 46% of total logistics costs. Managing these factors improves efficiency, resilience, sustainability, and decision-making.

Neutrosophic Cost Contribution Analysis

of Supply Routes

The Figure 1 compares truth cost contributions across routes, with $M_1 \rightarrow N_2$ showing the highest value. It highlights variation in cost distribution, helping identify the most and least expensive routes.

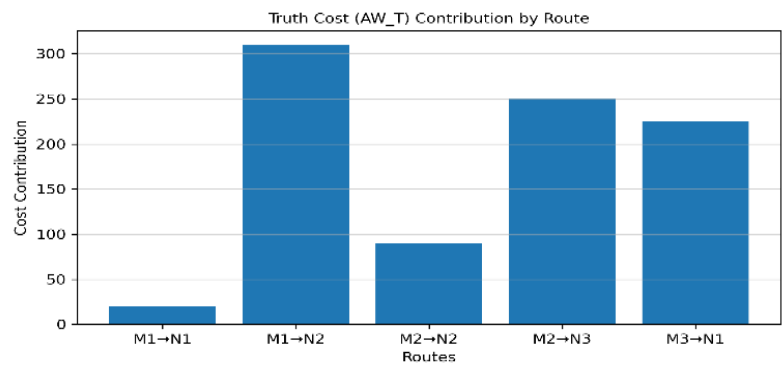


Figure 1. Truth cost AW_T contribution by route

This Figure 2 compares the contribution cost value and $M_1 \rightarrow N_1$ the lowest. across routes, with $M_1 \rightarrow N_2$ showing the highest

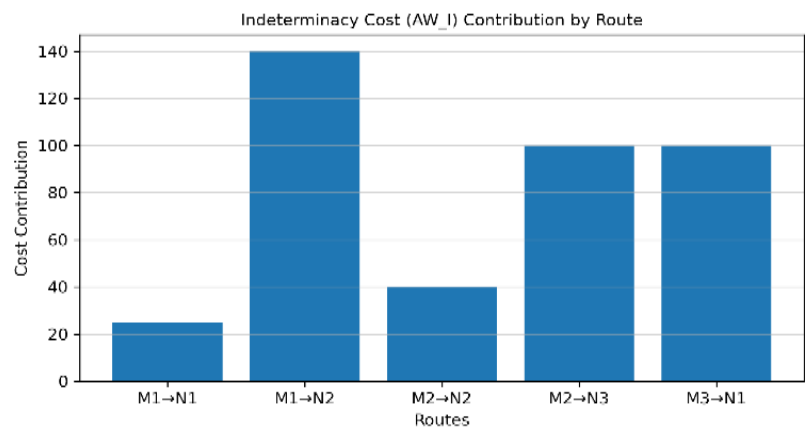


Figure 2. Indeterminacy cost AW_I contribution by route

Overall, the routes $M_2 \rightarrow N_3$ and $M_3 \rightarrow N_1$ also contribute strongly, while $M_2 \rightarrow N_1$ and $M_2 \rightarrow N_2$ are comparatively smaller. The Risk cost of Figure 3 contribution is highest for route, $M_1 \rightarrow N_2$ indicating that this route carries the greatest risk-related transportation cost.

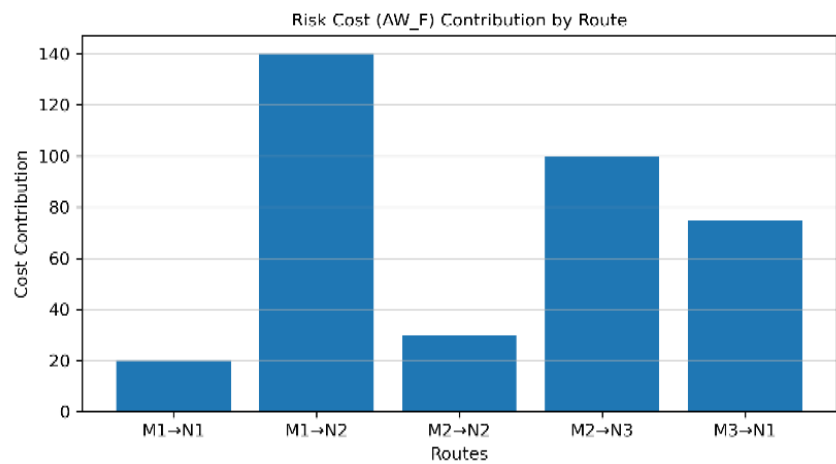


Figure 3. Falsity cost AW_F contribution by route

In contrast, $M_1 \rightarrow N_1$ and $M_2 \rightarrow N_2$ have the lowest risk costs, while $M_2 \rightarrow N_3$ and $M_3 \rightarrow N_1$ contribute moderate levels of risk to the overall transportation network.

FINAL DISTRIBUTION OF

NEUTROSOPHIC
COMPONENTS AND IMPACT OF
UNCERTAINTY REDUCTION AND
ROUTE-WISE NEUTROSOPHIC COST

COST DISTRIBUTION

The Figure 4 illustrates how the Neutrosophic cost of INR1690 is split into Truth (54.4%), Indeterminacy (24%), and Falsity (21.6%).

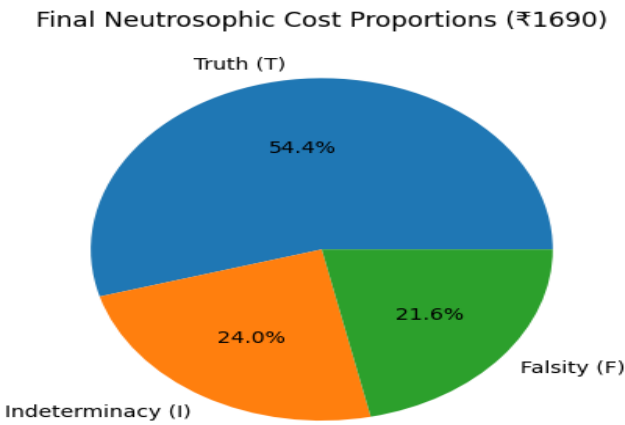


Figure 4. Neutrosophic cost distribution into T, I, and F

Truth is the largest share, meaning most of the outcomes in the system. cost comes from clearly defined, effective

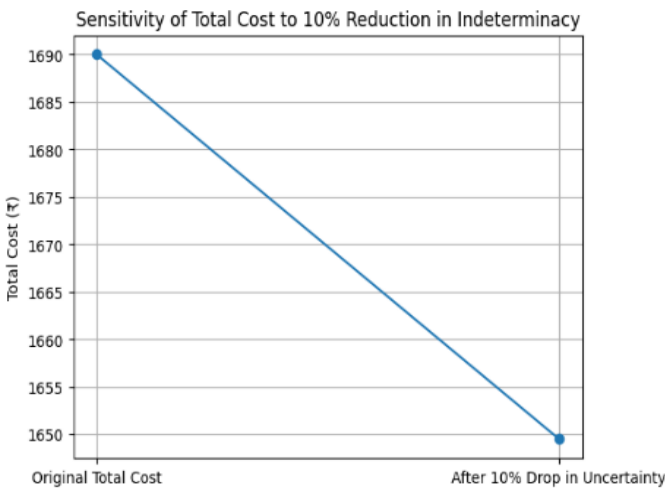


Figure 5. Impact of indeterminacy reduction on Neutrosophic cost

A 10% reduction in indeterminacy lowers the total neutrosophic cost from about INR1690 to INR1650 shows in Figure 5. This highlights the tangible benefit of uncertainty management in improving supply chain cost efficiency.

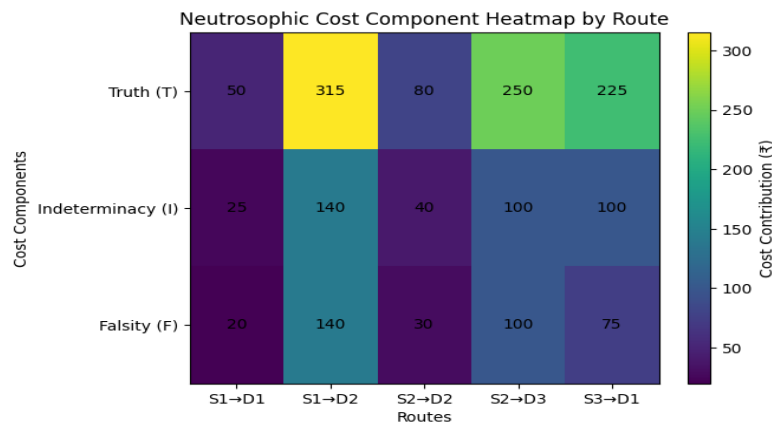


Figure 6. Route-wise neutrosophic cost components (T, I, F)

This Figure 6 reflects heat map shows that one route has the highest T, I, and F costs (most expensive and risky), while another route with T=50, I=25, F=20 is the most efficient and stable, supporting better route selection in the supply chain.

CONCLUSION

To plan transportation under risk and uncertainty, this study presents a robust supply chain logistics architecture that uses a Neutrosophic Absolute Width (NAW) Optimization approach. The NAW method preserves uncertainty dispersion while converting uncertain Neutrosophic costs—represented by pentagonal fuzzy numbers that capture truth, indeterminacy, and falsity—into crisp values. The model effectively produces risk-adjusted shipment strategies when combined with Vogel's Approximation Method and the MODI algorithm, as demonstrated in a steel rod distribution case study where logistics costs are greatly impacted by disruptions. The strategy improves supply chain resilience, resource efficiency, and alignment with SDGs 9, 12, and 13 by empowering decision-makers to recognize risky paths and weigh costs against dependability.

ACKNOWLEDGEMENTS

The authors sincerely thank the PG and Research Department of Mathematics, Cauvery College for Women (Autonomous), Tiruchirappalli, affiliated to Bharathidasan University, Tamil Nadu, India, for providing the academic environment and support necessary to carry out this research. The authors also acknowledge the institutional facilities and computational resources that supported the development and analysis of the proposed demand-based fuzzy transportation model.

Source of support: None

Conflict of interest: None

The authors declare that they have no conflict of

interest regarding the publication of this research article. There are no financial, personal, or professional relationships that could have influenced the research, analysis, results, or conclusions presented in this study.

REFERENCES

- Das, S., Kumar, S., Kar, S., & pal, T. (2019). Group decision making using Neutrosophic soft matrix: An algorithmic approach. *Journal of king saud university-Computer and information sciences*. 31 (4), 459-468. <https://doi.org/10.1016/j.jksuci.2017.05.001>
- Kaur, A., & Kumar, A. (2011). A new method for solving fuzzy transportation problems using ranking function. *Applied Mathematical Modelling*. 35 (12), 5652-5661. <https://doi.org/10.1016/j.apm.2011.05.012>
- Korukoglu, S., & Balli, S. (2011). An improved Vogel's approximation method for the transportation problem. *Mathematical and Computational Applications*. 16(2), 370-381. <https://doi.org/10.3390/mca16020370>
- Karak, M., Mahata, A., Rong, M., Mukherjee, S., Mondal, S.P., Broumi, S., & Roy, B. (2023). A Solution technique of transportation problem in neutrosophic environment. *Neutrosophic Systems with Applications*. 3, 17-34. <https://doi.org/10.5281/zenodo.8197046>
- Kalaiaarasi, R., Sumathi, M., & Sabina Begum, M. (2018). Optimization of fuzzy inventory model without shortage using pentagonal fuzzy number. *International Journal of Mechanical Engineering and Technology*. 9 (11), 2424-2437.
- Kalaiaarasi, K., & Swathi, S. (2024). Optimization for fuzzy inventory management in industrial processes using deep learning algorithms: A hybrid approach for enhancing demand forecasting and supply chain efficiency. *Advanced Engineering Letters*. 3(4), 141-153. <https://doi.org/10.46793/adeletters.2024.3.4>
- Kalaiaarasi, K., Venugopal, S., & Sivagama Sundari, A. (2023). Sustainable medical supply chain

- network during pandemic by using fuzzy inventory. AIP conference proceedings. 2649. <https://doi.org/10.1063/5.0147364>
- Kalaiaarasi, K., Nasreen Kausar., Broumi, S., & Cagin, T. (2025). The analysis of pentagonal fuzzy numbers in a neutrosophic fuzzy inventory management modelling with minimal insufficient supply required and fuzzy consumption. International Journal of Neutrosophic Science (IJNS). 25 (4), 472-483. <https://doi.org/10.54216/IJNS.250440>
- Roushan, A., Das, A., Dutta, A., & Bera, U.K. (2023). A pentagonal type-2 fuzzy variable defuzzification model with application in humanitarian supply chains. Decision Analytics Journal. 8, 100303. <https://doi.org/10.1016/j.dajour.2023.100303>
- Samuel, A.E. & Venkatachalapathy, M. (2011). Modified Vogel's approximation method for fuzzy transportation problem. Applied Mathematical Sciences. 5, 28, 1367-1372.